FreeBSD Handbook

The FreeBSD Documentation Project

FreeBSD Handbook

by The FreeBSD Documentation Project

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Welcome to FreeBSD! This handbook covers the installation and day to day use of *FreeBSD 4.9-RELEASE* and *FreeBSD 5.1-RELEASE*. This manual is a *work in progress* and is the work of many individuals. Many sections do not yet exist and some of those that do exist need to be updated. If you are interested in helping with this project, send email to the FreeBSD documentation project mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-doc). The latest version of this document is always available from the FreeBSD web site (../../../../index.html). It may also be downloaded in a variety of formats and compression options from the FreeBSD FTP server (ftp://ftp.FreeBSD.org/pub/FreeBSD/doc/) or one of the numerous mirror sites. If you would prefer to have a hard copy of the handbook, you can purchase one at the FreeBSD Mall (http://www.freebsdmall.com/). You may also want to search the handbook (../../../../search/index.html).

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Preface

Intended Audience

The FreeBSD newcomer will find that the first section of this book guides the user through the FreeBSD installation process and gently introduces the concepts and conventions that underpin UNIX®. Working through this section requires little more than the desire to explore, and the ability to take on board new concepts as they are introduced.

Once you have travelled this far, the second, far larger, section of the Handbook is a comprehensive reference to all manner of topics of interest to FreeBSD system administrators. Some of these chapters may recommend that you do some prior reading, and this is noted in the synopsis at the beginning of each chapter.

For a list of additional sources of information, please see Appendix B.

Changes from the First Edition

This second edition is the culmination of over two years of work by the dedicated members of the FreeBSD Documentation Project. The following are the major changes in this new edition:

- A complete Index has been added.
- All ASCII figures have been replaced by graphical diagrams.
- A standard synopsis has been added to each chapter to give a quick summary of what information the chapter contains, and what the reader is expected to know.
- The content has been logically reorganized into three parts: "Getting Started", "System Administration", and "Appendices".
- Chapter 2 ("Installing FreeBSD") was completely rewritten with many screenshots to make it much easier for new users to grasp the text.
- Chapter 3 ("UNIX Basics") has been expanded to contain additional information about processes, daemons, and signals.
- Chapter 4 ("Installing Applications") has been expanded to contain additional information about binary package management.
- Chapter 5 ("The X Window System") has been completely rewritten with an emphasis on using modern desktop technologies such as **KDE** and **GNOME** on XFree86™ 4.X.
- Chapter 7 ("The FreeBSD Booting Process") has been expanded.
- Chapter 12 ("Storage") has been written from what used to be two separate chapters on "Disks" and "Backups". We feel that the topics are easier to comprehend when presented as a single chapter. A section on RAID (both hardware and software) has also been added.
- Chapter 17 ("Serial Communications") has been completely reorganized and updated for FreeBSD 4.X/5.X.
- Chapter 18 ("PPP and SLIP") has been substantially updated.
- Many new sections have been added to Chapter 19 ("Advanced Networking").
- Chapter 20 ("Electronic Mail") has been expanded to include more information about configuring **sendmail**.

- Chapter 22 ("Linux Compatibility") has been expanded to include information about installing **Oracle®** and **SAP® R/3®**.
- The following new topics are covered in this second edition:
  - Configuration and Tuning (Chapter 6).
  - Multimedia (Chapter 16)

Organization of This Book

This book is split into three logically distinct sections. The first section, *Getting Started*, covers the installation and basic usage of FreeBSD. It is expected that the reader will follow these chapters in sequence, possibly skipping chapters covering familiar topics. The second section, *System Administration*, covers a broad collection of subjects that are of interest to more advanced FreeBSD users. Each section begins with a succinct synopsis that describes what the chapter covers and what the reader is expected to already know. This is meant to allow the casual reader to skip around to find chapters of interest. The third section contains appendices of reference information.

Chapter 1, Introduction

Introduces FreeBSD to a new user. It describes the history of the FreeBSD Project, its goals and development model.

Chapter 2, Installation

Walks a user through the entire installation process. Some advanced installation topics, such as installing through a serial console, are also covered.

Chapter 3, UNIX Basics

Covers the basic commands and functionality of the FreeBSD operating system. If you are familiar with Linux or another flavor of UNIX then you can probably skip this chapter.

Chapter 4, Installing Applications

Covers the installation of third-party software with both FreeBSD's innovative "Ports Collection" and standard binary packages.

Chapter 5, The X Window System

Describes the X Window System in general and using **XFree86** on FreeBSD in particular. Also describes common desktop environments such as **KDE** and **GNOME**.

Chapter 6, Configuration and Tuning

Describes the parameters available for system administrators to tune a FreeBSD system for optimum performance. Also describes the various configuration files used in FreeBSD and where to find them.

Chapter 7, Booting Process

Describes the FreeBSD boot process and explains how to control this process with configuration options.

Chapter 8, Users and Basic Account Management

Describes the creation and manipulation of user accounts. Also discusses resource limitations that can be set on users and other account management tasks.

Chapter 9, Configuring the FreeBSD Kernel

Explains why you might need to configure a new kernel and provides detailed instructions for configuring, building, and installing a custom kernel.

Chapter 10, Security

Describes many different tools available to help keep your FreeBSD system secure, including Kerberos, IPsec, OpenSSH, and network firewalls.

Chapter 11, Printing

Describes managing printers on FreeBSD, including information about banner pages, printer accounting, and initial setup.

Chapter 12, Storage

Describes how to manage storage media and filesystems with FreeBSD. This includes physical disks, RAID arrays, optical and tape media, memory-backed disks, and network filesystems.

Chapter 13, Vinum

Describes how to use Vinum, a logical volume manager which provides device-independent logical disks, and software RAID-0, RAID-1 and RAID-5.

Chapter 14, Localization

Describes how to use FreeBSD in languages other than English. Covers both system and application level localization.

Chapter 15, Desktop Applications

Lists some common desktop applications, such as web browsers and productivity suites, and describes how to install them on FreeBSD.

Chapter 16, Multimedia

Shows how to set up sound and video playback support for your system. Also describes some sample audio and video applications.

Chapter 17, Serial Communications

Explains how to connect terminals and modems to your FreeBSD system for both dial in and dial out connections.

Chapter 18, PPP and SLIP

Describes how to use PPP, SLIP, or PPP over Ethernet to connect to remote systems with FreeBSD.

Chapter 19, Advanced Networking

Describes many networking topics, including sharing an Internet connection with other computers on your LAN, using network filesystems, sharing account information via NIS, setting up a name server, and much more.

Chapter 20, Electronic Mail

Explains the different components of an email server and dives into simple configuration topics for the most popular mail server software: **sendmail**.

Chapter 21, The Cutting Edge

Explains the differences between FreeBSD-STABLE, FreeBSD-CURRENT, and FreeBSD releases. Describes which users would benefit from tracking a development system and outlines that process.

Chapter 22, Linux Binary Compatibility

Describes the Linux compatibility features of FreeBSD. Also provides detailed installation instructions for many popular Linux applications such as **Oracle**, **SAP R/3**, and **Mathematica®**.

Appendix A, Obtaining FreeBSD

Lists different sources for obtaining FreeBSD media on CDROM or DVD as well as different sites on the Internet that allow you to download and install FreeBSD.

Appendix B, Bibliography

This book touches on many different subjects that may leave you hungry for a more detailed explanation. The bibliography lists many excellent books that are referenced in the text.

Appendix C, Resources on the Internet

Describes the many forums available for FreeBSD users to post questions and engage in technical conversations about FreeBSD.

Appendix D, PGP Keys

Lists the PGP fingerprints of several FreeBSD Developers.

Conventions used in this book

To provide a consistent and easy to read text, several conventions are followed throughout the book.

Typographic Conventions

Italic

An *italic* font is used for filenames, URLs, emphasized text, and the first usage of technical terms.

`Monospace`

A `monospaced` font is used for error messages, commands, environment variables, names of ports, hostnames, user names, group names, device names, variables, and code fragments.

Bold

A **bold** font is used for applications, commands, and keys.

User Input

Keys are shown in **bold** to stand out from other text. Key combinations that are meant to be typed simultaneously are shown with '+' between the keys, such as:

Ctrl+**Alt**+**Del**

Meaning the user should type the **Ctrl**, **Alt**,and **Del** keys at the same time.

Keys that are meant to be typed in sequence will be separated with commas, for example:

Ctrl+**X**, **Ctrl**+**S**

Would mean that the user is expected to type the **Ctrl** and **X** keys simultaneously and then to type the **Ctrl** and **S** keys simultaneously.

Examples

Examples starting with `E:\>` indicate a MS-DOS® command. Unless otherwise noted, these commands may be executed from a "Command Prompt" window in a modern Microsoft® Windows® environment.

```
E:\> tools\fdimage floppies\kern.flp A:
```

Examples starting with `#` indicate a command that must be invoked as the superuser in FreeBSD. You can login as `root` to type the command, or login as your normal account and use su(1) to gain superuser privileges.

```
# dd if=kern.flp of=/dev/fd0
```

Examples starting with `%` indicate a command that should be invoked from a normal user account. Unless otherwise noted, C-shell syntax is used for setting environment variables and other shell commands.

```
% top
```

Acknowledgments

The book you are holding represents the efforts of many hundreds of people around the world. Whether they sent in fixes for typos, or submitted complete chapters, all the contributions have been useful.

Several companies have supported the development of this document by paying authors to work on it full-time, paying for publication, etc. In particular, BSDi (subsequently acquired by Wind River Systems (http://www.windriver.com)) paid members of the FreeBSD Documentation Project to work on improving this book full time leading up to the publication of the first printed edition in March 2000 (ISBN 1-57176-241-8). Wind River Systems then paid several additional authors to make a number of improvements to the print-output infrastructure and to add additional chapters to the text. This work culminated in the publication of the second printed edition in November 2001 (ISBN 1-57176-303-1).

I. Getting Started

This part of the FreeBSD Handbook is for users and administrators who are new to FreeBSD. These chapters:

- Introduce you to FreeBSD.
- Guide you through the installation process.
- Teach you UNIX basics and fundamentals.
- Show you how to install the wealth of third party applications available for FreeBSD.
- Introduce you to X, the UNIX windowing system, and detail how to configure a desktop environment that makes you more productive.

We have tried to keep the number of forward references in the text to a minimum so that you can read this section of the Handbook from front to back with the minimum page flipping required.

Chapter 1 Introduction

Restructured, reorganized, and parts rewritten by Jim Mock.

1.1 Synopsis

Thank you for your interest in FreeBSD! The following chapter covers various aspects of the FreeBSD Project, such as its history, goals, development model, and so on.

After reading this chapter, you will know:

- How FreeBSD relates to other computer operating systems.
- The history of the FreeBSD Project.
- The goals of the FreeBSD Project.
- The basics of the FreeBSD open-source development model.
- And of course: where the name "FreeBSD" comes from.

1.2 Welcome to FreeBSD!

FreeBSD is a 4.4BSD-Lite based operating system for Intel (x86), DEC Alpha™, and Sun UltraSPARC® computers. Ports to other architectures are also underway. You can also read about the history of FreeBSD, or the current release. If you are interested in contributing something to the Project (code, hardware, unmarked bills), see the Contributing to FreeBSD (../../articles/contributing/index.html) article.

1.2.1 What Can FreeBSD Do?

FreeBSD has many noteworthy features. Some of these are:

- *Preemptive multitasking* with dynamic priority adjustment to ensure smooth and fair sharing of the computer between applications and users, even under the heaviest of loads.
- *Multi-user facilities* which allow many people to use a FreeBSD system simultaneously for a variety of things. This means, for example, that system peripherals such as printers and tape drives are properly shared between all users on the system or the network and that individual resource limits can be placed on users or groups of users, protecting critical system resources from over-use.
- Strong *TCP/IP networking* with support for industry standards such as SLIP, PPP, NFS, DHCP, and NIS. This means that your FreeBSD machine can interoperate easily with other systems as well as act as an enterprise server, providing vital functions such as NFS (remote file access) and email services or putting your organization on the Internet with WWW, FTP, routing and firewall (security) services.
- *Memory protection* ensures that applications (or users) cannot interfere with each other. One application crashing will not affect others in any way.
- FreeBSD is a *32-bit* operating system (*64-bit* on the Alpha and UltraSPARC) and was designed as such from the ground up.

- The industry standard *X Window System* (X11R6) provides a graphical user interface (GUI) for the cost of a common VGA card and monitor and comes with full sources.
- *Binary compatibility* with many programs built for Linux, SCO, SVR4, BSDI and NetBSD.
- Thousands of *ready-to-run* applications are available from the FreeBSD *ports* and *packages* collection. Why search the net when you can find it all right here?
- Thousands of additional and *easy-to-port* applications are available on the Internet. FreeBSD is source code compatible with most popular commercial UNIX systems and thus most applications require few, if any, changes to compile.
- Demand paged *virtual memory* and "merged VM/buffer cache" design efficiently satisfies applications with large appetites for memory while still maintaining interactive response to other users.
- *SMP* support for machines with multiple CPUs.
- A full complement of *C*, *C++*, *Fortran*, and *Perl* development tools. Many additional languages for advanced research and development are also available in the ports and packages collection.
- *Source code* for the entire system means you have the greatest degree of control over your environment. Why be locked into a proprietary solution at the mercy of your vendor when you can have a truly open system?
- Extensive *online documentation*.
- *And many more!*

FreeBSD is based on the 4.4BSD-Lite release from Computer Systems Research Group (CSRG) at the University of California at Berkeley, and carries on the distinguished tradition of BSD systems development. In addition to the fine work provided by CSRG, the FreeBSD Project has put in many thousands of hours in fine tuning the system for maximum performance and reliability in real-life load situations. As many of the commercial giants struggle to field PC operating systems with such features, performance and reliability, FreeBSD can offer them *now*!

The applications to which FreeBSD can be put are truly limited only by your own imagination. From software development to factory automation, inventory control to azimuth correction of remote satellite antennae; if it can be done with a commercial UNIX product then it is more than likely that you can do it with FreeBSD too! FreeBSD also benefits significantly from literally thousands of high quality applications developed by research centers and universities around the world, often available at little to no cost. Commercial applications are also available and appearing in greater numbers every day.

Because the source code for FreeBSD itself is generally available, the system can also be customized to an almost unheard of degree for special applications or projects, and in ways not generally possible with operating systems from most major commercial vendors. Here is just a sampling of some of the applications in which people are currently using FreeBSD:

- *Internet Services:* The robust TCP/IP networking built into FreeBSD makes it an ideal platform for a variety of Internet services such as:
  - FTP servers
  - World Wide Web servers (standard or secure [SSL])
  - Firewalls and NAT ("IP masquerading") gateways
  - Electronic Mail servers
  - USENET News or Bulletin Board Systems
  - And more...

With FreeBSD, you can easily start out small with an inexpensive 386 class PC and upgrade all the way up to a quad-processor Xeon with RAID storage as your enterprise grows.

- *Education:* Are you a student of computer science or a related engineering field? There is no better way of learning about operating systems, computer architecture and networking than the hands on, under the hood experience that FreeBSD can provide. A number of freely available CAD, mathematical and graphic design packages also make it highly useful to those whose primary interest in a computer is to get *other* work done!
- *Research:* With source code for the entire system available, FreeBSD is an excellent platform for research in operating systems as well as other branches of computer science. FreeBSD's freely available nature also makes it possible for remote groups to collaborate on ideas or shared development without having to worry about special licensing agreements or limitations on what may be discussed in open forums.
- *Networking:* Need a new router? A name server (DNS)? A firewall to keep people out of your internal network? FreeBSD can easily turn that unused 386 or 486 PC sitting in the corner into an advanced router with sophisticated packet-filtering capabilities.
- *X Window workstation:* FreeBSD is a fine choice for an inexpensive X terminal solution, either using the freely available XFree86 server or one of the excellent commercial servers provided by Xi Graphics (http://www.xig.com). Unlike an X terminal, FreeBSD allows many applications to be run locally if desired, thus relieving the burden on a central server. FreeBSD can even boot "diskless", making individual workstations even cheaper and easier to administer.
- *Software Development:* The basic FreeBSD system comes with a full complement of development tools including the renowned GNU C/C++ compiler and debugger.

FreeBSD is available in both source and binary form on CDROM, DVD, and via anonymous FTP. Please see Appendix A for more information about obtaining FreeBSD.

1.2.2 Who Uses FreeBSD?

FreeBSD is used to power some of the biggest sites on the Internet, including:

- Yahoo! (http://www.yahoo.com/)
- Apache (http://www.apache.org/)
- Blue Mountain Arts (http://www.bluemountain.com/)
- Pair Networks (http://www.pair.com/)
- Sony Japan (http://www.sony.co.jp/)
- Netcraft (http://www.netcraft.com/)
- Weathernews (http://www.wni.com/)
- Supervalu (http://www.supervalu.com/)
- TELEHOUSE America (http://www.telehouse.com/)
- Sophos Anti-Virus (http://www.sophos.com/)
- JMA Wired (http://www.jmawired.com/)

and many more.

1.3 About the FreeBSD Project

The following section provides some background information on the project, including a brief history, project goals, and the development model of the project.

1.3.1 A Brief History of FreeBSD

Contributed by Jordan Hubbard.

The FreeBSD project had its genesis in the early part of 1993, partially as an outgrowth of the "Unofficial 386BSD Patchkit" by the patchkit's last 3 coordinators: Nate Williams, Rod Grimes and myself.

Our original goal was to produce an intermediate snapshot of 386BSD in order to fix a number of problems with it that the patchkit mechanism just was not capable of solving. Some of you may remember the early working title for the project being "386BSD 0.5" or "386BSD Interim" in reference to that fact.

386BSD was Bill Jolitz's operating system, which had been up to that point suffering rather severely from almost a year's worth of neglect. As the patchkit swelled ever more uncomfortably with each passing day, we were in unanimous agreement that something had to be done and decided to assist Bill by providing this interim "cleanup" snapshot. Those plans came to a rude halt when Bill Jolitz suddenly decided to withdraw his sanction from the project without any clear indication of what would be done instead.

It did not take us long to decide that the goal remained worthwhile, even without Bill's support, and so we adopted the name "FreeBSD", coined by David Greenman. Our initial objectives were set after consulting with the system's current users and, once it became clear that the project was on the road to perhaps even becoming a reality, I contacted Walnut Creek CDROM with an eye toward improving FreeBSD's distribution channels for those many unfortunates without easy access to the Internet. Walnut Creek CDROM not only supported the idea of distributing FreeBSD on CD but also went so far as to provide the project with a machine to work on and a fast Internet connection. Without Walnut Creek CDROM's almost unprecedented degree of faith in what was, at the time, a completely unknown project, it is quite unlikely that FreeBSD would have gotten as far, as fast, as it has today.

The first CDROM (and general net-wide) distribution was FreeBSD 1.0, released in December of 1993. This was based on the 4.3BSD-Lite ("Net/2") tape from U.C. Berkeley, with many components also provided by 386BSD and the Free Software Foundation. It was a fairly reasonable success for a first offering, and we followed it with the highly successful FreeBSD 1.1 release in May of 1994.

Around this time, some rather unexpected storm clouds formed on the horizon as Novell and U.C. Berkeley settled their long-running lawsuit over the legal status of the Berkeley Net/2 tape. A condition of that settlement was U.C. Berkeley's concession that large parts of Net/2 were "encumbered" code and the property of Novell, who had in turn acquired it from AT&T some time previously. What Berkeley got in return was Novell's "blessing" that the 4.4BSD-Lite release, when it was finally released, would be declared unencumbered and all existing Net/2 users would be strongly encouraged to switch. This included FreeBSD, and the project was given until the end of July 1994 to stop shipping its own Net/2 based product. Under the terms of that agreement, the project was allowed one last release before the deadline, that release being FreeBSD 1.1.5.1.

FreeBSD then set about the arduous task of literally re-inventing itself from a completely new and rather incomplete set of 4.4BSD-Lite bits. The "Lite" releases were light in part because Berkeley's CSRG had removed large chunks of code required for actually constructing a bootable running system (due to various legal requirements) and the fact that the Intel port of 4.4 was highly incomplete. It took the project until November of 1994 to make this transition, at which point it released FreeBSD 2.0 to the net and on CDROM (in late December). Despite being still more than a little rough around the edges, the release was a significant success and was followed by the more robust and easier to install FreeBSD 2.0.5 release in June of 1995.

We released FreeBSD 2.1.5 in August of 1996, and it appeared to be popular enough among the ISP and commercial communities that another release along the 2.1-STABLE branch was merited. This was FreeBSD 2.1.7.1, released in February 1997 and capping the end of mainstream development on 2.1-STABLE. Now in maintenance mode, only security enhancements and other critical bug fixes will be done on this branch (RELENG_2_1_0).

FreeBSD 2.2 was branched from the development mainline ("-CURRENT") in November 1996 as the RELENG_2_2 branch, and the first full release (2.2.1) was released in April 1997. Further releases along the 2.2 branch were done in the summer and fall of '97, the last of which (2.2.8) appeared in November 1998. The first official 3.0 release appeared in October 1998 and spelled the beginning of the end for the 2.2 branch.

The tree branched again on Jan 20, 1999, leading to the 4.0-CURRENT and 3.X-STABLE branches. From 3.X-STABLE, 3.1 was released on February 15, 1999, 3.2 on May 15, 1999, 3.3 on September 16, 1999, 3.4 on December 20, 1999, and 3.5 on June 24, 2000, which was followed a few days later by a minor point release update to 3.5.1, to incorporate some last-minute security fixes to Kerberos. This will be the final release in the 3.X branch.

There was another branch on March 13, 2000, which saw the emergence of the 4.X-STABLE branch, now considered to be the "current -stable branch". There have been several releases from it so far: 4.0-RELEASE was introduced in March 2000, and the most recent 4.9-RELEASE came out in October 2003. There will be additional releases along the 4.X-stable (RELENG_4) branch well into 2003.

The long-awaited 5.0-RELEASE was announced on January 19, 2003. The culmination of nearly three years of work, this release started FreeBSD on the path of advanced multiprocessor and application thread support and introduced support for the UltraSPARC and `ia64` platforms. This release was followed by 5.1 in June of 2003. Besides a number of new features, the 5.X releases also contain a number of major developments in the underlying system architecture. Along with these advances, however, comes a system that incorporates a tremendous amount of new and not-widely-tested code. For this reason, the 5.X releases are considered "New Technology" releases, while the 4.X series function as "Production" releases. In time, 5.X will be declared stable and work will commence on the next development branch, 6.0-CURRENT.

For now, long-term development projects continue to take place in the 5.X-CURRENT (trunk) branch, and SNAPshot releases of 5.X on CDROM (and, of course, on the net) are continually made available from the snapshot server (ftp://current.FreeBSD.org/pub/FreeBSD/snapshots/) as work progresses.

1.3.2 FreeBSD Project Goals

Contributed by Jordan Hubbard.

The goals of the FreeBSD Project are to provide software that may be used for any purpose and without strings attached. Many of us have a significant investment in the code (and project) and would certainly not mind a little financial compensation now and then, but we are definitely not prepared to insist on it. We believe that our first and foremost "mission" is to provide code to any and all comers, and for whatever purpose, so that the code gets the widest possible use and provides the widest possible benefit. This is, I believe, one of the most fundamental goals of Free Software and one that we enthusiastically support.

That code in our source tree which falls under the GNU General Public License (GPL) or Library General Public License (LGPL) comes with slightly more strings attached, though at least on the side of enforced access rather than the usual opposite. Due to the additional complexities that can evolve in the commercial use of GPL software we do, however, prefer software submitted under the more relaxed BSD copyright when it is a reasonable option to do so.

1.3.3 The FreeBSD Development Model

Contributed by Satoshi Asami.

The development of FreeBSD is a very open and flexible process, being literally built from the contributions of hundreds of people around the world, as can be seen from our list of contributors (../../articles/contributors/article.html). FreeBSD's development infrastructure allow these hundreds of developers to collaborate over the Internet. We are constantly on the lookout for new developers and ideas, and those interested in becoming more closely involved with the project need simply contact us at the FreeBSD technical discussions mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-hackers). The FreeBSD announcements mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-announce) is also available to those wishing to make other FreeBSD users aware of major areas of work.

Useful things to know about the FreeBSD project and its development process, whether working independently or in close cooperation:

The CVS repository

The central source tree for FreeBSD is maintained by CVS (http://www.cvshome.org/) (Concurrent Versions System), a freely available source code control tool that comes bundled with FreeBSD. The primary CVS repository (http://www.FreeBSD.org/cgi/cvsweb.cgi) resides on a machine in Santa Clara CA, USA from where it is replicated to numerous mirror machines throughout the world. The CVS tree, which contains the -CURRENT and -STABLE trees, can all be easily replicated to your own machine as well. Please refer to the Synchronizing your source tree section for more information on doing this.

The committers list

The *committers* are the people who have *write* access to the CVS tree, and are authorized to make modifications to the FreeBSD source (the term "committer" comes from the cvs(1) `commit` command, which is used to bring new changes into the CVS repository). The best way of making submissions for review by the committers list is to use the send-pr(1) command. If something appears to be jammed in the system, then you may also reach them by sending mail to the FreeBSD committer's mailing list.

The FreeBSD core team

The *FreeBSD core team* would be equivalent to the board of directors if the FreeBSD Project were a company. The primary task of the core team is to make sure the project, as a whole, is in good shape and is heading in the right directions. Inviting dedicated and responsible developers to join our group of committers is one of the functions of the core team, as is the recruitment of new core team members as others move on. The current core team was elected from a pool of committer candidates in June 2002. Elections are held every 2 years.

Some core team members also have specific areas of responsibility, meaning that they are committed to ensuring that some large portion of the system works as advertised. For a complete list of FreeBSD developers and their areas of responsibility, please see the Contributors List (../../articles/contributors/article.html)

> **Note:** Most members of the core team are volunteers when it comes to FreeBSD development and do not benefit from the project financially, so "commitment" should also not be misconstrued as meaning "guaranteed support." The "board of directors" analogy above is not very accurate, and it may be more suitable to say that these are the people who gave up their lives in favor of FreeBSD against their better judgment!

Outside contributors

Last, but definitely not least, the largest group of developers are the users themselves who provide feedback and bug fixes to us on an almost constant basis. The primary way of keeping in touch with FreeBSD's more non-centralized development is to subscribe to the FreeBSD technical discussions mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-hackers) where such things are discussed. See Appendix C for more information about the various FreeBSD mailing lists.

The FreeBSD Contributors List (../../articles/contributors/article.html) is a long and growing one, so why not join it by contributing something back to FreeBSD today?

Providing code is not the only way of contributing to the project; for a more complete list of things that need doing, please refer to the FreeBSD Project web site (../../../../index.html).

In summary, our development model is organized as a loose set of concentric circles. The centralized model is designed for the convenience of the *users* of FreeBSD, who are provided with an easy way of tracking one central code base, not to keep potential contributors out! Our desire is to present a stable operating system with a large set of coherent application programs that the users can easily install and use — this model works very well in accomplishing that.

All we ask of those who would join us as FreeBSD developers is some of the same dedication its current people have to its continued success!

1.3.4 The Current FreeBSD Release

FreeBSD is a freely available, full source 4.4BSD-Lite based release for Intel i386™, i486™, Pentium®, Pentium Pro, Celeron®, Pentium II, Pentium III, Pentium 4 (or compatible), Xeon™, DEC Alpha and Sun UltraSPARC based computer systems. It is based primarily on software from U.C. Berkeley's CSRG group, with some enhancements from NetBSD, OpenBSD, 386BSD, and the Free Software Foundation.

Since our release of FreeBSD 2.0 in late 94, the performance, feature set, and stability of FreeBSD has improved dramatically. The largest change is a revamped virtual memory system with a merged VM/file buffer cache that not only increases performance, but also reduces FreeBSD's memory footprint, making a 5 MB configuration a more acceptable minimum. Other enhancements include full NIS client and server support, transaction TCP support, dial-on-demand PPP, integrated DHCP support, an improved SCSI subsystem, ISDN support, support for ATM, FDDI, Fast and Gigabit Ethernet (1000 Mbit) adapters, improved support for the latest Adaptec controllers, and many thousands of bug fixes.

In addition to the base distributions, FreeBSD offers a ported software collection with thousands of commonly sought-after programs. At the time of this printing, there were over 9,200 ports! The list of ports ranges from http (WWW) servers, to games, languages, editors, and almost everything in between. The entire ports collection requires approximately 300 MB of storage, all ports being expressed as "deltas" to their original sources. This makes it much easier for us to update ports, and greatly reduces the disk space demands made by the older 1.0 ports collection. To compile a port, you simply change to the directory of the program you wish to install, type `make install`, and let the system do the rest. The full original distribution for each port you build is retrieved dynamically off the CDROM or a local FTP site, so you need only enough disk space to build the ports you want. Almost every port is also provided as a pre-compiled "package", which can be installed with a simple command (`pkg_add`) by those who do not wish to compile their own ports from source. More information on packages and ports can be found in Chapter 4.

A number of additional documents which you may find very helpful in the process of installing and using FreeBSD may now also be found in the `/usr/share/doc` directory on any recent FreeBSD machine. You may view the locally installed manuals with any HTML capable browser using the following URLs:

The FreeBSD Handbook

`/usr/share/doc/handbook/index.html`

The FreeBSD FAQ

`/usr/share/doc/faq/index.html`

You can also view the master (and most frequently updated) copies at http://www.FreeBSD.org/ (../../../../index.html).

Chapter 2 Installing FreeBSD

Restructured, reorganized, and parts rewritten by Jim Mock. The sysinstall walkthrough, screenshots, and general copy by Randy Pratt.

2.1 Synopsis

FreeBSD is provided with a text-based, easy to use installation program called **sysinstall**. This is the default installation program for FreeBSD, although vendors are free to provide their own installation suite if they wish. This chapter describes how to use **sysinstall** to install FreeBSD.

After reading this chapter, you will know:

- How to create the FreeBSD installation disks.
- How FreeBSD refers to, and subdivides, your hard disks.
- How to start **sysinstall**.
- The questions **sysinstall** will ask you, what they mean, and how to answer them.

Before reading this chapter, you should:

- Read the supported hardware list that shipped with the version of FreeBSD you are installing, and verify that your hardware is supported.

> **Note:** In general, these installation instructions are written for i386 ("PC compatible") architecture computers. Where applicable, instructions specific to other platforms (for example, Alpha) will be listed. Although this guide is kept as up to date as possible, you may find minor differences between the installer and what is shown here. It is suggested that you use this chapter as a general guide rather than a literal installation manual.

2.2 Pre-installation Tasks

2.2.1 Inventory Your Computer

Before installing FreeBSD you should attempt to inventory the components in your computer. The FreeBSD installation routines will show you the components (hard disks, network cards, CDROM drives, and so forth) with their model number and manufacturer. FreeBSD will also attempt to determine the correct configuration for these devices, which includes information about IRQ and IO port usage. Due to the vagaries of PC hardware this process is not always completely successful, and you may need to correct FreeBSD's determination of your configuration.

If you already have another operating system installed, such as Windows or Linux, it is a good idea to use the facilities provided by those operating systems to see how your hardware is already configured. If you are not sure what settings an expansion card is using, you may find it printed on the card itself. Popular IRQ numbers are 3, 5, and 7, and IO port addresses are normally written as hexadecimal numbers, such as 0x330.

We recommend you print or write down this information before installing FreeBSD. It may help to use a table, like this:

Table 2-1. Sample Device Inventory

Device Name	IRQ	IO port(s)	Notes
First hard disk	N/A	N/A	40 GB, made by Seagate, first IDE master
CDROM	N/A	N/A	First IDE slave
Second hard disk	N/A	N/A	20 GB, made by IBM, second IDE master
First IDE controller	14	0x1f0	
Network card	N/A	N/A	Intel® 10/100
Modem	N/A	N/A	3Com® 56K faxmodem, on COM1
. . .			

2.2.2 Backup Your Data

If the computer you will be installing FreeBSD on contains valuable data, then ensure you have it backed up, and that you have tested the backups before installing FreeBSD. The FreeBSD installation routine will prompt you before writing any data to your disk, but once that process has started it cannot be undone.

2.2.3 Decide Where to Install FreeBSD

If you want FreeBSD to use your entire hard disk, then there is nothing more to concern yourself with at this point — you can skip this section.

However, if you need FreeBSD to co-exist with other operating systems then you need to have a rough understanding of how data is laid out on the disk, and how this affects you.

2.2.3.1 Disk Layouts for the i386™

A PC disk can be divided into discrete chunks. These chunks are called *partitions*. By design, the PC only supports four partitions per disk. These partitions are called *primary partitions*. To work around this limitation and allow more than four partitions, a new partition type was created, the *extended partition*. A disk may contain only one extended partition. Special partitions, called *logical partitions*, can be created inside this extended partition.

Each partition has a *partition ID*, which is a number used to identify the type of data on the partition. FreeBSD partitions have the partition ID of `165`.

In general, each operating system that you use will identify partitions in a particular way. For example, DOS, and its descendants, like Windows, assign each primary and logical partition a *drive letter*, starting with `C:`.

FreeBSD must be installed into a primary partition. FreeBSD can keep all its data, including any files that you create, on this one partition. However, if you have multiple disks, then you can create a FreeBSD partition on all, or some, of them. When you install FreeBSD, you must have one partition available. This might be a blank partition that you have prepared, or it might be an existing partition that contains data that you no longer care about.

If you are already using all the partitions on all your disks, then you will have to free one of them for FreeBSD using the tools provided by the other operating systems you use (e.g., `fdisk` on DOS or Windows).

If you have a spare partition then you can use that. However, you may need to shrink one or more of your existing partitions first.

A minimal installation of FreeBSD takes as little as 100 MB of disk space. However, that is a *very* minimal install, leaving almost no space for your own files. A more realistic minimum is 250 MB without a graphical environment, and 350 MB or more if you want a graphical user interface. If you intend to install a lot of third party software as well, then you will need more space.

You can use a commercial tool such as **PartitionMagic®** to resize your partitions to make space for FreeBSD. The `tools` directory on the CDROM contains two free software tools which can carry out this task, namely **FIPS** and **PResizer**. **FIPS**, **PResizer**, and **PartitionMagic** can resize FAT16 and FAT32 partitions — used in MS-DOS through Windows ME. **PartitionMagic** is the only known application that can resize NTFS. Documentation for both of these is available in the same directory.

> **Warning:** Incorrect use of these tools can delete the data on your disk. Be sure that you have recent, working backups before using them.

Example 2-1. Using an Existing Partition Unchanged

Suppose that you have a computer with a single 4 GB disk that already has a version of Windows installed, and you have split the disk into two drive letters, `C:` and `D:`, each of which is 2 GB in size. You have 1 GB of data on `C:`, and 0.5 GB of data on `D:`.

This means that your disk has two partitions on it, one per drive letter. You can copy all your existing data from `D:` to `C:`, which will free up the second partition, ready for FreeBSD.

Example 2-2. Shrinking an Existing Partition

Suppose that you have a computer with a single 4 GB disk that already has a version of Windows installed. When you installed Windows you created one large partition, giving you a `C:` drive that is 4 GB in size. You are currently using 1.5 GB of space, and want FreeBSD to have 2 GB of space.

In order to install FreeBSD you will need to either:

1. Backup your Windows data, and then reinstall Windows, asking for a 2 GB partition at install time.
2. Use one of the tools such as **PartitionMagic**, described above, to shrink your Windows partition.

2.2.3.2 Disk Layouts for the Alpha

You will need a dedicated disk for FreeBSD on the Alpha. It is not possible to share a disk with another operating system at this time. Depending on the specific Alpha machine you have, this disk can either be a SCSI disk or an IDE disk, as long as your machine is capable of booting from it.

Following the conventions of the Digital / Compaq manuals all SRM input is shown in uppercase. SRM is case insensitive.

To find the names and types of disks in your machine, use the `SHOW DEVICE` command from the SRM console prompt:

```
>>>SHOW DEVICE
dka0.0.0.4.0            DKA0           TOSHIBA CD-ROM XM-57  3476
dkc0.0.0.1009.0         DKC0                     RZ1BB-BS  0658
dkc100.1.0.1009.0       DKC100           SEAGATE ST34501W  0015
dva0.0.0.0.1            DVA0
ewa0.0.0.3.0            EWA0            00-00-F8-75-6D-01
pkc0.7.0.1009.0         PKC0                SCSI Bus ID 7  5.27
pqa0.0.0.4.0            PQA0                     PCI EIDE
pqb0.0.1.4.0            PQB0                     PCI EIDE
```

This example is from a Digital Personal Workstation 433au and shows three disks attached to the machine. The first is a CDROM drive called `DKA0` and the other two are disks and are called `DKC0` and `DKC100` respectively.

Disks with names of the form `DKx` are SCSI disks. For example `DKA100` refers to a SCSI disk with SCSI target ID 1 on the first SCSI bus (A), whereas `DKC300` refers to a SCSI disk with SCSI ID 3 on the third SCSI bus (C). Devicename `PKx` refers to the SCSI host bus adapter. As seen in the `SHOW DEVICE` output SCSI CDROM drives are treated as any other SCSI hard disk drive.

IDE disks have names similar to `DQx`, while `PQx` is the associated IDE controller.

2.2.4 Collect Your Network Configuration Details

If you intend to connect to a network as part of your FreeBSD installation (for example, if you will be installing from an FTP site or an NFS server), then you need to know your network configuration. You will be prompted for this information during the installation so that FreeBSD can connect to the network to complete the install.

2.2.4.1 Connecting to an Ethernet Network or Cable/DSL Modem

If you connect to an Ethernet network, or you have an Internet connection using an Ethernet adapter via cable or DSL, then you will need the following information:

1. IP address
2. IP address of the default gateway
3. Hostname
4. DNS server IP addresses
5. Subnet Mask

If you do not know this information, then ask your system administrator or service provider. They may say that this information is assigned automatically, using *DHCP*. If so, make a note of this.

2.2.4.2 Connecting Using a Modem

If you dial up to an ISP using a regular modem then you can still install FreeBSD over the Internet, it will just take a very long time.

You will need to know:

1. The phone number to dial for your ISP
2. The COM: port your modem is connected to
3. The username and password for your ISP account

2.2.5 Check for FreeBSD Errata

Although the FreeBSD project strives to ensure that each release of FreeBSD is as stable as possible, bugs do occasionally creep into the process. On very rare occasions those bugs affect the installation process. As these problems are discovered and fixed, they are noted in the FreeBSD Errata (http://www.freebsd.org/releases/5.1R/errata.html), which is found on the FreeBSD web site. You should check the errata before installing to make sure that there are no late-breaking problems which you should be aware of.

Information about all the releases, including the errata for each release, can be found on the release information (../../../../releases/index.html) section of the FreeBSD web site (../../../../index.html).

2.2.6 Obtain the FreeBSD Installation Files

The FreeBSD installation process can install FreeBSD from files located in the any of the following places:

Local Media

- A CDROM or DVD
- A DOS partition on the same computer
- A SCSI or QIC tape
- Floppy disks

Network

- An FTP site, going through a firewall, or using an HTTP proxy, as necessary
- An NFS server
- A dedicated parallel or serial connection

If you have purchased FreeBSD on CD or DVD then you already have everything you need, and should proceed to the next section (Preparing the Boot Media).

If you have not obtained the FreeBSD installation files you should skip ahead to Section 2.13 which explains how to prepare to install FreeBSD from any of the above. After reading that section, you should come back here, and read on to Section 2.2.7.

2.2.7 Prepare the Boot Media

The FreeBSD installation process is started by booting your computer into the FreeBSD installer—it is not a program you run within another operating system. Your computer normally boots using the operating system installed on your hard disk, but it can also be configured to use a "bootable" floppy disk. Most modern computers can also boot from a CDROM in the CDROM drive.

> **Tip:** If you have FreeBSD on CDROM or DVD (either one you purchased or you prepared yourself), and your computer allows you to boot from the CDROM or DVD (typically a BIOS option called "Boot Order" or similar), then you can skip this section. The FreeBSD CDROM and DVD images are bootable and can be used to install FreeBSD without any other special preparation.

To create boot floppy images, follow these steps:

1. Acquire the Boot Floppy Images

   The boot disks are available on your installation media in the `floppies/` directory, and can also be downloaded from the floppies directory (ftp://ftp.FreeBSD.org/pub/FreeBSD/releases/i386/5.1-RELEASE/floppies/) for the i386 architecture and from this floppies directory (ftp://ftp.FreeBSD.org/pub/FreeBSD/releases/alpha/5.1-RELEASE/floppies/) for the Alpha architecture.

   The floppy images have a `.flp` extension. The `floppies/` directory contains a number of different images, and the ones you will need to use depends on the version of FreeBSD you are installing, and in some cases, the hardware you are installing to. In most cases you will just need two files, `kern.flp` and `mfsroot.flp`. Additional device drivers may be necessary for some systems. These drivers are provided on the `drivers.flp` image. Check `README.TXT` in the same directory for the most up to date information about these floppy images.

   > **Important:** Your FTP program must use *binary mode* to download these disk images. Some web browsers have been known to use *text* (or *ASCII*) mode, which will be apparent if you cannot boot from the disks.

2. Prepare the Floppy Disks

   You must prepare one floppy disk per image file you had to download. It is imperative that these disks are free from defects. The easiest way to test this is to format the disks for yourself. Do not trust pre-formatted floppies. The format utility in Windows will not tell about the presence of bad blocks, it simply marks them as "bad" and ignores them. It is advised that you use brand new floppies if choosing this installation route.

   > **Important:** If you try to install FreeBSD and the installation program crashes, freezes, or otherwise misbehaves, one of the first things to suspect is the floppies. Try writing the floppy image files to new disks and try again.

3. Write the Image Files to the Floppy Disks

   The `.flp` files are *not* regular files you copy to the disk. They are images of the complete contents of the disk. This means that you *cannot* simply copy files from one disk to another. Instead, you must use specific tools to write the images directly to the disk.

   If you are creating the floppies on a computer running MS-DOS/Windows, then we provide a tool to do this called `fdimage`.

   If you are using the floppies from the CDROM, and your CDROM is the `E:` drive, then you would run this:

   ```
   E:\> tools\fdimage floppies\kern.flp A:
   ```

Repeat this command for each `.flp` file, replacing the floppy disk each time, being sure to label the disks with the name of the file that you copied to them. Adjust the command line as necessary, depending on where you have placed the `.flp` files. If you do not have the CDROM, then `fdimage` can be downloaded from the `tools` directory (ftp://ftp.FreeBSD.org/pub/FreeBSD/tools/) on the FreeBSD FTP site.

If you are writing the floppies on a UNIX system (such as another FreeBSD system) you can use the dd(1) command to write the image files directly to disk. On FreeBSD, you would run:

```
# dd if=kern.flp of=/dev/fd0
```

On FreeBSD, `/dev/fd0` refers to the first floppy disk (the `A:` drive). `/dev/fd1` would be the `B:` drive, and so on. Other UNIX variants might have different names for the floppy disk devices, and you will need to check the documentation for the system as necessary.

You are now ready to start installing FreeBSD.

2.3 Starting the Installation

Important: By default, the installation will not make any changes to your disk(s) until you see the following message:

```
Last Chance: Are you SURE you want continue the installation?

If you're running this on a disk with data you wish to save then WE
STRONGLY ENCOURAGE YOU TO MAKE PROPER BACKUPS before proceeding!

We can take no responsibility for lost disk contents!
```

The install can be exited at any time prior to the final warning without changing the contents of the hard drive. If you are concerned that you have configured something incorrectly you can just turn the computer off before this point, and no damage will be done.

2.3.1 Booting

2.3.1.1 Booting for the i386

1. Start with your computer turned off.
2. Turn on the computer. As it starts it should display an option to enter the system set up menu, or BIOS, commonly reached by keys like **F2**, **F10**, **Del,** or **Alt**+**S**. Use whichever keystroke is indicated on screen. In some cases your computer may display a graphic while it starts. Typically, pressing **Esc** will dismiss the graphic and allow you to see the necessary messages.
3. Find the setting that controls which devices the system boots from. This is usually labeled as the "Boot Order" and commonly shown as a list of devices, such as `Floppy`, `CDROM`, `First Hard Disk`, and so on.

If you needed to prepare boot floppies, then make sure that the floppy disk is selected. If you are booting from the CDROM then make sure that that is selected instead. In case of doubt, you should consult the manual that came with your computer, and/or its motherboard.

Make the change, then save and exit. The computer should now restart.

4. If you needed to prepare boot floppies, as described in Section 2.2.7, then one of them will be the first boot disc, probably the one containing `kern.flp`. Put this disc in your floppy drive.

   If you are booting from CDROM, then you will need to turn on the computer, and insert the CDROM at the first opportunity.

   If your computer starts up as normal and loads your existing operating system, then either:

   1. The disks were not inserted early enough in the boot process. Leave them in, and try restarting your computer.
   2. The BIOS changes earlier did not work correctly. You should redo that step until you get the right option.
   3. Your particular BIOS does not support booting from the desired media.

5. FreeBSD will start to boot. If you are booting from CDROM you will see a display similar to this (version information omitted):

```
Verifying DMI Pool Data ........
Boot from ATAPI CD-ROM :
 1. FD 2.88MB  System Type-(00)
Uncompressing ... done

BTX loader 1.00 BTX version is 1.01
Console: internal video/keyboard
BIOS drive A: is disk0
BIOS drive B: is disk1
BIOS drive C: is disk2
BIOS drive C: is disk3
BIOS 639kB/261120kB available memory

FreeBSD/i386 bootstrap loader, Revision 0.8

/kernel text=0x277391 data=0x3268c+0x332a8 |

|
Hit [Enter] to boot immediately, or any other key for command prompt.
Booting [kernel] in 9 seconds... _
```

   If you are booting from floppy disc, you will see a display similar to this (version information omitted):

```
Verifying DMI Pool Data ........

BTX loader 1.00  BTX version is 1.01
Console: internal video/keyboard
BIOS drive A: is disk0
BIOS drive C: is disk1
BIOS 639kB/261120kB available memory

FreeBSD/i386 bootstrap loader, Revision 0.8
```

```
/kernel text=0x277391 data=0x3268c+0x332a8 |

Please insert MFS root floppy and press enter:
```

Follow these instructions by removing the `kern.flp` disc, insert the `mfsroot.flp` disc, and press **Enter**.

6. Whether you booted from floppy or CDROM, the boot process will then get to this point:

   ```
   Hit [Enter] to boot immediately, or any other key for command prompt.
   Booting [kernel] in 9 seconds... _
   ```

   Either wait ten seconds, or press **Enter**. This will then launch the kernel configuration menu.

2.3.1.2 Booting for the Alpha

1. Start with your computer turned off.
2. Turn on the computer and wait for a boot monitor prompt.
3. If you needed to prepare boot floppies, as described in Section 2.2.7 then one of them will be the first boot disc, probably the one containing `kern.flp`. Put this disc in your floppy drive and type the following command to boot the disk (substituting the name of your floppy drive if necessary):

   >>>**BOOT DVA0 -FLAGS '' -FILE ''**

   If you are booting from CDROM, insert the CDROM into the drive and type the following command to start the installation (substituting the name of the appropriate CDROM drive if necessary):

   >>>**BOOT DKA0 -FLAGS '' -FILE ''**

4. FreeBSD will start to boot. If you are booting from a floppy disc, at some point you will see the message:

   ```
   Please insert MFS root floppy and press enter:
   ```

   Follow these instructions by removing the `kern.flp` disc, insert the `mfsroot.flp` disc, and press **Enter**.

5. Whether you booted from floppy or CDROM, the boot process will then get to this point:

   ```
   Hit [Enter] to boot immediately, or any other key for command prompt.
   Booting [kernel] in 9 seconds... _
   ```

   Either wait ten seconds, or press **Enter**. This will then launch the kernel configuration menu.

2.3.2 Kernel Configuration

> **Note:** From FreeBSD versions 5.0 and later, userconfig has been deprecated in favor of the new device.hints(5) method. For more information on device.hints(5) please visit Section 7.5

The *kernel* is the core of the operating system. It is responsible for many things, including access to all the devices you may have on your system, such as hard disks, network cards, sound cards, and so on. Each piece of hardware supported by the FreeBSD kernel has a driver associated with it. Each driver has a two or three letter name, such as `sa` for the SCSI sequential access driver, or `sio` for the Serial I/O driver (which manages COM ports).

When the kernel starts, each driver checks the system to see whether or not the hardware it supports exists on your system. If it does, then the driver configures the hardware and makes it available to the rest of the kernel.

This checking is commonly referred to as *device probing*. Unfortunately, it is not always possible to do this in a safe way. Some hardware drivers do not co-exist well, and probing for one piece of hardware can sometimes leave another in an inconsistent state. This is a basic limitation of the PC design.

Many older devices are called ISA devices—as opposed to PCI devices. The ISA specification requires each device to have some information hard coded into it, typically the Interrupt Request Line number (IRQ) and IO port address that the driver uses. This information is commonly set by using physical *jumpers* on the card, or by using a DOS based utility.

This was often a source of problems, because it was not possible to have two devices that shared the same IRQ or port address.

Newer devices follow the PCI specification, which does not require this, as the devices are supposed to cooperate with the BIOS, and are told which IRQ and IO port addresses to use.

If you have any ISA devices in your computer then FreeBSD's driver for that device will need to be configured with the IRQ and port address that you have set the card to. This is why carrying out an inventory of your hardware (see Section 2.2.1) can be useful.

Unfortunately, the default IRQs and memory ports used by some drivers clash. This is because some ISA devices are shipped with IRQs or memory ports that clash. The defaults in FreeBSD's drivers are deliberately set to mirror the manufacturer's defaults, so that, out of the box, as many devices as possible will work.

This is almost never an issue when running FreeBSD day-to-day. Your computer will not normally contain two pieces of hardware that clash, because one of them would not work (irrespective of the operating system you are using).

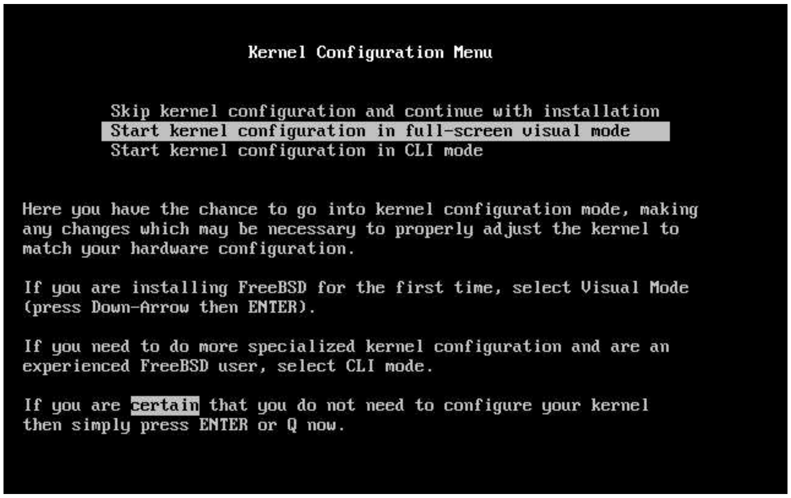
It becomes an issue when you are installing FreeBSD for the first time because the kernel used to carry out the install has to contain as many drivers as possible, so that many different hardware configurations can be supported. This means that some of those drivers will have conflicting configurations. The devices are probed in a strict order, and if you own a device that is probed late in the process, but conflicted with an earlier probe, then your hardware might not function or be probed correctly when you install FreeBSD.

Because of this, the first thing you have the opportunity to do when installing FreeBSD is look at the list of drivers that are configured into the kernel, and either disable some of them, if you do not own that device, or confirm (and alter) the driver's configuration if you do own the device but the defaults are wrong.

This probably sounds much more complicated than it actually is.

Figure 2-1 shows the first kernel configuration menu. We recommend that you choose the Start kernel confi guration in full-screen visual mode option, as it presents the easiest interface for the new user.

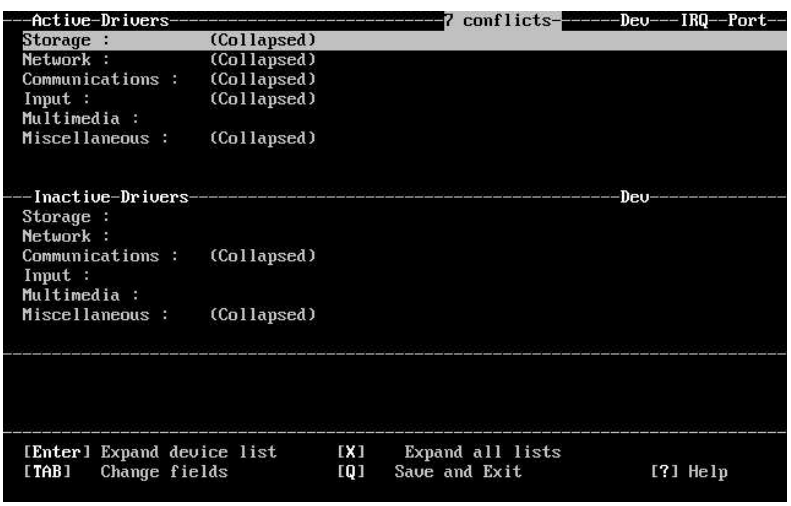
Figure 2-1. Kernel Configuration Menu



The kernel configuration screen (Figure 2-2) is then divided into four sections:

1. A collapsible list of all the drivers that are currently marked as “active”, subdivided into groups such as `Storage`, and `Network`. Each driver is shown as a description, its two or three letter driver name, and the IRQ and memory port used by that driver. In addition, if an active driver conflicts with another active driver then `CONF` is shown next to the driver name. This section also shows the total number of conflicting drivers that are currently active.
2. Drivers that have been marked inactive. They remain in the kernel, but they will not probe for their device when the kernel starts. These are subdivided into groups in the same way as the active driver list.
3. More detail about the currently selected driver, including its IRQ and memory port address.
4. Information about the keystrokes that are valid at this point in time.

Figure 2-2. The Kernel Device Configuration Visual Interface



Do not worry if any conflicts are listed, it is to be expected; all the drivers are enabled, and as has already been explained, some of them will conflict with one another.

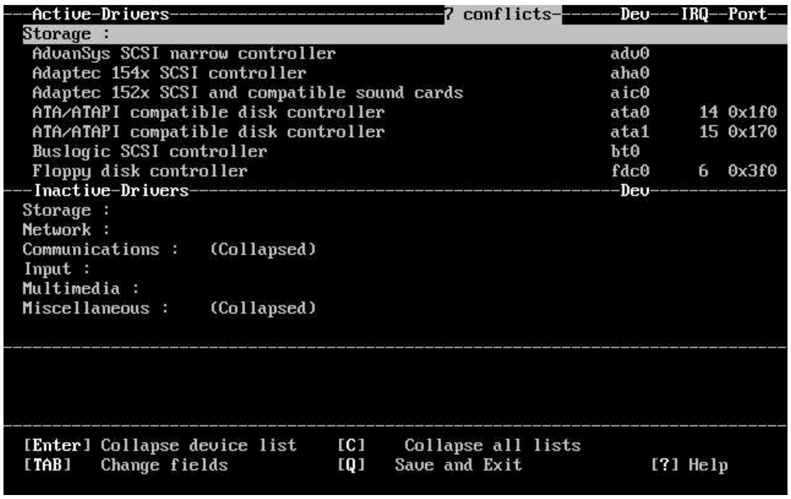
You now have to work through the list of drivers, resolving the conflicts.

Resolving Driver Conflicts

1. Press **X**. This will completely expand the list of drivers, so you can see all of them. You will need to use the arrow keys to scroll back and forth through the active driver list.

   Figure 2-3 shows the result of pressing **X**.

   Figure 2-3. Expanded Driver List



2. Disable all the drivers for devices that you do not have. To disable a driver, highlight it with the arrow keys and press **Del**. The driver will be moved to the `Inactive Drivers` list.

   If you inadvertently disable a device that you need then press **Tab** to switch to the `Inactive Drivers` list, select the driver that you disabled, and press **Enter** to move it back to the active list.

   > **Warning:** Do not disable `sc0`. This controls the screen, and you will need this unless you are installing over a serial cable.

   > **Warning:** Only disable `atkbd0` if you are using a USB keyboard. If you have a normal keyboard then you must keep `atkbd0`.

3. If there are no conflicts listed then you can skip this step. Otherwise, the remaining conflicts need to be examined. If they do not have the indication of an "allowed conflict" in the message area, then either the IRQ/address for device probe will need to be changed, *or* the IRQ/address on the hardware will need to be changed.

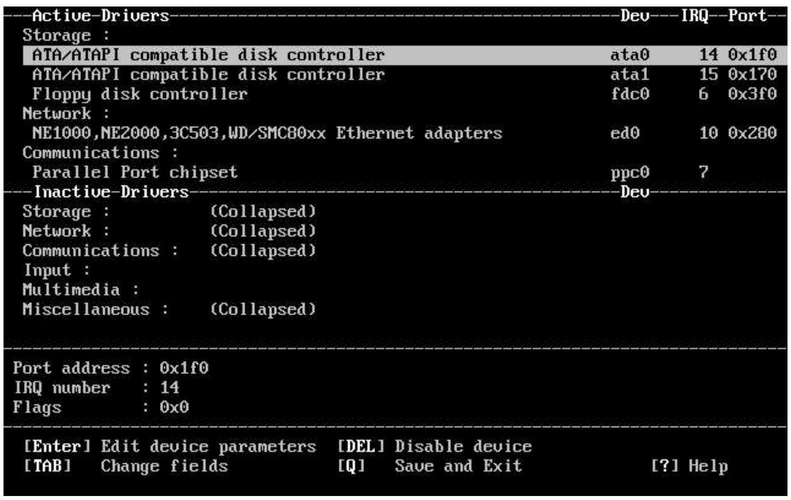
To change the driver's configuration for IRQ and IO port address, select the device and press **Enter**. The cursor will move to the third section of the screen, and you can change the values. You should enter the values for IRQ and port address that you discovered when you made your hardware inventory. Press **Q** to finish editing the device's configuration and return to the active driver list.

If you are not sure what these figures should be then you can try using `-1`. Some FreeBSD drivers can safely probe the hardware to discover what the correct value should be, and a value of `-1` configures them to do this.

The procedure for changing the address on the hardware varies from device to device. For some devices you may need to physically remove the card from your computer and adjust jumper settings or DIP switches. Other cards may have come with a DOS floppy that contains the programs used to reconfigure the card. In any case, you should refer to the documentation that came with the device. This will obviously entail restarting your computer, so you will need to boot back into the FreeBSD installation routine when you have reconfigured the card.

4. When all the conflicts have been resolved the screen will look similar to Figure 2-4.

Figure 2-4. Driver Configuration With No Conflicts



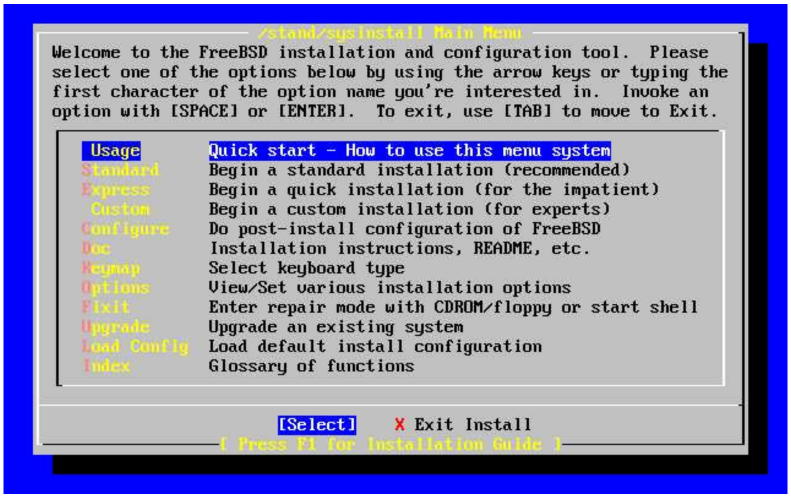
As you can see, the active driver list is now much smaller, with only drivers for the hardware that actually exists being listed.

You can now save these changes, and move on to the next step of the install. Press **Q** to quit the device configuration interface. This message will appear:

```
Save these parameters before exiting? ([Y]es/[N]o/[C]ancel)
```

Answer **Y** to save the parameters to memory (it will be saved to disk if you finish the install) and the probing will start. After displaying the probe results in white on black text **sysinstall** will start and display its main menu (Figure 2-5).

Figure 2-5. Sysinstall Main Menu



2.3.3 Reviewing the Device Probe Results

The last few hundred lines that have been displayed on screen are stored and can be reviewed.

To review the buffer, press **Scroll Lock**. This turns on scrolling in the display. You can then use the arrow keys, or **PageUp** and **PageDown** to view the results. Press **Scroll Lock** again to stop scrolling.

Do this now, to review the text that scrolled off the screen when the kernel was carrying out the device probes. You will see text similar to Figure 2-6, although the precise text will differ depending on the devices that you have in your computer.

Figure 2-6. Typical Device Probe Results

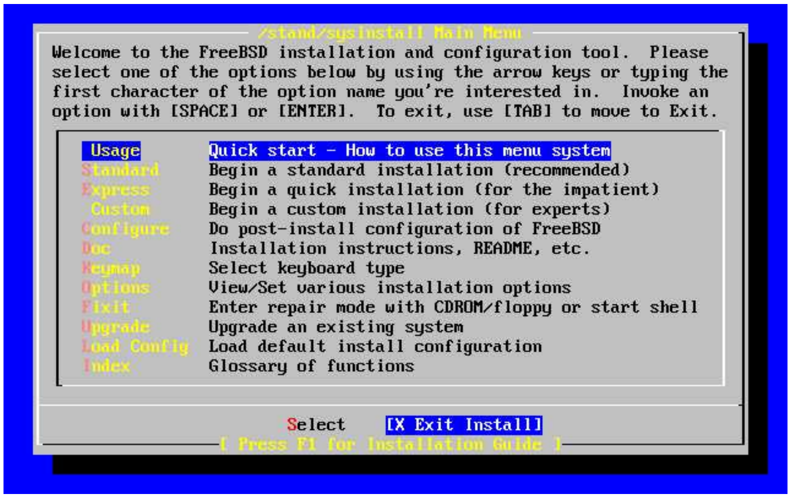
```
avail memory = 253050880 (247120K bytes)
Preloaded elf kernel "kernel" at 0xc0817000.
Preloaded mfs_root "/mfsroot" at 0xc0817084.
md0: Preloaded image </mfsroot> 4423680 bytes at 0xc03ddcd4

md1: Malloc disk
Using $PIR table, 4 entries at 0xc00fde60
npx0: <math processor> on motherboard
npx0: INT 16 interface
pcib0: <Host to PCI bridge> on motherboard
pci0: <PCI bus> on pcib0
pcib1:<VIA 82C598MVP (Apollo MVP3) PCI-PCI (AGP) bridge> at device 1.0 on pci0
pci1: <PCI bus> on pcib1
pci1: <Matrox MGA G200 AGP graphics accelerator> at 0.0 irq 11
isab0: <VIA 82C586 PCI-ISA bridge> at device 7.0 on pci0
isa0: <iSA bus> on isab0
atapci0: <VIA 82C586 ATA33 controller> port 0xe000-0xe00f at device 7.1 on pci0
ata0: at 0x1f0 irq 14 on atapci0
ata1: at 0x170 irq 15 on atapci0
```

```
uhci0 <VIA 83C572 USB controller> port 0xe400-0xe41f irq 10 at device 7.2 on pci
0
usb0: <VIA 83572 USB controller> on uhci0
usb0: USB revision 1.0
uhub0: VIA UHCI root hub, class 9/0, rev 1.00/1.00, addr1
uhub0: 2 ports with 2 removable, self powered
pci0: <unknown card> (vendor=0x1106, dev=0x3040) at 7.3
dc0: <ADMtek AN985 10/100BaseTX> port 0xe800-0xe8ff mem 0xdb000000-0xeb0003ff ir
q 11 at device 8.0 on pci0
dc0: Ethernet address: 00:04:5a:74:6b:b5
miibus0: <MII bus> on dc0
ukphy0: <Generic IEEE 802.3u media interface> on miibus0
ukphy0: 10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, auto
ed0: <NE2000 PCI Ethernet (RealTek 8029)> port 0xec00-0xec1f irq 9 at device 10.
0 on pci0
ed0 address 52:54:05:de:73:1b, type NE2000 (16 bit)
isa0: too many dependant configs (8)
isa0: unexpected small tag 14
orm0: <Option ROM> at iomem 0xc0000-0xc7fff on isa0
fdc0: <NEC 72065B or clone> at port 0x3f0-0x3f5,0x3f7 irq 6 drq2 on isa0
fdc0: FIFO enabled, 8 bytes threshold
fd0: <1440-KB 3.5" drive> on fdc0 drive 0
atkbdc0: <Keyboard controller (i8042)> at port 0x60,0x64 on isa0
atkbd0: <AT Keyboard> flags 0x1 irq1 on atkbdc0
kbd0 at atkbd0
psm0: <PS/2 Mouse> irq 12 on atkbdc0
psm0: model Generic PS/@ mouse, device ID 0
vga0: <Generic ISA VGA> at port 0x3c0-0x3df iomem 0xa0000-0xbffff on isa0
sc0: <System console> at flags 0x100 on isa0
sc0: VGA <16 virtual consoles, flags=0x300>
sio0 at port 0x3f8-0x3ff irq 4 flags 0x10 on isa0
sio0: type 16550A
sio1 at port 0x2f8-0x2ff irq 3 on isa0
sio1: type 16550A
ppc0: <Parallel port> at port 0x378-0x37f irq 7 on isa0
pppc0: SMC-like chipset (ECP/EPP/PS2/NIBBLE) in COMPATIBLE mode
ppc0: FIFO with 16/16/15 bytes threshold
plip0: <PLIP network interface> on ppbus0
ad0: 8063MB <IBM-DHEA-38451> [16383/16/63] at ata0-master UDMA33
acd0: CD-RW <LITE-ON LTR-1210B> at ata1-slave PIO4
Mounting root from ufs:/dev/md0c
/stand/sysinstall running as init on vty0
```

Check the probe results carefully to make sure that FreeBSD found all the devices you expected. If a device was not found, then it will not be listed. If the device's driver required configuring with the IRQ and port address then you should check that you entered them correctly.

If you need to make changes to the UserConfig device probing, it is easy to exit the **sysinstall** program and start over again. It is also a good way to become more familiar with the process.

Figure 2-7. Select Sysinstall Exit



Use the arrow keys to select Exit Install from the Main Install Screen menu. The following message will display:

```
                    User Confirmation Requested
        Are you sure you wish to exit? The system will reboot
          (be sure to remove any floppies from the drives).

                          [ Yes ]    No
```

The install program will start again if the CDROM is left in the drive and [Yes] is selected.

If you are booting from floppies it will be necessary to remove the `mfsroot.flp` floppy and replace it with `kern.flp` before rebooting.

2.4 Introducing Sysinstall

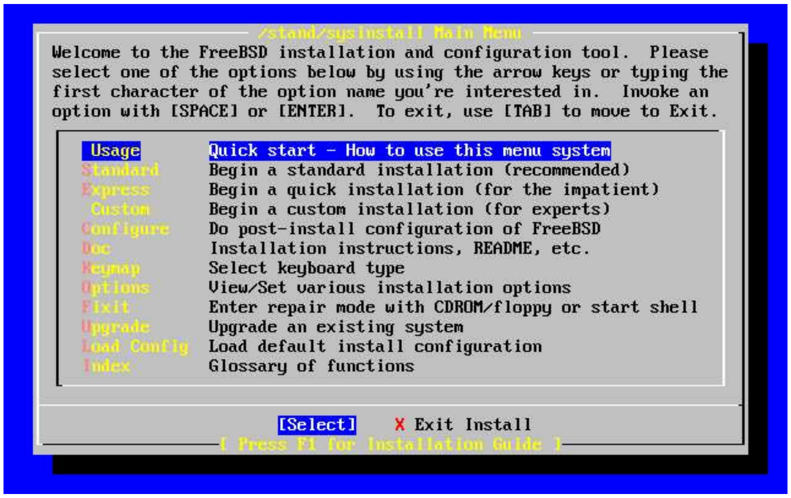
The **sysinstall** utility is the installation application provided by the FreeBSD Project. It is console based and is divided into a number of menus and screens that you can use to configure and control the installation process.

The **sysinstall** menu system is controlled by the arrow keys, **Enter**, **Space**, and other keys. A detailed description of these keys and what they do is contained in **sysinstall**'s usage information.

To review this information, ensure that the Usage entry is highlighted and that the [Select] button is selected, as shown in Figure 2-8, then press **Enter**.

The instructions for using the menu system will be displayed. After reviewing them, press **Enter** to return to the Main Menu.

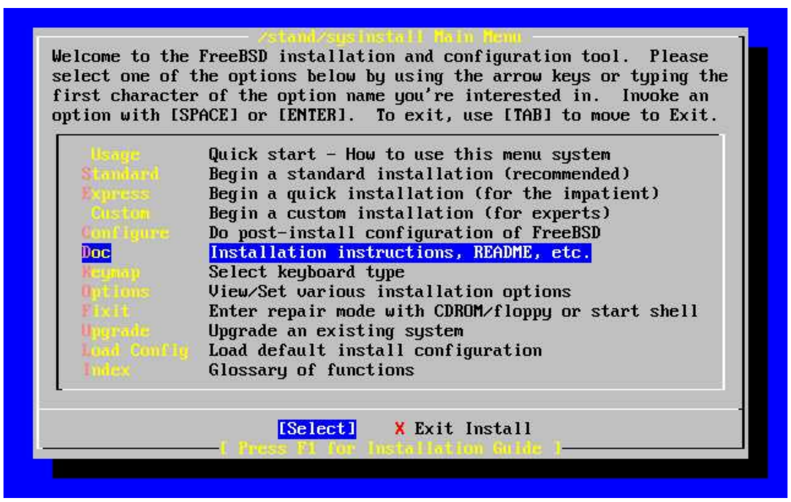
Figure 2-8. Selecting Usage from Sysinstall Main Menu



2.4.1 Selecting the Documentation Menu

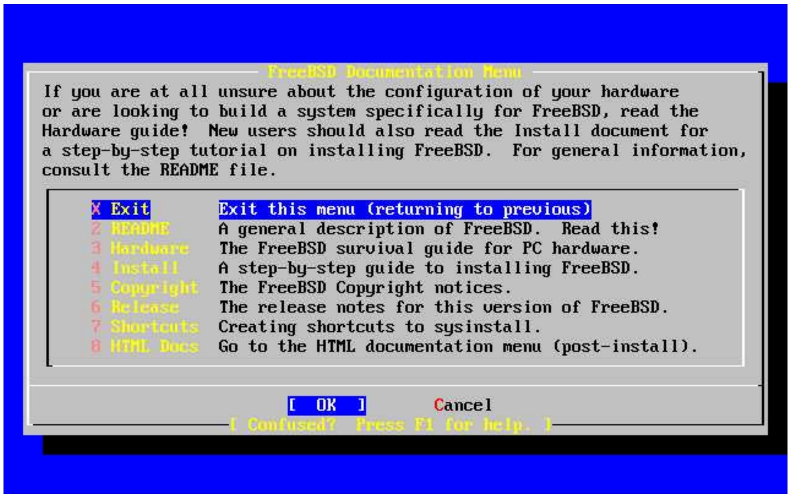
From the Main Menu, select `Doc` with the arrow keys and press **Enter**.

Figure 2-9. Selecting Documentation Menu



This will display the Documentation Menu.

Figure 2-10. Sysinstall Documentation Menu



It is important to read the documents provided.

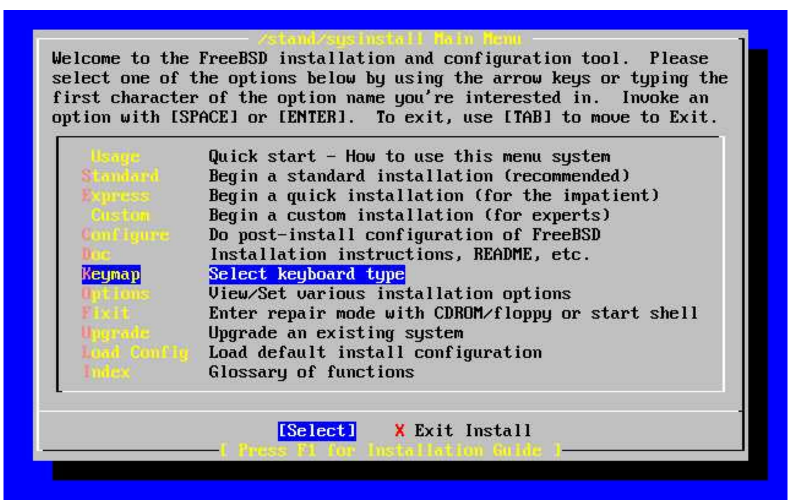
To view a document, select it with the arrow keys and press **Enter**. When finished reading a document, pressing **Enter** will return to the Documentation Menu.

To return to the Main Installation Menu, select Exit with the arrow keys and press **Enter**.

2.4.2 Selecting the Keymap Menu

To change the keyboard mapping, use the arrow keys to select Keymap from the menu and press **Enter**. This is only required if you are using a non-standard or non-US keyboard.

Figure 2-11. Sysinstall Main Menu

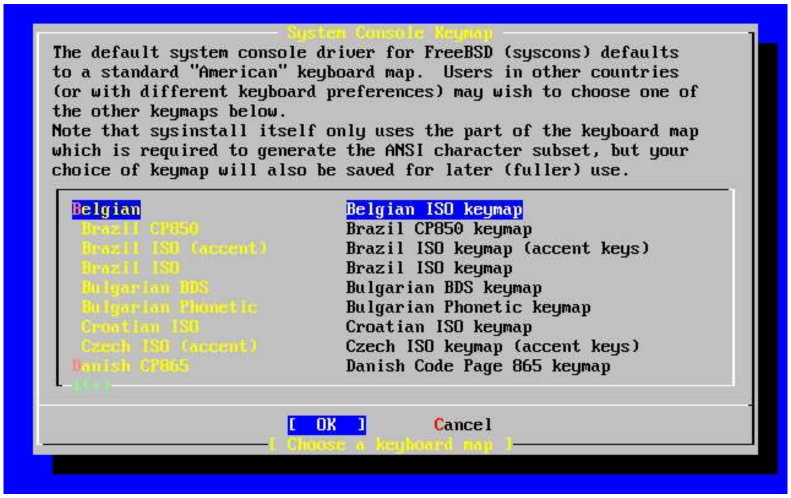


A different keyboard mapping may be chosen by selecting the menu item using up/down arrow keys and pressing **Space**. Pressing **Space** again will unselect the item. When finished, choose the [OK] using the arrow keys and press

Enter.

Only a partial list is shown in this screen representation. Selecting [Cancel] by pressing **Tab** will use the default keymap and return to the Main Install Menu.

Figure 2-12. Sysinstall Keymap Menu



2.4.3 Installation Options Screen

Select Options and press **Enter**.

Figure 2-13. Sysinstall Main Menu

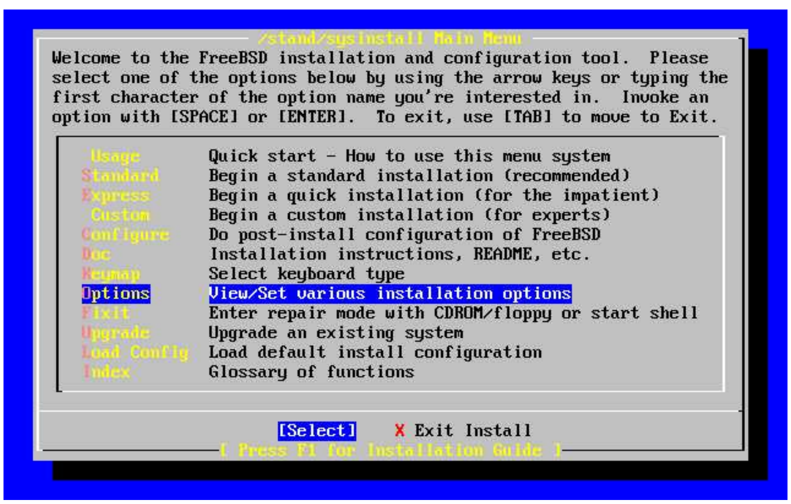
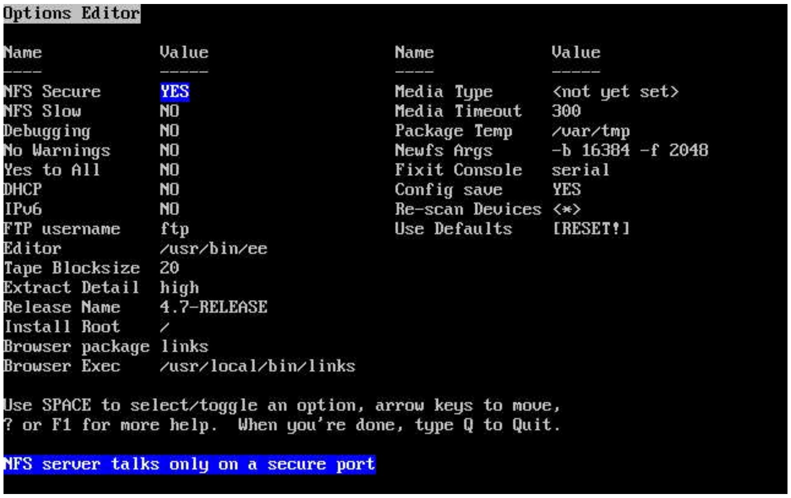


Figure 2-14. Sysinstall Options



The default values are usually fine for most users and do not need to be changed. The release name will vary according to the version being installed.

The description of the selected item will appear at the bottom of the screen highlighted in blue. Notice that one of the options is Use Defaults to reset all values to startup defaults.

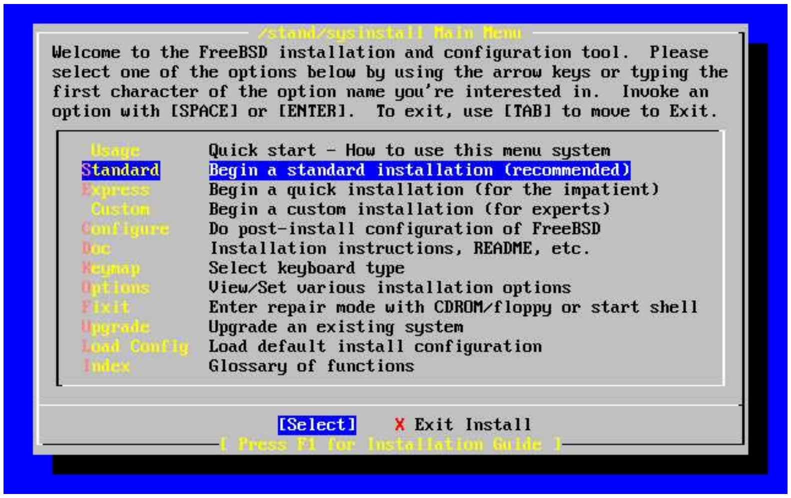
Press **F1** to read the help screen about the various options.

Pressing **Q** will return to the Main Install menu.

2.4.4 Begin a Standard Installation

The Standard installation is the option recommended for those new to UNIX or FreeBSD. Use the arrow keys to select Standard and then press **Enter** to start the installation.

Figure 2-15. Begin Standard Installation



2.5 Allocating Disk Space

Your first task is to allocate disk space for FreeBSD, and label that space so that **sysinstall** can prepare it. In order to do this you need to know how FreeBSD expects to find information on the disk.

2.5.1 BIOS Drive Numbering

Before you install and configure FreeBSD on your system, there is an important subject that you should be aware of, especially if you have multiple hard drives.

In a PC running a BIOS-dependent operating system such as MS-DOS or Microsoft Windows, the BIOS is able to abstract the normal disk drive order, and the operating system goes along with the change. This allows the user to boot from a disk drive other than the so-called "primary master". This is especially convenient for some users who have found that the simplest and cheapest way to keep a system backup is to buy an identical second hard drive, and perform routine copies of the first drive to the second drive using **Ghost®** or **XCOPY** . Then, if the first drive fails, or is attacked by a virus, or is scribbled upon by an operating system defect, he can easily recover by instructing the BIOS to logically swap the drives. It is like switching the cables on the drives, but without having to open the case.

More expensive systems with SCSI controllers often include BIOS extensions which allow the SCSI drives to be re-ordered in a similar fashion for up to seven drives.

A user who is accustomed to taking advantage of these features may become surprised when the results with FreeBSD are not as expected. FreeBSD does not use the BIOS, and does not know the "logical BIOS drive mapping". This can lead to very perplexing situations, especially when drives are physically identical in geometry, and have also been made as data clones of one another.

When using FreeBSD, always restore the BIOS to natural drive numbering before installing FreeBSD, and then leave it that way. If you need to switch drives around, then do so, but do it the hard way, and open the case and move the jumpers and cables.

An Illustration from the Files of Bill and Fred's Exceptional Adventures:

Bill breaks-down an older Wintel box to make another FreeBSD box for Fred. Bill installs a single SCSI drive as SCSI unit zero and installs FreeBSD on it.

Fred begins using the system, but after several days notices that the older SCSI drive is reporting numerous soft errors and reports this fact to Bill.

After several more days, Bill decides it is time to address the situation, so he grabs an identical SCSI drive from the disk drive "archive" in the back room. An initial surface scan indicates that this drive is functioning well, so Bill installs this drive as SCSI unit four and makes an image copy from drive zero to drive four. Now that the new drive is installed and functioning nicely, Bill decides that it is a good idea to start using it, so he uses features in the SCSI BIOS to re-order the disk drives so that the system boots from SCSI unit four. FreeBSD boots and runs just fine.

Fred continues his work for several days, and soon Bill and Fred decide that it is time for a new adventure -- time to upgrade to a newer version of FreeBSD. Bill removes SCSI unit zero because it was a bit flaky and replaces it with another identical disk drive from the "archive". Bill then installs the new version of FreeBSD onto the new SCSI unit zero using Fred's magic Internet FTP floppies. The installation goes well.

Fred uses the new version of FreeBSD for a few days, and certifies that it is good enough for use in the engineering department. It is time to copy all of his work from the old version. So Fred mounts SCSI unit four (the latest copy of the older FreeBSD version). Fred is dismayed to find that none of his precious work is present on SCSI unit four.

Where did the data go?

When Bill made an image copy of the original SCSI unit zero onto SCSI unit four, unit four became the "new clone". When Bill re-ordered the SCSI BIOS so that he could boot from SCSI unit four, he was only fooling himself. FreeBSD was still running on SCSI unit zero. Making this kind of BIOS change will cause some or all of the Boot and Loader code to be fetched from the selected BIOS drive, but when the FreeBSD kernel drivers take-over, the BIOS drive numbering will be ignored, and FreeBSD will transition back to normal drive numbering. In the illustration at hand, the system continued to operate on the original SCSI unit zero, and all of Fred's data was there, not on SCSI unit four. The fact that the system appeared to be running on SCSI unit four was simply an artifact of human expectations.

We are delighted to mention that no data bytes were killed or harmed in any way by our discovery of this phenomenon. The older SCSI unit zero was retrieved from the bone pile, and all of Fred's work was returned to him, (and now Bill knows that he can count as high as zero).

Although SCSI drives were used in this illustration, the concepts apply equally to IDE drives.

2.5.2 Creating Slices Using FDisk

> **Note:** No changes you make at this point will be written to the disk. If you think you have made a mistake and want to start again you can use the menus to exit **sysinstall** and try again or press **U** to use the Undo option. If you get confused and can not see how to exit you can always turn your computer off.

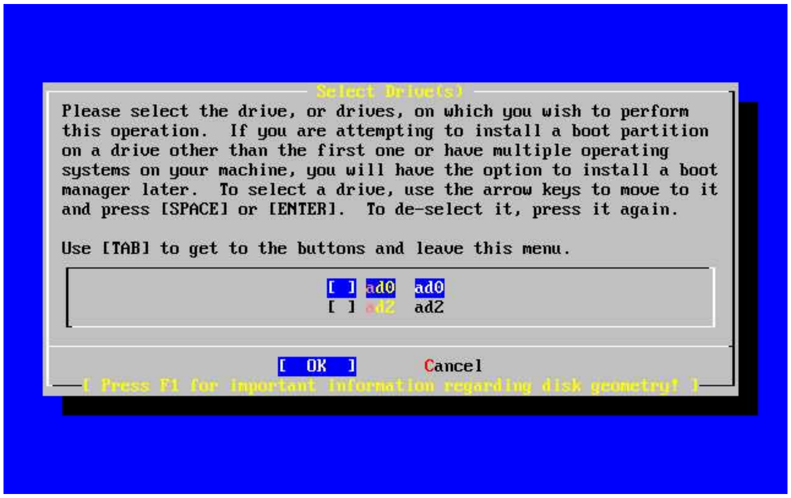
After choosing to begin a standard installation in **sysinstall** you will be shown this message:

```
                                Message
In the next menu, you will need to set up a DOS-style ("fdisk")
```

```
partitioning scheme for your hard disk. If you simply wish to devote
all disk space to FreeBSD (overwriting anything else that might be on
the disk(s) selected) then use the (A)ll command to select the default
partitioning scheme followed by a (Q)uit. If you wish to allocate only
free space to FreeBSD, move to a partition marked "unused" and use the
(C)reate command.
                              [  OK  ]

                    [ Press enter or space ]
```

Press **Enter** as instructed. You will then be shown a list of all the hard drives that the kernel found when it carried out the device probes. Figure 2-16 shows an example from a system with two IDE disks. They have been called `ad0` and `ad2`.

Figure 2-16. Select Drive for FDisk



You might be wondering why `ad1` is not listed here. Why has it been missed?

Consider what would happen if you had two IDE hard disks, one as the master on the first IDE controller, and one as the master on the second IDE controller. If FreeBSD numbered these as it found them, as `ad0` and `ad1` then everything would work.

But if you then added a third disk, as the slave device on the first IDE controller, it would now be `ad1`, and the previous `ad1` would become `ad2`. Because device names (such as `ad1s1a`) are used to find filesystems, you may suddenly discover that some of your filesystems no longer appear correctly, and you would need to change your FreeBSD configuration.

To work around this, the kernel can be configured to name IDE disks based on where they are, and not the order in which they were found. With this scheme the master disk on the second IDE controller will *always* be `ad2`, even if there are no `ad0` or `ad1` devices.

This configuration is the default for the FreeBSD kernel, which is why this display shows `ad0` and `ad2`. The machine on which this screenshot was taken had IDE disks on both master channels of the IDE controllers, and no disks on the slave channels.

You should select the disk on which you want to install FreeBSD, and then press [OK]. **FDisk** will start, with a display similar to that shown in Figure 2-17.

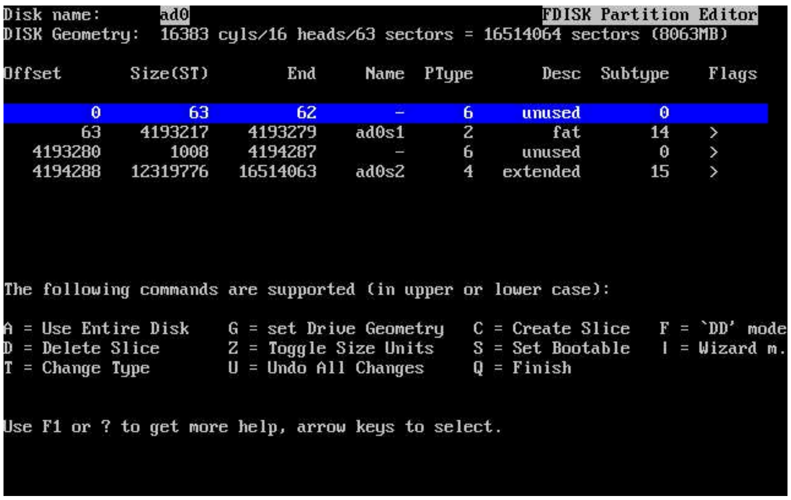
The **FDisk** display is broken into three sections.

The first section, covering the first two lines of the display, shows details about the currently selected disk, including its FreeBSD name, the disk geometry, and the total size of the disk.

The second section shows the slices that are currently on the disk, where they start and end, how large they are, the name FreeBSD gives them, and their description and sub-type. This example shows two small unused slices, which are artifacts of disk layout schemes on the PC. It also shows one large FAT slice, which almost certainly appears as `C:` in MS-DOS / Windows, and an extended slice, which may contain other drive letters for MS-DOS / Windows.

The third section shows the commands that are available in **FDisk**.

Figure 2-17. Typical Fdisk Partitions before Editing



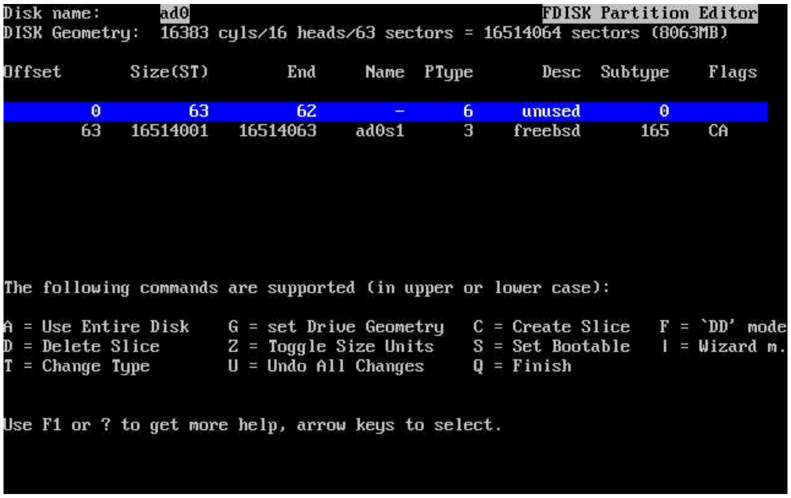
What you do now will depend on how you want to slice up your disk.

If you want to use FreeBSD for the entire disk (which will delete all the other data on this disk when you confirm that you want **sysinstall** to continue later in the installation process) then you can press **A**, which corresponds to the Use Entire Disk option. The existing slices will be removed, and replaced with a small area flagged as `unused` (again, an artifact of PC disk layout), and then one large slice for FreeBSD. If you do this, then you should select the newly created FreeBSD slice using the arrow keys, and press **S** to mark the slice as being bootable. The screen will then look very similar to Figure 2-18. Note the `A` in the `Flags` column, which indicates that this slice is *active*, and will be booted from.

If you will be deleting an existing slice to make space for FreeBSD then you should select the slice using the arrow keys, and then press **D**. You can then press **C**, and be prompted for size of slice you want to create. Enter the appropriate figure and press **Enter**. The default value in this box represents the largest possible slice you can make, which could be the largest contiguous block of unallocated space or the size of the entire hard disk.

If you have already made space for FreeBSD (perhaps by using a tool such as **PartitionMagic**) then you can press **C** to create a new slice. Again, you will be prompted for the size of slice you would like to create.

Figure 2-18. Fdisk Partition Using Entire Disk



When finished, press **Q**. Your changes will be saved in **sysinstall**, but will not yet be written to disk.

2.5.3 Install a Boot Manager

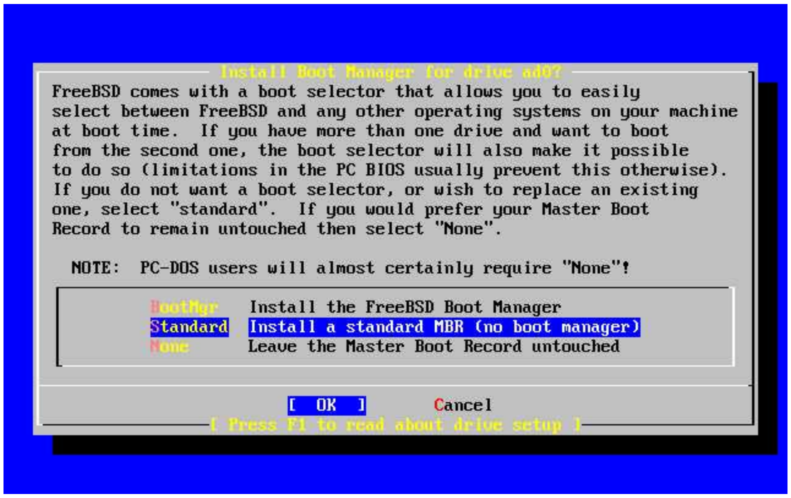
You now have the option to install a boot manager. In general, you should choose to install the FreeBSD boot manager if:

- You have more than one drive, and have installed FreeBSD onto a drive other than the first one.
- You have installed FreeBSD alongside another operating system on the same disk, and you want to choose whether to start FreeBSD or the other operating system when you start the computer.

If FreeBSD is going to be the only operating system on this machine, installed on the first hard disk, then the Standard boot manager will suffice. Choose None if you are using a third-party boot manager capable of booting FreeBSD.

Make your choice and press **Enter**.

Figure 2-19. Sysinstall Boot Manager Menu



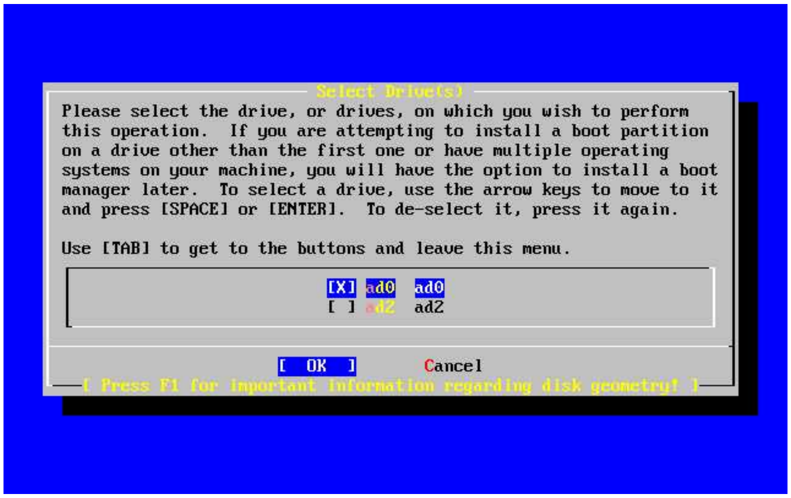
The help screen, reached by pressing **F1**, discusses the problems that can be encountered when trying to share the hard disk between operating systems.

2.5.4 Creating Slices on Another Drive

If there is more than one drive, it will return to the Select Drives screen after the boot manager selection. If you wish to install FreeBSD on to more than one disk, then you can select another disk here and repeat the slice process using **FDisk**.

> **Important:** If you are installing FreeBSD on a drive other than your first, then the FreeBSD boot manager needs to be installed on both drives.

Figure 2-20. Exit Select Drive



The **Tab** key toggles between the last drive selected, [OK], and [Cancel].

Press the **Tab** once to toggle to the [OK], then press **Enter** to continue with the installation.

2.5.5 Creating Partitions Using Disklabel

You must now create some partitions inside each slice that you have just created. Remember that each partition is lettered, from a through to h, and that partitions b, c, and d have conventional meanings that you should adhere to.

Certain applications can benefit from particular partition schemes, especially if you are laying out partitions across more than one disk. However, for this, your first FreeBSD installation, you do not need to give too much thought to how you partition the disk. It is more important that you install FreeBSD and start learning how to use it. You can always re-install FreeBSD to change your partition scheme when you are more familiar with the operating system.

This scheme features four partitions—one for swap space, and three for filesystems.

Table 2-2. Partition Layout for First Disk

Partition	Filesystem	Size	Description
a	/	100 MB	This is the root filesystem. Every other filesystem will be mounted somewhere under this one. 100 MB is a reasonable size for this filesystem. You will not be storing too much data on it, as a regular FreeBSD install will put about 40 MB of data here. The remaining space is for temporary data, and also leaves expansion space if future versions of FreeBSD need more space in /.

Partition	Filesystem	Size	Description
`b`	N/A	2-3 x RAM	The system's swap space is kept on this partition. Choosing the right amount of swap space can be a bit of an art. A good rule of thumb is that your swap space should be two or three times as much as the available physical memory (RAM). You should also have at least 64 MB of swap, so if you have less than 32 MB of RAM in your computer then set the swap amount to 64 MB. If you have more than one disk then you can put swap space on each disk. FreeBSD will then use each disk for swap, which effectively speeds up the act of swapping. In this case, calculate the total amount of swap you need (e.g., 128 MB), and then divide this by the number of disks you have (e.g., two disks) to give the amount of swap you should put on each disk, in this example, 64 MB of swap per disk.
`e`	`/var`	50 MB	The `/var` directory contains files that are constantly varying; log files, and other administrative files. Many of these files are read-from or written-to extensively during FreeBSD's day-to-day running. Putting these files on another filesystem allows FreeBSD to optimize the access of these files without affecting other files in other directories that do not have the same access pattern.
`f`	`/usr`	Rest of disk	All your other files will typically be stored in `/usr` and its subdirectories.

If you will be installing FreeBSD on to more than one disk then you must also create partitions in the other slices that you configured. The easiest way to do this is to create two partitions on each disk, one for the swap space, and one for a filesystem.

Table 2-3. Partition Layout for Subsequent Disks

Partition	Filesystem	Size	Description
`b`	N/A	See description	As already discussed, you can split swap space across each disk. Even though the `a` partition is free, convention dictates that swap space stays on the `b` partition.

Partition	Filesystem	Size	Description
`e`	/disk*n*	Rest of disk	The rest of the disk is taken up with one big partition. This could easily be put on the `a` partition, instead of the `e` partition. However, convention says that the `a` partition on a slice is reserved for the filesystem that will be the root (`/`) filesystem. You do not have to follow this convention, but **sysinstall** does, so following it yourself makes the installation slightly cleaner. You can choose to mount this filesystem anywhere; this example suggests that you mount them as directories `/disk`*n*, where *n* is a number that changes for each disk. But you can use another scheme if you prefer.

Having chosen your partition layout you can now create it using **sysinstall**. You will see this message:

```
                                Message
Now, you need to create BSD partitions inside of the fdisk
partition(s) just created. If you have a reasonable amount of disk
space (200MB or more) and don't have any special requirements, simply
use the (A)uto command to allocate space automatically. If you have
more specific needs or just don't care for the layout chosen by
(A)uto, press F1 for more information on manual layout.

                               [  OK  ]
                         [ Press enter or space ]
```

Press **Enter** to start the FreeBSD partition editor, called **Disklabel**.

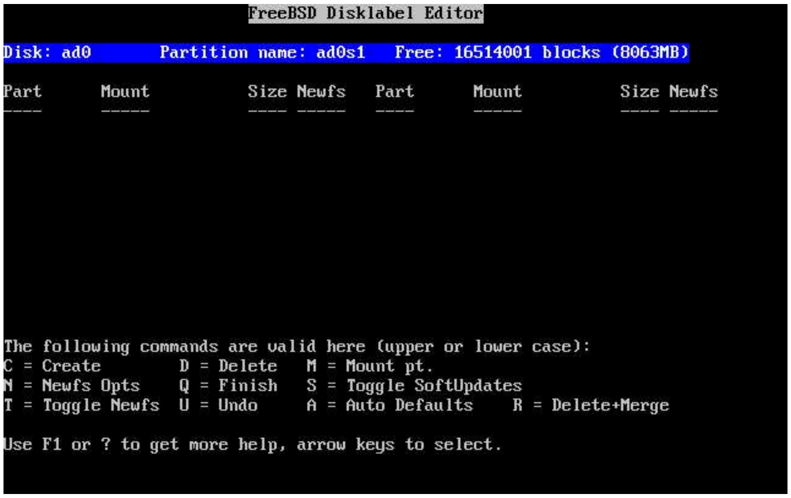
Figure 2-21 shows the display when you first start **Disklabel**. The display is divided in to three sections.

The first few lines show the name of the disk you are currently working on, and the slice that contains the partitions you are creating (at this point **Disklabel** calls this the `Partition name` rather than slice name). This display also shows the amount of free space within the slice; that is, space that was set aside in the slice, but that has not yet been assigned to a partition.

The middle of the display shows the partitions that have been created, the name of the filesystem that each partition contains, their size, and some options pertaining to the creation of the filesystem.

The bottom third of the screen shows the keystrokes that are valid in **Disklabel**.

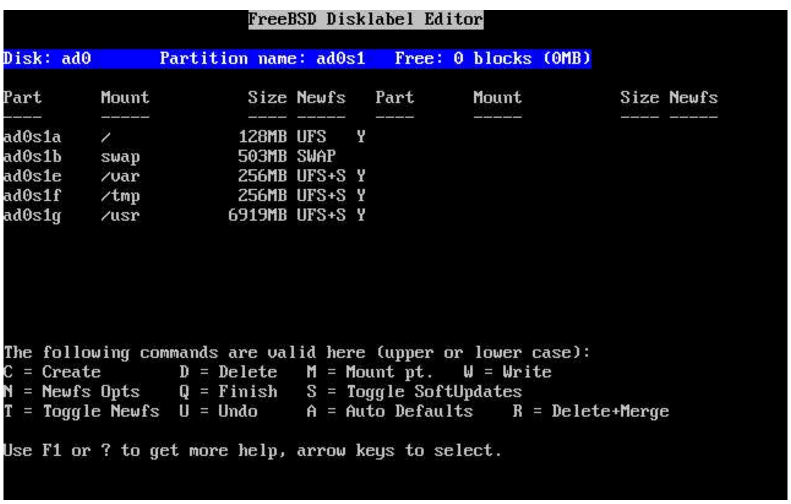
Figure 2-21. Sysinstall Disklabel Editor



Disklabel can automatically create partitions for you and assign them default sizes. Try this now, by Pressing **A**. You will see a display similar to that shown in Figure 2-22. Depending on the size of the disk you are using, the defaults may or may not be appropriate. This does not matter, as you do not have to accept the defaults.

> **Note:** Beginning with FreeBSD 4.5, the default partitioning assigns the `/tmp` directory its own partition instead of being part of the `/` partition. This helps avoid filling the `/` partition with temporary files.

Figure 2-22. Sysinstall Disklabel Editor with Auto Defaults



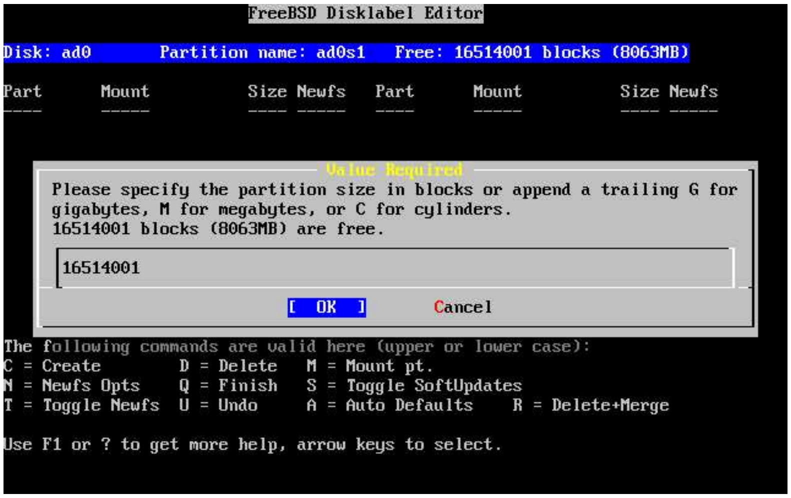
If you choose to not use the default partitions and wish to replace them with your own, use the arrow keys to select the first partition, and press **D** to delete it. Repeat this to delete all the suggested partitions.

To create the first partition (a, mounted as `/` — root), make sure the proper disk slice at the top of the screen is selected and press **C**. A dialog box will appear prompting you for the size of the new partition (as shown in

Figure 2-23). You can enter the size as the number of disk blocks you want to use, or as a number followed by either `M` for megabytes, `G` for gigabytes, or `C` for cylinders.

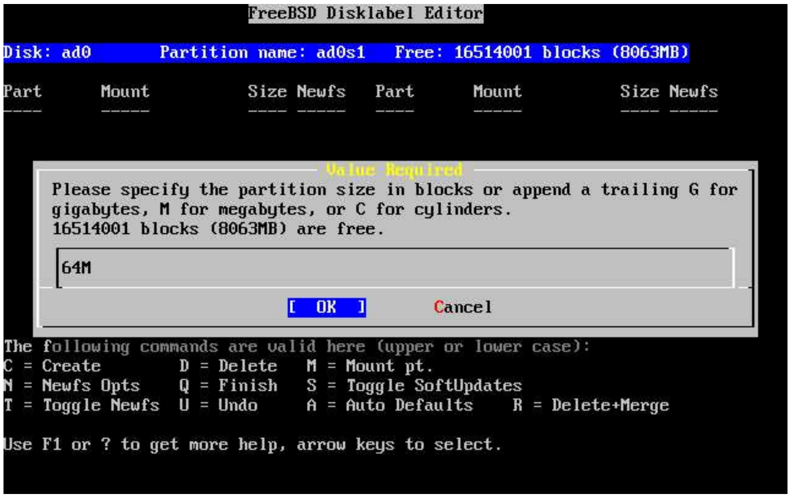
> **Note:** Beginning with FreeBSD 5.X, users can: select UFS2 using the `Custom Newfs` (**Z**) option, create labels with `Auto Defaults` and modify them with the `Custom Newfs` option or add `-O 2` during the regular creation period. Do not forget to add `-U` for SoftUpdates if you use the `Custom Newfs` option!

Figure 2-23. Free Space for Root Partition



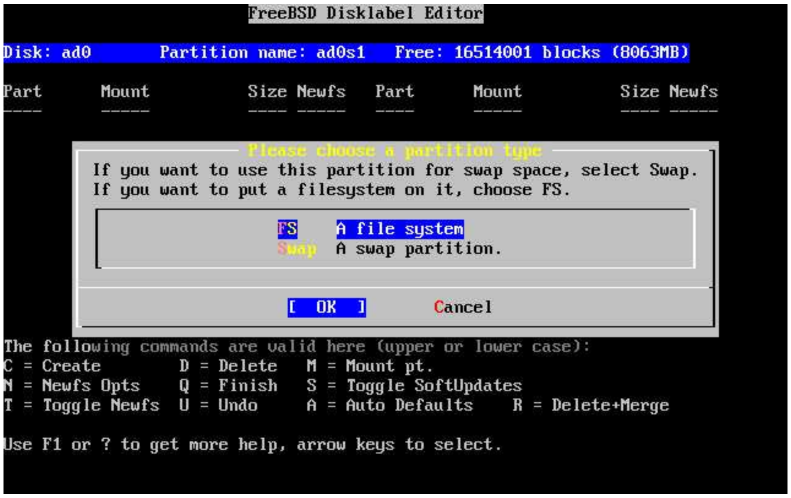
The default size shown will create a partition that takes up the rest of the slice. If you are using the partition sizes described in the earlier example, then delete the existing figure using **Backspace**, and then type in **`64M`**, as shown in Figure 2-24. Then press [OK].

Figure 2-24. Edit Root Partition Size



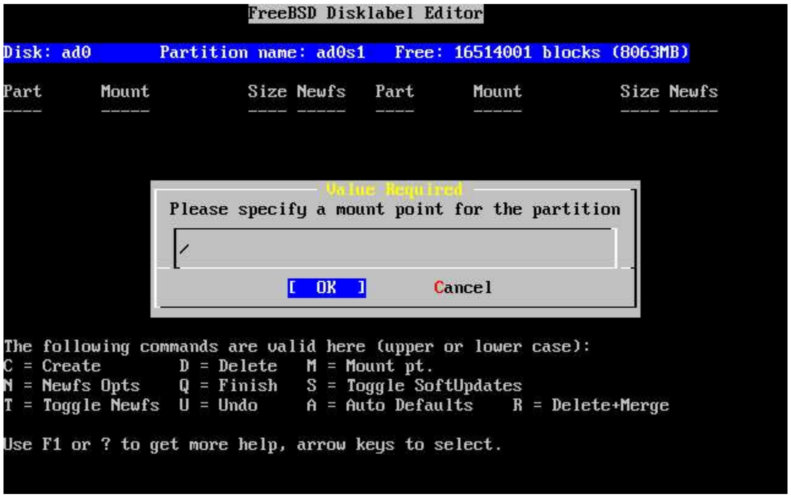
Having chosen the partition's size you will then be asked whether this partition will contain a filesystem or swap space. The dialog box is shown in Figure 2-25. This first partition will contain a filesystem, so check that FS is selected and press **Enter**.

Figure 2-25. Choose the Root Partition Type



Finally, because you are creating a filesystem, you must tell **Disklabel** where the filesystem is to be mounted. The dialog box is shown in Figure 2-26. The root filesystem's mount point is `/`, so type **/**, and then press **Enter**.

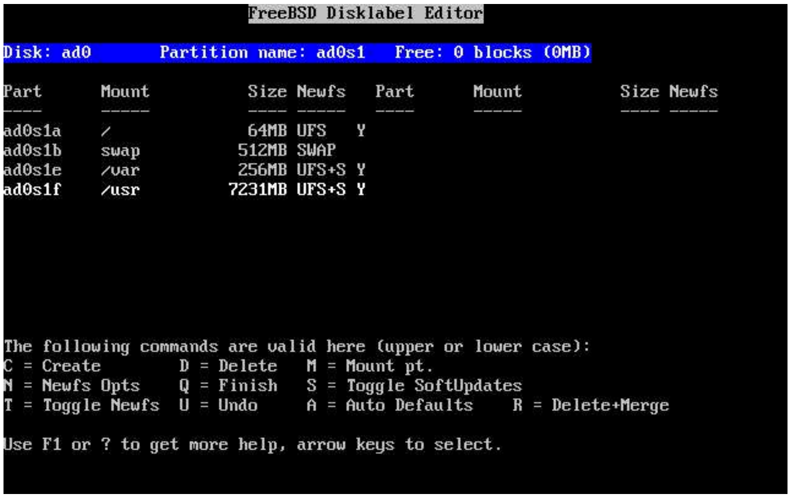
Figure 2-26. Choose the Root Mount Point



The display will then update to show you the newly created partition. You should repeat this procedure for the other partitions. When you create the swap partition, you will not be prompted for the filesystem mount point, as swap partitions are never mounted. When you create the final partition, `/usr`, you can leave the suggested size as is, to use the rest of the slice.

Your final FreeBSD DiskLabel Editor screen will appear similar to Figure 2-27, although your values chosen may be different. Press **Q** to finish.

Figure 2-27. Sysinstall Disklabel Editor



2.6 Choosing What to Install

2.6.1 Select the Distribution Set

Deciding which distribution set to install will depend largely on the intended use of the system and the amount of disk space available. The predefined options range from installing the smallest possible configuration to everything. Those who are new to UNIX and/or FreeBSD should almost certainly select one of these canned options. Customizing a distribution set is typically for the more experienced user.

Press **F1** for more information on the distribution set options and what they contain. When finished reviewing the help, pressing **Enter** will return to the Select Distributions Menu.

If a graphical user interface is desired then a distribution set that is preceded by an X should be chosen. The configuration of **XFree86** and selection of a default desktop is part of the post-installation steps.

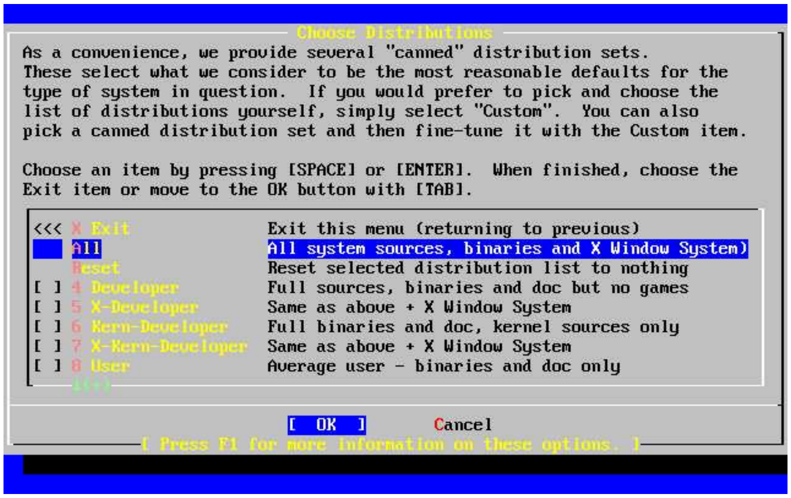
The default version of **XFree86** that is installed depends on the version of the FreeBSD that you are installing. For FreeBSD versions prior to 4.6, **XFree86 3.X** is installed. For FreeBSD 4.6 and later, **XFree86 4.X** is the default.

You should check to see whether your video card is supported at the XFree86 (http://www.xfree86.org/) web site. If your video card is not supported under the default version that FreeBSD will install, you should select a distribution without X for installation. After installation, install and configure the appropriate version of **XFree86** using the ports collection.

If compiling a custom kernel is anticipated, select an option which includes the source code. For more information on why a custom kernel should be built or how to build a custom kernel, see Chapter 9.

Obviously, the most versatile system is one that includes everything. If there is adequate disk space, select All as shown in Figure 2-28 by using the arrow keys and press **Enter**. If there is a concern about disk space consider using an option that is more suitable for the situation. Do not fret over the perfect choice, as other distributions can be added after installation.

Figure 2-28. Choose Distributions



2.6.2 Installing the Ports Collection

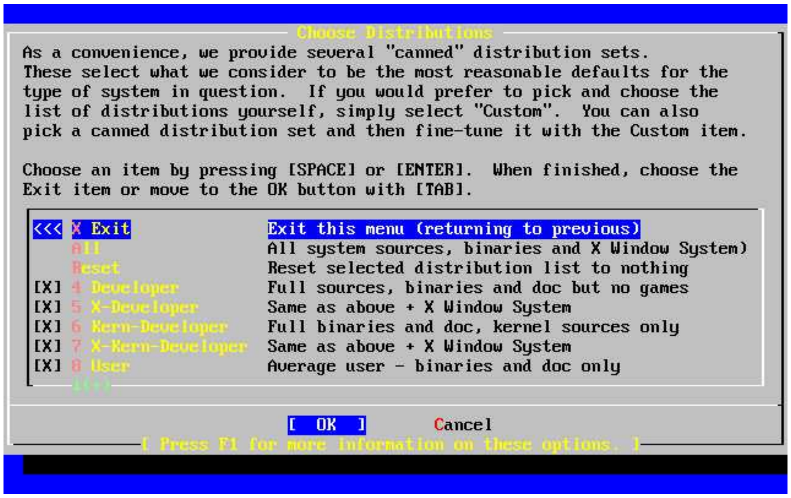
After selecting the desired distribution, an opportunity to install the FreeBSD Ports Collection is presented. The ports collection is an easy and convenient way to install software. The ports collection does not contain the source code necessary to compile the software. Instead, it is a collection of files which automates the downloading, compiling and installation of third-party software packages. Chapter 4 discusses how to use the ports collection.

The installation program does not check to see if you have adequate space. Select this option only if you have adequate hard disk space. As of FreeBSD 5.1, the FreeBSD Ports Collection takes up about 300 MB of disk space. You can safely assume a larger value for more recent versions of FreeBSD.

```
                        User Confirmation Requested
Would you like to install the FreeBSD ports collection?

This will give you ready access to over 9,200 ported software packages,
at a cost of around 300 MB of disk space when "clean" and possibly much
more than that if a lot of the distribution tarballs are loaded
(unless you have the extra CDs from a FreeBSD CD/DVD distribution
available and can mount it on /cdrom, in which case this is far less
of a problem).

The ports collection is a very valuable resource and well worth having
on your /usr partition, so it is advisable to say Yes to this option.

For more information on the ports collection & the latest ports,
visit:
    http://www.FreeBSD.org/ports

                             [ Yes ]     No
```

Select [Yes] with the arrow keys to install the ports collection or [No] to skip this option. Press **Enter** to continue. The Choose Distributions menu will redisplay.

Figure 2-29. Confirm Distributions



If satisfied with the options, select Exit with the arrow keys, ensure that [OK] is highlighted, and pressing **Enter** to continue.

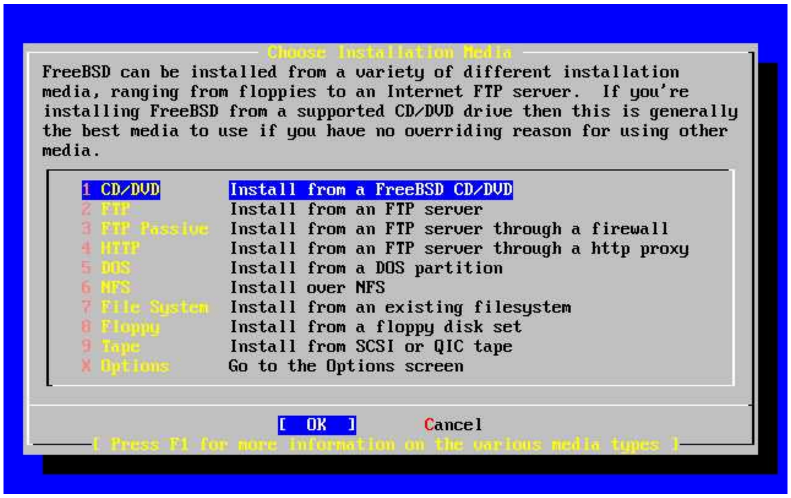
2.7 Choosing Your Installation Media

If Installing from a CDROM or DVD, use the arrow keys to highlight Install from a FreeBSD CD/DVD. Ensure that [OK] is highlighted, then press **Enter** to proceed with the installation.

For other methods of installation, select the appropriate option and follow the instructions.

Press **F1** to display the Online Help for installation media. Press **Enter** to return to the media selection menu.

Figure 2-30. Choose Installation Media



FTP Installation Modes: There are three FTP installation modes you can choose from: active FTP, passive FTP, or via a HTTP proxy.

FTP Active: Install from an FTP server

This option will make all FTP transfers use "Active" mode. This will not work through firewalls, but will often work with older FTP servers that do not support passive mode. If your connection hangs with passive mode (the default), try active!

FTP Passive: Install from an FTP server through a firewall

This option instructs **sysinstall** to use "Passive" mode for all FTP operations. This allows the user to pass through firewalls that do not allow incoming connections on random TCP ports.

FTP via a HTTP proxy: Install from an FTP server through a http proxy

This option instructs **sysinstall** to use the HTTP protocol (like a web browser) to connect to a proxy for all FTP operations. The proxy will translate the requests and send them to the FTP server. This allows the user to pass through firewalls that do not allow FTP at all, but offer a HTTP proxy. In this case, you have to specify the proxy in addition to the FTP server.

For a proxy FTP server, you should usually give the name of the server you really want as a part of the username, after an "@" sign. The proxy server then "fakes" the real server. For example, assuming you want to install from `ftp.FreeBSD.org`, using the proxy FTP server `foo.example.com`, listening on port 1024.

In this case, you go to the options menu, set the FTP username to `ftp@ftp.FreeBSD.org`, and the password to your email address. As your installation media, you specify FTP (or passive FTP, if the proxy supports it), and the URL `ftp://foo.example.com:1234/pub/FreeBSD`.

Since `/pub/FreeBSD` from `ftp.FreeBSD.org` is proxied under `foo.example.com`, you are able to install from *that* machine (which will fetch the files from `ftp.FreeBSD.org` as your installation requests them).

2.8 Committing to the Installation

The installation can now proceed if desired. This is also the last chance for aborting the installation to prevent changes to the hard drive.

```
                       User Confirmation Requested
 Last Chance! Are you SURE you want to continue the installation?

 If you're running this on a disk with data you wish to save then WE
 STRONGLY ENCOURAGE YOU TO MAKE PROPER BACKUPS before proceeding!

 We can take no responsibility for lost disk contents!

                             [ Yes ]    No
```

Select [Yes] and press **Enter** to proceed.

The installation time will vary according to the distribution chosen, installation media, and the speed of the computer. There will be a series of messages displayed indicating the status.

The installation is complete when the following message is displayed:

```
                               Message

Congratulations! You now have FreeBSD installed on your system.

We will now move on to the final configuration questions.
For any option you do not wish to configure, simply select No.

If you wish to re-enter this utility after the system is up, you may
do so by typing: /stand/sysinstall .

                                 [ OK ]

                      [  Press enter to continue  ]
```

Press **Enter** to proceed with post-installation configurations.

Selecting [No] and pressing **Enter** will abort the installation so no changes will be made to your system. The following message will appear:

```
                                Message
Installation complete with some errors.  You may wish to scroll
through the debugging messages on VTY1 with the scroll-lock feature.
You can also choose "No" at the next prompt and go back into the
installation menus to retry whichever operations have failed.

                                 [ OK ]
```

This message is generated because nothing was installed. Pressing **Enter** will return to the Main Installation Menu to exit the installation.

2.9 Post-installation

Configuration of various options follows the successful installation. An option can be configured by re-entering the configuration options before booting the new FreeBSD system or after installation using `/stand/sysinstall` and selecting Confi gure.

2.9.1 Network Device Configuration

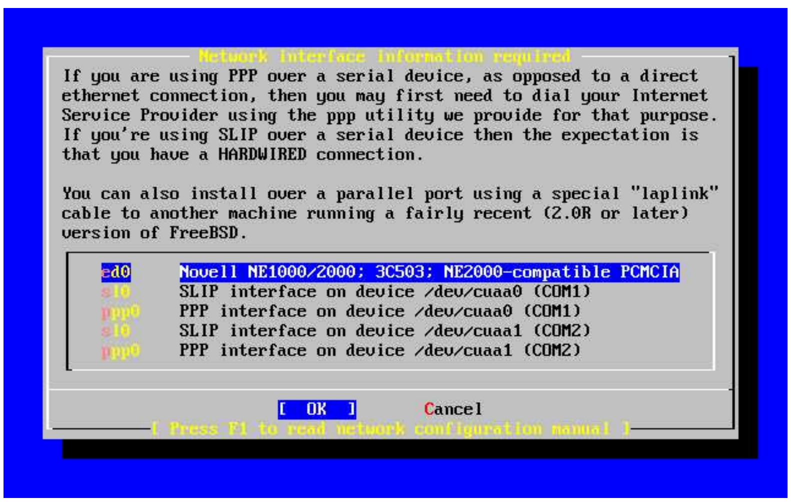
If you previously configured PPP for an FTP install, this screen will not display and can be configured later as described above.

For detailed information on Local Area Networks and configuring FreeBSD as a gateway/router refer to the Advanced Networking chapter.

```
                      User Confirmation Requested
   Would you like to configure any Ethernet or SLIP/PPP network devices?

                             [ Yes ]   No
```

To configure a network device, select [Yes] and press **Enter**. Otherwise, select [No] to continue.

Figure 2-31. Selecting an Ethernet Device



Select the interface to be configured with the arrow keys and press **Enter**.

```
                      User Confirmation Requested
       Do you want to try IPv6 configuration of the interface?

                              Yes   [ No ]
```

In this private local area network, the current Internet type protocol (IPv4) was sufficient and [No] was selected with the arrow keys and **Enter** pressed.

If you are connected to an existing IPv6 network with an RA server, then choose [Yes] and press **Enter**. It will take several seconds to scan for RA servers.

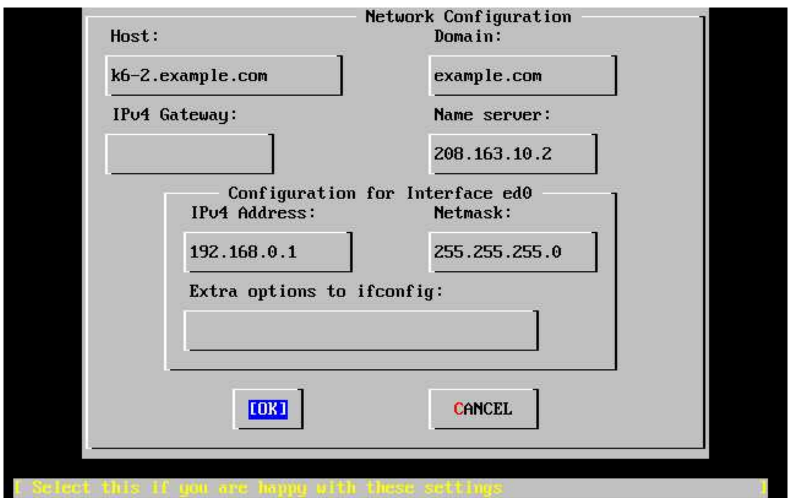
```
                    User Confirmation Requested
     Do you want to try DHCP configuration of the interface?

                          Yes   [ No ]
```

If DHCP (Dynamic Host Configuration Protocol) is not required select [No] with the arrow keys and press **Enter**.

Selecting [Yes] will execute **dhclient**, and if successful, will fill in the network configuration information automatically. Refer to Section 19.10 for more information.

The following Network Configuration screen shows the configuration of the Ethernet device for a system that will act as the gateway for a Local Area Network.

Figure 2-32. Set Network Configuration for ed0



Use **Tab** to select the information fields and fill in appropriate information:

Host

The fully-qualified hostname, such as `k6-2.example.com` in this case.

Domain

The name of the domain that your machine is in, such as `example.com` for this case.

IPv4 Gateway

IP address of host forwarding packets to non-local destinations. You must fill this in if the machine is a node on the network. *Leave this field blank* if the machine is the gateway to the Internet for the network. The IPv4 Gateway is also known as the default gateway or default route.

Name server

IP address of your local DNS server. There is no local DNS server on this private local area network so the IP address of the provider's DNS server (`208.163.10.2`) was used.

IPv4 address

The IP address to be used for this interface was `192.168.0.1`

Netmask

The address block being used for this local area network is a Class C block (`192.168.0.0 - 192.168.255.255`). The default netmask is for a Class C network (`255.255.255.0`).

Extra options to ifconfig

Any interface-specific options to `ifconfig` you would like to add. There were none in this case.

Use **Tab** to select [OK] when finished and press **Enter**.

```
                      User Confirmation Requested
        Would you like to Bring Up the ed0 interface right now?

                             [ Yes ]   No
```

Choosing [Yes] and pressing **Enter** will bring the machine up on the network and be ready for use. However, this does not accomplish much during installation, since the machine still needs to be rebooted.

2.9.2 Configure Gateway

```
                      User Confirmation Requested
       Do you want this machine to function as a network gateway?

                             [ Yes ]    No
```

If the machine will be acting as the gateway for a local area network and forwarding packets between other machines then select [Yes] and press **Enter**. If the machine is a node on a network then select [No] and press **Enter** to continue.

2.9.3 Configure Internet Services

```
                      User Confirmation Requested
Do you want to configure inetd and the network services that it provides?

                              Yes   [ No ]
```

If [No] is selected, various services such **telnetd** will not be enabled. This means that remote users will not be able to **telnet** into this machine. Local users will be still be able to access remote machines with **telnet**.

These services can be enabled after installation by editing `/etc/inetd.conf` with your favorite text editor. See Section 19.14.1 for more information.

Select [Yes] if you wish to configure these services during install. An additional confirmation will display:

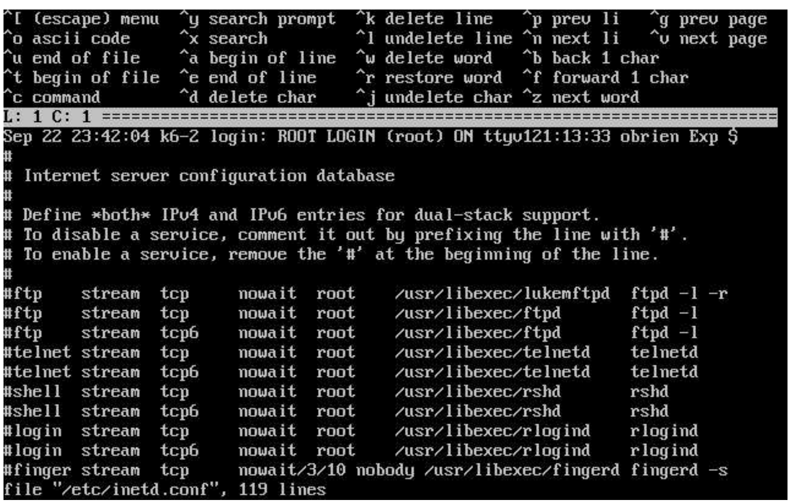
```
                      User Confirmation Requested
The Internet Super Server (inetd) allows a number of simple Internet
services to be enabled, including finger, ftp and telnetd.  Enabling
these services may increase risk of security problems by increasing
the exposure of your system.

With this in mind, do you wish to enable inetd?

                             [ Yes ]   No
```

Select [Yes] to continue.

```
                      User Confirmation Requested
inetd(8) relies on its configuration file, /etc/inetd.conf, to determine
which of its Internet services will be available.  The default FreeBSD
inetd.conf(5) leaves all services disabled by default, so they must be
specifically enabled in the configuration file before they will
function, even once inetd(8) is enabled.  Note that services for
IPv6 must be separately enabled from IPv4 services.

Select [Yes] now to invoke an editor on /etc/inetd.conf, or [No] to
use the current settings.

                             [ Yes ]   No
```

Selecting [Yes] will allow adding services by deleting the # at the beginning of a line.

Figure 2-33. Editing `inetd.conf`



After adding the desired services, pressing **Esc** will display a menu which will allow exiting and saving the changes.

2.9.4 Anonymous FTP

```
                      User Confirmation Requested
```

```
Do you want to have anonymous FTP access to this machine?

                              Yes    [ No ]
```

2.9.4.1 Deny Anonymous FTP

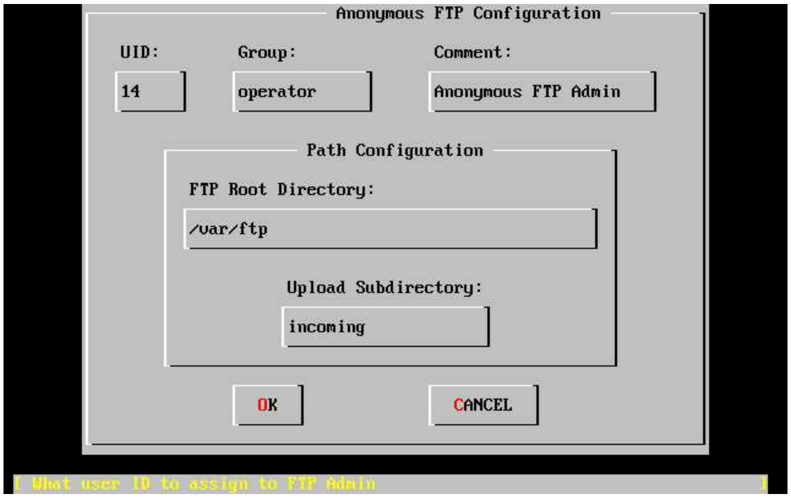
Selecting the default [No] and pressing **Enter** will still allow users who have accounts with passwords to use FTP to access the machine.

2.9.4.2 Allow Anonymous FTP

Anyone can access your machine if you elect to allow anonymous FTP connections. The security implications should be considered before enabling this option. For more information about security see Chapter 10.

To allow anonymous FTP, use the arrow keys to select [Yes] and press **Enter**. The following screen (or similar) will display:

Figure 2-34. Default Anonymous FTP Configuration



Pressing **F1** will display the help:

```
This screen allows you to configure the anonymous FTP user.

The following configuration values are editable:

UID:     The user ID you wish to assign to the anonymous FTP user.
         All files uploaded will be owned by this ID.

Group:   Which group you wish the anonymous FTP user to be in.

Comment: String describing this user in /etc/passwd


FTP Root Directory:
```

```
        Where files available for anonymous FTP will be kept.

Upload subdirectory:

        Where files uploaded by anonymous FTP users will go.
```

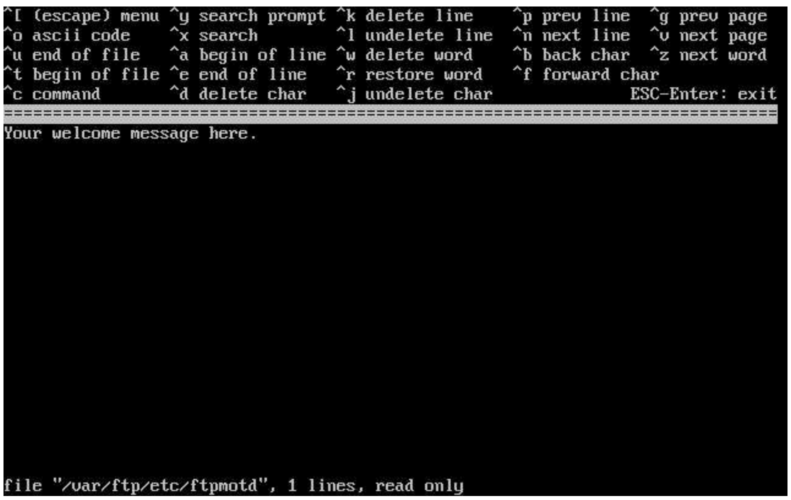
The ftp root directory will be put in `/var` by default. If you do not have enough room there for the anticipated FTP needs, the `/usr` directory could be used by setting the FTP Root Directory to `/usr/ftp`.

When you are satisfied with the values, press **Enter** to continue.

```
                    User Confirmation Requested
         Create a welcome message file for anonymous FTP users?

                         [ Yes ]    No
```

If you select [Yes] and press **Enter**, an editor will automatically start allowing you to edit the message.

Figure 2-35. Edit the FTP Welcome Message



This is a text editor called `ee`. Use the instructions to change the message or change the message later using a text editor of your choice. Note the file name/location at the bottom of the editor screen.

Press **Esc** and a pop-up menu will default to a) leave editor. Press **Enter** to exit and continue. Press **Enter** again to save changes if you made any./para>

2.9.5 Configure Network File System

Network File System (NFS) allows sharing of files across a network. A machine can be configured as a server, a client, or both. Refer to Section 19.6 for a more information.

2.9.5.1 NFS Server

```
                 User Confirmation Requested
```

```
 Do you want to configure this machine as an NFS server?

                             Yes    [ No ]
```

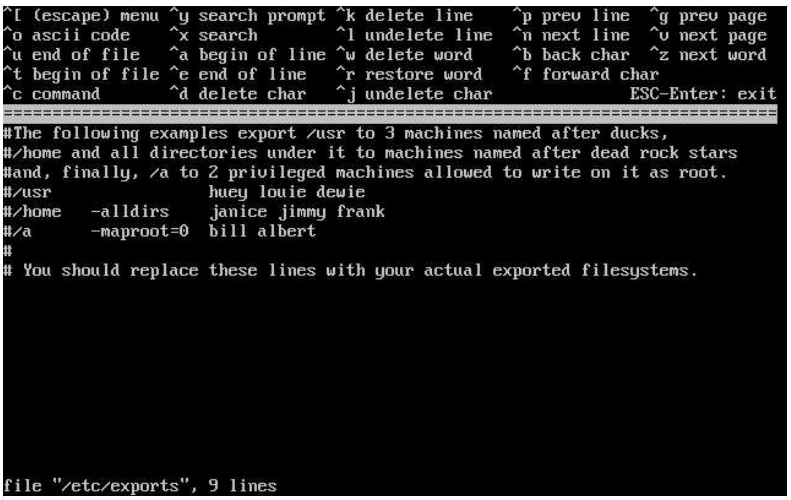
If there is no need for a Network File System server, select [No] and press **Enter**.

If [Yes] is chosen, a message will pop-up indicating that the `exports` file must be created.

```
                               Message
Operating as an NFS server means that you must first configure an
/etc/exports file to indicate which hosts are allowed certain kinds of
access to your local filesystems.
Press [Enter] now to invoke an editor on /etc/exports
                               [ OK ]
```

Press **Enter** to continue. A text editor will start allowing the `exports` file to be created and edited.

Figure 2-36. Editing `exports`



Use the instructions to add the actual exported filesystems now or later using a text editor of your choice. Note the file name/location at the bottom of the editor screen.

Press **Esc** and a pop-up menu will default to a) leave editor. Press **Enter** to exit and continue.

2.9.5.2 NFS Client

The NFS client allows your machine to access NFS servers.

```
                       User Confirmation Requested
 Do you want to configure this machine as an NFS client?

                             Yes   [ No ]
```

With the arrow keys, select [Yes] or [No] as appropriate and press **Enter**.

2.9.6 Security Profile

A "security profile" is a set of configuration options that attempts to achieve the desired ratio of security to convenience by enabling and disabling certain programs and other settings. The more severe the security profile, the fewer programs will be enabled by default. This is one of the basic principles of security: do not run anything except what you must.

Please note that the security profile is just a default setting. All programs can be enabled and disabled after you have installed FreeBSD by editing or adding the appropriate line(s) to `/etc/rc.conf`. For more information, please see the rc.conf(5) manual page.

The following table describes what each of the security profiles does. The columns are the choices you have for a security profile, and the rows are the program or feature that the profile enables or disables.

Table 2-4. Possible Security Profiles

	Extreme	Moderate
sendmail(8)	NO	YES
sshd(8)	NO	YES
portmap(8)	NO	MAYBE [a]
NFS server	NO	YES
securelevel(8)	YES [b]	NO

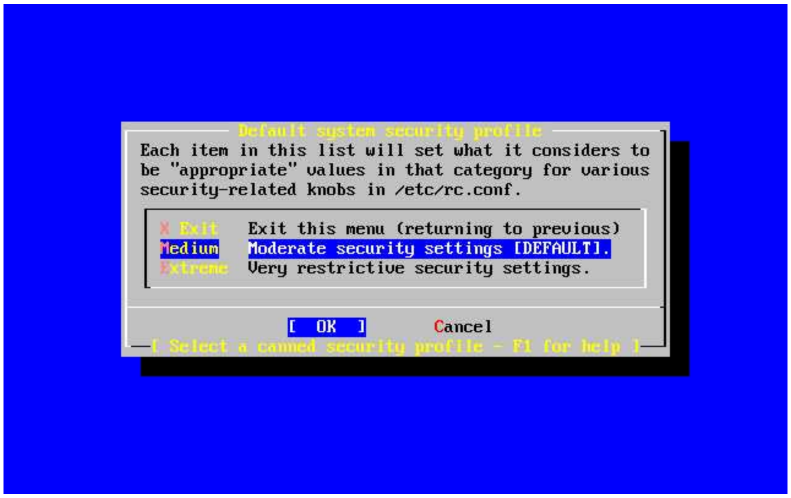
Notes: a. The portmapper is enabled if the machine has been configured as an NFS client or server earlier in the installation. b. If you

```
                      User Confirmation Requested
 Do you want to select a default security profile for this host (select
 No for "medium" security)?

                           [ Yes ]    No
```

Selecting [No] and pressing **Enter** will set the security profile to medium.

Selecting [Yes] and pressing **Enter** will allow selecting a different security profile.

Figure 2-37. Security Profile Options



Press **F1** to display the help. Press **Enter** to return to selection menu.

Use the arrow keys to choose Medium unless your are sure that another level is required for your needs. With [OK] highlighted, press **Enter**.

An appropriate confirmation message will display depending on which security setting was chosen.

```
                              Message

Moderate security settings have been selected.

Sendmail and SSHd have been enabled, securelevels are
disabled, and NFS server setting have been left intact.
PLEASE NOTE that this still does not save you from having
to properly secure your system in other ways or exercise
due diligence in your administration, this simply picks
a standard set of out-of-box defaults to start with.

To change any of these settings later, edit /etc/rc.conf

                               [OK]
```

```
                              Message

Extreme security settings have been selected.

Sendmail, SSHd, and NFS services have been disabled, and
securelevels have been enabled.
PLEASE NOTE that this still does not save you from having
to properly secure your system in other ways or exercise
due diligence in your administration, this simply picks
a more secure set of out-of-box defaults to start with.

To change any of these settings later, edit /etc/rc.conf
```

```
                                [OK]
```

Press **Enter** to continue with the post-installation configuration.

> **Warning:** The security profile is not a silver bullet! Even if you use the extreme setting, you need to keep up with security issues by reading an appropriate mailing list (../handbook/eresources.html#ERESOURCES-MAIL), using good passwords and passphrases, and generally adhering to good security practices. It simply sets up the desired security to convenience ratio out of the box.

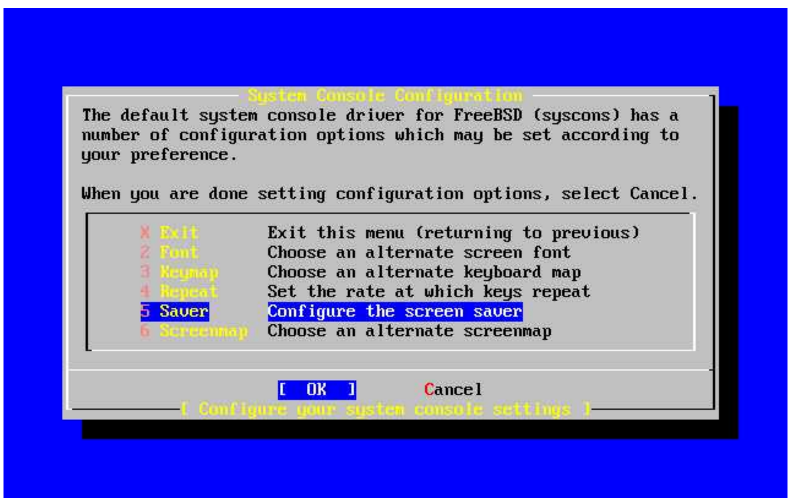
2.9.7 System Console Settings

There are several options available to customize the system console.

```
                         User Confirmation Requested
          Would you like to customize your system console settings?

                               [ Yes ]   No
```

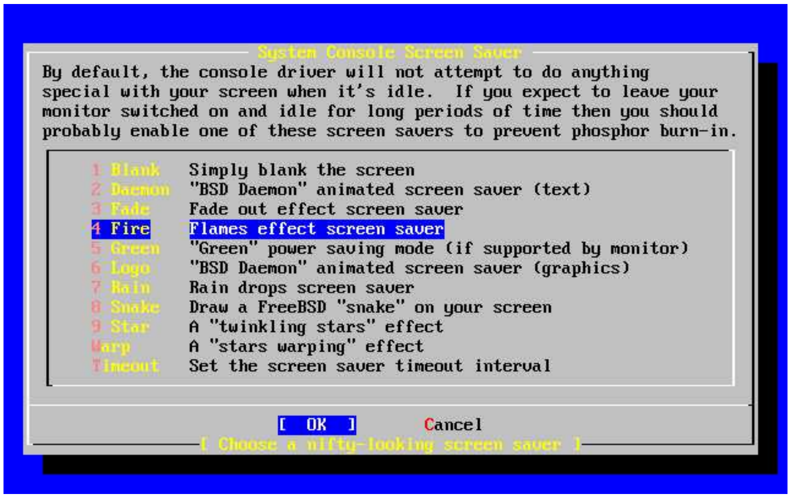
To view and configure the options, select [Yes] and press **Enter**.

Figure 2-38. System Console Configuration Options



A commonly used option is the screen saver. Use the arrow keys to select Saver and then press **Enter**.

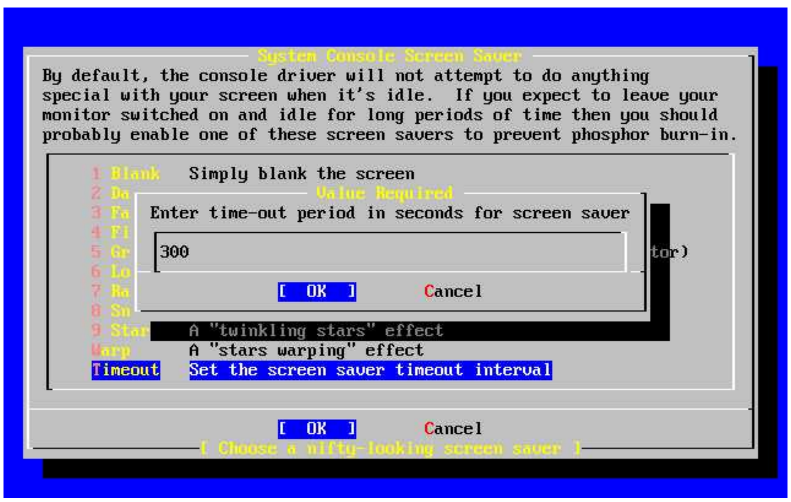
Figure 2-39. Screen Saver Options



Select the desired screen saver using the arrow keys and then press **Enter**. The System Console Configuration menu will redisplay.

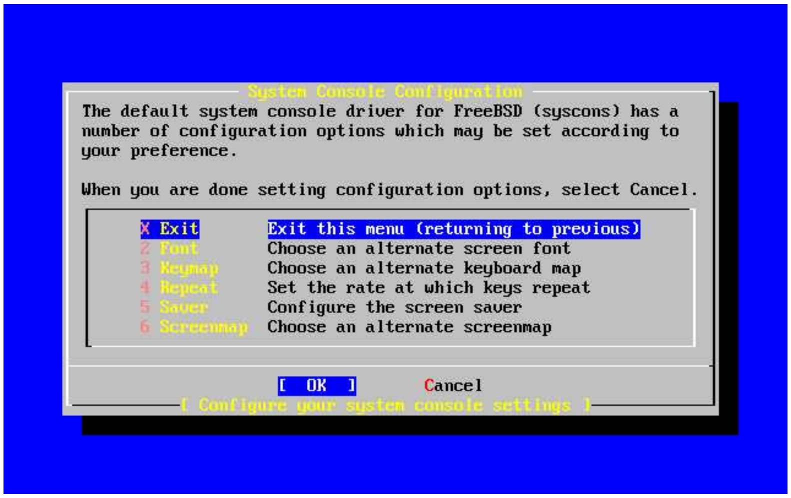
The default time interval is 300 seconds. To change the time interval, select Saver again. At the Screen Saver Options menu, select Timeout using the arrow keys and press **Enter**. A pop-up menu will appear:

Figure 2-40. Screen Saver Timeout



The value can be changed, then select [OK] and press **Enter** to return to the System Console Configuration menu.

Figure 2-41. System Console Configuration Exit



Selecting Exit and pressing **Enter** will continue with the post-installation configurations.

2.9.8 Setting the Time Zone

Setting the time zone for your machine will allow it to automatically correct for any regional time changes and perform other time zone related functions properly.

The example shown is for a machine located in the Eastern time zone of the United States. Your selections will vary according to your geographical location.

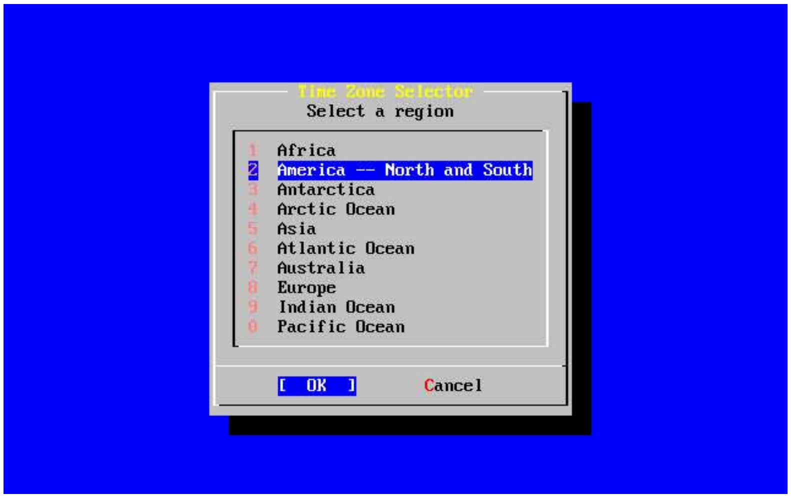
```
                      User Confirmation Requested
          Would you like to set this machine's time zone now?

                            [ Yes ]   No
```

Select [Yes] and press **Enter** to set the time zone.

```
                      User Confirmation Requested
 Is this machine's CMOS clock set to UTC? If it is set to local time
 or you don't know, please choose NO here!

                              Yes   [ No ]
```

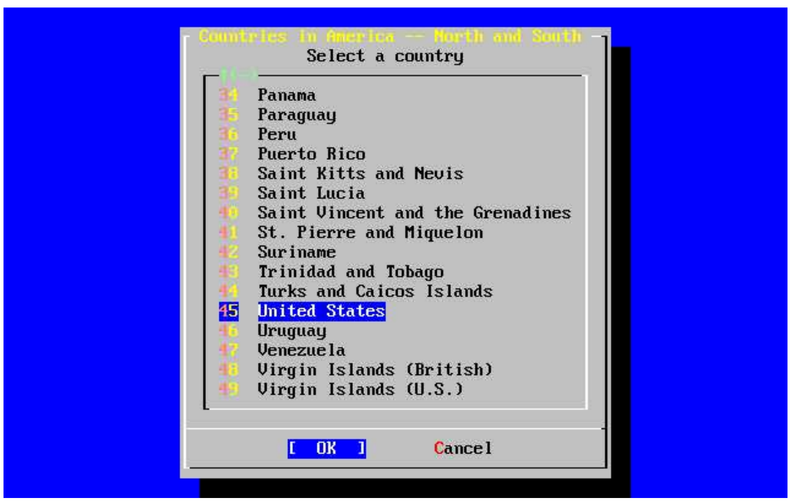
Select [Yes] or [No] according to how the machine's clock is configured and press **Enter**.

Figure 2-42. Select Your Region



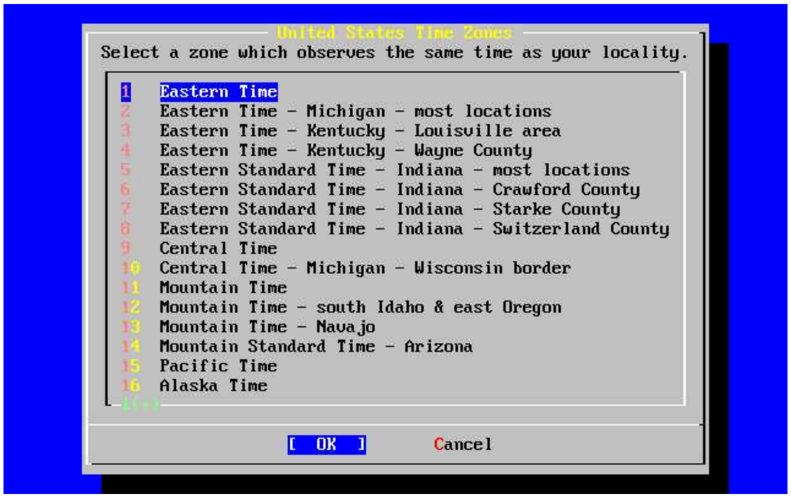
The appropriate region is selected using the arrow keys and then pressing **Enter**.

Figure 2-43. Select Your Country



Select the appropriate country using the arrow keys and press **Enter**.

Figure 2-44. Select Your Time Zone



The appropriate time zone is selected using the arrow keys and pressing **Enter**.

```
                     Confirmation
     Does the abbreviation 'EDT' look reasonable?

                     [ Yes ]   No
```

Confirm the abbreviation for the time zone is correct. If it looks okay, press **Enter** to continue with the post-installation configuration.

2.9.9 Linux Compatibility

```
                  User Confirmation Requested
         Would you like to enable Linux binary compatibility?

                        [ Yes ]   No
```

Selecting [Yes] and pressing **Enter** will allow running Linux software on FreeBSD. The install will add the appropriate packages for Linux compatibility.

If installing by FTP, the machine will need to be connected to the Internet. Sometimes a remote ftp site will not have all the distributions like the Linux binary compatibility. This can be installed later if necessary.

2.9.10 Mouse Settings

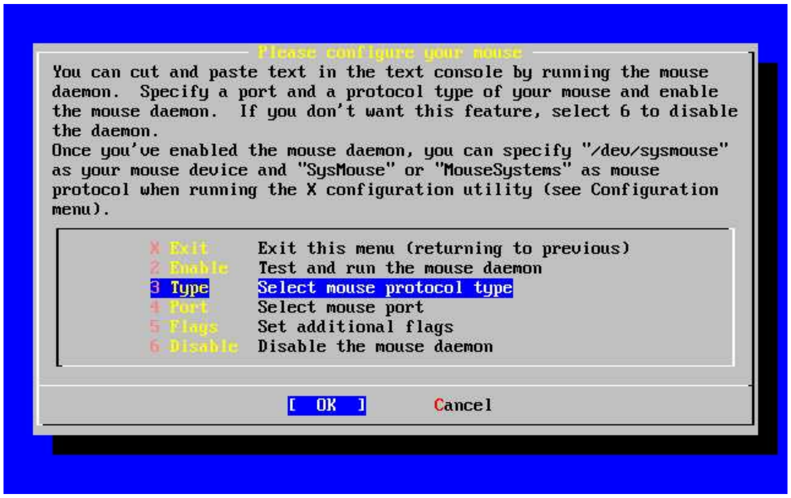
This option will allow you to cut and paste text in the console and user programs with a 3-button mouse. If using a 2-button mouse, refer to manual page, moused(8), after installation for details on emulating the 3-button style. This example depicts a non-USB mouse configuration (such as a PS/2 or COM port mouse):

```
                   User Confirmation Requested
         Does this system have a non-USB mouse attached to it?
```

[Yes]   No

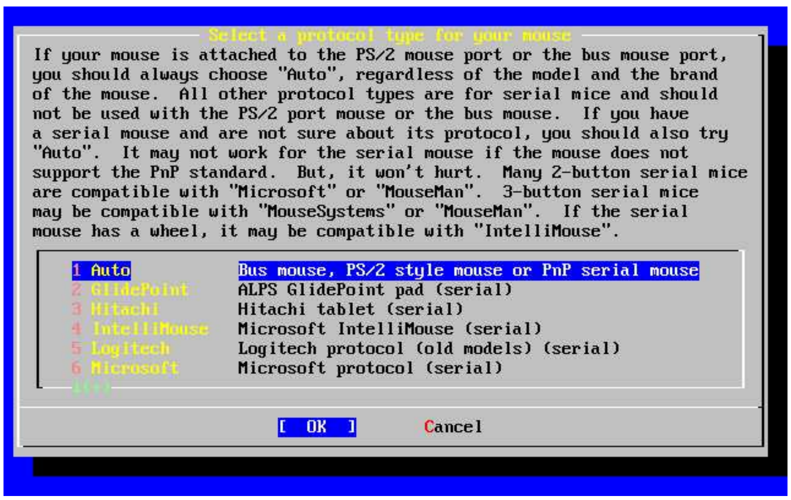
Select [Yes] for a non-USB mouse or [No] for a USB mouse and press **Enter**.

Figure 2-45. Select Mouse Protocol Type



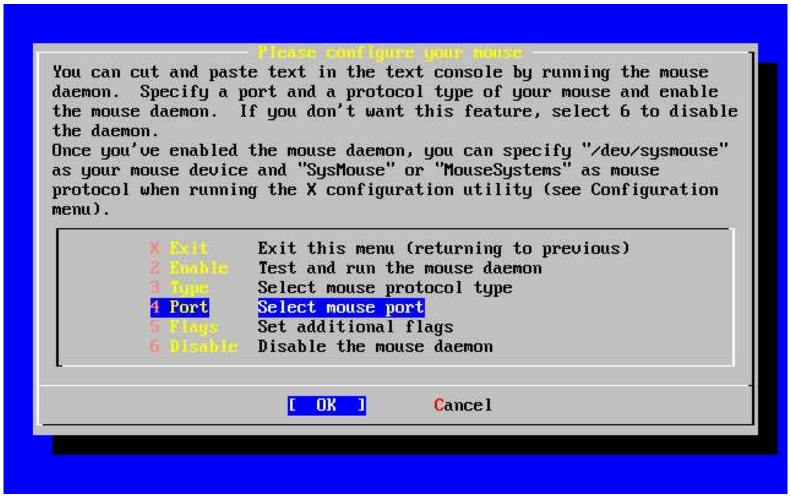
Use the arrow keys to select Type and press **Enter**.

Figure 2-46. Set Mouse Protocol



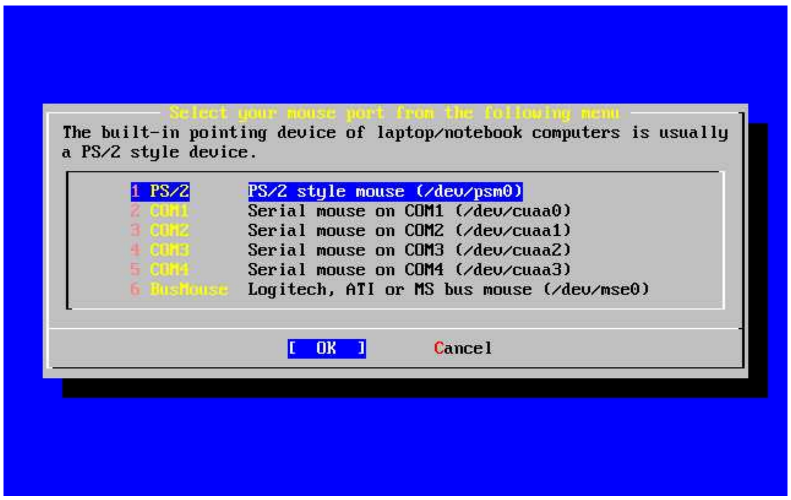
The mouse used in this example is a PS/2 type, so the default Auto was appropriate. To change protocol, use the arrow keys to select another option. Ensure that [OK] is highlighted and press **Enter** to exit this menu.

Figure 2-47. Configure Mouse Port



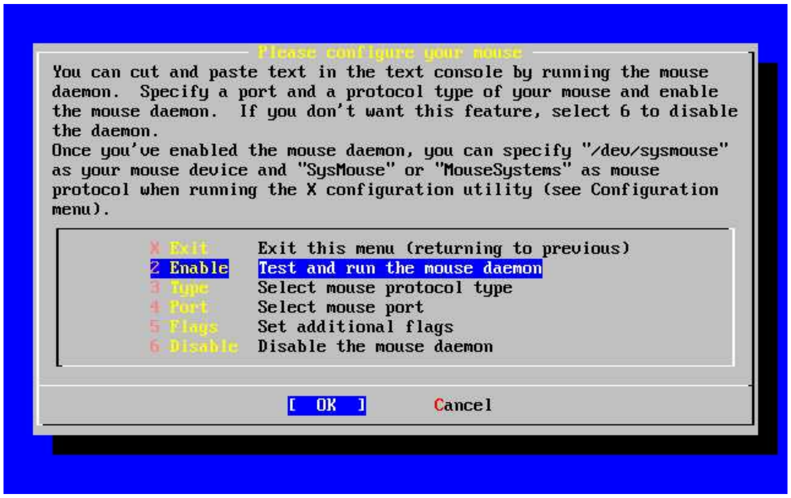
Use the arrow keys to select Port and press **Enter**.

Figure 2-48. Setting the Mouse Port



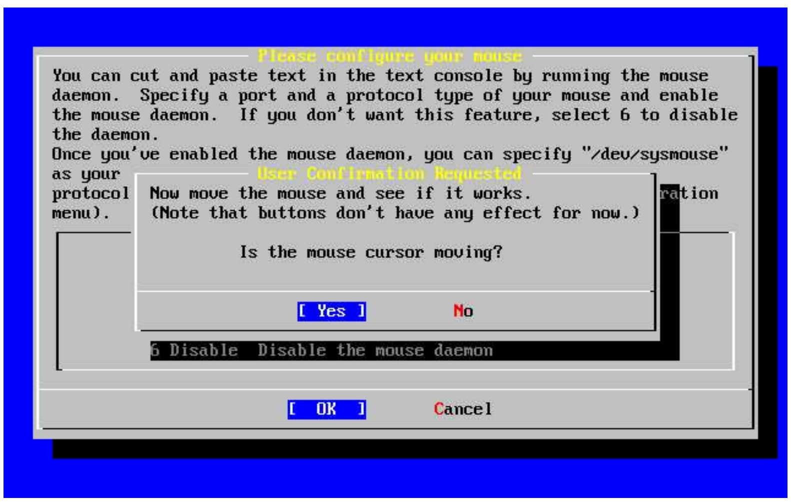
This system had a PS/2 mouse, so the default PS/2 was appropriate. To change the port, use the arrow keys and then press **Enter**.

Figure 2-49. Enable the Mouse Daemon



Last, use the arrow keys to select Enable, and press **Enter** to enable and test the mouse daemon.

Figure 2-50. Test the Mouse Daemon



Move the mouse around the screen and verify the cursor shown responds properly. If it does, select [Yes] and press **Enter**. If not, the mouse has not been configured correctly — select [No] and try using different configuration options.

Select Exit with the arrow keys and press **Enter** to return to continue with the post-installation configuration.

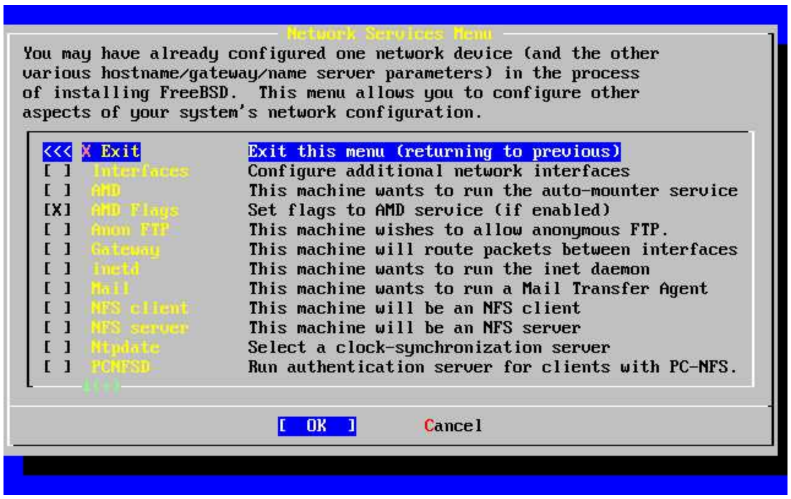
2.9.11 Configure Additional Network Services

Configuring network services can be a daunting task for new users if they lack previous knowledge in this area. Networking, including the Internet, is critical to all modern operating systems including FreeBSD; as a result, it is very useful to have some understanding FreeBSD's extensive networking capabilities. Doing this during the installation will ensure users have some understanding of the various services available to them.

Network services are programs that accept input from anywhere on the network. Every effort is made to make sure these programs will not do anything "harmful". Unfortunately, programmers are not perfect and through time there have been cases where bugs in network services have been exploited by attackers to do bad things. It is important that you only enable the network services you know that you need. If in doubt it is best if you do not enable a network service until you find out that you do need it. You can always enable it later by re-running **sysinstall** or by using the features provided by the `/etc/rc.conf` file.

Selecting the "Networking" option will display a menu similar to the one below:

Figure 2-51. Network Configuration Upper-level



The first option, Interfaces, was previously covered during the Network Device Configuration section; thus this option can safely be ignored.

Selecting the `AMD` option adds support for the BSD auto mount utility. This is usually used in conjunction with the NFS protocol (see below) for automatically mounting remote file systems. No special configuration is required here.

Next in line is the AMD flags option. When selected, a menu will pop up for you to enter specific AMD flags. The menu already contains a set of default options:

```
-a /.amd_mnt -l syslog /host /etc/amd.map /net /etc/amd.map
```

The `-a` option sets the default mount location which is specified here as `/.amd_mnt`. The `-l` option specifies the default `log` file; however, when `syslogd` is specified all log activity will be sent to the system log daemon. The `/host` directory is used to mount an exported file system from a remote host, while `/net` directory is used to mount an exported file system from an IP address. The `/etc/amd.map` file defines the default options for AMD exports.

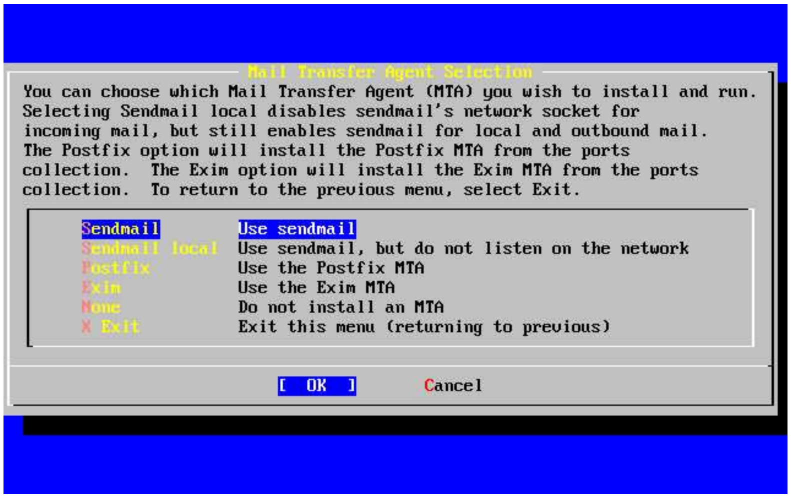
The Anon FTP permits anonymous FTP connections. Select this option to make this machine an anonymous FTP server. Be aware of the security risks involved with this option. Another menu will be displayed to explain the security risks and configuration in depth.

The `Gateway` configuration menu will set the machine up to be a gateway as explained previously. This can be used to unset the gateway option if you accidentally selected it during the installation process.

The `Inetd` option can be used to configure or completely disable the inetd(8) daemon as discussed above.

The `Mail` is used to configure the system's default MTA or Mail Transfer Agent. Selecting this option will bring up the following menu:

Figure 2-52. Select a default MTA



Here you are offered a choice as to which MTA to install and set as the default. An MTA is nothing more than a mail server which delivers email to users on the system or the Internet.

Selecting **Sendmail** will install the popular **Sendmail** server which is the FreeBSD default. The `Sendmail local` option will set **Sendmail** to be the default MTA, but disable its ability to receive incoming email from the Internet. The other options here, **Postfix** and **Exim** act similar to **Sendmail**. They both deliver email; however, some users prefer these alternatives to the **Sendmail** MTA.

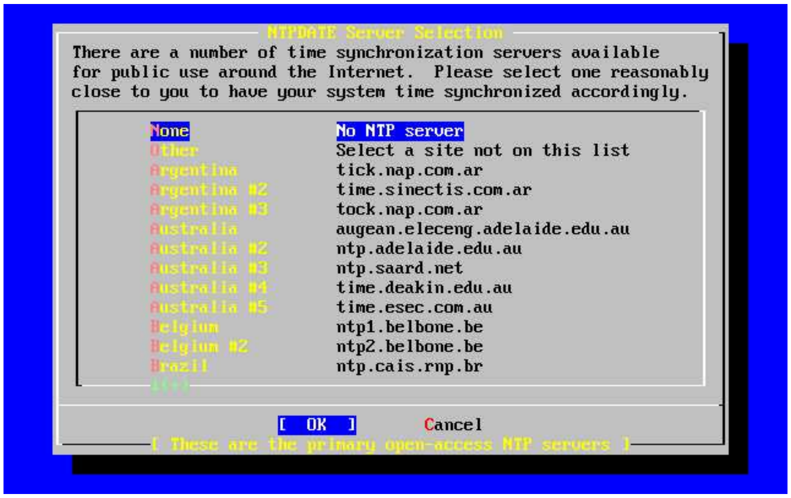
After selecting an MTA, or choosing not to select an MTA, the network configuration menu will appear with the next option being NFS client.

The NFS client will configure the system to communicate with a server via NFS. An NFS server makes file systems available to other machines on the network via the NFS protocol. If this is a stand alone machine, this option can remain unselected. The system may require more configuration later; see Section 19.6 for more information about client and server configuration.

Below that option is the NFS server option, permitting you to set the system up as an NFS server. This adds the required information to start up the RPC remote procedure call services. RPC is used to coordinate connections between hosts and programs.

Next in line is the `Ntpdate` option, which deals with time synchronization. When selected, a menu like the one below shows up:

Figure 2-53. Ntpdate Configuration

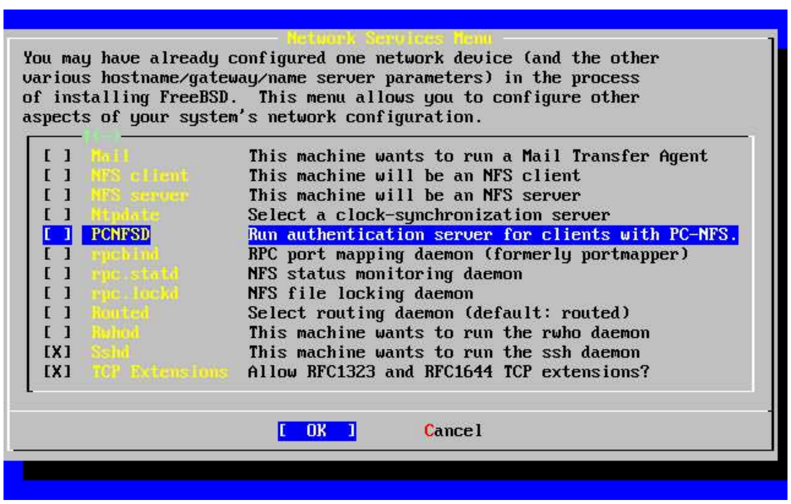


From this menu, select the server which is the closest to your location. Selecting a close one will make the time synchronization more accurate as a server further from your location may have more connection latency.

The next option is the PCNFSD selection. This option will install the `net/pcnfsd` package from the ports collection. This is a useful utility which provides NFS authentication services for systems which are unable to provide their own, such as Microsoft's DOS operating system.

Now you must scroll down a bit to see the other options:

Figure 2-54. Network Configuration Lower-level



The rpcbind(8), rpc.statd(8), and rpc.lockd(8) utilities are all used for Remote Procedure Calls (RPC). The `rpcbind.8` utility manages communication between NFS servers and clients, and is required for NFS servers to operate correctly. The `rpc.statd` daemon interacts with the `rpc.statd` daemon on other hosts to provide status monitoring. The reported status is usually held in the `/var/db/statd.status` file. The final option listed here is the `rpc.lockd` option, which, when selected, will provide file locking services. This is usually used with `rpc.statd` to monitor what hosts are requesting locks and how frequently they request them. While these last two options are marvelous for debugging, they are not required for NFS servers and clients to operate correctly.

As you progress down the list the next item here is `Routed`, which is the routing daemon. The routed(8) utility manages network routing tables, discovers multicast routers, and supplies a copy of the routing tables to any physically connected host on the network upon request. This is mainly used for machines which act as a gateway for the local network (see the icmp(4) and udp(4) manual pages). When selected, a menu will be presented requesting the default location of the utility. The default location is already defined for you and can be selected with the **Enter** key. You will then be presented with yet another menu, this time asking for the flags you wish to pass on to `routed`. The default is `-q` and it should already appear on the screen.

Next in line is the `Rwhod` option which, when selected, will start the rwhod(8) daemon during system initialization. The `rwhod` utility broadcasts system messages across the network periodically, or collects them when in "consumer" mode. More information can be found in the ruptime(1) and rwho(1) manual pages.

The next to the last option in the list is for the sshd(8) daemon. This is the secure shell server for **OpenSSH** and it is highly recommended over the standard `telnet` and FTP servers. The `sshd` server is used to create a secure connection from one host to another by using encrypted connections.

Finally there is the TCP Extensions option. This enables the TCP Extensions defined in RFC 1323 and RFC 1644. While on many hosts this can speed up connections, it can also cause some connections to be dropped. It is not recommended for servers, but may be beneficial for stand alone machines.

Now that you have configured the network services, you can scroll up to the very top item which is `Exit` and continue on to the next configuration section.

2.9.12 Configure X Server

In order to use a graphical user interface such as **KDE**, **GNOME**, or others, the X server will need to be configured.

> **Note:** In order to run **XFree86** as a non `root` user you will need to have `x11/wrapper` installed. This is installed by default beginning with FreeBSD 4.7. For earlier versions this can be added from the Package Selection menu.

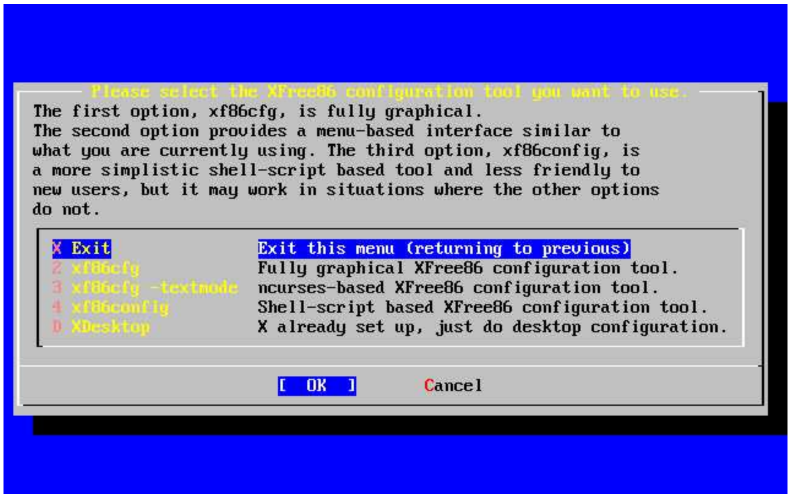
To see whether your video card is supported, check the XFree86 (http://www.xfree86.org/) web site.

```
                  User Confirmation Requested
     Would you like to configure your X server at this time?

                          [ Yes ]   No
```

> **Warning:** It is necessary to know your monitor specifications and video card information. Equipment damage can occur if settings are incorrect. If you do not have this information, select [No] and perform the configuration after installation when you have the information using `/stand/sysinstall`, selecting Configure and then XFree86. Improper configuration of the X server at this time can leave the machine in a frozen state. It is often advised to configure the X server once the installation has completed.

If you have graphics card and monitor information, select [Yes] and press **Enter** to proceed with configuring the X server.

Figure 2-55. Select Configuration Method Menu



There are several ways to configure the X server. Use the arrow keys to select one of the methods and press **Enter**. Be sure to read all instructions carefully.

The **xf86cfg** and **xf86cfg -textmode** methods may make the screen go dark and take a few seconds to start. Be patient.

The following will illustrate the use of the **xf86config** configuration tool. The configuration choices you make will depend on the hardware in the system so your choices will probably be different than those shown:

```
                                Message
 You have configured and been running the mouse daemon.
 Choose "/dev/sysmouse" as the mouse port and "SysMouse" or
 "MouseSystems" as the mouse protocol in the X configuration utility.

                                 [ OK ]

                      [ Press enter to continue ]
```

This indicates that the mouse daemon previously configured has been detected. Press **Enter** to continue.

Starting **xf86config** will display a brief introduction:

```
This program will create a basic XF86Config file, based on menu selections you
make.

The XF86Config file usually resides in /usr/X11R6/etc/X11 or /etc/X11. A sample
XF86Config file is supplied with XFree86; it is configured for a standard
VGA card and monitor with 640x480 resolution. This program will ask for a
pathname when it is ready to write the file.

You can either take the sample XF86Config as a base and edit it for your
configuration, or let this program produce a base XF86Config file for your
configuration and fine-tune it.

Before continuing with this program, make sure you know what video card
```

```
you have, and preferably also the chipset it uses and the amount of video
memory on your video card. SuperProbe may be able to help with this.

Press enter to continue, or ctrl-c to abort.
```

Pressing **Enter** will start the mouse configuration. Be sure to follow the instructions and use "Mouse Systems" as the mouse protocol and `/dev/sysmouse` as the mouse port even if using a PS/2 mouse is shown as an illustration.

```
First specify a mouse protocol type. Choose one from the following list:

 1.  Microsoft compatible (2-button protocol)
 2.  Mouse Systems (3-button protocol) & FreeBSD moused protocol
 3.  Bus Mouse
 4.  PS/2 Mouse
 5.  Logitech Mouse (serial, old type, Logitech protocol)
 6.  Logitech MouseMan (Microsoft compatible)
 7.  MM Series
 8.  MM HitTablet
 9.  Microsoft IntelliMouse

If you have a two-button mouse, it is most likely of type 1, and if you have
a three-button mouse, it can probably support both protocol 1 and 2. There are
two main varieties of the latter type: mice with a switch to select the
protocol, and mice that default to 1 and require a button to be held at
boot-time to select protocol 2. Some mice can be convinced to do 2 by sending
a special sequence to the serial port (see the ClearDTR/ClearRTS options).

Enter a protocol number: 2

You have selected a Mouse Systems protocol mouse. If your mouse is normally
in Microsoft-compatible mode, enabling the ClearDTR and ClearRTS options
may cause it to switch to Mouse Systems mode when the server starts.

Please answer the following question with either ’y’ or ’n’.
Do you want to enable ClearDTR and ClearRTS? n

You have selected a three-button mouse protocol. It is recommended that you
do not enable Emulate3Buttons, unless the third button doesn’t work.

Please answer the following question with either ’y’ or ’n’.
Do you want to enable Emulate3Buttons? y

Now give the full device name that the mouse is connected to, for example
/dev/tty00. Just pressing enter will use the default, /dev/mouse.
On FreeBSD, the default is /dev/sysmouse.

Mouse device: /dev/sysmouse
```

The keyboard is the next item to be configured. A generic 101-key model is shown for illustration. Any name may be used for the variant or simply press **Enter** to accept the default value.

```
Please select one of the following keyboard types that is the better
description of your keyboard. If nothing really matches,
```

```
choose 1 (Generic 101-key PC)

  1  Generic 101-key PC
  2  Generic 102-key (Intl) PC
  3  Generic 104-key PC
  4  Generic 105-key (Intl) PC
  5  Dell 101-key PC
  6  Everex STEPnote
  7  Keytronic FlexPro
  8  Microsoft Natural
  9  Northgate OmniKey 101
 10  Winbook Model XP5
 11  Japanese 106-key
 12  PC-98xx Series
 13  Brazilian ABNT2
 14  HP Internet
 15  Logitech iTouch
 16  Logitech Cordless Desktop Pro
 17  Logitech Internet Keyboard
 18  Logitech Internet Navigator Keyboard
 19  Compaq Internet
 20  Microsoft Natural Pro
 21  Genius Comfy KB-16M
 22  IBM Rapid Access
 23  IBM Rapid Access II
 24  Chicony Internet Keyboard
 25  Dell Internet Keyboard

Enter a number to choose the keyboard.

1


Please select the layout corresponding to your keyboard


  1  U.S. English
  2  U.S. English w/ ISO9995-3
  3  U.S. English w/ deadkeys
  4  Albanian
  5  Arabic
  6  Armenian
  7  Azerbaidjani
  8  Belarusian
  9  Belgian
 10  Bengali
 11  Brazilian
 12  Bulgarian
 13  Burmese
 14  Canadian
 15  Croatian
 16  Czech
 17  Czech (qwerty)
```

```
 18  Danish

Enter a number to choose the country.
Press enter for the next page

1


Please enter a variant name for 'us' layout. Or just press enter
for default variant

us


Please answer the following question with either 'y' or 'n'.
Do you want to select additional XKB options (group switcher,
group indicator, etc.)? n
```

Next, we proceed to the configuration for the monitor. Do not exceed the ratings of your monitor. Damage could occur. If you have any doubts, do the configuration after you have the information.

```
Now we want to set the specifications of the monitor. The two critical
parameters are the vertical refresh rate, which is the rate at which the
whole screen is refreshed, and most importantly the horizontal sync rate,
which is the rate at which scanlines are displayed.

The valid range for horizontal sync and vertical sync should be documented
in the manual of your monitor. If in doubt, check the monitor database
/usr/X11R6/lib/X11/doc/Monitors to see if your monitor is there.

Press enter to continue, or ctrl-c to abort.



You must indicate the horizontal sync range of your monitor. You can either
select one of the predefined ranges below that correspond to industry-
standard monitor types, or give a specific range.

It is VERY IMPORTANT that you do not specify a monitor type with a horizontal
sync range that is beyond the capabilities of your monitor. If in doubt,
choose a conservative setting.

    hsync in kHz; monitor type with characteristic modes
 1  31.5; Standard VGA, 640x480 @ 60 Hz
 2  31.5 - 35.1; Super VGA, 800x600 @ 56 Hz
 3  31.5, 35.5; 8514 Compatible, 1024x768 @ 87 Hz interlaced (no 800x600)
 4  31.5, 35.15, 35.5; Super VGA, 1024x768 @ 87 Hz interlaced, 800x600 @ 56 Hz
 5  31.5 - 37.9; Extended Super VGA, 800x600 @ 60 Hz, 640x480 @ 72 Hz
 6  31.5 - 48.5; Non-Interlaced SVGA, 1024x768 @ 60 Hz, 800x600 @ 72 Hz
 7  31.5 - 57.0; High Frequency SVGA, 1024x768 @ 70 Hz
 8  31.5 - 64.3; Monitor that can do 1280x1024 @ 60 Hz
 9  31.5 - 79.0; Monitor that can do 1280x1024 @ 74 Hz
10  31.5 - 82.0; Monitor that can do 1280x1024 @ 76 Hz
```

```
11  Enter your own horizontal sync range

Enter your choice (1-11): 6

You must indicate the vertical sync range of your monitor. You can either
select one of the predefined ranges below that correspond to industry-
standard monitor types, or give a specific range. For interlaced modes,
the number that counts is the high one (e.g. 87 Hz rather than 43 Hz).

 1  50-70
 2  50-90
 3  50-100
 4  40-150
 5  Enter your own vertical sync range

Enter your choice: 2

You must now enter a few identification/description strings, namely an
identifier, a vendor name, and a model name. Just pressing enter will fill
in default names.

The strings are free-form, spaces are allowed.
Enter an identifier for your monitor definition: Hitachi
```

The selection of a video card driver from a list is next. If you pass your card on the list, continue to press **Enter** and the list will repeat. Only an excerpt from the list is shown:

```
Now we must configure video card specific settings. At this point you can
choose to make a selection out of a database of video card definitions.
Because there can be variation in Ramdacs and clock generators even
between cards of the same model, it is not sensible to blindly copy
the settings (e.g. a Device section). For this reason, after you make a
selection, you will still be asked about the components of the card, with
the settings from the chosen database entry presented as a strong hint.

The database entries include information about the chipset, what driver to
run, the Ramdac and ClockChip, and comments that will be included in the
Device section. However, a lot of definitions only hint about what driver
to run (based on the chipset the card uses) and are untested.

If you can’t find your card in the database, there’s nothing to worry about.
You should only choose a database entry that is exactly the same model as
your card; choosing one that looks similar is just a bad idea (e.g. a
GemStone Snail 64 may be as different from a GemStone Snail 64+ in terms of
hardware as can be).

Do you want to look at the card database? y



288  Matrox Millennium G200 8MB                        mgag200
289  Matrox Millennium G200 SD 16MB                    mgag200
290  Matrox Millennium G200 SD 4MB                     mgag200
```

```
291  Matrox Millennium G200 SD 8MB                       mgag200
292  Matrox Millennium G400                              mgag400
293  Matrox Millennium II 16MB                           mga2164w
294  Matrox Millennium II 4MB                            mga2164w
295  Matrox Millennium II 8MB                            mga2164w
296  Matrox Mystique                                     mga1064sg
297  Matrox Mystique G200 16MB                           mgag200
298  Matrox Mystique G200 4MB                            mgag200
299  Matrox Mystique G200 8MB                            mgag200
300  Matrox Productiva G100 4MB                          mgag100
301  Matrox Productiva G100 8MB                          mgag100
302  MediaGX                                             mediagx
303  MediaVision Proaxcel 128                            ET6000
304  Mirage Z-128                                        ET6000
305  Miro CRYSTAL VRX                                    Verite 1000

Enter a number to choose the corresponding card definition.
Press enter for the next page, q to continue configuration.

288

Your selected card definition:

Identifier: Matrox Millennium G200 8MB
Chipset:    mgag200
Driver:     mga
Do NOT probe clocks or use any Clocks line.

Press enter to continue, or ctrl-c to abort.



Now you must give information about your video card. This will be used for
the "Device" section of your video card in XF86Config.

You must indicate how much video memory you have. It is probably a good
idea to use the same approximate amount as that detected by the server you
intend to use. If you encounter problems that are due to the used server
not supporting the amount memory you have (e.g. ATI Mach64 is limited to
1024K with the SVGA server), specify the maximum amount supported by the
server.

How much video memory do you have on your video card:

 1  256K
 2  512K
 3  1024K
 4  2048K
 5  4096K
 6  Other

Enter your choice: 6
```

```
Amount of video memory in Kbytes: 8192

You must now enter a few identification/description strings, namely an
identifier, a vendor name, and a model name. Just pressing enter will fill
in default names (possibly from a card definition).

Your card definition is Matrox Millennium G200 8MB.

The strings are free-form, spaces are allowed.
Enter an identifier for your video card definition:
```

Next, the video modes are set for the resolutions desired. Typically, useful ranges are 640x480, 800x600, and 1024x768 but those are a function of video card capability, monitor size, and eye comfort. When selecting a color depth, select the highest mode that your card will support.

```
For each depth, a list of modes (resolutions) is defined. The default
resolution that the server will start-up with will be the first listed
mode that can be supported by the monitor and card.
Currently it is set to:

"640x480" "800x600" "1024x768" "1280x1024" for 8-bit
"640x480" "800x600" "1024x768" "1280x1024" for 16-bit
"640x480" "800x600" "1024x768" "1280x1024" for 24-bit

Modes that cannot be supported due to monitor or clock constraints will
be automatically skipped by the server.

 1  Change the modes for 8-bit (256 colors)
 2  Change the modes for 16-bit (32K/64K colors)
 3  Change the modes for 24-bit (24-bit color)
 4  The modes are OK, continue.

Enter your choice: 2

Select modes from the following list:

 1  "640x400"
 2  "640x480"
 3  "800x600"
 4  "1024x768"
 5  "1280x1024"
 6  "320x200"
 7  "320x240"
 8  "400x300"
 9  "1152x864"
 a  "1600x1200"
 b  "1800x1400"
 c  "512x384"

Please type the digits corresponding to the modes that you want to select.
For example, 432 selects "1024x768" "800x600" "640x480", with a
default mode of 1024x768.
```

```
Which modes? 432

You can have a virtual screen (desktop), which is screen area that is larger
than the physical screen and which is panned by moving the mouse to the edge
of the screen. If you don't want virtual desktop at a certain resolution,
you cannot have modes listed that are larger. Each color depth can have a
differently-sized virtual screen

Please answer the following question with either 'y' or 'n'.
Do you want a virtual screen that is larger than the physical screen? n



For each depth, a list of modes (resolutions) is defined. The default
resolution that the server will start-up with will be the first listed
mode that can be supported by the monitor and card.
Currently it is set to:

"640x480" "800x600" "1024x768" "1280x1024" for 8-bit
"1024x768" "800x600" "640x480" for 16-bit
"640x480" "800x600" "1024x768" "1280x1024" for 24-bit

Modes that cannot be supported due to monitor or clock constraints will
be automatically skipped by the server.

 1  Change the modes for 8-bit (256 colors)
 2  Change the modes for 16-bit (32K/64K colors)
 3  Change the modes for 24-bit (24-bit color)
 4  The modes are OK, continue.

Enter your choice: 4



Please specify which color depth you want to use by default:

  1  1 bit (monochrome)
  2  4 bits (16 colors)
  3  8 bits (256 colors)
  4  16 bits (65536 colors)
  5  24 bits (16 million colors)

Enter a number to choose the default depth.

4
```

Finally, the configuration needs to be saved. Be sure to enter `/etc/XF86Config` as the location for saving the configuration.

```
I am going to write the XF86Config file now. Make sure you don't accidently
overwrite a previously configured one.

Shall I write it to /etc/X11/XF86Config? y
```

If the configuration fails, you can try the configuration again by selecting [Yes] when the following message appears:

```
          User Confirmation Requested
The XFree86 configuration process seems to have
failed.  Would you like to try again?

             [ Yes ]         No
```

If you have trouble configuring **XFree86**, select [No] and press **Enter** and continue with the installation process. After installation you can use `xf86cfg -textmode` or `xf86config` to access the command line configuration utilities as `root`. There is an additional method for configuring **XFree86** described in Chapter 5. If you choose not to configure **XFree86** at this time the next menu will be for package selection.

The default setting which allows the server to be killed is the hotkey sequence **Ctrl**+**Alt**+**Backspace**. This can be executed if something is wrong with the server settings and prevent hardware damage.

The default setting that allows video mode switching will permit changing of the mode while running X with the hotkey sequence **Ctrl**+**Alt**+**+** or **Ctrl**+**Alt**+**-**.

After installation, the display can be adjusted for height, width, or centering by using **xvidtune** after you have **XFree86** running with **xvidtune**.

There are warnings that improper settings can damage your equipment. Heed them. If in doubt, do not do it. Instead, use the monitor controls to adjust the display for X Window. There may be some display differences when switching back to text mode, but it is better than damaging equipment.

Read the xvidtune(1) manual page before making any adjustments.

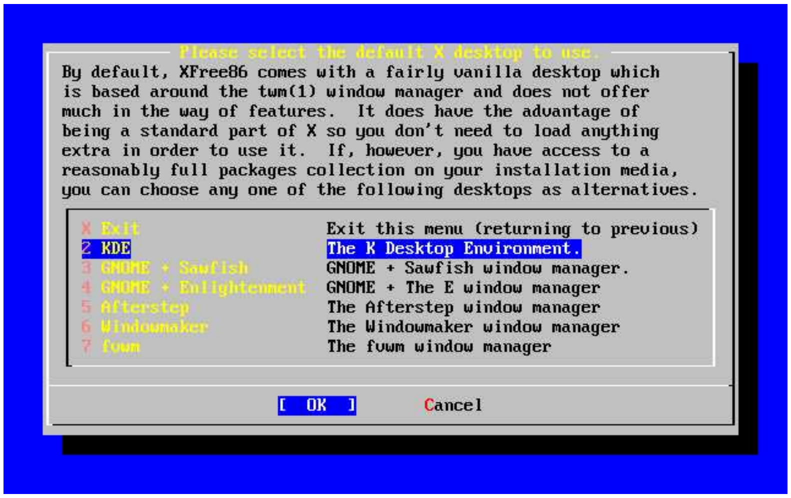
Following a successful **XFree86** configuration, it will proceed to the selection of a default desktop.

2.9.13 Select Default X Desktop

There are a variety of window managers available. They range from very basic environments to full desktop environments with a large suite of software. Some require only minimal disk space and low memory while others with more features require much more. The best way to determine which is most suitable for you is to try a few different ones. Those are available from the ports collection or as packages and can be added after installation.

You can select one of the popular desktops to be installed and configured as the default desktop. This will allow you to start it right after installation.

Figure 2-56. Select Default Desktop



Use the arrow keys to select a desktop and press **Enter**. Installation of the selected desktop will proceed.

2.9.14 Install Packages

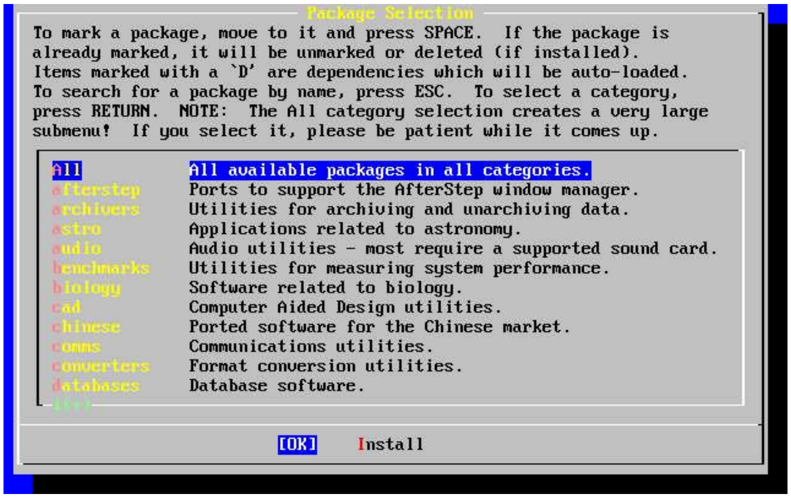
Packages are pre-compiled binaries and are a convenient way to install software.

Installation of one package is shown for purposes of illustration. Additional packages can also be added at this time if desired. After installation `/stand/sysinstall` can be used to add additional packages.

```
                        User Confirmation Requested
 The FreeBSD package collection is a collection of hundreds of
 ready-to-run applications, from text editors to games to WEB servers
 and more. Would you like to browse the collection now?

                                [ Yes ]    No
```

Selecting [Yes] and pressing **Enter** will be followed by the Package Selection screens:

Figure 2-57. Select Package Category

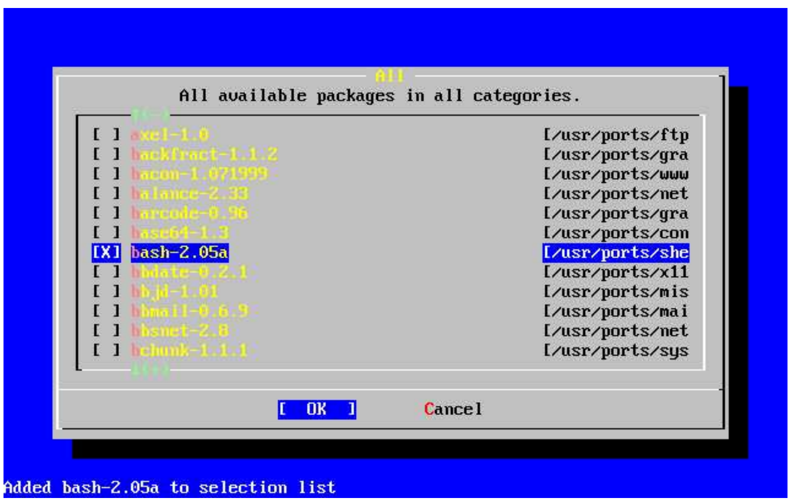


Only packages on the current installation media are available for installation at any given time.

All packages available will be displayed if All is selected or you can select a particular category. Highlight your selection with the arrow keys and press **Enter**.

A menu will display showing all the packages available for the selection made:

Figure 2-58. Select Packages



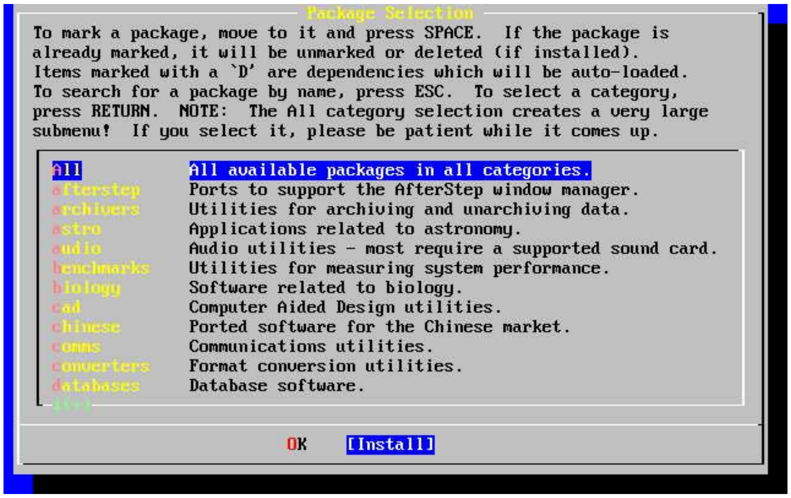
The **bash** shell is shown selected. Select as many as desired by highlighting the package and pressing the **Space** key. A short description of each package will appear in the lower left corner of the screen.

Pressing the **Tab** key will toggle between the last selected package, [OK], and [Cancel].

When you have finished marking the packages for installation, press **Tab** once to toggle to the [OK] and press **Enter** to return to the Package Selection menu.

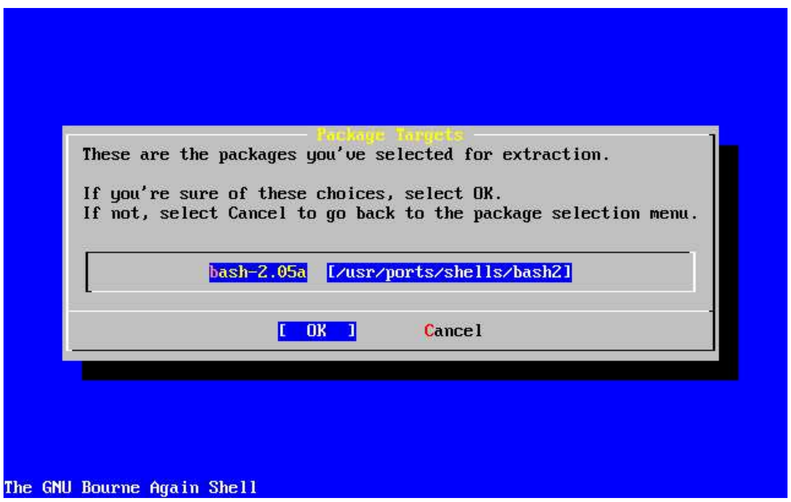
The left and right arrow keys will also toggle between [OK] and [Cancel]. This method can also be used to select [OK] and press **Enter** to return to the Package Selection menu.

Figure 2-59. Install Packages



Use the **Tab** and arrow keys to select [Install] and press **Enter**. You will then need to confirm that you want to install the packages:

Figure 2-60. Confirm Package Installation



Selecting [OK] and pressing **Enter** will start the package installation. Installing messages will appear until completed. Make note if there are any error messages.

The final configuration continues after packages are installed. If you end up not selecting any packages, and wish to return to the final configuration, select Install anyways.

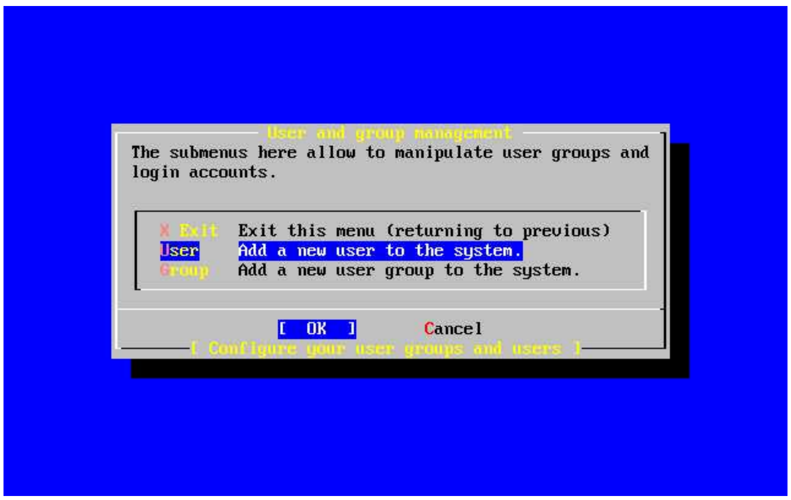
2.9.15 Add Users/Groups

You should add at least one user during the installation so that you can use the system without being logged in as `root`. The root partition is generally small and running applications as `root` can quickly fill it. A bigger danger is noted below:

```
                    User Confirmation Requested
Would you like to add any initial user accounts to the system? Adding
at least one account for yourself at this stage is suggested since
working as the "root" user is dangerous (it is easy to do things which
adversely affect the entire system).

                          [ Yes ]   No
```

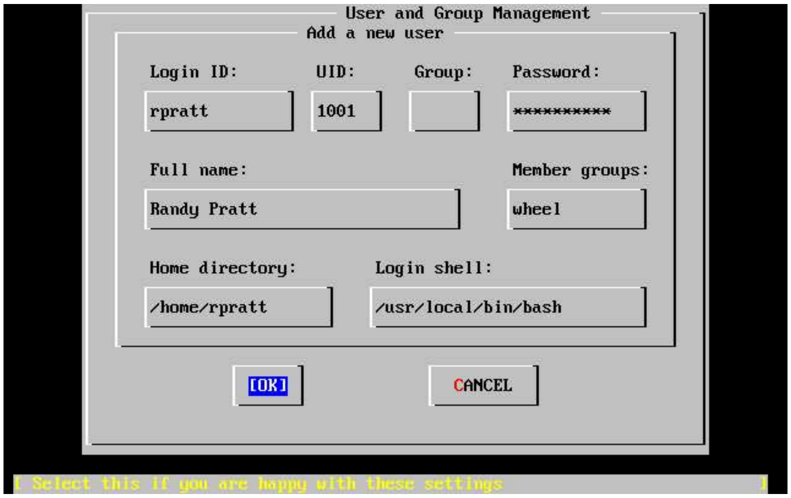
Select [Yes] and press **Enter** to continue with adding a user.

Figure 2-61. Select User



Select User with the arrow keys and press **Enter**.

Figure 2-62. Add User Information



The following descriptions will appear in the lower part of the screen as the items are selected with **Tab** to assist with entering the required information:

Login ID

The login name of the new user (mandatory).

UID

The numerical ID for this user (leave blank for automatic choice).

Group

The login group name for this user (leave blank for automatic choice).

Password

The password for this user (enter this field with care!).

Full name

The user’s full name (comment).

Member groups

The groups this user belongs to (i.e. gets access rights for).

Home directory

The user’s home directory (leave blank for default).

Login shell

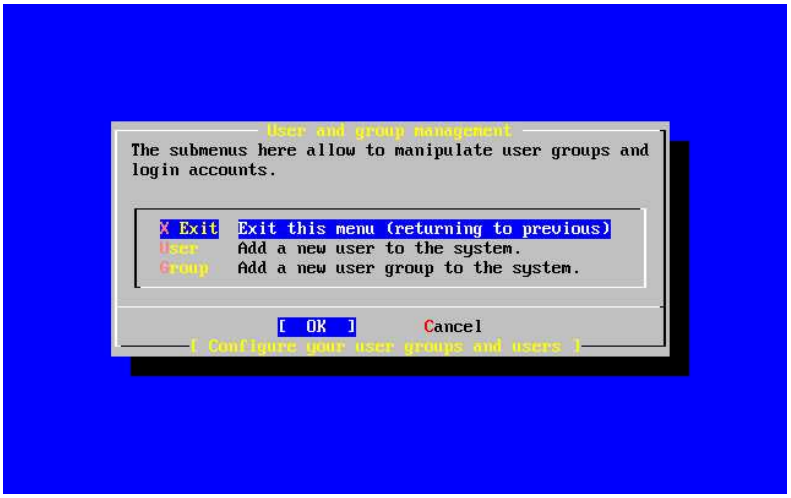
The user’s login shell (leave blank for default, e.g. `/bin/sh`).

The login shell was changed from `/bin/sh` to `/usr/local/bin/bash` to use the **bash** shell that was previously installed as a package. Do not try to use a shell that does not exist or you will not be able to login. The most common shell used in the BSD-world is the C shell, which can be indicated as `/bin/tcsh`.

The user was also added to the `wheel` group to be able to become a superuser with `root` privileges.

When you are satisfied, press [OK] and the User and Group Management menu will redisplay:

Figure 2-63. Exit User and Group Management



Groups can also be added at this time if specific needs are known. Otherwise, this may be accessed through using `/stand/sysinstall` after installation is completed.

When you are finished adding users, select Exit with the arrow keys and press **Enter** to continue the installation.

2.9.16 Set the `root` Password

```
                        Message
 Now you must set the system manager's password.
 This is the password you'll use to log in as "root".

                         [ OK ]

               [ Press enter to continue ]
```

Press **Enter** to set the `root` password.

The password will need to be typed in twice correctly. Needless to say, make sure you have a way of finding the password if you forget.

```
Changing local password for root.
New password :
Retype new password :
```

The installation will continue after the password is successfully entered.

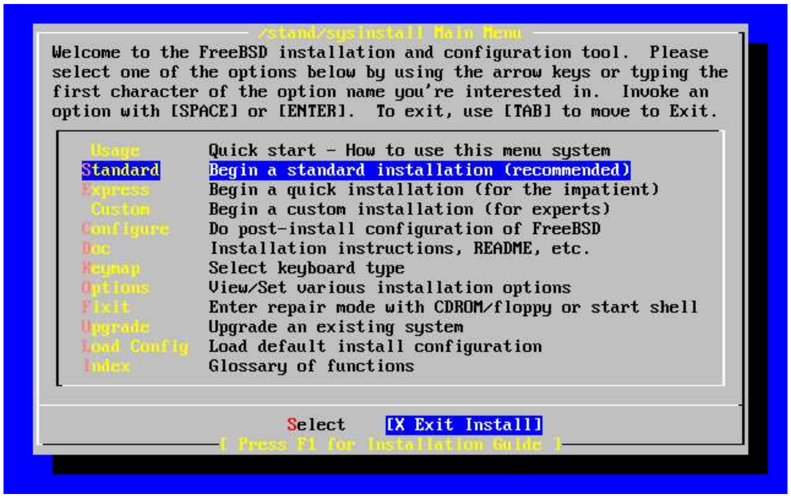
2.9.17 Exiting Install

If you need to configure additional network devices or any other configuration, you can do it at this point or after installation with `/stand/sysinstall`.

```
                    User Confirmation Requested
Visit the general configuration menu for a chance to set any last
options?

                             Yes   [ No ]
```

Select [No] with the arrow keys and press **Enter** to return to the Main Installation Menu.

Figure 2-64. Exit Install



Select [X Exit Install] with the arrow keys and press **Enter**. You will be asked to confirm exiting the installation:

```
                    User Confirmation Requested
Are you sure you wish to exit? The system will reboot (be sure to
remove any floppies from the drives).

                           [ Yes ]   No
```

Select [Yes] and remove the floppy if booting from the floppy. The CDROM drive is locked until the machine starts to reboot. The CDROM drive is then unlocked and the disk can be removed from drive (quickly).

The system will reboot so watch for any error messages that may appear.

2.9.18 FreeBSD Bootup

2.9.18.1 FreeBSD Bootup on the i386

If everything went well, you will see messages scroll off the screen and you will arrive at a login prompt. You can view the content of the messages by pressing **Scroll-Lock** and using **PgUp** and **PgDn**. Pressing **Scroll-Lock** again will return to the prompt.

The entire message may not display (buffer limitation) but it can be viewed from the command line after logging in by typing `dmesg` at the prompt.

Login using the username/password you set during installation (`rpratt`, in this example). Avoid logging in as `root` except when necessary.

Typical boot messages (version information omitted):

```
Copyright (c) 1992-2002 The FreeBSD Project.
Copyright (c) 1979, 1980, 1983, 1986, 1988, 1989, 1991, 1992, 1993, 1994
        The Regents of the University of California. All rights reserved.

Timecounter "i8254"  frequency 1193182 Hz
CPU: AMD-K6(tm) 3D processor (300.68-MHz 586-class CPU)
  Origin = "AuthenticAMD"  Id = 0x580  Stepping = 0
  Features=0x8001bf<FPU,VME,DE,PSE,TSC,MSR,MCE,CX8,MMX>
  AMD Features=0x80000800<SYSCALL,3DNow!>
real memory  = 268435456 (262144K bytes)
config> di sn0
config> di lnc0
config> di le0
config> di ie0
config> di fe0
config> di cs0
config> di bt0
config> di aic0
config> di aha0
config> di adv0
config> q
avail memory = 256311296 (250304K bytes)
Preloaded elf kernel "kernel" at 0xc0491000.
Preloaded userconfig_script "/boot/kernel.conf" at 0xc049109c.
md0: Malloc disk
Using $PIR table, 4 entries at 0xc00fde60
npx0: <math processor> on motherboard
npx0: INT 16 interface
pcib0: <Host to PCI bridge> on motherboard
pci0: <PCI bus> on pcib0
pcib1: <VIA 82C598MVP (Apollo MVP3) PCI-PCI (AGP) bridge> at device 1.0 on pci0
pci1: <PCI bus> on pcib1
pci1: <Matrox MGA G200 AGP graphics accelerator> at 0.0 irq 11
isab0: <VIA 82C586 PCI-ISA bridge> at device 7.0 on pci0
isa0: <ISA bus> on isab0
atapci0: <VIA 82C586 ATA33 controller> port 0xe000-0xe00f at device 7.1 on pci0
ata0: at 0x1f0 irq 14 on atapci0
ata1: at 0x170 irq 15 on atapci0
uhci0: <VIA 83C572 USB controller> port 0xe400-0xe41f irq 10 at device 7.2 on pci0
usb0: <VIA 83C572 USB controller> on uhci0
usb0: USB revision 1.0
uhub0: VIA UHCI root hub, class 9/0, rev 1.00/1.00, addr 1
uhub0: 2 ports with 2 removable, self powered
chip1: <VIA 82C586B ACPI interface> at device 7.3 on pci0
ed0: <NE2000 PCI Ethernet (RealTek 8029)> port 0xe800-0xe81f irq 9 at
device 10.0 on pci0
```

```
ed0: address 52:54:05:de:73:1b, type NE2000 (16 bit)
isa0: too many dependant configs (8)
isa0: unexpected small tag 14
fdc0: <NEC 72065B or clone> at port 0x3f0-0x3f5,0x3f7 irq 6 drq 2 on isa0
fdc0: FIFO enabled, 8 bytes threshold
fd0: <1440-KB 3.5" drive> on fdc0 drive 0
atkbdc0: <keyboard controller (i8042)> at port 0x60-0x64 on isa0
atkbd0: <AT Keyboard> flags 0x1 irq 1 on atkbdc0
kbd0 at atkbd0
psm0: <PS/2 Mouse> irq 12 on atkbdc0
psm0: model Generic PS/2 mouse, device ID 0
vga0: <Generic ISA VGA> at port 0x3c0-0x3df iomem 0xa0000-0xbffff on isa0
sc0: <System console> at flags 0x1 on isa0
sc0: VGA <16 virtual consoles, flags=0x300>
sio0 at port 0x3f8-0x3ff irq 4 flags 0x10 on isa0
sio0: type 16550A
sio1 at port 0x2f8-0x2ff irq 3 on isa0
sio1: type 16550A
ppc0: <Parallel port> at port 0x378-0x37f irq 7 on isa0
ppc0: SMC-like chipset (ECP/EPP/PS2/NIBBLE) in COMPATIBLE mode
ppc0: FIFO with 16/16/15 bytes threshold
ppbus0: IEEE1284 device found /NIBBLE
Probing for PnP devices on ppbus0:
plip0: <PLIP network interface> on ppbus0
lpt0: <Printer> on ppbus0
lpt0: Interrupt-driven port
ppi0: <Parallel I/O> on ppbus0
ad0: 8063MB <IBM-DHEA-38451> [16383/16/63] at ata0-master using UDMA33
ad2: 8063MB <IBM-DHEA-38451> [16383/16/63] at ata1-master using UDMA33
acd0: CDROM <DELTA OTC-H101/ST3 F/W by OIPD> at ata0-slave using PIO4
Mounting root from ufs:/dev/ad0s1a
swapon: adding /dev/ad0s1b as swap device
Automatic boot in progress...
/dev/ad0s1a: FILESYSTEM CLEAN; SKIPPING CHECKS
/dev/ad0s1a: clean, 48752 free (552 frags, 6025 blocks, 0.9% fragmentation)
/dev/ad0s1f: FILESYSTEM CLEAN; SKIPPING CHECKS
/dev/ad0s1f: clean, 128997 free (21 frags, 16122 blocks, 0.0% fragmentation)
/dev/ad0s1g: FILESYSTEM CLEAN; SKIPPING CHECKS
/dev/ad0s1g: clean, 3036299 free (43175 frags, 374073 blocks, 1.3% fragmentation)
/dev/ad0s1e: filesystem CLEAN; SKIPPING CHECKS
/dev/ad0s1e: clean, 128193 free (17 frags, 16022 blocks, 0.0% fragmentation)
Doing initial network setup: hostname.
ed0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet 192.168.0.1 netmask 0xffffff00 broadcast 192.168.0.255
        inet6 fe80::5054::5ff::fede:731b%ed0 prefixlen 64 tentative scopeid 0x1
        ether 52:54:05:de:73:1b
lo0: flags=8049<UP,LOOPBACK,RUNNING,MULTICAST> mtu 16384
        inet6 fe80::1%lo0 prefixlen 64 scopeid 0x8
        inet6 ::1 prefixlen 128
        inet 127.0.0.1 netmask 0xff000000
Additional routing options: IP gateway=YES TCP keepalive=YES
routing daemons:.
additional daemons: syslogd.
```

```
Doing additional network setup:.
Starting final network daemons: creating ssh RSA host key
Generating public/private rsa1 key pair.
Your identification has been saved in /etc/ssh/ssh_host_key.
Your public key has been saved in /etc/ssh/ssh_host_key.pub.
The key fingerprint is:
cd:76:89:16:69:0e:d0:6e:f8:66:d0:07:26:3c:7e:2d root@k6-2.example.com
 creating ssh DSA host key
Generating public/private dsa key pair.
Your identification has been saved in /etc/ssh/ssh_host_dsa_key.
Your public key has been saved in /etc/ssh/ssh_host_dsa_key.pub.
The key fingerprint is:
f9:a1:a9:47:c4:ad:f9:8d:52:b8:b8:ff:8c:ad:2d:e6 root@k6-2.example.com.
setting ELF ldconfig path: /usr/lib /usr/lib/compat /usr/X11R6/lib
/usr/local/lib
a.out ldconfig path: /usr/lib/aout /usr/lib/compat/aout /usr/X11R6/lib/aout
starting standard daemons: inetd cron sshd usbd sendmail.
Initial rc.i386 initialization:.
rc.i386 configuring syscons: blank_time screensaver moused.
Additional ABI support: linux.
Local package initialization:.
Additional TCP options:.

FreeBSD/i386 (k6-2.example.com) (ttyv0)

login: rpratt
Password:
```

Generating the RSA and DSA keys may take some time on slower machines. This happens only on the initial boot-up of a new installation. Subsequent boots will be faster.

If the X server has been configured and a Default Desktop chosen, it can be started by typing `startx` at the command line.

2.9.18.2 Bootup of FreeBSD on the Alpha

Once the install procedure has finished, you will be able to start FreeBSD by typing something like this to the SRM prompt:

>>>**BOOT DKC0**

This instructs the firmware to boot the specified disk. To make FreeBSD boot automatically in the future, use these commands:

>>> **SET BOOT_OSFLAGS A**
>>> **SET BOOT_FILE ”**
>>> **SET BOOTDEF_DEV DKC0**
>>> **SET AUTO_ACTION BOOT**

The boot messages will be similar (but not identical) to those produced by FreeBSD booting on the i386.

2.9.19 FreeBSD Shutdown

It is important to properly shutdown the operating system. Do not just turn off power. First, become a superuser by typing `su` at the command line and entering the `root` password. This will work only if the user is a member of the `wheel` group. Otherwise, login as `root` and use `shutdown -h now`.

```
The operating system has halted.
Please press any key to reboot.
```

It is safe to turn off the power after the shutdown command has been issued and the message "Please press any key to reboot" appears. If any key is pressed instead of turning off the power switch, the system will reboot.

You could also use the **Ctrl**+**Alt**+**Del** key combination to reboot the system, however this is not recommended during normal operation.

2.10 Supported Hardware

FreeBSD currently runs on a wide variety of ISA, VLB, EISA, and PCI bus-based PCs with Intel, AMD, Cyrix, or NexGen "x86" processors, as well as a number of machines based on the Compaq Alpha processor. Support for generic IDE or ESDI drive configurations, various SCSI controllers, PCMCIA cards, USB devices, and network and serial cards is also provided. FreeBSD also supports IBM's microchannel (MCA) bus.

A list of supported hardware is provided with each FreeBSD release in the FreeBSD Hardware Notes. This document can usually be found in a file named `HARDWARE.TXT`, in the top-level directory of a CDROM or FTP distribution or in **sysinstall**'s documentation menu. It lists, for a given architecture, what hardware devices are known to be supported by each release of FreeBSD. Copies of the supported hardware list for various releases and architectures can also be found on the Release Information (http://www.FreeBSD.org/releases/index.html) page of the FreeBSD Web site.

2.11 Troubleshooting

The following section covers basic installation troubleshooting, such as common problems people have reported. There are also a few questions and answers for people wishing to dual-boot FreeBSD with MS-DOS.

2.11.1 What to Do If Something Goes Wrong

Due to various limitations of the PC architecture, it is impossible for probing to be 100% reliable, however, there are a few things you can do if it fails.

Check the Hardware Notes document for your version of FreeBSD to make sure your hardware is supported.

If your hardware is supported and you still experience lock-ups or other problems, reset your computer, and when the visual kernel configuration option is given, choose it. This will allow you to go through your hardware and supply information to the system about it. The kernel on the boot disks is configured assuming that most hardware devices are in their factory default configuration in terms of IRQs, IO addresses, and DMA channels. If your hardware has been reconfigured, you will most likely need to use the configuration editor to tell FreeBSD where to find things.

It is also possible that a probe for a device not present will cause a later probe for another device that is present to fail. In that case, the probes for the conflicting driver(s) should be disabled.

Note: Some installation problems can be avoided or alleviated by updating the firmware on various hardware components, most notably the motherboard. The motherboard firmware may also be referred to as BIOS and most of the motherboard or computer manufactures have a website where the upgrades and upgrade information may be located.

Most manufacturers strongly advise against upgrading the motherboard BIOS unless there is a good reason for doing so, which could possibly be a critical update of sorts. The upgrade process *can* go wrong, causing permanent damage to the BIOS chip.

Warning: Do not disable any drivers you will need during the installation, such as your screen (`sc0`). If the installation wedges or fails mysteriously after leaving the configuration editor, you have probably removed or changed something you should not have. Reboot and try again.

In configuration mode, you can:

- List the device drivers installed in the kernel.
- Disable device drivers for hardware that is not present in your system.
- Change IRQs, DRQs, and IO port addresses used by a device driver.

After adjusting the kernel to match your hardware configuration, type `Q` to boot with the new settings. Once the installation has completed, any changes you made in the configuration mode will be permanent so you do not have to reconfigure every time you boot. It is still highly likely that you will eventually want to build a custom kernel.

2.11.2 Dealing with Existing MS-DOS® Partitions

Many users wish to install FreeBSD on PCs inhabited by Microsoft based operating systems. For those instances, FreeBSD has a utility known as **FIPS**. This utility can be found in the `tools` directory on the install CD-ROM, or downloaded from one of various FreeBSD mirrors.

The **FIPS** utility allows you to split an existing MS-DOS partition into two pieces, preserving the original partition and allowing you to install onto the second free piece. You first need to defragment your MS-DOS partition using the Windows; **Disk Defragmenter** utility (go into Explorer, right-click on the hard drive, and choose to defrag your hard drive), or use **Norton Disk Tools**. Now you can run the **FIPS** utility. It will prompt you for the rest of the information, just follow the on screen instructions. Afterwards, you can reboot and install FreeBSD on the new free slice. See the Distributions menu for an estimate of how much free space you will need for the kind of installation you want.

There is also a very useful product from PowerQuest (http://www.powerquest.com (http://www.powerquest.com/)) called **PartitionMagic**. This application has far more functionality than **FIPS**, and is highly recommended if you plan to add/remove operating systems often. It does cost money, so if you plan to install FreeBSD and keep it installed, **FIPS** will probably be fine for you.

2.11.3 Using MS-DOS and Windows® File Systems

At this time, FreeBSD does not support file systems compressed with the **Double Space™** application. Therefore the file system will need to be uncompressed before FreeBSD can access the data. This can be done by running the **Compression Agent** located in the Start> Programs > System Tools menu.

FreeBSD can support MS-DOS based file systems. This requires you use the mount_msdos(8) command (in FreeBSD 5.X, the command is mount_msdosfs(8)) with the required parameters. The utilities most common usage is:

```
# mount_msdos /dev/ad0s1 /mnt
```

In this example, the MS-DOS file system is located on the first partition of the primary hard disk. Your situation may be different, check the output from the `dmesg`, and `mount` commands. They should produce enough information too give an idea of the partition layout.

> **Note:** Extended MS-DOS file systems are usually mapped after the FreeBSD partitions. In other words, the slice number may be higher than the ones FreeBSD is using. For instance, the first MS-DOS partition may be `/dev/ad0s1`, the FreeBSD partition may be `/dev/ad0s2`, with the extended MS-DOS partition being located on `/dev/ad0s3`. To some, this can be confusing at first.

NTFS partitions can also be mounted in a similar manner using the mount_ntfs(8) command.

2.11.4 Alpha User's Questions and Answers

This section answers some commonly asked questions about installing FreeBSD on Alpha systems.

1. Can I boot from the ARC or Alpha BIOS Console?

No. FreeBSD, like Compaq Tru64 and VMS, will only boot from the SRM console.

2. Help, I have no space! Do I need to delete everything first?

Unfortunately, yes.

3. Can I mount my Compaq Tru64 or VMS filesystems?

No, not at this time.

2.12 Advanced Installation Guide

Contributed by Valentino Vaschetto.

This section describes how to install FreeBSD in exceptional cases.

2.12.1 Installing FreeBSD on a System without a Monitor or Keyboard

This type of installation is called a "headless install", because the machine that you are trying to install FreeBSD on either does not have a monitor attached to it, or does not even have a VGA output. How is this possible you ask?

Using a serial console. A serial console is basically using another machine to act as the main display and keyboard for a system. To do this, just follow the steps to create installation floppies, explained in Section 2.2.7.

To modify these floppies to boot into a serial console, follow these steps:

1. Enabling the Boot Floppies to Boot into a Serial Console

   If you were to boot into the floppies that you just made, FreeBSD would boot into its normal install mode. We want FreeBSD to boot into a serial console for our install. To do this, you have to mount the `kern.flp` floppy onto your FreeBSD system using the mount(8) command.

   ```
   # mount /dev/fd0 /floppy
   ```

   Now that you have the floppy mounted, you must change into the floppy directory:

   ```
   # cd /floppy
   ```

   Here is where you must set the floppy to boot into a serial console. You have to make a file called `boot.config` containing `/boot/loader -h`. All this does is pass a flag to the bootloader to boot into a serial console.

   ```
   # echo "/boot/loader -h" > boot.config
   ```

   Now that you have your floppy configured correctly, you must unmount the floppy using the umount(8) command:

   ```
   # cd /
   # umount /mnt
   ```

   Now you can remove the floppy from the floppy drive.

2. Connecting Your Null Modem Cable

   You now need to connect a null modem cable between the two machines. Just connect the cable to the serial ports of the 2 machines. *A normal serial cable will not work here*, you need a null modem cable because it has some of the wires inside crossed over.

3. Booting Up for the Install

   It is now time to go ahead and start the install. Put the `kern.flp` floppy in the floppy drive of the machine you are doing the headless install on, and power on the machine.

4. Connecting to Your Headless Machine

   Now you have to connect to that machine with cu(1):

   ```
   # cu -l /dev/cuaa0
   ```

That's it! You should now be able to control the headless machine through your `cu` session. It will ask you to put in the `mfsroot.flp`, and then it will come up with a selection of what kind of terminal to use. Select the FreeBSD color console and proceed with your install!

2.13 Preparing Your Own Installation Media

> **Note:** To prevent repetition, "FreeBSD disk" in this context means a FreeBSD CDROM or DVD that you have purchased or produced yourself.

There may be some situations in which you need to create your own FreeBSD installation media and/or source. This might be physical media, such as a tape, or a source that **sysinstall** can use to retrieve the files, such as a local FTP site, or an MS-DOS partition.

For example:

- You have many machines connected to your local network, and one FreeBSD disk. You want to create a local FTP site using the contents of the FreeBSD disk, and then have your machines use this local FTP site instead of needing to connect to the Internet.
- You have a FreeBSD disk, and FreeBSD does not recognize your CD/DVD drive, but MS-DOS/Windows does. You want to copy the FreeBSD installations files to a DOS partition on the same computer, and then install FreeBSD using those files.
- The computer you want to install on does not have a CD/DVD drive or a network card, but you can connect a "Laplink-style" serial or parallel cable to a computer that does.
- You want to create a tape that can be used to install FreeBSD.

2.13.1 Creating an Installation CDROM

As part of each release, the FreeBSD project makes available two CDROM images ("ISO images"). These images can be written ("burned") to CDs if you have a CD writer, and then used to install FreeBSD. If you have a CD writer, and bandwidth is cheap, then this is the easiest way to install FreeBSD.

1. Download the Correct ISO Images

   The ISO images for each release can be downloaded from `ftp://ftp.FreeBSD.org/pub/FreeBSD/ISO-IMAGES-`*`arch`*`/`*`version`* or the closest mirror. Substitute *`arch`* and *`version`* as appropriate.

   That directory will normally contain the following images:

   Table 2-5. FreeBSD ISO Image Names and Meanings

Filename	Contains
`version``-mini.iso`	Everything you need to install FreeBSD.
`version``-disc1.iso`	Everything you need to install FreeBSD, and as many additional third party packages as would fit on the disc.
`version``-disc2.iso`	A "live filesystem", which is used in conjunction with the "Repair" facility in **sysinstall**. A copy of the FreeBSD CVS tree. As many additional third party packages as would fit on the disc.

   You *must* download one of either the mini ISO image, or the image of disc one. Do not download both of them, since the disc one image contains everything that the mini ISO image contains.

   Use the mini ISO if Internet access is cheap for you. It will let you install FreeBSD, and you can then install third party packages by downloading them using the ports/packages system (see Chapter 4) as necessary.

   Use the image of disc one if you want a reasonable selection of third party packages on the disc as well.

   The additional disc images are useful, but not essential, especially if you have high-speed access to the Internet.

2. Write the CDs

   You must then write the CD images to disc. If you will be doing this on another FreeBSD system then see Section 12.5 for more information (in particular, Section 12.5.3 and Section 12.5.4).

   If you will be doing this on another platform then you will need to use whatever utilities exist to control your CD writer on that platform. The images provided are in the standard ISO format, which many CD writing applications support.

2.13.2 Creating a Local FTP Site with a FreeBSD Disk

FreeBSD disks are laid out in the same way as the FTP site. This makes it very easy for you to create a local FTP site that can be used by other machines on your network when installing FreeBSD.

1. On the FreeBSD computer that will host the FTP site, ensure that the CDROM is in the drive, and mounted on `/cdrom`.

   ```
   # mount /cdrom
   ```

2. Create an account for anonymous FTP in `/etc/passwd`. Do this by editing `/etc/passwd` using vipw(8) and adding this line.

   ```
   ftp:*:99:99::0:0:FTP:/cdrom:/nonexistent
   ```

3. Ensure that the FTP service is enabled in `/etc/inetd.conf`.

Anyone with network connectivity to your machine can now chose a media type of FTP and type in **`ftp://`*`your machine`*** after picking "Other" in the FTP sites menu during the install.

> **Warning:** This approach is OK for a machine that is on your local network, and that is protected by your firewall. Offering up FTP services to other machines over the Internet (and not your local network) exposes your computer to the attention of crackers and other undesirables. We strongly recommend that you follow good security practices if you do this.

2.13.3 Creating Installation Floppies

If you must install from floppy disk (which we suggest you do *not* do), either due to unsupported hardware or simply because you insist on doing things the hard way, you must first prepare some floppies for the installation.

At a minimum, you will need as many 1.44 MB or 1.2 MB floppies as it takes to hold all the files in the `bin` (binary distribution) directory. If you are preparing the floppies from DOS, then they *MUST* be formatted using the MS-DOS `FORMAT` command. If you are using Windows, use Explorer to format the disks (right-click on the `A:` drive, and select "Format".

Do *not* trust factory pre-formatted floppies. Format them again yourself, just to be sure. Many problems reported by our users in the past have resulted from the use of improperly formatted media, which is why we are making a point of it now.

If you are creating the floppies on another FreeBSD machine, a format is still not a bad idea, though you do not need to put a DOS filesystem on each floppy. You can use the `disklabel` and `newfs` commands to put a UFS filesystem on them instead, as the following sequence of commands (for a 3.5" 1.44 MB floppy) illustrates:

```
# fdformat -f 1440 fd0.1440
# disklabel -w -r fd0.1440 floppy3
# newfs -t 2 -u 18 -l 1 -i 65536 /dev/fd0
```

> **Note:** Use `fd0.1200` and `floppy5` for 5.25" 1.2 MB disks.

Then you can mount and write to them like any other filesystem.

After you have formatted the floppies, you will need to copy the files to them. The distribution files are split into chunks conveniently sized so that five of them will fit on a conventional 1.44 MB floppy. Go through all your floppies, packing as many files as will fit on each one, until you have all of the distributions you want packed up in this fashion. Each distribution should go into a subdirectory on the floppy, e.g.: `a:\bin\bin.aa`, `a:\bin\bin.ab`, and so on.

Once you come to the Media screen during the install process, select "Floppy" and you will be prompted for the rest.

2.13.4 Installing from an MS-DOS Partition

To prepare for an installation from an MS-DOS partition, copy the files from the distribution into a directory called `freebsd` in the root directory of the partition. For example, `c:\freebsd`. The directory structure of the CDROM or FTP site must be partially reproduced within this directory, so we suggest using the DOS `xcopy` command if you are copying it from a CD. For example, to prepare for a minimal installation of FreeBSD:

```
C:\> md c:\freebsd
C:\> xcopy e:\bin c:\freebsd\bin\ /s
C:\> xcopy e:\manpages c:\freebsd\manpages\ /s
```

Assuming that `C:` is where you have free space and `E:` is where your CDROM is mounted.

If you do not have a CDROM drive, you can download the distribution from ftp.FreeBSD.org (ftp://ftp.FreeBSD.org/pub/FreeBSD/releases/i386/5.1-RELEASE/). Each distribution is in its own directory; for example, the *base* distribution can be found in the 5.1/base/ (ftp://ftp.FreeBSD.org/pub/FreeBSD/releases/i386/5.1-RELEASE/base/) directory.

> **Note:** In the 4.X and older releases of FreeBSD the "base" distribution is called "bin". Adjust the sample commands and URLs above accordingly, if you are using one of these versions.

For as many distributions you wish to install from an MS-DOS partition (and you have the free space for), install each one under `c:\freebsd` — the `BIN` distribution is the only one required for a minimum installation.

2.13.5 Creating an Installation Tape

Installing from tape is probably the easiest method, short of an online FTP install or CDROM install. The installation program expects the files to be simply tarred onto the tape. After getting all of the distribution files you are interested in, simply tar them onto the tape:

```
# cd /freebsd/distdir
# tar cvf /dev/rwt0 dist1 ... dist2
```

When you perform the installation, you should make sure that you leave enough room in some temporary directory (which you will be allowed to choose) to accommodate the *full* contents of the tape you have created. Due to the non-random access nature of tapes, this method of installation requires quite a bit of temporary storage. You should expect to require as much temporary storage as you have data written on tape.

> **Note:** When starting the installation, the tape must be in the drive *before* booting from the boot floppy. The installation probe may otherwise fail to find it.

2.13.6 Before Installing over a Network

There are three types of network installations available. Serial port (SLIP or PPP), Parallel port (PLIP (laplink cable)), or Ethernet (a standard Ethernet controller (includes some PCMCIA)).

The SLIP support is rather primitive, and limited primarily to hard-wired links, such as a serial cable running between a laptop computer and another computer. The link should be hard-wired as the SLIP installation does not currently offer a dialing capability; that facility is provided with the PPP utility, which should be used in preference to SLIP whenever possible.

If you are using a modem, then PPP is almost certainly your only choice. Make sure that you have your service provider's information handy as you will need to know it fairly early in the installation process.

If you use PAP or CHAP to connect your ISP (in other words, if you can connect to the ISP in Windows without using a script), then all you will need to do is type in `dial` at the **ppp** prompt. Otherwise, you will need to know how to dial your ISP using the "AT commands" specific to your modem, as the PPP dialer provides only a very simple terminal emulator. Please refer to the user-ppp handbook and FAQ (../faq/ppp.html) entries for further information. If you have problems, logging can be directed to the screen using the command `set log local ...`.

If a hard-wired connection to another FreeBSD (2.0-R or later) machine is available, you might also consider installing over a "laplink" parallel port cable. The data rate over the parallel port is much higher than what is typically possible over a serial line (up to 50 kbytes/sec), thus resulting in a quicker installation.

Finally, for the fastest possible network installation, an Ethernet adapter is always a good choice! FreeBSD supports most common PC Ethernet cards; a table of supported cards (and their required settings) is provided in the Hardware Notes for each release of FreeBSD. If you are using one of the supported PCMCIA Ethernet cards, also be sure that it is plugged in *before* the laptop is powered on! FreeBSD does not, unfortunately, currently support hot insertion of PCMCIA cards during installation.

You will also need to know your IP address on the network, the netmask value for your address class, and the name of your machine. If you are installing over a PPP connection and do not have a static IP, fear not, the IP address can be dynamically assigned by your ISP. Your system administrator can tell you which values to use for your particular network setup. If you will be referring to other hosts by name rather than IP address, you will also need a name server and possibly the address of a gateway (if you are using PPP, it is your provider's IP address) to use in talking to it. If you want to install by FTP via a HTTP proxy, you will also need the proxy's address. If you do not know the answers to all or most of these questions, then you should really probably talk to your system administrator or ISP *before* trying this type of installation.

2.13.6.1 Before Installing via NFS

The NFS installation is fairly straight-forward. Simply copy the FreeBSD distribution files you want onto an NFS server and then point the NFS media selection at it.

If this server supports only "privileged port" (as is generally the default for Sun workstations), you will need to set this option in the Options menu before installation can proceed.

If you have a poor quality Ethernet card which suffers from very slow transfer rates, you may also wish to toggle the appropriate Options flag.

In order for NFS installation to work, the server must support subdir mounts, for example, if your FreeBSD 5.1 distribution directory lives on: `ziggy:/usr/archive/stuff/FreeBSD`, then `ziggy` will have to allow the direct mounting of `/usr/archive/stuff/FreeBSD`, not just `/usr` or `/usr/archive/stuff`.

In FreeBSD's `/etc/exports` file, this is controlled by the `-alldirs` options. Other NFS servers may have different conventions. If you are getting "permission denied" messages from the server, then it is likely that you do not have this enabled properly.

Chapter 3 UNIX Basics

Rewritten by Chris Shumway.

3.1 Synopsis

The following chapter will cover the basic commands and functionality of the FreeBSD operating system. Much of this material is relevant for any UNIX like operating system. Feel free to skim over this chapter if you are familiar with the material. If you are new to FreeBSD, then you will definitely want to read through this chapter carefully.

After reading this chapter, you will know:

- How to use the "virtual consoles" of FreeBSD.
- How UNIX file permissions work.
- The default FreeBSD file system layout.
- How to mount and unmount file systems.
- What processes, daemons, and signals are.
- What a shell is, and how to change your default login environment.
- How to use basic text editors.
- What devices and device nodes are.
- What binary format is used under FreeBSD.
- How to read manual pages for more information.

3.2 Virtual Consoles and Terminals

FreeBSD can be used in various ways. One of them is typing commands to a text terminal. A lot of the flexibility and power of a UNIX operating system is readily available at your hands when using FreeBSD this way. This section describes what "terminals" and "consoles" are, and how you can use them in FreeBSD.

3.2.1 The Console

If you have not configured FreeBSD to automatically start a graphical environment during startup, the system will present you with a login prompt after it boots, right after the startup scripts finish running. You will see something similar to:

```
Additional ABI support:.
Local package initialization:.
Additional TCP options:.

Fri Sep 20 13:01:06 EEST 2002

FreeBSD/i386 (pc3.example.org) (ttyv0)
```

```
login:
```

The messages might be a bit different on your system, but you will see something similar. The last two lines are what we are interested in right now. The second last line reads:

```
FreeBSD/i386 (pc3.example.org) (ttyv0)
```

This line contains some bits of information about the system you have just booted. You are looking at a "FreeBSD" console, running on an Intel or compatible processor of the x86 architecture[1]. The name of this machine (every UNIX machine has a name) is `pc3.example.org`, and you are now looking at its system console—the `ttyv0` terminal.

Finally, the last line is always:

```
login:
```

This is the part where you are supposed to type in your "username" to log into FreeBSD. The next section describes how you can do this.

3.2.2 Logging into FreeBSD

FreeBSD is a multiuser, multiprocessing system. This is the formal description that is usually given to a system that can be used by many different people, who simultaneously run a lot of programs on a single machine.

Every multiuser system needs some way to distinguish one "user" from the rest. In FreeBSD (and all the UNIX like operating systems), this is accomplished by requiring that every user must "log into" the system before being able to run programs. Every user has a unique name (the "username") and a personal, secret key (the "password"). FreeBSD will ask for these two before allowing a user to run any programs.

Right after FreeBSD boots and finishes running its startup scripts[2], it will present you with a prompt and ask for a valid username:

```
login:
```

For the sake of this example, let us assume that your username is `john`. Type `john` at this prompt and press **Enter**. You should then be presented with a prompt to enter a "password":

```
login: john
Password:
```

Type in `john`'s password now, and press **Enter**. The password is *not echoed!* You need not worry about this right now. Suffice it to say that it is done for security reasons.

If you have typed your password correctly, you should by now be logged into FreeBSD and ready to try out all the available commands.

You should see the MOTD or message of the day followed by a command prompt (a `#`, `$`, or `%` character). This indicates you have successfully logged into FreeBSD.

3.2.3 Multiple Consoles

Running UNIX commands in one console is fine, but FreeBSD can run many programs at once. Having one console where commands can be typed would be a bit of a waste when an operating system like FreeBSD can run dozens of programs at the same time. This is where "virtual consoles" can be very helpful.

FreeBSD can be configured to present you with many different virtual consoles. You can switch from one of them to any other virtual console by pressing a couple of keys on your keyboard. Each console has its own different output channel, and FreeBSD takes care of properly redirecting keyboard input and monitor output as you switch from one virtual console to the next.

Special key combinations have been reserved by FreeBSD for switching consoles[3]. You can use **Alt-F1**, **Alt-F2**, through **Alt-F8** to switch to a different virtual console in FreeBSD.

As you are switching from one console to the next, FreeBSD takes care of saving and restoring the screen output. The result is an "illusion" of having multiple "virtual" screens and keyboards that you can use to type commands for FreeBSD to run. The programs that you launch on one virtual console do not stop running when that console is not visible. They continue running when you have switched to a different virtual console.

3.2.4 The `/etc/ttys` File

The default configuration of FreeBSD will start up with eight virtual consoles. This is not a hardwired setting though, and you can easily customize your installation to boot with more or fewer virtual consoles. The number and settings of the virtual consoles are configured in the `/etc/ttys` file.

You can use the `/etc/ttys` file to configure the virtual consoles of FreeBSD. Each uncommented line in this file (lines that do not start with a `#` character) contains settings for a single terminal or virtual console. The default version of this file that ships with FreeBSD configures nine virtual consoles, and enables eight of them. They are the lines that start with `ttyv`:

```
# name  getty                           type    status          comments
#
ttyv0   "/usr/libexec/getty Pc"         cons25  on  secure
# Virtual terminals
ttyv1   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv2   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv3   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv4   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv5   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv6   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv7   "/usr/libexec/getty Pc"         cons25  on  secure
ttyv8   "/usr/X11R6/bin/xdm -nodaemon"  xterm   off secure
```

For a detailed description of every column in this file and all the options you can use to set things up for the virtual consoles, consult the ttys(5) manual page.

3.2.5 Single User Mode Console

A detailed description of what "single user mode" is can be found in Section 7.6.2. It is worth noting that there is only one console when you are running FreeBSD in single user mode. There are no virtual consoles available. The settings of the single user mode console can also be found in the `/etc/ttys` file. Look for the line that starts with `console`:

```
# name  getty                           type    status          comments
#
```

```
# If console is marked "insecure", then init will ask for the root password
# when going to single-user mode.
console none                            unknown off secure
```

> **Note:** As the comments above the `console` line indicate, you can edit this line and change `secure` to `insecure`. If you do that, when FreeBSD boots into single user mode, it will still ask for the `root` password.
>
> *Be careful when changing this to `insecure`.* If you ever forget the `root` password, booting into single user mode is a bit involved. It is still possible, but it might be a bit hard for someone who is not very comfortable with the FreeBSD booting process and the programs involved.

3.3 Permissions

FreeBSD, being a direct descendant of BSD UNIX, is based on several key UNIX concepts. The first and most pronounced is that FreeBSD is a multi-user operating system. The system can handle several users all working simultaneously on completely unrelated tasks. The system is responsible for properly sharing and managing requests for hardware devices, peripherals, memory, and CPU time fairly to each user.

Because the system is capable of supporting multiple users, everything the system manages has a set of permissions governing who can read, write, and execute the resource. These permissions are stored as three octets broken into three pieces, one for the owner of the file, one for the group that the file belongs to, and one for everyone else. This numerical representation works like this:

Value	Permission	Directory Listing
0	No read, no write, no execute	`---`
1	No read, no write, execute	`--x`
2	No read, write, no execute	`-w-`
3	No read, write, execute	`-wx`
4	Read, no write, no execute	`r--`
5	Read, no write, execute	`r-x`
6	Read, write, no execute	`rw-`
7	Read, write, execute	`rwx`

You can use the `-l` command line argument to ls(1) to view a long directory listing that includes a column with information about a file's permissions for the owner, group, and everyone else. For example, a `ls -l` in an arbitrary directory may show:

```
% ls -l
total 530
-rw-r--r--  1 root  wheel     512 Sep  5 12:31 myfile
-rw-r--r--  1 root  wheel     512 Sep  5 12:31 otherfile
-rw-r--r--  1 root  wheel    7680 Sep  5 12:31 email.txt
...
```

Here is how the first column of `ls -l` is broken up:

```
-rw-r--r--
```

The first (leftmost) character tells if this file is a regular file, a directory, a special character device, a socket, or any other special pseudo-file device. In this case, the `-` indicates a regular file. The next three characters, `rw-` in this example, give the permissions for the owner of the file. The next three characters, `r--`, give the permissions for the group that the file belongs to. The final three characters, `r--`, give the permissions for the rest of the world. A dash means that the permission is turned off. In the case of this file, the permissions are set so the owner can read and write to the file, the group can read the file, and the rest of the world can only read the file. According to the table above, the permissions for this file would be `644`, where each digit represents the three parts of the file's permission.

This is all well and good, but how does the system control permissions on devices? FreeBSD actually treats most hardware devices as a file that programs can open, read, and write data to just like any other file. These special device files are stored on the `/dev` directory.

Directories are also treated as files. They have read, write, and execute permissions. The executable bit for a directory has a slightly different meaning than that of files. When a directory is marked executable, it means it can be traversed into, that is, it is possible to "cd" (change directory) into it. This also means that within the directory it is possible to access files whose names are known (subject, of course, to the permissions on the files themselves).

In particular, in order to perform a directory listing, read permission must be set on the directory, whilst to delete a file that one knows the name of, it is necessary to have write *and* execute permissions to the directory containing the file.

There are more permission bits, but they are primarily used in special circumstances such as setuid binaries and sticky directories. If you want more information on file permissions and how to set them, be sure to look at the chmod(1) manual page.

3.3.1 Symbolic Permissions

Contributed by Tom Rhodes.

Symbolic permissions, sometimes referred to as symbolic expressions, use characters in place of octal values to assign permissions to files or directories. Symbolic expressions use the syntax of (who) (action) (permissions), where the following values are available:

Option	Letter	Represents
(who)	u	User
(who)	g	Group owner
(who)	o	Other
(who)	a	All ("world")
(action)	+	Adding permissions
(action)	-	Removing permissions
(action)	=	Explicitly set permissions
(permissions)	r	Read
(permissions)	w	Write
(permissions)	x	Execute
(permissions)	t	Sticky bit
(permissions)	s	Set UID or GID

These values are used with the chmod(1) command just like before, but with letters. For an example, you could use the following command to block other users from accessing *`FILE`*:

```
% chmod go= FILE
```

A comma separated list can be provided when more than one set of changes to a file must be made. For example the following command will remove the groups and "world" write permission on *`FILE`*, then it adds the execute permissions for everyone:

```
% chmod go-w,a+x FILE
```

3.4 Directory Structure

The FreeBSD directory hierarchy is fundamental to obtaining an overall understanding of the system. The most important concept to grasp is that of the root directory, "/". This directory is the first one mounted at boot time and it contains the base system necessary to prepare the operating system for multi-user operation. The root directory also contains mount points for every other file system that you may want to mount.

A mount point is a directory where additional file systems can be grafted onto the root file system. Standard mount points include `/usr`, `/var`, `/mnt`, and `/cdrom`. These directories are usually referenced to entries in the file `/etc/fstab`. `/etc/fstab` is a table of various file systems and mount points for reference by the system. Most of the file systems in `/etc/fstab` are mounted automatically at boot time from the script rc(8) unless they contain the `noauto` option. Consult the fstab(5) manual page for more information on the format of the `/etc/fstab` file and the options it contains.

A complete description of the file system hierarchy is available in hier(7). For now, a brief overview of the most common directories will suffice.

Directory	Description
`/`	Root directory of the file system.
`/bin/`	User utilities fundamental to both single-user and multi-user environments.
`/boot/`	Programs and configuration files used during operating system bootstrap.
`/boot/defaults/`	Default bootstrapping configuration files; see loader.conf(5).
`/dev/`	Device nodes; see intro(4).
`/etc/`	System configuration files and scripts.
`/etc/defaults/`	Default system configuration files; see rc(8).
`/etc/mail/`	Configuration files for mail transport agents such as sendmail(8).
`/etc/namedb/`	`named` configuration files; see named(8).
`/etc/periodic/`	Scripts that are run daily, weekly, and monthly, via cron(8); see periodic(8).
`/etc/ppp/`	`ppp` configuration files; see ppp(8).

Directory	Description
/mnt/	Empty directory commonly used by system administrators as a temporary mount point.
/proc/	Process file system; see procfs(5), mount_procfs(8).
/root/	Home directory for the root account.
/sbin/	System programs and administration utilities fundamental to both single-user and multi-user environments.
/stand/	Programs used in a standalone environment.
/tmp/	Temporary files, usually a mfs(8) memory-based file system (the contents of /tmp are usually NOT preserved across a system reboot).
/usr/	The majority of user utilities and applications.
/usr/bin/	Common utilities, programming tools, and applications.
/usr/include/	Standard C include files.
/usr/lib/	Archive libraries.
/usr/libdata/	Miscellaneous utility data files.
/usr/libexec/	System daemons & system utilities (executed by other programs).
/usr/local/	Local executables, libraries, etc. Also used as the default destination for the FreeBSD ports framework. Within /usr/local, the general layout sketched out by hier(7) for /usr should be used. Exceptions are the man directory, which is directly under /usr/local rather than under /usr/local/share, and the ports documentation is in share/doc/*port*.
/usr/obj/	Architecture-specific target tree produced by building the /usr/src tree.
/usr/ports	The FreeBSD ports collection (optional).
/usr/sbin/	System daemons & system utilities (executed by users).
/usr/share/	Architecture-independent files.
/usr/src/	BSD and/or local source files.
/usr/X11R6/	X11R6 distribution executables, libraries, etc (optional).
/var/	Multi-purpose log, temporary, transient, and spool files.
/var/log/	Miscellaneous system log files.
/var/mail/	User mailbox files.
/var/spool/	Miscellaneous printer and mail system spooling directories.
/var/tmp/	Temporary files that are kept between system reboots.
/var/yp	NIS maps.

3.5 Disk Organization

The smallest unit of organization that FreeBSD uses to find files is the filename. Filenames are case-sensitive, which means that `readme.txt` and `README.TXT` are two separate files. FreeBSD does not use the extension (`.txt`) of a file to determine whether the file is program, or a document, or some other form of data.

Files are stored in directories. A directory may contain no files, or it may contain many hundreds of files. A directory can also contain other directories, allowing you to build up a hierarchy of directories within one another. This makes it much easier to organize your data.

Files and directories are referenced by giving the file or directory name, followed by a forward slash, `/`, followed by any other directory names that are necessary. If you have directory `foo`, which contains directory `bar`, which contains the file `readme.txt`, then the full name, or *path* to the file is `foo/bar/readme.txt`.

Directories and files are stored in a filesystem. Each filesystem contains exactly one directory at the very top level, called the *root directory* for that filesystem. This root directory can then contain other directories.

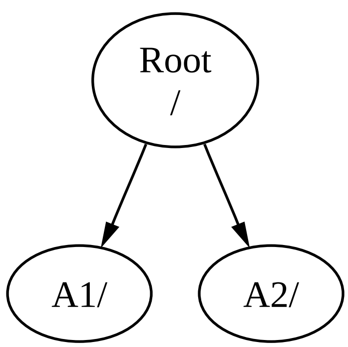
So far this is probably similar to any other operating system you may have used. There are a few differences; for example, DOS uses `\` to separate file and directory names, while Mac OS® uses `:`.

FreeBSD does not use drive letters, or other drive names in the path. You would not write `c:/foo/bar/readme.txt` on FreeBSD.

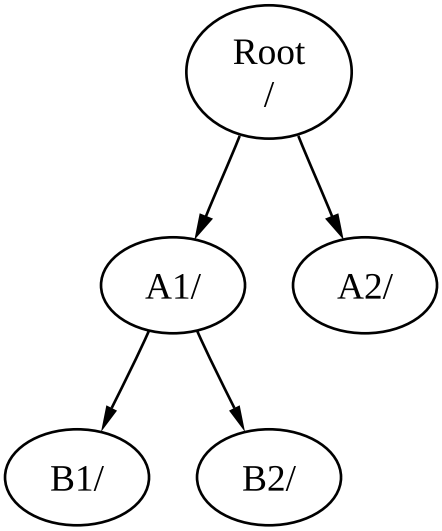
Instead, one filesystem is designated the *root filesystem*. The root filesystem's root directory is referred to as `/`. Every other filesystem is then *mounted* under the root filesystem. No matter how many disks you have on your FreeBSD system, every directory appears to be part of the same disk.

Suppose you have three filesystems, called `A`, `B`, and `C`. Each filesystem has one root directory, which contains two other directories, called `A1`, `A2` (and likewise `B1`, `B2` and `C1`, `C2`).

Call `A` the root filesystem. If you used the `ls` command to view the contents of this directory you would see two subdirectories, `A1` and `A2`. The directory tree looks like this:

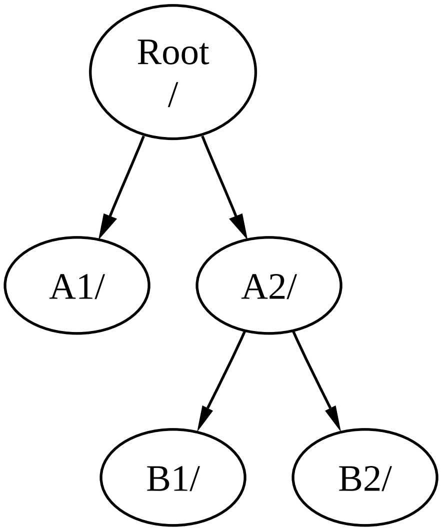


A filesystem must be mounted on to a directory in another filesystem. So now suppose that you mount filesystem `B` on to the directory `A1`. The root directory of `B` replaces `A1`, and the directories in `B` appear accordingly:



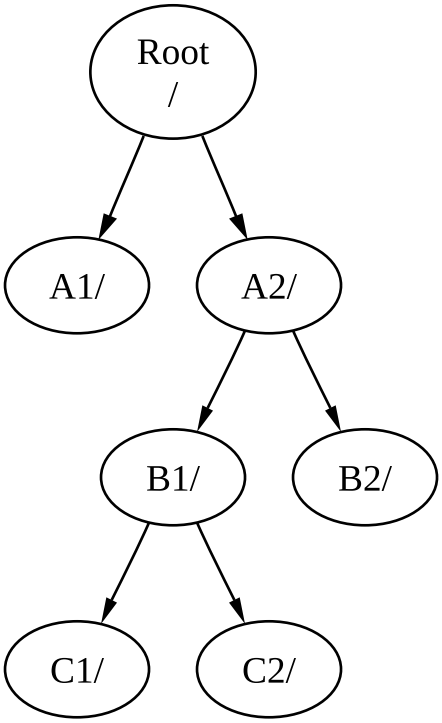
Any files that are in the `B1` or `B2` directories can be reached with the path `/A1/B1` or `/A1/B2` as necessary. Any files that were in `/A1` have been temporarily hidden. They will reappear if `B` is *unmounted* from A.

If `B` had been mounted on `A2` then the diagram would look like this:

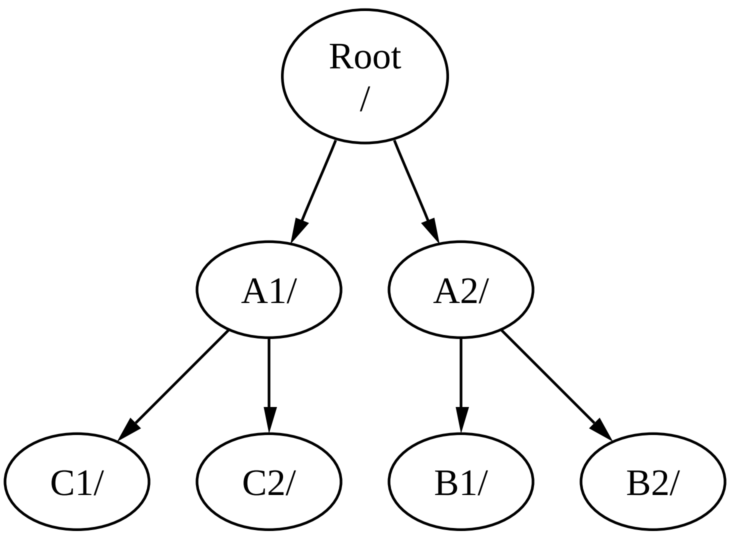


and the paths would be `/A2/B1` and `/A2/B2` respectively.

Filesystems can be mounted on top of one another. Continuing the last example, the `C` filesystem could be mounted on top of the `B1` directory in the `B` filesystem, leading to this arrangement:



Or `C` could be mounted directly on to the `A` filesystem, under the `A1` directory:



If you are familiar with DOS, this is similar, although not identical, to the `join` command.

This is not normally something you need to concern yourself with. Typically you create filesystems when installing FreeBSD and decide where to mount them, and then never change them unless you add a new disk.

It is entirely possible to have one large root filesystem, and not need to create any others. There are some drawbacks to this approach, and one advantage.

Benefits of Multiple Filesystems

- Different filesystems can have different *mount options*. For example, with careful planning, the root filesystem can be mounted read-only, making it impossible for you to inadvertently delete or edit a critical file. Separating user-writable filesystems, such as `/home`, from other filesystems also allows them to be mounted *nosuid*; this option prevents the *suid*/*guid* bits on executables stored on the filesystem from taking effect, possibly improving security.
- FreeBSD automatically optimizes the layout of files on a filesystem, depending on how the filesystem is being used. So a filesystem that contains many small files that are written frequently will have a different optimization to one that contains fewer, larger files. By having one big filesystem this optimization breaks down.
- FreeBSD's filesystems are very robust should you lose power. However, a power loss at a critical point could still damage the structure of the filesystem. By splitting your data over multiple filesystems it is more likely that the system will still come up, making it easier for you to restore from backup as necessary.

Benefit of a Single Filesystem

- Filesystems are a fixed size. If you create a filesystem when you install FreeBSD and give it a specific size, you may later discover that you need to make the partition bigger. This is not easily accomplished without backing up, recreating the filesystem with the new size, and then restoring the backed up data.

> **Important:** FreeBSD 4.4 and later versions feature the growfs(8) command, which makes it possible to increase the size of filesystem on the fly, removing this limitation.

Filesystems are contained in partitions. This does not have the same meaning as the earlier usage of the term partition in this chapter, because of FreeBSD's UNIX heritage. Each partition is identified by a letter from `a` through to `h`. Each partition can contain only one filesystem, which means that filesystems are often described by either their typical mount point in the filesystem hierarchy, or the letter of the partition they are contained in.

FreeBSD also uses disk space for *swap space*. Swap space provides FreeBSD with *virtual memory*. This allows your computer to behave as though it has much more memory than it actually does. When FreeBSD runs out of memory it moves some of the data that is not currently being used to the swap space, and moves it back in (moving something else out) when it needs it.

Some partitions have certain conventions associated with them.

Partition	Convention
a	Normally contains the root filesystem
b	Normally contains swap space
c	Normally the same size as the enclosing slice. This allows utilities that need to work on the entire slice (for example, a bad block scanner) to work on the `c` partition. You would not normally create a filesystem on this partition.
d	Partition `d` used to have a special meaning associated with it, although that is now gone. To this day, some tools may operate oddly if told to work on partition `d`, so **sysinstall** will not normally create partition `d`.

Each partition-that-contains-a-filesystem is stored in what FreeBSD calls a *slice*. Slice is FreeBSD's term for what were earlier called partitions, and again, this is because of FreeBSD's UNIX background. Slices are numbered, starting at 1, through to 4.

Slice numbers follow the device name, prefixed with an `s`, starting at 1. So "da0*s1*" is the first slice on the first SCSI drive. There can only be four physical slices on a disk, but you can have logical slices inside physical slices of the appropriate type. These extended slices are numbered starting at 5, so "ad0*s5*" is the first extended slice on the first IDE disk. These devices are used by file systems that expect to occupy a slice.

Slices, "dangerously dedicated" physical drives, and other drives contain *partitions*, which are represented as letters from `a` to `h`. This letter is appended to the device name, so "da0*a*" is the a partition on the first da drive, which is "dangerously dedicated". "ad1s3*e*" is the fifth partition in the third slice of the second IDE disk drive.

Finally, each disk on the system is identified. A disk name starts with a code that indicates the type of disk, and then a number, indicating which disk it is. Unlike slices, disk numbering starts at 0. Common codes that you will see are listed in Table 3-1.

When referring to a partition FreeBSD requires that you also name the slice and disk that contains the partition, and when referring to a slice you should also refer to the disk name. Do this by listing the disk name, `s`, the slice number, and then the partition letter. Examples are shown in Example 3-1.

Example 3-2 shows a conceptual model of the disk layout that should help make things clearer.

In order to install FreeBSD you must first configure the disk slices, then create partitions within the slice you will use for FreeBSD, and then create a filesystem (or swap space) in each partition, and decide where that filesystem will be mounted.

Table 3-1. Disk Device Codes

Code	Meaning
`ad`	ATAPI (IDE) disk
`da`	SCSI direct access disk
`acd`	ATAPI (IDE) CDROM
`cd`	SCSI CDROM
`fd`	Floppy disk

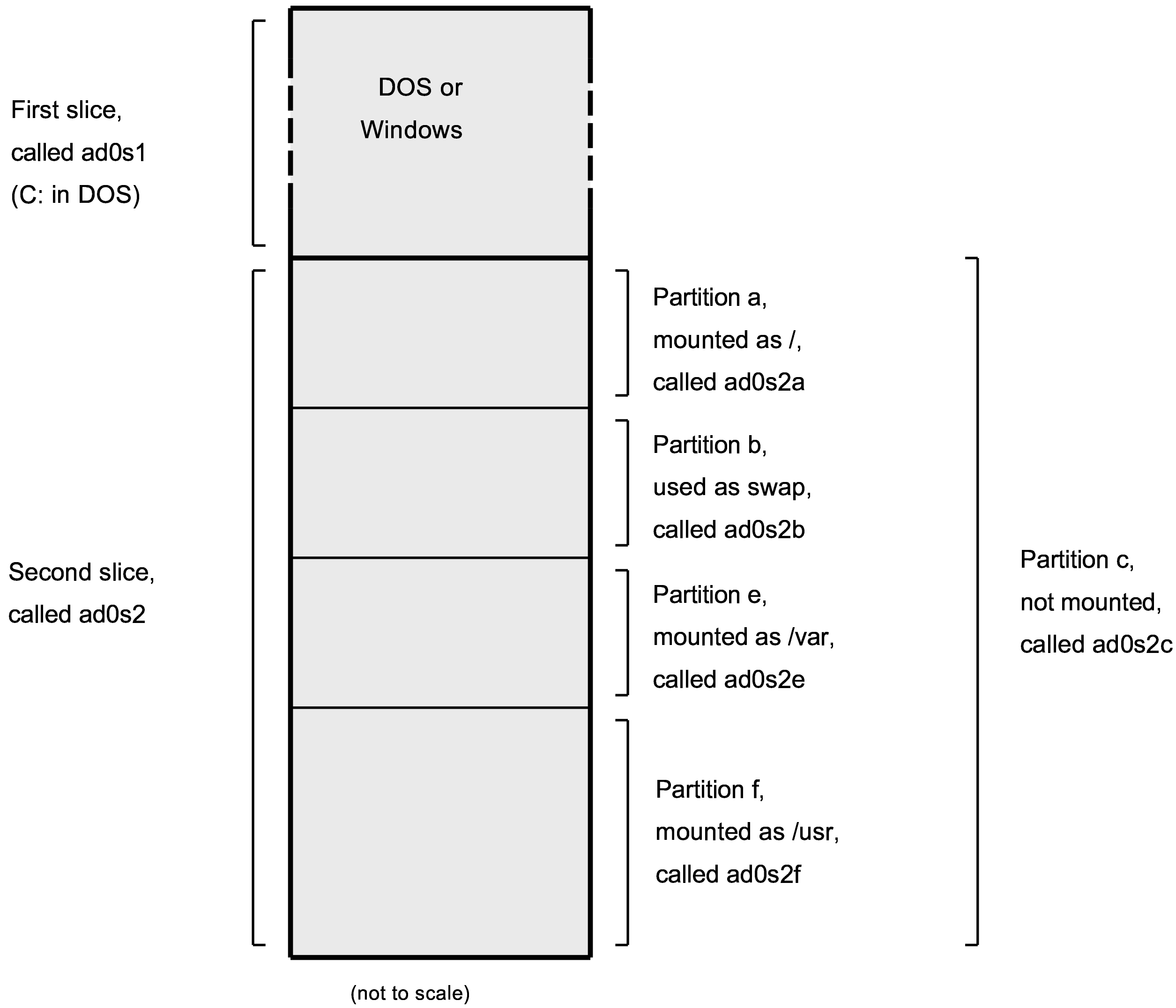
Example 3-1. Sample Disk, Slice, and Partition Names

Name	Meaning
`ad0s1a`	The first partition (`a`) on the first slice (`s1`) on the first IDE disk (`ad0`).
`da1s2e`	The fifth partition (`e`) on the second slice (`s2`) on the second SCSI disk (`da1`).

Example 3-2. Conceptual Model of a Disk

This diagram shows FreeBSD's view of the first IDE disk attached to the system. Assume that the disk is 4 GB in size, and contains two 2 GB slices (DOS partitions). The first slice contains a DOS disk, `C:`, and the second slice contains a FreeBSD installation. This example FreeBSD installation has three partitions, and a swap partition.

The three partitions will each hold a filesystem. Partition `a` will be used for the root filesystem, `e` for the `/var` directory hierarchy, and `f` for the `/usr` directory hierarchy.



3.6 Mounting and Unmounting File Systems

The file system is best visualized as a tree, rooted, as it were, at `/`. `/dev`, `/usr`, and the other directories in the root directory are branches, which may have their own branches, such as `/usr/local`, and so on.

There are various reasons to house some of these directories on separate file systems. `/var` contains the directories `log/`, `spool/`, and various types of temporary files, and as such, may get filled up. Filling up the root file system is not a good idea, so splitting `/var` from `/` is often favorable.

Another common reason to contain certain directory trees on other file systems is if they are to be housed on separate physical disks, or are separate virtual disks, such as Network File System mounts, or CDROM drives.

3.6.1 The `fstab` File

During the boot process, file systems listed in `/etc/fstab` are automatically mounted (unless they are listed with the `noauto` option).

The `/etc/fstab` file contains a list of lines of the following format:

```
device       /mount-point fstype     options      dumpfreq     passno
```

`device`

A device name (which should exist), as explained in Section 12.2.

`mount-point`

A directory (which should exist), on which to mount the file system.

`fstype`

The file system type to pass to mount(8). The default FreeBSD file system is `ufs`.

`options`

Either `rw` for read-write file systems, or `ro` for read-only file systems, followed by any other options that may be needed. A common option is `noauto` for file systems not normally mounted during the boot sequence. Other options are listed in the mount(8) manual page.

`dumpfreq`

This is used by dump(8) to determine which file systems require dumping. If the field is missing, a value of zero is assumed.

`passno`

This determines the order in which file systems should be checked. File systems that should be skipped should have their `passno` set to zero. The root file system (which needs to be checked before everything else) should have its `passno` set to one, and other file systems' `passno` should be set to values greater than one. If more than one file systems have the same `passno` then fsck(8) will attempt to check file systems in parallel if possible.

3.6.2 The `mount` Command

The mount(8) command is what is ultimately used to mount file systems.

In its most basic form, you use:

```
# mount device mountpoint
```

There are plenty of options, as mentioned in the mount(8) manual page, but the most common are:

Mount Options

`-a`

Mount all the file systems listed in `/etc/fstab`. Except those marked as "noauto", excluded by the `-t` flag, or those that are already mounted.

`-d`

Do everything except for the actual mount system call. This option is useful in conjunction with the `-v` flag to determine what mount(8) is actually trying to do.

`-f`

Force the mount of an unclean file system (dangerous), or forces the revocation of write access when downgrading a file system's mount status from read-write to read-only.

`-r`

Mount the file system read-only. This is identical to using the `rdonly` argument to the `-o` option.

`-t` *`fstype`*

Mount the given file system as the given file system type, or mount only file systems of the given type, if given the `-a` option.

"ufs" is the default file system type.

`-u`

Update mount options on the file system.

`-v`

Be verbose.

`-w`

Mount the file system read-write.

The `-o` option takes a comma-separated list of the options, including the following:

nodev

Do not interpret special devices on the file system. This is a useful security option.

noexec

Do not allow execution of binaries on this file system. This is also a useful security option.

nosuid

Do not interpret setuid or setgid flags on the file system. This is also a useful security option.

3.6.3 The umount Command

The umount(8) command takes, as a parameter, one of a mountpoint, a device name, or the `-a` or `-A` option.

All forms take `-f` to force unmounting, and `-v` for verbosity. Be warned that `-f` is not generally a good idea. Forcibly unmounting file systems might crash the computer or damage data on the file system.

`-a` and `-A` are used to unmount all mounted file systems, possibly modified by the file system types listed after `-t`. `-A`, however, does not attempt to unmount the root file system.

3.7 Processes

FreeBSD is a multi-tasking operating system. This means that it seems as though more than one program is running at once. Each program running at any one time is called a *process*. Every command you run will start at least one new process, and there are a number of system processes that run all the time, keeping the system functional.

Each process is uniquely identified by a number called a *process ID*, or *PID*, and, like files, each process also has one owner and group. The owner and group information is used to determine what files and devices the process can open, using the file permissions discussed earlier. Most processes also have a parent process. The parent process is the process that started them. For example, if you are typing commands to the shell then the shell is a process, and any commands you run are also processes. Each process you run in this way will have your shell as its parent process. The exception to this is a special process called init(8). `init` is always the first process, so its PID is always 1. `init` is started automatically by the kernel when FreeBSD starts.

Two commands are particularly useful to see the processes on the system, ps(1) and top(1). The `ps` command is used to show a static list of the currently running processes, and can show their PID, how much memory they are using, the command line they were started with, and so on. The `top` command displays all the running processes, and updates the display every few seconds, so that you can interactively see what your computer is doing.

By default, `ps` only shows you the commands that are running and are owned by you. For example:

```
% ps
  PID  TT  STAT      TIME COMMAND
  298  p0  Ss     0:01.10 tcsh
 7078  p0  S      2:40.88 xemacs mdoc.xsl (xemacs-21.1.14)
37393  p0  I      0:03.11 xemacs freebsd.dsl (xemacs-21.1.14)
48630  p0  S      2:50.89 /usr/local/lib/netscape-linux/navigator-linux-4.77.bi
48730  p0  IW     0:00.00 (dns helper) (navigator-linux-)
72210  p0  R+     0:00.00 ps
  390  p1  Is     0:01.14 tcsh
 7059  p2  Is+    1:36.18 /usr/local/bin/mutt -y
 6688  p3  IWs    0:00.00 tcsh
10735  p4  IWs    0:00.00 tcsh
20256  p5  IWs    0:00.00 tcsh
  262  v0  IWs    0:00.00 -tcsh (tcsh)
  270  v0  IW+    0:00.00 /bin/sh /usr/X11R6/bin/startx -- -bpp 16
  280  v0  IW+    0:00.00 xinit /home/nik/.xinitrc -- -bpp 16
  284  v0  IW     0:00.00 /bin/sh /home/nik/.xinitrc
  285  v0  S      0:38.45 /usr/X11R6/bin/sawfish
```

As you can see in this example, the output from ps(1) is organized into a number of columns. `PID` is the process ID discussed earlier. PIDs are assigned starting from 1, go up to 99999, and wrap around back to the beginning when you run out. The `TT` column shows the tty the program is running on, and can safely be ignored for the moment. `STAT` shows the program's state, and again, can be safely ignored. `TIME` is the amount of time the program has been running on the CPU—this is usually not the elapsed time since you started the program, as most programs spend a lot of time waiting for things to happen before they need to spend time on the CPU. Finally, `COMMAND` is the command line that was used to run the program.

ps(1) supports a number of different options to change the information that is displayed. One of the most useful sets is `auxww`. `a` displays information about all the running processes, not just your own. `u` displays the username of the process' owner, as well as memory usage. `x` displays information about daemon processes, and `ww` causes ps(1) to display the full command line, rather than truncating it once it gets too long to fit on the screen.

The output from top(1) is similar. A sample session looks like this:

```
% top
last pid: 72257;  load averages:  0.13,  0.09,  0.03    up 0+13:38:33  22:39:10
47 processes:  1 running, 46 sleeping
CPU states: 12.6% user,  0.0% nice,  7.8% system,  0.0% interrupt, 79.7% idle
Mem: 36M Active, 5256K Inact, 13M Wired, 6312K Cache, 15M Buf, 408K Free
Swap: 256M Total, 38M Used, 217M Free, 15% Inuse

  PID USERNAME PRI NICE  SIZE    RES STATE    TIME   WCPU    CPU COMMAND
72257 nik       28   0  1960K  1044K RUN      0:00 14.86%  1.42% top
 7078 nik        2   0 15280K 10960K select   2:54  0.88%  0.88% xemacs-21.1.14
  281 nik        2   0 18636K  7112K select   5:36  0.73%  0.73% XF86_SVGA
  296 nik        2   0  3240K  1644K select   0:12  0.05%  0.05% xterm
48630 nik        2   0 29816K  9148K select   3:18  0.00%  0.00% navigator-linu
  175 root       2   0   924K   252K select   1:41  0.00%  0.00% syslogd
 7059 nik        2   0  7260K  4644K poll     1:38  0.00%  0.00% mutt
...
```

The output is split into two sections. The header (the first five lines) shows the PID of the last process to run, the system load averages (which are a measure of how busy the system is), the system uptime (time since the last reboot) and the current time. The other figures in the header relate to how many processes are running (47 in this case), how much memory and swap space has been taken up, and how much time the system is spending in different CPU states.

Below that are a series of columns containing similar information to the output from ps(1). As before you can see the PID, the username, the amount of CPU time taken, and the command that was run. top(1) also defaults to showing you the amount of memory space taken by the process. This is split into two columns, one for total size, and one for resident size—total size is how much memory the application has needed, and the resident size is how much it is actually using at the moment. In this example you can see that **Netscape®** has required almost 30 MB of RAM, but is currently only using 9 MB.

top(1) automatically updates this display every two seconds; this can be changed with the `s` option.

3.8 Daemons, Signals, and Killing Processes

When you run an editor it is easy to control the editor, tell it to load files, and so on. You can do this because the editor provides facilities to do so, and because the editor is attached to a *terminal*. Some programs are not designed to be run with continuous user input, and so they disconnect from the terminal at the first opportunity. For example, a web server spends all day responding to web requests, it normally does not need any input from you. Programs that transport email from site to site are another example of this class of application.

We call these programs *daemons*. Daemons were characters in Greek mythology; neither good or evil, they were little attendant spirits that, by and large, did useful things for mankind. Much like the web servers and mail servers of today do useful things. This is why the BSD mascot has, for a long time, been the cheerful looking daemon with sneakers and a pitchfork.

There is a convention to name programs that normally run as daemons with a trailing "d". **BIND** is the Berkeley Internet Name Daemon (and the actual program that executes is called `named`), the **Apache** web server program is called `httpd`, the line printer spooling daemon is `lpd` and so on. This is a convention, not a hard and fast rule; for example, the main mail daemon for the **Sendmail** application is called `sendmail`, and not `maild`, as you might imagine.

Sometimes you will need to communicate with a daemon process. These communications are called *signals*, and you can communicate with a daemon (or with any other running process) by sending it a signal. There are a number of different signals that you can send—some of them have a specific meaning, others are interpreted by the application, and the application's documentation will tell you how that application interprets signals. You can only send a signal to a process that you own. If you send a signal to someone else's process with kill(1) or kill(2) permission will be denied. The exception to this is the `root` user, who can send signals to everyone's processes.

FreeBSD will also send applications signals in some cases. If an application is badly written, and tries to access memory that it is not supposed to, FreeBSD sends the process the *Segmentation Violation* signal (`SIGSEGV`). If an application has used the alarm(3) system call to be alerted after a period of time has elapsed then it will be sent the Alarm signal (`SIGALRM`), and so on.

Two signals can be used to stop a process, `SIGTERM` and `SIGKILL`. `SIGTERM` is the polite way to kill a process; the process can *catch* the signal, realize that you want it to shut down, close any log files it may have open, and generally finish whatever it is doing at the time before shutting down. In some cases a process may even ignore `SIGTERM` if it is in the middle of some task that can not be interrupted.

`SIGKILL` can not be ignored by a process. This is the "I do not care what you are doing, stop right now" signal. If you send `SIGKILL` to a process then FreeBSD will stop that process there and then[4].

The other signals you might want to use are `SIGHUP`, `SIGUSR1`, and `SIGUSR2`. These are general purpose signals, and different applications will do different things when they are sent.

Suppose that you have changed your web server's configuration file—you would like to tell the web server to re-read its configuration. You could stop and restart `httpd`, but this would result in a brief outage period on your web server, which may be undesirable. Most daemons are written to respond to the `SIGHUP` signal by re-reading their configuration file. So instead of killing and restarting `httpd` you would send it the `SIGHUP` signal. Because there is no standard way to respond to these signals, different daemons will have different behavior, so be sure and read the documentation for the daemon in question.

Signals are sent using the kill(1) command, as this example shows.

Sending a Signal to a Process

This example shows how to send a signal to inetd(8). The `inetd` configuration file is `/etc/inetd.conf`, and `inetd` will re-read this configuration file when it is sent `SIGHUP`.

1. Find the process ID of the process you want to send the signal to. Do this using ps(1) and grep(1). The grep(1) command is used to search through output, looking for the string you specify. This command is run as a normal user, and inetd(8) is run as `root`, so the `ax` options must be given to ps(1).

   ```
   % ps -ax | grep inetd
     198  ??  IWs    0:00.00 inetd -wW
   ```

So the inetd(8) PID is 198. In some cases the `grep inetd` command might also occur in this output. This is because of the way ps(1) has to find the list of running processes.

2. Use kill(1) to send the signal. Because inetd(8) is being run by `root` you must use su(1) to become `root` first.

```
% su
Password:
# /bin/kill -s HUP 198
```

In common with most UNIX commands, kill(1) will not print any output if it is successful. If you send a signal to a process that you do not own then you will see `kill: PID: Operation not permitted`. If you mistype the PID you will either send the signal to the wrong process, which could be bad, or, if you are lucky, you will have sent the signal to a PID that is not currently in use, and you will see `kill: PID: No such process`.

> **Why Use `/bin/kill`?:** Many shells provide the `kill` command as a built in command; that is, the shell will send the signal directly, rather than running `/bin/kill`. This can be very useful, but different shells have a different syntax for specifying the name of the signal to send. Rather than try to learn all of them, it can be simpler just to use the `/bin/kill ...` command directly.

Sending other signals is very similar, just substitute `TERM` or `KILL` in the command line as necessary.

> **Important:** Killing random process on the system can be a bad idea. In particular, init(8), process ID 1, is very special. Running `/bin/kill -s KILL 1` is a quick way to shutdown your system. *Always* double check the arguments you run kill(1) with *before* you press **Return**.

3.9 Shells

In FreeBSD, a lot of everyday work is done in a command line interface called a shell. A shell's main job is to take commands from the input channel and execute them. A lot of shells also have built in functions to help everyday tasks such as file management, file globbing, command line editing, command macros, and environment variables. FreeBSD comes with a set of shells, such as `sh`, the Bourne Shell, and `tcsh`, the improved C-shell. Many other shells are available from the FreeBSD Ports Collection, such as `zsh` and `bash`.

Which shell do you use? It is really a matter of taste. If you are a C programmer you might feel more comfortable with a C-like shell such as `tcsh`. If you have come from Linux or are new to a UNIX command line interface you might try `bash`. The point is that each shell has unique properties that may or may not work with your preferred working environment, and that you have a choice of what shell to use.

One common feature in a shell is filename completion. Given the typing of the first few letters of a command or filename, you can usually have the shell automatically complete the rest of the command or filename by hitting the **Tab** key on the keyboard. Here is an example. Suppose you have two files called `foobar` and `foo.bar`. You want to delete `foo.bar`. So what you would type on the keyboard is: `rm fo[Tab].[Tab]`.

The shell would print out `rm foo[BEEP].bar`.

The [BEEP] is the console bell, which is the shell telling me it was unable to totally complete the filename because there is more than one match. Both `foobar` and `foo.bar` start with `fo`, but it was able to complete to `foo`. If you type in `.`, then hit **Tab** again, the shell would be able to fill in the rest of the filename for you.

Another feature of the shell is the use of environment variables. Environment variables are a variable key pair stored in the shell's environment space. This space can be read by any program invoked by the shell, and thus contains a lot of program configuration. Here is a list of common environment variables and what they mean:

Variable	Description
`USER`	Current logged in user's name.
`PATH`	Colon separated list of directories to search for binaries.
`DISPLAY`	Network name of the X11 display to connect to, if available.
`SHELL`	The current shell.
`TERM`	The name of the user's terminal. Used to determine the capabilities of the terminal.
`TERMCAP`	Database entry of the terminal escape codes to perform various terminal functions.
`OSTYPE`	Type of operating system. e.g., FreeBSD.
`MACHTYPE`	The CPU architecture that the system is running on.
`EDITOR`	The user's preferred text editor.
`PAGER`	The user's preferred text pager.
`MANPATH`	Colon separated list of directories to search for manual pages.

Setting an environment variable differs somewhat from shell to shell. For example, in the C-Style shells such as `tcsh` and `csh`, you would use `setenv` to set environment variables. Under Bourne shells such as `sh` and `bash`, you would use `export` to set your current environment variables. For example, to set or modify the `EDITOR` environment variable, under `csh` or `tcsh` a command like this would set `EDITOR` to `/usr/local/bin/emacs`:

```
% setenv EDITOR /usr/local/bin/emacs
```

Under Bourne shells:

```
% export EDITOR="/usr/local/bin/emacs"
```

You can also make most shells expand the environment variable by placing a `$` character in front of it on the command line. For example, `echo $TERM` would print out whatever `$TERM` is set to, because the shell expands `$TERM` and passes it on to `echo`.

Shells treat a lot of special characters, called meta-characters as special representations of data. The most common one is the `*` character, which represents any number of characters in a filename. These special meta-characters can be used to do filename globbing. For example, typing in `echo *` is almost the same as typing in `ls` because the shell takes all the files that match `*` and puts them on the command line for `echo` to see.

To prevent the shell from interpreting these special characters, they can be escaped from the shell by putting a backslash (`\`) character in front of them. `echo $TERM` prints whatever your terminal is set to. `echo \$TERM` prints `$TERM` as is.

3.9.1 Changing Your Shell

The easiest way to change your shell is to use the `chsh` command. Running `chsh` will place you into the editor that is in your `EDITOR` environment variable; if it is not set, you will be placed in `vi`. Change the "Shell:" line accordingly.

You can also give `chsh` the `-s` option; this will set your shell for you, without requiring you to enter an editor. For example, if you wanted to change your shell to `bash`, the following should do the trick:

```
% chsh -s /usr/local/bin/bash
```

Running `chsh` with no parameters and editing the shell from there would work also.

> **Note:** The shell that you wish to use *must* be present in the `/etc/shells` file. If you have installed a shell from the ports collection, then this should have been done for you already. If you installed the shell by hand, you must do this.
>
> For example, if you installed `bash` by hand and placed it into `/usr/local/bin`, you would want to:
>
> ```
> # echo "/usr/local/bin/bash" >> /etc/shells
> ```
>
> Then rerun `chsh`.

3.10 Text Editors

A lot of configuration in FreeBSD is done by editing text files. Because of this, it would be a good idea to become familiar with a text editor. FreeBSD comes with a few as part of the base system, and many more are available in the ports collection.

The easiest and simplest editor to learn is an editor called **ee**, which stands for easy editor. To start **ee**, one would type at the command line `ee filename` where *filename* is the name of the file to be edited. For example, to edit `/etc/rc.conf`, type in `ee /etc/rc.conf`. Once inside of `ee`, all of the commands for manipulating the editor's functions are listed at the top of the display. The caret `^` character represents the **Ctrl** key on the keyboard, so `^e` expands to the key combination **Ctrl**+**e**. To leave **ee**, hit the **Esc** key, then choose leave editor. The editor will prompt you to save any changes if the file has been modified.

FreeBSD also comes with more powerful text editors such as `vi` as part of the base system, while other editors, like `emacs` and `vim`, are part of the FreeBSD Ports Collection. These editors offer much more functionality and power at the expense of being a little more complicated to learn. However if you plan on doing a lot of text editing, learning a more powerful editor such as `vim` or `emacs` will save you much more time in the long run.

3.11 Devices and Device Nodes

A device is a term used mostly for hardware-related activities in a system, including disks, printers, graphics cards, and keyboards. When FreeBSD boots, the majority of what FreeBSD displays are devices being detected. You can look through the boot messages again by viewing `/var/run/dmesg.boot`.

For example, `acd0` is the first IDE CDROM drive, while `kbd0` represents the keyboard.

Most of these devices in a UNIX operating system must be accessed through special files called device nodes, which are located in the `/dev` directory.

3.11.1 Creating Device Nodes

When adding a new device to your system, or compiling in support for additional devices, you may need to create one or more device nodes for the new devices.

3.11.1.1 MAKEDEV Script

On systems without `DEVFS` (this concerns all FreeBSD versions before 5.0), device nodes are created using the MAKEDEV(8) script as shown below:

```
# cd /dev
# sh MAKEDEV ad1
```

This example would make the proper device nodes for the second IDE drive when installed.

3.11.1.2 DEVFS (DEVice File System)

The device file system, or `DEVFS`, provides access to kernel's device namespace in the global file system namespace. Instead of having to create and modify device nodes, `DEVFS` maintains this particular file system for you.

See the devfs(5) manual page for more information.

`DEVFS` is used by default in FreeBSD 5.0 and above.

3.12 Binary Formats

To understand why FreeBSD uses the ELF format, you must first know a little about the three currently "dominant" executable formats for UNIX:

- a.out(5)

  The oldest and "classic" UNIX object format. It uses a short and compact header with a magic number at the beginning that is often used to characterize the format (see a.out(5) for more details). It contains three loaded segments: .text, .data, and .bss plus a symbol table and a string table.

- COFF

  The SVR3 object format. The header now comprises a section table, so you can have more than just .text, .data, and .bss sections.

- ELF

  The successor to COFF, featuring multiple sections and 32-bit or 64-bit possible values. One major drawback: ELF was also designed with the assumption that there would be only one ABI per system architecture. That assumption is actually quite incorrect, and not even in the commercial SYSV world (which has at least three ABIs: SVR4, Solaris, SCO) does it hold true.

FreeBSD tries to work around this problem somewhat by providing a utility for *branding* a known ELF executable with information about the ABI it is compliant with. See the manual page for brandelf(1) for more information.

FreeBSD comes from the "classic" camp and used the a.out(5) format, a technology tried and proven through many generations of BSD releases, until the beginning of the 3.X branch. Though it was possible to build and run native ELF binaries (and kernels) on a FreeBSD system for some time before that, FreeBSD initially resisted the "push" to switch to ELF as the default format. Why? Well, when the Linux camp made their painful transition to ELF, it was not so much to flee the `a.out` executable format as it was their inflexible jump-table based shared library mechanism, which made the construction of shared libraries very difficult for vendors and developers alike. Since the ELF tools available offered a solution to the shared library problem and were generally seen as "the way forward" anyway, the migration cost was accepted as necessary and the transition made. FreeBSD's shared library mechanism is based more closely on Sun's SunOS™ style shared library mechanism and, as such, is very easy to use.

So, why are there so many different formats?

Back in the dim, dark past, there was simple hardware. This simple hardware supported a simple, small system. `a.out` was completely adequate for the job of representing binaries on this simple system (a PDP-11). As people ported UNIX from this simple system, they retained the `a.out` format because it was sufficient for the early ports of UNIX to architectures like the Motorola 68k, VAXen, etc.

Then some bright hardware engineer decided that if he could force software to do some sleazy tricks, then he would be able to shave a few gates off the design and allow his CPU core to run faster. While it was made to work with this new kind of hardware (known these days as RISC), `a.out` was ill-suited for this hardware, so many formats were developed to get to a better performance from this hardware than the limited, simple `a.out` format could offer. Things like COFF, ECOFF, and a few obscure others were invented and their limitations explored before things seemed to settle on ELF.

In addition, program sizes were getting huge and disks (and physical memory) were still relatively small so the concept of a shared library was born. The VM system also became more sophisticated. While each one of these advancements was done using the `a.out` format, its usefulness was stretched more and more with each new feature. In addition, people wanted to dynamically load things at run time, or to junk parts of their program after the init code had run to save in core memory and swap space. Languages became more sophisticated and people wanted code called before main automatically. Lots of hacks were done to the `a.out` format to allow all of these things to happen, and they basically worked for a time. In time, `a.out` was not up to handling all these problems without an ever increasing overhead in code and complexity. While ELF solved many of these problems, it would be painful to switch from the system that basically worked. So ELF had to wait until it was more painful to remain with `a.out` than it was to migrate to ELF.

However, as time passed, the build tools that FreeBSD derived their build tools from (the assembler and loader especially) evolved in two parallel trees. The FreeBSD tree added shared libraries and fixed some bugs. The GNU folks that originally write these programs rewrote them and added simpler support for building cross compilers, plugging in different formats at will, and so on. Since many people wanted to build cross compilers targeting FreeBSD, they were out of luck since the older sources that FreeBSD had for **as** and **ld** were not up to the task. The new GNU tools chain (**binutils**) does support cross compiling, ELF, shared libraries, C++ extensions, etc. In addition, many vendors are releasing ELF binaries, and it is a good thing for FreeBSD to run them.

ELF is more expressive than `a.out` and allows more extensibility in the base system. The ELF tools are better maintained, and offer cross compilation support, which is important to many people. ELF may be a little slower than `a.out`, but trying to measure it can be difficult. There are also numerous details that are different between the two in how they map pages, handle init code, etc. None of these are very important, but they are differences. In time support for `a.out` will be moved out of the `GENERIC` kernel, and eventually removed from the kernel once the need to run legacy `a.out` programs is past.

3.13 For More Information

3.13.1 Manual Pages

The most comprehensive documentation on FreeBSD is in the form of manual pages. Nearly every program on the system comes with a short reference manual explaining the basic operation and various arguments. These manuals can be viewed with the `man` command. Use of the `man` command is simple:

```
% man command
```

`command` is the name of the command you wish to learn about. For example, to learn more about `ls` command type:

```
% man ls
```

The online manual is divided up into numbered sections:

1. User commands.
2. System calls and error numbers.
3. Functions in the C libraries.
4. Device drivers.
5. File formats.
6. Games and other diversions.
7. Miscellaneous information.
8. System maintenance and operation commands.
9. Kernel developers.

In some cases, the same topic may appear in more than one section of the online manual. For example, there is a `chmod` user command and a `chmod()` system call. In this case, you can tell the `man` command which one you want by specifying the section:

```
% man 1 chmod
```

This will display the manual page for the user command `chmod`. References to a particular section of the online manual are traditionally placed in parenthesis in written documentation, so chmod(1) refers to the `chmod` user command and chmod(2) refers to the system call.

This is fine if you know the name of the command and simply wish to know how to use it, but what if you cannot recall the command name? You can use `man` to search for keywords in the command descriptions by using the `-k` switch:

```
% man -k mail
```

With this command you will be presented with a list of commands that have the keyword "mail" in their descriptions. This is actually functionally equivalent to using the `apropos` command.

So, you are looking at all those fancy commands in `/usr/bin` but do not have the faintest idea what most of them actually do? Simply do:

```
% cd /usr/bin
% man -f *
```

or

```
% cd /usr/bin
% whatis *
```

which does the same thing.

3.13.2 GNU Info Files

FreeBSD includes many applications and utilities produced by the Free Software Foundation (FSF). In addition to manual pages, these programs come with more extensive hypertext documents called `info` files which can be viewed with the `info` command or, if you installed **emacs**, the info mode of **emacs**.

To use the info(1) command, simply type:

```
% info
```

For a brief introduction, type `h`. For a quick command reference, type `?`.

Notes

1. This is what `i386` means. Note that even if you are not running FreeBSD on an Intel 386 CPU, this is going to be `i386`. It is not the type of your processor, but the processor "architecture" that is shown here.
2. Startup scripts are programs that are run automatically by FreeBSD when booting. Their main function is to set things up for everything else to run, and start any services that you have configured to run in the background doing useful things.
3. A fairly technical and accurate description of all the details of the FreeBSD console and keyboard drivers can be found in the manual pages of syscons(4), atkbd(4), vidcontrol(1) and kbdcontrol(1). We will not expand on the details here, but the interested reader can always consult the manual pages for a more detailed and thorough explanation of how things work.
4. Not quite true—there are a few things that can not be interrupted. For example, if the process is trying to read from a file that is on another computer on the network, and the other computer has gone away for some reason (been turned off, or the network has a fault), then the process is said to be "uninterruptible". Eventually the process will time out, typically after two minutes. As soon as this time out occurs the process will be killed.

Chapter 4 Installing Applications: Packages and Ports

4.1 Synopsis

FreeBSD is bundled with a rich collection of system tools as part of the base system. However, there is only so much one can do before needing to install an additional third-party application to get real work done. FreeBSD provides two complementary technologies for installing third party software on your system: the FreeBSD Ports Collection, and binary software packages. Either system may be used to install the newest version of your favorite applications from local media or straight off the network.

After reading this chapter, you will know:

- How to install third-party binary software packages.
- How to build third-party software from the ports collection.
- How to remove previously installed packages or ports.
- How to override the default values that the ports collection uses.
- How to upgrade your ports.

4.2 Overview of Software Installation

If you have used a UNIX system before you will know that the typical procedure for installing third party software goes something like this:

1. Download the software, which might be distributed in source code format, or as a binary.
2. Unpack the software from its distribution format (typically a tarball compressed with compress(1), gzip(1), or bzip2(1)).
3. Locate the documentation (perhaps an `INSTALL` or `README` file, or some files in a `doc/` subdirectory) and read up on how to install the software.
4. If the software was distributed in source format, compile it. This may involve editing a `Makefile`, or running a `configure` script, and other work.
5. Test and install the software.

And that is only if everything goes well. If you are installing a software package that was not deliberately ported to FreeBSD you may even have to go in and edit the code to make it work properly.

Should you want to, you can continue to install software the “traditional” way with FreeBSD. However, FreeBSD provides two technologies which can save you a lot of effort: packages and ports. At the time of writing, over 9,200 third party applications have been made available in this way.

For any given application, the FreeBSD package for that application is a single file which you must download. The package contains pre-compiled copies of all the commands for the application, as well as any configuration files or documentation. A downloaded package file can be manipulated with FreeBSD package management commands, such as pkg_add(1), pkg_delete(1), pkg_info(1), and so on. Installing a new application can be carried out with a single command.

A FreeBSD port for an application is a collection of files designed to automate the process of compiling an application from source code.

Remember that there are a number of steps you would normally carry out if you compiled a program yourself (downloading, unpacking, patching, compiling, installing). The files that make up a port contain all the necessary information to allow the system to do this for you. You run a handful of simple commands and the source code for the application is automatically downloaded, extracted, patched, compiled, and installed for you.

In fact, the ports system can also be used to generate packages which can later be manipulated with `pkg_add` and the other package management commands that will be introduced shortly.

Both packages and ports understand *dependencies*. Suppose you want to install an application that depends on a specific library being installed. Both the application and the library have been made available as FreeBSD ports and packages. If you use the `pkg_add` command or the ports system to add the application, both will notice that the library has not been installed, and automatically install the library first.

Given that the two technologies are quite similar, you might be wondering why FreeBSD bothers with both. Packages and ports both have their own strengths, and which one you use will depend on your own preference.

Package Benefits

- A compressed package tarball is typically smaller than the compressed tarball containing the source code for the application.
- Packages do not require any additional compilation. For large applications, such as **Mozilla**, **KDE**, or **GNOME** this can be important, particularly if you are on a slow system.
- Packages do not require any understanding of the process involved in compiling software on FreeBSD.

Ports Benefits

- Packages are normally compiled with conservative options, because they have to run on the maximum number of systems. By installing from the port, you can tweak the compilation options to (for example) generate code that is specific to a Pentium IV or Athlon processor.
- Some applications have compile time options relating to what they can and cannot do. For example, **Apache** can be configured with a wide variety of different built-in options. By building from the port you do not have to accept the default options, and can set them yourself.

  In some cases, multiple packages will exist for the same application to specify certain settings. For example, **Ghostscript** is available as a `ghostscript` package and a `ghostscript-nox11` package, depending on whether or not you have installed an X11 server. This sort of rough tweaking is possible with packages, but rapidly becomes impossible if an application has more than one or two different compile time options.

- The licensing conditions of some software distributions forbid binary distribution. They must be distributed as source code.
- Some people do not trust binary distributions. At least with source code, you can (in theory) read through it and look for potential problems yourself.
- If you have local patches, you will need the source in order to apply them.

- Some people like having code around, so they can read it if they get bored, hack it, borrow from it (license permitting, of course), and so on.

To keep track of updated ports, subscribe to the FreeBSD ports mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-ports) and the FreeBSD ports bugs mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-ports-bugs).

The remainder of this chapter will explain how to use packages and ports to install and manage third party software on FreeBSD.

4.3 Finding Your Application

Before you can install any applications you need to know what you want, and what the application is called.

FreeBSD's list of available applications is growing all the time. Fortunately, there are a number of ways to find what you want:

- The FreeBSD web site maintains an up-to-date searchable list of all the available applications, at http://www.FreeBSD.org/ports/ (../../../../ports/index.html). The ports are divided into categories, and you may either search for an application by name (if you know it), or see all the applications available in a category.
- Dan Langille maintains FreshPorts, at http://www.FreshPorts.org/. FreshPorts tracks changes to the applications in the ports tree as they happen, allows you to "watch" one or more ports, and can send you email when they are updated.
- If you do not know the name of the application you want, try using a site like FreshMeat (http://www.freshmeat.net/) to find an application, then check back at the FreeBSD site to see if the application has been ported yet.

4.4 Using the Packages System

Contributed by Chern Lee.

4.4.1 Installing a Package

You can use the pkg_add(1) utility to install a FreeBSD software package from a local file or from a server on the network.

Example 4-1. Downloading a Package Manually and Installing It Locally

```
# ftp -a ftp2.FreeBSD.org
Connected to ftp2.FreeBSD.org.
220 ftp2.FreeBSD.org FTP server (Version 6.00LS) ready.
331 Guest login ok, send your email address as password.
230-
230-     This machine is in Vienna, VA, USA, hosted by Verio.
230-         Questions? E-mail freebsd@vienna.verio.net.
230-
230-
230 Guest login ok, access restrictions apply.
```

```
Remote system type is UNIX.
Using binary mode to transfer files.
ftp> cd /pub/FreeBSD/ports/packages/sysutils/
250 CWD command successful.
ftp> get lsof-4.56.4.tgz
local: lsof-4.56.4.tgz remote: lsof-4.56.4.tgz
200 PORT command successful.
150 Opening BINARY mode data connection for 'lsof-4.56.4.tgz' (92375 bytes).
100% |**************************************************| 92375       00:00 ETA
226 Transfer complete.
92375 bytes received in 5.60 seconds (16.11 KB/s)
ftp> exit
# pkg_add lsof-4.56.4.tgz
```

If you do not have a source of local packages (such as a FreeBSD CD-ROM set) then it will probably be easier to use the `-r` option to pkg_add(1). This will cause the utility to automatically determine the correct object format and release and then fetch and install the package from an FTP site.

```
# pkg_add -r lsof
```

The example above would download the correct package and add it without any further user intervention. pkg_add(1) uses fetch(3) to download the files, which honors various environment variables, including `FTP_PASSIVE_MODE`, `FTP_PROXY`, and `FTP_PASSWORD`. You may need to set one or more of these if you are behind a firewall, or need to use an FTP/HTTP proxy. See fetch(3) for the complete list. Note that in the example above `lsof` is used instead of `lsof-4.56.4`. When the remote fetching feature is used, the version number of the package must be removed. pkg_add(1) will automatically fetch the latest version of the application.

Package files are distributed in `.tgz` and `.tbz` formats. You can find them at ftp://ftp.FreeBSD.org/pub/FreeBSD/ports/packages/, or on the FreeBSD CD-ROM distribution. Every CD on the FreeBSD 4-CD set (and the PowerPak, etc.) contains packages in the `/packages` directory. The layout of the packages is similar to that of the `/usr/ports` tree. Each category has its own directory, and every package can be found within the `All` directory.

The directory structure of the package system matches the ports layout; they work with each other to form the entire package/port system.

4.4.2 Managing Packages

pkg_info(1) is a utility that lists and describes the various packages installed.

```
# pkg_info
cvsup-16.1          A general network file distribution system optimized for CV
docbook-1.2         Meta-port for the different versions of the DocBook DTD
...
```

pkg_version(1) is a utility that summarizes the versions of all installed packages. It compares the package version to the current version found in the ports tree.

```
# pkg_version
cvsup                      =
docbook                    =
...
```

The symbols in the second column indicate the relative age of the installed version and the version available in the local ports tree.

Symbol	Meaning
=	The version of the installed package matches the one found in the local ports tree.
<	The installed version is older than the one available in the ports tree.
>	The installed version is newer than the one found in the local ports tree. (The local ports tree is probably out of date.)
?	The installed package cannot be found in the ports index. (This can happen, for instance, if an installed port is removed from the ports collection or renamed.)
*	There are multiple versions of the package.

4.4.3 Deleting a Package

To remove a previously installed software package, use the pkg_delete(1) utility.

```
# pkg_delete xchat-1.7.1
```

4.4.4 Miscellaneous

All package information is stored within the `/var/db/pkg` directory. The installed file list and descriptions of each package can be found within files in this directory.

4.5 Using the Ports Collection

The following sections provide basic instructions on using the ports collection to install or remove programs from your system.

4.5.1 Obtaining the Ports Collection

Before you can install ports, you must first obtain the ports collection—which is essentially a set of `Makefiles`, patches, and description files placed in `/usr/ports`.

When installing your FreeBSD system, **Sysinstall** asked if you would like to install the ports collection. If you chose no, you can follow these instructions to obtain the ports collection:

Sysinstall Method

This method involves using **sysinstall** again to manually install the ports collection.

1. As `root`, run `/stand/sysinstall` as shown below:

```
# /stand/sysinstall
```

2. Scroll down and select Configure, press **Enter**.
3. Scroll down and select Distributions, press **Enter**.
4. Scroll down to ports, press **Space**.
5. Scroll up to Exit, press **Enter**.
6. Select your desired installation media, such as CDROM, FTP, and so on.
7. Scroll up to Exit and press **Enter**.
8. Press **X** to exit **sysinstall**.

The alternative method to obtain and keep your ports collection up to date is by using **CVSup**. Look at the ports **CVSup** file, `/usr/share/examples/cvsup/ports-supfile`. See Using CVSup (Section A.5) for more information on using **CVSup** and this file.

CVSup Method

This is a quick method for getting the ports collection using **CVSup**. If you want to keep your ports tree up to date, or learn more about **CVSup**, read the previously mentioned sections.

1. Install the `net/cvsup` port. See CVSup Installation (Section A.5.2) for more details.
2. As `root`, copy `/usr/share/examples/cvsup/ports-supfile` to a new location, such as `/root` or your home directory.
3. Edit `ports-supfile`.
4. Change *`CHANGE_THIS.FreeBSD.org`* to a **CVSup** server near you. See CVSup Mirrors (Section A.5.7) for a complete listing of mirror sites.
5. Run `cvsup`:

   ```
   # cvsup -g -L 2 /root/ports-supfile
   ```

6. Running this command later will download and apply all the recent changes to your ports collection, except actually rebuilding the ports for your own system.

4.5.2 Installing Ports

The first thing that should be explained when it comes to the ports collection is what is actually meant by a "skeleton". In a nutshell, a port skeleton is a minimal set of files that tell your FreeBSD system how to cleanly compile and install a program. Each port skeleton includes:

- A `Makefile`. The `Makefile` contains various statements that specify how the application should be compiled and where it should be installed on your system.
- A `distinfo` file. This file contains information about the files that must be downloaded to build the port and their checksums, to verify that files have not been corrupted during the download using md5(1).
- A `files` directory. This directory contains patches to make the program compile and install on your FreeBSD system. Patches are basically small files that specify changes to particular files. They are in plain text format, and

basically say "Remove line 10" or "Change line 26 to this ...". Patches are also known as "diffs" because they are generated by the diff(1) program.

This directory may also contain other files used to build the port.

- A `pkg-descr` file. This is a more detailed, often multiple-line, description of the program.
- A `pkg-plist` file. This is a list of all the files that will be installed by the port. It also tells the ports system what files to remove upon deinstallation.

Some ports have other files, such as `pkg-message`. The ports system uses these files to handle special situations. If you want more details on these files, and on ports in general, check out the FreeBSD Porter's Handbook (../porters-handbook/index.html).

Now that you have enough background information to know what the ports collection is used for, you are ready to install your first port. There are two ways this can be done, and each is explained below.

Before we get into that, however, you will need to choose a port to install. There are a few ways to do this, with the easiest method being the ports listing on the FreeBSD web site (../../../../ports/index.html). You can browse through the ports listed there or use the search function on the site. Each port also includes a description so you can read a bit about each port before deciding to install it.

Another method is to use the whereis(1) command. Simply type `whereis` *`file`*, where *`file`* is the program you want to install. If it is found on your system, you will be told where it is, as follows:

```
# whereis lsof
lsof: /usr/ports/sysutils/lsof
```

This tells us that `lsof` (a system utility) can be found in the `/usr/ports/sysutils/lsof` directory.

Yet another way to find a particular port is by using the ports collection's built-in search mechanism. To use the search feature, you will need to be in the `/usr/ports` directory. Once in that directory, run `make search name=`*`program-name`* where *`program-name`* is the name of the program you want to find. For example, if you were looking for `lsof`:

```
# cd /usr/ports
# make search name=lsof
Port:   lsof-4.56.4
Path:   /usr/ports/sysutils/lsof
Info:   Lists information about open files (similar to fstat(1))
Maint:  obrien@FreeBSD.org
Index:  sysutils
B-deps:
R-deps:
```

The part of the output you want to pay particular attention to is the "Path:" line, since that tells you where to find the port. The other information provided is not needed in order to install the port, so it will not be covered here.

For more in-depth searching you can also use `make search key=`*`string`* where *`string`* is some text to search for. This searches port names, comments, descriptions and dependencies and can be used to find ports which relate to a particular subject if you don't know the name of the program you are looking for.

In both of these cases, the search string is case-insensitive. Searching for "LSOF" will yield the same results as searching for "lsof".

> **Note:** You must be logged in as `root` to install ports.

Now that you have found a port you would like to install, you are ready to do the actual installation. The port includes instructions on how to build source code, but does not include the actual source code. You can get the source code from a CD-ROM or from the Internet. Source code is distributed in whatever manner the software author desires. Frequently this is a tarred and gzipped file, but it might be compressed with some other tool or even uncompressed. The program source code, whatever form it comes in, is called a "distfile". You can get the distfile from a CD-ROM or from the Internet.

4.5.2.1 Installing Ports from a CD-ROM

The FreeBSD Project's official CD-ROM images no longer include distfiles. They take up a lot of room that is better used for precompiled packages. CD-ROM products such as the FreeBSD PowerPak do include distfiles, and you can order these sets from a vendor such as the FreeBSD Mall (http://www.freebsdmall.com/). This section assumes you have such a FreeBSD CD-ROM set.

Place your FreeBSD CD-ROM in the drive. Mount it on `/cdrom`. (If you use a different mount point, the install will not work.) To begin, change to the directory for the port you want to install:

```
# cd /usr/ports/sysutils/lsof
```

Once inside the `lsof` directory, you will see the port skeleton. The next step is to compile, or "build", the port. This is done by simply typing `make` at the prompt. Once you have done so, you should see something like this:

```
# make
>> lsof_4.57D.freebsd.tar.gz doesn't seem to exist in /usr/ports/distfiles/.
>> Attempting to fetch from file:/cdrom/ports/distfiles/.
===>  Extracting for lsof-4.57
...
[extraction output snipped]
...
>> Checksum OK for lsof_4.57D.freebsd.tar.gz.
===>  Patching for lsof-4.57
===>  Applying FreeBSD patches for lsof-4.57
===>  Configuring for lsof-4.57
...
[configure output snipped]
...
===>  Building for lsof-4.57
...
[compilation output snipped]
...
#
```

Notice that once the compile is complete you are returned to your prompt. The next step is to install the port. In order to install it, you simply need to tack one word onto the `make` command, and that word is `install`:

```
# make install
===>  Installing for lsof-4.57
...
[installation output snipped]
```

```
...
===>   Generating temporary packing list
===>   Compressing manual pages for lsof-4.57
===>   Registering installation for lsof-4.57
===>  SECURITY NOTE:
      This port has installed the following binaries which execute with
      increased privileges.
#
```

Once you are returned to your prompt, you should be able to run the application you just installed. Since `lsof` is a program that runs with increased privileges, a security warning is shown. During the building and installation of ports, you should take heed of any other warnings that may appear.

> **Note:** You can save an extra step by just running `make install` instead of `make` and `make install` as two separate steps.

> **Note:** Some shells keep a cache of the commands that are available in the directories listed in the `PATH` environment variable, to speed up lookup operations for the executable file of these commands. If you are using one of these shells, you might have to use the `rehash` command after installing a port, before the newly installed commands can be used. This is true for both shells that are part of the base-system (such as `tcsh`) and shells that are available as ports (for instance, `shells/zsh`).

> **Note:** Please be aware that the licenses of a few ports do not allow for inclusion on the CD-ROM. This could be because a registration form needs to be filled out before downloading or redistribution is not allowed, or for another reason. If you wish to install a port not included on the CD-ROM, you will need to be online in order to do so (see the next section).

4.5.2.2 Installing Ports from the Internet

As with the last section, this section makes an assumption that you have a working Internet connection. If you do not, you will need to perform the CD-ROM installation, or put a copy of the distfile into `/usr/ports/distfiles` manually.

Installing a port from the Internet is done exactly the same way as it would be if you were installing from a CD-ROM. The only difference between the two is that the distfile is downloaded from the Internet instead of read from the CD-ROM.

The steps involved are identical:

```
# make install
>> lsof_4.57D.freebsd.tar.gz doesn't seem to exist in /usr/ports/distfiles/.
>> Attempting to fetch from ftp://ftp.FreeBSD.org/pub/FreeBSD/ports/distfiles/.
Receiving lsof_4.57D.freebsd.tar.gz (439860 bytes): 100%
439860 bytes transferred in 18.0 seconds (23.90 kBps)
===>  Extracting for lsof-4.57
...
```

```
[extraction output snipped]
...
>> Checksum OK for lsof_4.57D.freebsd.tar.gz.
===>  Patching for lsof-4.57
===>  Applying FreeBSD patches for lsof-4.57
===>  Configuring for lsof-4.57
...
[configure output snipped]
...
===>  Building for lsof-4.57
...
[compilation output snipped]
...
===>  Installing for lsof-4.57
...
[installation output snipped]
...
===>   Generating temporary packing list
===>   Compressing manual pages for lsof-4.57
===>   Registering installation for lsof-4.57
===>  SECURITY NOTE:
      This port has installed the following binaries which execute with
      increased privileges.
#
```

As you can see, the only difference is the line that tells you where the system is fetching the port distfile from.

The ports system uses fetch(1) to download the files, which honors various environment variables, including `FTP_PASSIVE_MODE`, `FTP_PROXY`, and `FTP_PASSWORD`. You may need to set one or more of these if you are behind a firewall, or need to use an FTP/HTTP proxy. See fetch(3) for the complete list.

For users which cannot be connected all the time, the `make fetch` option is provided. Just run this command at the top level directory (`/usr/ports`) and the required files will be downloaded for you. This command will also work in the lower level categories, for example: `/usr/ports/net`. Note that if a port depends on libraries or other ports this will *not* fetch the distfiles of those ports too. Replace `fetch` with `fetch-recursive` if you want to fetch all the dependencies of a port too.

> **Note:** You can build all the ports in a category or as a whole by running `make` in the top level directory, just like the aforementioned `make fetch` method. This is dangerous, however, as some ports cannot co-exist. In other cases, some ports can install two different files with the same filename.

In some rare cases, users may need to acquire the tarballs from a site other than the `MASTER_SITES` (the location where files are downloaded from). You can override the `MASTER_SITES` option with the following command:

```
# cd /usr/ports/directory
```

```
# make MASTER_SITE_OVERRIDE= \
ftp://ftp.FreeBSD.org/pub/FreeBSD/ports/distfiles/ fetch
```

In this example we change the `MASTER_SITES` option to `ftp.FreeBSD.org/pub/FreeBSD/ports/distfiles/`.

Note: Some ports allow (or even require) you to provide build options which can enable/disable parts of the application which are unneeded, certain security options, and other customizations. A few which come to mind are `www/mozilla`, `security/gpgme`, and `mail/sylpheed-claws`. A message will be displayed when options such as these are available.

4.5.2.3 Overriding the Default Ports Directories

Sometimes it is useful (or mandatory) to use a different distfiles and ports directory. The `PORTSDIR` and `PREFIX` variables can override the default directories. For example:

```
# make PORTSDIR=/usr/home/example/ports install
```

will compile the port in `/usr/home/example/ports` and install everything under `/usr/local`.

```
# make PREFIX=/usr/home/example/local install
```

will compile it in `/usr/ports` and install it in `/usr/home/example/local`.

And of course,

```
# make PORTSDIR=../ports PREFIX=../local install
```

will combine the two (it is too long to completely write on this page, but it should give you the general idea).

Alternatively, these variables can also be set as part of your environment. Read the manual page for your shell for instructions on doing so.

4.5.2.4 Dealing with `imake`

Some ports that use `imake` (a part of the X Windows System) do not work well with `PREFIX`, and will insist on installing under `/usr/X11R6`. Similarly, some Perl ports ignore `PREFIX` and install in the Perl tree. Making these ports respect `PREFIX` is a difficult or impossible job.

4.5.3 Removing Installed Ports

Now that you know how to install ports, you are probably wondering how to remove them, just in case you install one and later on decide that you installed the wrong port. We will remove our previous example (which was `lsof` for those of you not paying attention). As with installing ports, the first thing you must do is change to the port directory, `/usr/ports/sysutils/lsof`. After you change directories, you are ready to uninstall `lsof`. This is done with the `make deinstall` command:

```
# cd /usr/ports/sysutils/lsof
# make deinstall
===>  Deinstalling for lsof-4.57
```

That was easy enough. You have removed `lsof` from your system. If you would like to reinstall it, you can do so by running `make reinstall` from the `/usr/ports/sysutils/lsof` directory.

The `make deinstall` and `make reinstall` sequence does not work once you have run `make clean`. If you want to deinstall a port after cleaning, use pkg_delete(1) as discussed in the Packages section of the Handbook.

4.5.4 Ports and Disk Space

Using the ports collection can defiantly eat up your disk space. For this reason you should always remember to clean up the work directories using the `make clean` option. This will remove the `work` directory after a port has been built, and installed. You can also remove the tar files from the `distfiles` directory, and remove the installed ports when their use has delimited.

Some users choose to limit the port categories by placing an entry in the `refuse` file. This way when they run the **CVSup** application, it will not download the files in that category.

4.5.5 Upgrading Ports

Keeping your ports up to date can be a tedious job. For instance, to upgrade a port you would go to the ports directory, build the port, deinstall the old port, install the new port, and then clean up after the build. Imagine doing that for five ports, tedious right? This was a large problem for system administrators to deal with, and now we have utilities which do this for us. For instance the `sysutils/portupgrade` utility will do everything for you! Just install it like you would any other port, using the `make install clean` command.

Now create a database with the `pkgdb -F` command. This will read the list of installed ports and create a database file in the `/var/db/pkg` directory. Now when you run `portupgrade -a`, it will read this and the ports `INDEX` file. Finally, `portupgrade` will begin to download, build, backup, install, and clean the ports which have been updated. Other utilities exist which will do this, check out the `ports/sysutils` directory and see what you come up with.

4.6 Post-installation Activities

After installing a new application you will normally want to read any documentation it may have included, edit any configuration files that are required, ensure that the application starts at boot time (if it is a daemon), and so on.

The exact steps you need to take to configure each application will obviously be different. However, if you have just installed a new application and are wondering "What now?" these tips might help:

- Use pkg_info(1) to find out which files were installed, and where. For example, if you have just installed FooPackage version 1.0.0, then this command

  ```
  # pkg_info -L foopackage-1.0.0 | less
  ```

  will show all the files installed by the package. Pay special attention to files in `man/` directories, which will be manual pages, `etc/` directories, which will be configuration files, and `doc/`, which will be more comprehensive documentation.

  If you are not sure which version of the application was just installed, a command like this

  ```
  # pkg_info | grep -i foopackage
  ```

  will find all the installed packages that have *`foopackage`* in the package name. Replace *`foopackage`* in your command line as necessary.

- Once you have identified where the application's manual pages have been installed, review them using man(1). Similarly, look over the sample configuration files, and any additional documentation that may have been provided.
- If the application has a web site, check it for additional documentation, frequently asked questions, and so forth. If you are not sure of the web site address it may be listed in the output from

  ```
  # pkg_info foopackage-1.0.0
  ```

  A `WWW:` line, if present, should provide a URL for the application's web site.

- Ports that should start at boot (such as Internet servers) will usually install a sample script in `/usr/local/etc/rc.d`. You should review this script for correctness and edit or rename it if needed. See Starting Services for more information.

4.7 Dealing with Broken Ports

If you come across a port that does not work for you, there are a few things you can do, including:

1. Fix it! The Porter's Handbook (../porters-handbook/index.html) includes detailed information on the "Ports" infrastructure so that you can fix the occasional broken port or even submit your own!
2. Gripe—*by email only*! Send email to the maintainer of the port first. Type `make maintainer` or read the `Makefile` to find the maintainer's email address. Remember to include the name and version of the port (send the `$FreeBSD:` line from the `Makefile`) and the output leading up to the error when you email the maintainer. If you do not get a response from the maintainer, you can use send-pr(1) to submit a bug report.
3. Grab the package from an FTP site near you. The "master" package collection is on `ftp.FreeBSD.org` in the packages directory (ftp://ftp.FreeBSD.org/pub/FreeBSD/ports/packages/), but be sure to check your local mirror *first*! These are more likely to work than trying to compile from source and are a lot faster as well. Use the pkg_add(1) program to install the package on your system.

Chapter 5 The X Window System

5.1 Synopsis

FreeBSD uses **XFree86** to provide users with a powerful graphical user interface. **XFree86** is an open-source implementation of the X Window System. This chapter will cover installation and configuration of **XFree86** on a FreeBSD system. For more information on **XFree86** and video hardware that it supports, check the XFree86 (http://www.XFree86.org/) web site.

After reading this chapter, you will know:

- The various components of the X Window System, and how they interoperate.
- How to install and configure **XFree86**.
- How to install and use different window managers.
- How to use TrueType® fonts in **XFree86**.
- How to set up your system for graphical logins (**XDM**).

Before reading this chapter, you should:

- Know how to install additional third-party software (Chapter 4).

5.2 Understanding X

Using X for the first time can be somewhat of a shock to someone familiar with other graphical environments, such as Microsoft Windows or Mac OS.

It is not necessary to understand all of the details of various X components and how they interact; however, some basic knowledge makes it possible to take advantage of X's strengths.

5.2.1 Why X?

X is not the first window system written for UNIX, but it is the most popular. X's original development team had worked on another window system before writing X. That system's name was "W" (for "Window"). X is just the next letter in the Roman alphabet.

X can be called "X", "X Window System", "X11", and other terms. Calling X11 "X Windows" can offend some people; see X(7) for a bit more insight on this.

5.2.2 The X Client/Server Model

X was designed from the beginning to be network-centric, and adopts a "client-server" model. In the X model, the "X server" runs on the computer that has the keyboard, monitor, and mouse attached. The server is responsible for managing the display, handling input from the keyboard and mouse, and so on. Each X application (such as **XTerm**, or **Netscape**) is a "client". A client sends messages to the server such as "Please draw a window at these coordinates", and the server sends back messages such as "The user just clicked on the OK button".

If there is only one computer involved, such as in a home or small office environment, the X server and the X clients will be running on the same computer. However, it is perfectly possible to run the X server on a less powerful desktop computer, and run X applications (the clients) on, say, the powerful and expensive machine that serves the office. In this scenario the communication between the X client and server takes place over the network.

This confuses some people, because the X terminology is exactly backward to what they expect. They expect the "X server" to be the big powerful machine down the hall, and the "X client" to be the machine on their desk.

Remember that the X server is the machine with the monitor and keyboard, and the X clients are the programs that display the windows.

There is nothing in the protocol that forces the client and server machines to be running the same operating system, or even to be running on the same type of computer. It is certainly possible to run an X server on Microsoft Windows or Apple's Mac OS, and there are various free and commercial applications available that do exactly that.

The X server that ships with FreeBSD is called **XFree86**, and is available for free, under a license very similar to the FreeBSD license. Commercial X servers for FreeBSD are also available.

5.2.3 The Window Manager

The X design philosophy is much like the UNIX design philosophy, "tools, not policy". This means that X does not try to dictate how a task is to be accomplished. Instead, tools are provided to the user, and it is the user's responsibility to decide how to use those tools.

This philosophy extends to X not dictating what windows should look like on screen, how to move them around with the mouse, what keystrokes should be used to move between windows (i.e., **Alt**+**Tab**, in the case of Microsoft Windows), what the title bars on each window should look like, whether or not they have close buttons on them, and so on.

Instead, X delegates this responsibility to an application called a "Window Manager". There are dozens of window managers available for X: **AfterStep**, **Blackbox**, **ctwm**, **Enlightenment**, **fvwm**, **Sawfish**, **twm**, **Window Maker**, and more. Each of these window managers provides a different look and feel; some of them support "virtual desktops"; some of them allow customized keystrokes to manage the desktop; some have a "Start" button or similar device; some are "themeable", allowing a complete change of look-and-feel by applying a new theme. These window managers, and many more, are available in the `x11-wm` category of the Ports Collection.

In addition, the **KDE** and **GNOME** desktop environments both have their own window managers which integrate with the desktop.

Each window manager also has a different configuration mechanism; some expect configuration file written by hand, others feature GUI tools for most of the configuration tasks; at least one (**sawfish**) has a configuration file written in a dialect of the Lisp language.

> **Focus Policy:** Another feature the window manager is responsible for is the mouse "focus policy". Every windowing system needs some means of choosing a window to be actively receiving keystrokes, and should visibly indicate which window is active as well.
>
> A familiar focus policy is called "click-to-focus". This is the model utilized by Microsoft Windows, in which a window becomes active upon receiving a mouse click.
>
> X does not support any particular focus policy. Instead, the window manager controls which window has the focus at any one time. Different window managers will support different focus methods. All of them support click to focus, and the majority of them support several others.
>
> The most popular focus policies are:

focus-follows-mouse

The window that is under the mouse pointer is the window that has the focus. This may not necessarily be the window that is on top of all the other windows. The focus is changed by pointing at another window, there is no need to click in it as well.

sloppy-focus

This policy is a small extension to focus-follows-mouse. With focus-follows-mouse, if the mouse is moved over the root window (or background) then no window has the focus, and keystrokes are simply lost. With sloppy-focus, focus is only changed when the cursor enters a new window, and not when exiting the current window.

click-to-focus

The active window is selected by mouse click. The window may then be "raised", and appear in front of all other windows. All keystrokes will now be directed to this window, even if the cursor is moved to another window.

Many window managers support other policies, as well as variations on these. Be sure to consult the documentation for the window manager itself.

5.2.4 Widgets

The X approach of providing tools and not policy extends to the widgets that seen on screen in each application.

"Widget" is a term for all the items in the user interface that can be clicked or manipulated in some way; buttons, check boxes, radio buttons, icons, lists, and so on. Microsoft Windows calls these "controls".

Microsoft Windows and Apple's Mac OS both have a very rigid widget policy. Application developers are supposed to ensure that their applications share a common look and feel. With X, it was not considered sensible to mandate a particular graphical style, or set of widgets to adhere to.

As a result, do not expect X applications to have a common look and feel. There are several popular widget sets and variations, including the original Athena widget set from MIT, **Motif®** (on which the widget set in Microsoft Windows was modeled, all bevelled edges and three shades of grey), **OpenLook**, and others.

Most newer X applications today will use a modern-looking widget set, either Qt, used by **KDE**, or **GTK**, used by the **GNOME** project. In this respect, there is some convergence in look-and-feel of the UNIX desktop, which certainly makes things easier for the novice user.

5.3 Installing XFree86™

Before installing **XFree86**, decide on which version to run. **XFree86 3.X** is a maintenance branch of **XFree86** development. It is very stable, and it supports a huge number of graphics cards. However, no new development is being done on the software. **XFree86 4.X** is a complete redesign of the system with many new features such as better support for fonts and anti-aliasing. Unfortunately this new architecture requires that the video drivers be rewritten, and some of the older cards that were supported in 3.X are not yet supported in 4.X. As all new developments and support for new graphics cards are done on that branch, **XFree86 4.X** is now the default version of the X Window System on FreeBSD.

The FreeBSD setup program offers users the opportunity to install and configure **XFree86 4.X** during installation (covered in Section 2.9.12). To install and run **XFree86 3.X**, wait until after the base FreeBSD system is installed, and then install **XFree86**. For example, to build and install **XFree86 3.X** from the ports collection:

```
# cd /usr/ports/x11/XFree86
# make all install clean
```

Alternatively, either version of **XFree86** can be installed directly from the FreeBSD binaries provided on the XFree86 web site (http://www.XFree86.org/). A binary package to use with pkg_add(1) tool is also available for **XFree86 4.X**. When the remote fetching feature of pkg_add(1) is used, the version number of the package must be removed. pkg_add(1) will automatically fetch the latest version of the application. So to fetch and install the package of **XFree86 4.X**, simply type:

```
# pkg_add -r XFree86
```

You can also use the ports collection to install **XFree86 4.X**, for that you simply need to type the following commands:

```
# cd /usr/ports/x11/XFree86-4
# make install clean
```

> **Note:** The examples above will install the complete **XFree86** distribution including the servers, clients, fonts etc. Separate packages and ports for different parts of **XFree86 4.X** are also available.

The rest of this chapter will explain how to configure **XFree86**, and how to set up a productive desktop environment.

5.4 XFree86 Configuration

Contributed by Christopher Shumway.

5.4.1 Before Starting

Before configuration of **XFree86 4.X**, the following information about the target system is needed:

- Monitor specifications
- Video Adapter chipset
- Video Adapter memory

The specifications for the monitor are used by **XFree86** to determine the resolution and refresh rate to run at. These specifications can usually be obtained from the documentation that came with the monitor or from the manufacturer's website. There are two ranges of numbers that are needed, the horizontal scan rate and the vertical synchronization rate.

The video adapter's chipset defines what driver module **XFree86** uses to talk to the graphics hardware. With most chipsets, this can be automatically determined, but it is still useful to know in case the automatic detection does not work correctly.

Video memory on the graphic adapter determines the resolution and color depth which the system can run at. This is important to know so the user knows the limitations of the system.

5.4.2 Configuring XFree86 4.X

Configuration of **XFree86 4.X** is a multi-step process. The first step is to build an initial configuration file with the `-configure` option to **XFree86**. As the super user, simply run:

```
# XFree86 -configure
```

This will generate a skeleton **XFree86** configuration file in the `/root` directory called `XF86Config.new` (in fact the directory used is the one covered by the environment variable `$HOME`, and it will depend from the way you got the superuser rights). The **XFree86** program will attempt to probe the graphics hardware on the system and will write a configuration file to load the proper drivers for the detected hardware on the target system.

The next step is to test the existing configuration to verify that **XFree86** can work with the graphics hardware on the target system. To perform this task, the user needs to run:

```
# XFree86 -xf86config XF86Config.new
```

If a black and grey grid and an X mouse cursor appear, the configuration was successful. To exit the test, just press **Ctrl**+**Alt**+**Backspace** simultaneously.

> **Note:** If the mouse does not work, be sure the device has been configured. See Section 2.9.10 in the FreeBSD install chapter.

Next, tune the `XF86Config.new` configuration file to taste. Open the file in a text editor such as emacs(1) or ee(1). First, add the frequencies for the target system's monitor. These are usually expressed as a horizontal and vertical synchronization rate. These values are added to the `XF86Config.new` file under the `"Monitor"` section:

```
Section "Monitor"
        Identifier   "Monitor0"
        VendorName   "Monitor Vendor"
        ModelName    "Monitor Model"
        HorizSync    30-107
        VertRefresh  48-120
EndSection
```

The `HorizSync` and `VertRefresh` keywords may not exist in the configuration file. If they do not, they need to be added, with the correct horizontal synchronization rate placed after the `Horizsync` keyword and the vertical synchronization rate after the `VertRefresh` keyword. In the example above the target monitor's rates were entered.

X allows DPMS (Energy Star) features to be used with capable monitors. The xset(1) program controls the time-outs and can force standby, suspend, or off modes. If you wish to enable DPMS features for your monitor, you must add the following line to the monitor section:

```
        Option       "DPMS"
```

While the `XF86Config.new` configuration file is still open in an editor, select the default resolution and color depth desired. This is defined in the `"Screen"` section:

```
Section "Screen"
        Identifier "Screen0"
        Device     "Card0"
        Monitor    "Monitor0"
        DefaultDepth 24
        SubSection "Display"
                Depth     24
                Modes     "1024x768"
        EndSubSection
EndSection
```

The `DefaultDepth` keyword describes the color depth to run at by default. This can be overridden with the `-bpp` command line switch to XFree86(1). The `Modes` keyword describes the resolution to run at for the given color depth. Note that only VESA standard modes are supported as defined by the target system's graphics hardware. In the example above, the default color depth is twenty-four bits per pixel. At this color depth, the accepted resolution is one thousand twenty-four pixels by seven hundred and sixty-eight pixels.

Finally, write the configuration file and test it using the test mode given above. If all is well, the configuration file needs to be installed in a common location where XFree86(1) can find it. This is typically `/etc/X11/XF86Config` or `/usr/X11R6/etc/X11/XF86Config`.

```
# cp XF86Config.new /etc/X11/XF86Config
```

Once the configuration file has been placed in a common location, configuration is complete. In order to start **XFree86 4.X** with startx(1), install the `x11/wrapper` port. **XFree86 4.X** can also be started with xdm(1).

> **Note:** There is also a graphical tool for configuration, xf86cfg(1), that comes with the **XFree86 4.X** distribution. It allows to interactively define your configuration by choosing the appropiate drivers and settings. This program can be used under console as well, just use the command `xf86cfg -textmode`. For more details, refer to the xf86cfg(1) manual page.

5.4.3 Advanced Configuration Topics

5.4.3.1 Configuration with Intel® i810 Graphics Chipsets

Configuration with Intel i810 integrated chipsets requires the `agpgart` AGP programming interface for **XFree86** to drive the card. The agp(4) driver is in the `GENERIC` kernel since releases 4.8-RELEASE and 5.0-RELEASE. On prior releases, you will have to add the following line:

```
device agp
```

in your kernel configuration file and rebuild a new kernel. Instead, you may want to load the `agp.ko` kernel module automatically with the loader(8) at boot time. For that, simply add this line to `/boot/loader.conf`:

```
agp_load="YES"
```

Next, if you are running FreeBSD 4.X or earlier, a device node needs to be created for the programming interface. To create the AGP device node, run MAKEDEV(8) in the `/dev` directory:

```
# cd /dev
# sh MAKEDEV agpgart
```

> **Note:** FreeBSD 5.X or later will use devfs(5) to allocate device nodes transparently, therefore the MAKEDEV(8) step is not required.

This will allow configuration of the hardware as any other graphics board. Note on systems without the agp(4) driver compiled in the kernel, trying to load the module with kldload(8) will not work. This driver has to be in the kernel at boot time through being compiled in or using `/boot/loader.conf`.

If you are using **XFree86 4.1.0** (or later) and messages about unresolved symbols like `fbPictureInit` appear, try adding the following line after `Driver "i810"` in the **XFree86** configuration file:

```
Option "NoDDC"
```

5.5 Using Fonts in XFree86

Contributed by Murray Stokely.

5.5.1 Type1 Fonts

The default fonts that ship with **XFree86** are less than ideal for typical desktop publishing applications. Large presentation fonts show up jagged and unprofessional looking, and small fonts in **Netscape** are almost completely unintelligible. However, there are several free, high quality Type1 (PostScript®) fonts available which can be readily used with **XFree86**, either version 3.X or version 4.X. For instance, the URW font collection (`x11-fonts/urwfonts`) includes high quality versions of standard type1 fonts (Times Roman®, Helvetica®, Palatino® and others). The Freefonts collection (`x11-fonts/freefonts`) includes many more fonts, but most of them are intended for use in graphics software such as the **Gimp**, and are not complete enough to serve as screen fonts. In addition, **XFree86** can be configured to use TrueType fonts with a minimum of effort: see the section on TrueType fonts later.

To install the above Type1 font collections from the ports collection, run the following commands:

```
# cd /usr/ports/x11-fonts/urwfonts
# make install clean
```

And likewise with the freefont or other collections. To tell the X server that these fonts exist, add an appropriate line to the `XF86Config` file (in `/etc/` for **XFree86** version 3, or in `/etc/X11/` for version 4), which reads:

```
FontPath "/usr/X11R6/lib/X11/fonts/URW/"
```

Alternatively, at the command line in the X session run:

```
% xset fp+ /usr/X11R6/lib/X11/fonts/URW
% xset fp rehash
```

This will work but will be lost when the X session is closed, unless it is added to the startup file (`~/.xinitrc` for a normal `startx` session, or `~/.xsession` when logging in through a graphical login manager like **XDM**). A third way is to use the new `XftConfig` file: see the section on anti-aliasing.

5.5.2 TrueType® Fonts

XFree86 4.X has built in support for rendering TrueType fonts. There are two different modules that can enable this functionality. The freetype module is used in this example because it is more consistent with the other font rendering back-ends. To enable the freetype module just add the following line to the `"Module"` section of the `/etc/X11/XF86Config` file.

```
Load  "freetype"
```

For **XFree86 3.3.X**, a separate TrueType font server is needed. **Xfstt** is commonly used for this purpose. To install **Xfstt**, simply install the port `x11-servers/Xfstt`.

Now make a directory for the TrueType fonts (for example, `/usr/X11R6/lib/X11/fonts/TrueType`) and copy all of the TrueType fonts into this directory. Keep in mind that TrueType fonts cannot be directly taken from a Macintosh®; they must be in UNIX/DOS/Windows format for use by **XFree86**. Once the files have been copied into this directory, use **ttmkfdir** to create a `fonts.dir` file, so that the X font renderer knows that these new files have been installed. `ttmkfdir` is available from the FreeBSD Ports Collection as `x11-fonts/ttmkfdir`.

```
# cd /usr/X11R6/lib/X11/fonts/TrueType
# ttmkfdir > fonts.dir
```

Now add the TrueType directory to the font path. This is just the same as described above for Type1 fonts, that is, use

```
% xset fp+ /usr/X11R6/lib/X11/fonts/TrueType
% xset fp rehash
```

or add a `FontPath` line to the `XF86Config` file.

That's it. Now **Netscape**, **Gimp**, **StarOffice™**, and all of the other X applications should now recognize the installed TrueType fonts. Extremely small fonts (as with text in a high resolution display on a web page) and extremely large fonts (within **StarOffice**) will look much better now.

5.5.3 Anti-Aliased Fonts

Updated for XFree86 4.3 by Joe Marcus Clarke.

Anti-aliasing has been available in **XFree86** since 4.0.2. However, font configuration was cumbersome before the introduction of **XFree86** 4.3.0. Starting in version 4.3.0, all fonts in `/usr/X11R6/lib/X11/fonts/` and `~/.fonts/` are automatically made available for anti-aliasing to Xft-aware applications. Not all applications are Xft-aware yet, but many have received Xft support. Examples of Xft-aware applications include Qt 2.3 and higher (the toolkit for the **KDE** desktop), Gtk+ 2.0 and higher (the toolkit for the **GNOME** desktop), and **Mozilla** 1.2 and higher.

In order to control which fonts are anti-aliased, or to configure anti-aliasing properties, create (or edit, if it already exists) the file `/usr/X11R6/etc/fonts/local.conf`. Several advanced features of the Xft font system can be tuned using this file; this section describes only some simple possibilities. For more details, please see fonts-conf(5).

This file must be in XML format. Pay careful attention to case, and make sure all tags are properly closed. The file begins with the usual XML header followed by a DOCTYPE definition, and then the `<fontconfig>` tag:

```
<?xml version="1.0"?>
<!DOCTYPE fontconfig SYSTEM "fonts.dtd">
<fontconfig>
```

As previously stated, all fonts in `/usr/X11R6/lib/X11/fonts/` as well as `~/.fonts/` are already made available to Xft-aware applications. If you wish to add another directory outside of these two directory trees, add a line similar to the following to `/usr/X11R6/etc/fonts/local.conf`:

```
<dir>/path/to/my/fonts</dir>
```

After adding new fonts, and especially new font directories, you should run the following command to rebuild the font caches:

```
# fc-cache -f
```

Anti-aliasing makes borders slightly fuzzy, which makes very small text more readable and removes “staircases” from large text, but can cause eyestrain if applied to normal text. To exclude point sizes smaller than 14 point from anti-aliasing, include these lines:

```
<match target="font">
    <test name="size" compare="less">
        <double>14</double>
    </test>
    <edit name="antialias" mode="assign">
        <bool>false</bool>
    </edit>
</match>
```

Spacing for some monospaced fonts may also be inappropriate with anti-aliasing. This seems to be an issue with **KDE**, in particular. One possible fix for this is to force the spacing for such fonts to be 100. Add the following lines:

```
<match target="pattern" name="family">
    <test qual="any" name="family">
        <string>fixed</string>
    </test>
    <edit name="family" mode="assign">
        <string>mono</string>
    </edit>
 </match>
 <match target="pattern" name="family">
     <test qual="any" name="family">
         <string>console</string>
     </test>
     <edit name="family" mode="assign">
         <string>mono</string>
     </edit>
 </match>
```

(this aliases the other common names for fixed fonts as `"mono"`), and then add:

```
<match target="pattern" name="family">
    <test qual="any" name="family">
        <string>mono</string>
    </test>
    <edit name="spacing" mode="assign">
        <int>100</int>
    </edit>
</match>
```

Certain fonts, such as Helvetica, may have a problem when anti-aliased. Usually this manifests itself as a font that seems cut in half vertically. At worst, it may cause applications such as **Mozilla** to crash. To avoid this, consider adding the following to `local.conf`:

```
<match target="pattern" name="family">
    <test qual="any" name="family">
        <string>Helvetica</string>
    </test>
    <edit name="family" mode="assign">
        <string>sans-serif</string>
    </edit>
</match>
```

Once you have finished editing `local.conf` make sure you end the file with the `</fontconfig>` tag. Not doing this will cause your changes to be ignored.

The default font set that comes with **XFree86** is not very desirable when it comes to anti-aliasing. A much better set of default fonts can be found in the `x11-fonts/bitstream-vera` port. This port will install a `/usr/X11R6/etc/fonts/local.conf` file if one does not exist already. If the file does exist, the port will create a `/usr/X11R6/etc/fonts/local.conf-vera` file. Merge the contents of this file into `/usr/X11R6/etc/fonts/local.conf`, and the Bitstream fonts will automatically replace the default **XFree86** Serif, Sans Serif, and Monospaced fonts.

Finally, users can add their own settings via their personal `.fonts.conf` files. To do this, each user should simply create a `~/.fonts.conf`. This file must also be in XML format.

One last point: with an LCD screen, sub-pixel sampling may be desired. This basically treats the (horizontally separated) red, green and blue components separately to improve the horizontal resolution; the results can be dramatic. To enable this, add the line somewhere in the `local.conf` file:

```
<match target="font">
    <test qual="all" name="rgba">
        <const>unknown</const>
    </test>
    <edit name="rgba" mode="assign">
        <const>rgb</const>
    </edit>
</match>
```

> **Note:** Depending on the sort of display, `rgb` may need to be changed to `bgr`, `vrgb` or `vbgr`: experiment and see which works best.

Anti-aliasing should be enabled the next time the X server is started. However, programs must know how to take advantage of it. At present, the Qt toolkit does, so the entire **KDE** environment can use anti-aliased fonts (see Section 5.7.3.2 on **KDE** for details). Gtk+ and **GNOME** can also be made to use anti-aliasing via the "Font" capplet (see Section 5.7.1.3 for details). By default, **Mozilla** 1.2 and greater will automatically use anti-aliasing. To disable this, rebuild **Mozilla** with the `-DWITHOUT_XFT` flag.

5.6 The X Display Manager

Contributed by Seth Kingsley.

5.6.1 Overview

The X Display Manager (**XDM**) is an optional part of the X Window System that is used for login session management. This is useful for several types of situations, including minimal "X Terminals", desktops, and large network display servers. Since the X Window System is network and protocol independent, there are a wide variety of possible configurations for running X clients and servers on different machines connected by a network. **XDM** provides a graphical interface for choosing which display server to connect to, and entering authorization information such as a login and password combination.

Think of **XDM** as providing the same functionality to the user as the getty(8) utility (see Section 17.3.2 for details). That is, it performs system logins to the display being connected to and then runs a session manager on behalf of the user (usually an X window manager). **XDM** then waits for this program to exit, signaling that the user is done and should be logged out of the display. At this point, **XDM** can display the login and display chooser screens for the next user to login.

5.6.2 Using XDM

The **XDM** daemon program is located in `/usr/X11R6/bin/xdm`. This program can be run at any time as `root` and it will start managing the X display on the local machine. If **XDM** is to be run every time the machine boots up, a convenient way to do this is by adding an entry to `/etc/ttys`. For more information about the format and usage of this file, see Section 17.3.2.1. There is a line in the default `/etc/ttys` file for running the **XDM** daemon on a virtual terminal:

```
ttyv8   "/usr/X11R6/bin/xdm -nodaemon"  xterm   off secure
```

By default this entry is disabled; in order to enable it change field 5 from `off` to `on` and restart init(8) using the directions in Section 17.3.2.2. The first field, the name of the terminal this program will manage, is `ttyv8`. This means that **XDM** will start running on the 9th virtual terminal.

5.6.3 Configuring XDM

The **XDM** configuration directory is located in `/usr/X11R6/lib/X11/xdm`. In this directory there are several files used to change the behavior and appearance of **XDM**. Typically these files will be found:

File	Description

File	Description
`Xaccess`	Client authorization ruleset.
`Xresources`	Default X resource values.
`Xservers`	List of remote and local displays to manage.
`Xsession`	Default session script for logins.
`Xsetup_*`	Script to launch applications before the login interface.
`xdm-config`	Global configuration for all displays running on this machine.
`xdm-errors`	Errors generated by the server program.
`xdm-pid`	The process ID of the currently running XDM.

Also in this directory are a few scripts and programs used to set up the desktop when **XDM** is running. The purpose of each of these files will be briefly described. The exact syntax and usage of all of these files is described in xdm(1).

The default configuration is a simple rectangular login window with the hostname of the machine displayed at the top in a large font and "Login:" and "Password:" prompts below. This is a good starting point for changing the look and feel of **XDM** screens.

5.6.3.1 Xaccess

The protocol for connecting to **XDM** controlled displays is called the X Display Manager Connection Protocol (XDMCP). This file is a ruleset for controlling XDMCP connections from remote machines. By default, it allows any client to connect, but that does not matter unless the `xdm-config` is changed to listen for remote connections.

5.6.3.2 Xresources

This is an application-defaults file for the display chooser and the login screens. This is where the appearance of the login program can be modified. The format is identical to the app-defaults file described in the **XFree86** documentation.

5.6.3.3 Xservers

This is a list of the remote displays the chooser should provide as choices.

5.6.3.4 Xsession

This is the default session script for **XDM** to run after a user has logged in. Normally each user will have a customized session script in `~/.xsession` that overrides this script.

5.6.3.5 Xsetup_*

These will be run automatically before displaying the chooser or login interfaces. There is a script for each display being used, named `Xsetup_` followed by the local display number (for instance `Xsetup_0`). Typically these scripts will run one or two programs in the background such as `xconsole`.

5.6.3.6 xdm-config

This contains settings in the form of app-defaults that are applicable to every display that this installation manages.

5.6.3.7 xdm-errors

This contains the output of the X servers that **XDM** is trying to run. If a display that **XDM** is trying to start hangs for some reason, this is a good place to look for error messages. These messages are also written to the user's `~/.xsession-errors` file on a per-session basis.

5.6.4 Running a Network Display Server

In order for other clients to connect to the display server, edit the access control rules, and enable the connection listener. By default these are set to conservative values. To make **XDM** listen for connections, first comment out a line in the `xdm-config` file:

```
! SECURITY: do not listen for XDMCP or Chooser requests
! Comment out this line if you want to manage X terminals with xdm
DisplayManager.requestPort:     0
```

and then restart **XDM**. Remember that comments in app-defaults files begin with a "!" character, not the usual "#". More strict access controls may be desired. Look at the example entries in `Xaccess`, and refer to the xdm(1) manual page.

5.6.5 Replacements for XDM

Several replacements for the default **XDM** program exist. One of them, **KDM** (bundled with **KDE**) is described later in this chapter. **KDM** offers many visual improvements and cosmetic frills, as well as the functionality to allow users to choose their window manager of choice at login time.

5.7 Desktop Environments

Contributed by Valentino Vaschetto.

This section describes the different desktop environments available for X on FreeBSD. A "desktop environment" can mean anything ranging from a simple window manager to a complete suite of desktop applications, such as **KDE** or **GNOME**.

5.7.1 GNOME

5.7.1.1 About GNOME

GNOME is a user-friendly desktop environment that enables users to easily use and configure their computers. **GNOME** includes a panel (for starting applications and displaying status), a desktop (where data and applications can be placed), a set of standard desktop tools and applications, and a set of conventions that make it easy for applications to cooperate and be consistent with each other. Users of other operating systems or environments should feel right at home using the powerful graphics-driven environment that **GNOME** provides. More information regarding **GNOME** on FreeBSD can be found on the FreeBSD GNOME Project (http://www.FreeBSD.org/gnome)'s web site.

5.7.1.2 Installing GNOME

The easiest way to install **GNOME** is through the "Desktop Configuration" menu during the FreeBSD installation process as described in Section 2.9.13 of Chapter 2. It can also be easily installed from a package or the ports collection:

To install the **GNOME** package from the network, simply type:

```
# pkg_add -r gnome2
```

To build **GNOME** from source, use the ports tree:

```
# cd /usr/ports/x11/gnome2
# make install clean
```

Once **GNOME** is installed, the X server must be told to start **GNOME** instead of a default window manager. If a custom `.xinitrc` is already in place, simply replace the line that starts the current window manager with one that starts **/usr/X11R6/bin/gnome-session** instead. If nothing special has been done to configuration file, then it is enough to simply type:

```
% echo "/usr/X11R6/bin/gnome-session" > ~/.xinitrc
```

Next, type `startx`, and the **GNOME** desktop environment will be started.

> **Note:** If a display manager, like **XDM**, is being used, this will not work. Instead, create an executable `.xsession` file with the same command in it. To do this, edit the file and replace the existing window manager command with **/usr/X11R6/bin/gnome-session**:

```
% echo "#!/bin/sh" > ~/.xsession
% echo "/usr/X11R6/bin/gnome-session" >> ~/.xsession
% chmod +x ~/.xsession
```

Another option is to configure the display manager to allow choosing the window manager at login time; the section on KDE details explains how to do this for **kdm**, the display manager of **KDE**.

5.7.1.3 Anti-aliased Fonts with GNOME

Starting with version 4.0.2, **XFree86** supports anti-aliasing via its "RENDER" extension. Gtk+ 2.0 and greater (the toolkit used by **GNOME**) can make use of this functionality. Configuring anti-aliasing is described in Section 5.5.3. So, with up-to-date software, anti-aliasing is possible within the **GNOME** desktop. Just go to Applications⟶Desktop Preferences⟶Font, and select either Best shapes, Best contrast, or Subpixel smoothing (LCDs). For a Gtk+ application that is not part of the **GNOME** desktop, set the environment variable `GDK_USE_XFT` to `1` before launching the program.

5.7.2 KDE

5.7.2.1 About KDE

KDE is an easy to use contemporary desktop environment. Some of the things that **KDE** brings to the user are:

- A beautiful contemporary desktop
- A desktop exhibiting complete network transparency
- An integrated help system allowing for convenient, consistent access to help on the use of the **KDE** desktop and its applications
- Consistent look and feel of all **KDE** applications
- Standardized menu and toolbars, keybindings, color-schemes, etc.
- Internationalization: **KDE** is available in more than 40 languages
- Centralized consisted dialog driven desktop configuration
- A great number of useful **KDE** applications

KDE has an office application suite based on **KDE**'s "KParts" technology consisting of a spread-sheet, a presentation application, an organizer, a news client and more. **KDE** also comes with a web browser called **Konqueror**, which represents a solid competitor to other existing web browsers on UNIX systems. More information on **KDE** can be found on the KDE website (http://www.kde.org/). For FreeBSD specific informations and resources on **KDE**, consult the FreeBSD-KDE team (http://freebsd.kde.org/)'s website.

5.7.2.2 Installing KDE

Just as with **GNOME** or any other desktop environment, the easiest way to install **KDE** is through the "Desktop Configuration" menu during the FreeBSD installation process as described in Section 2.9.13 of Chapter 2. Once again, the software can be easily installed from a package or from the ports collection:

To install the **KDE** package from the network, simply type:

```
# pkg_add -r kde
```

pkg_add(1) will automatically fetch the latest version of the application.

To build **KDE** from source, use the ports tree:

```
# cd /usr/ports/x11/kde3
# make install clean
```

After **KDE** has been installed, the X server must be told to launch this application instead of the default window manager. This is accomplished by editing the `.xinitrc` file:

```
% echo "exec startkde" > ~/.xinitrc
```

Now, whenever the X Window System is invoked with `startx`, **KDE** will be the desktop.

If a display manager such as **xdm** is being used, the configuration is slightly different. Edit the `.xsession` file instead. Instructions for **kdm** are described later in this chapter.

5.7.3 More Details on KDE

Now that **KDE** is installed on the system, most things can be discovered through the help pages, or just by pointing and clicking at various menus. Windows or Mac® users will feel quite at home.

The best reference for **KDE** is the on-line documentation. **KDE** comes with its own web browser, **Konqueror**, dozens of useful applications, and extensive documentation. The remainder of this section discusses the technical items that are difficult to learn by random exploration.

5.7.3.1 The KDE Display Manager

An administrator of a multi-user system may wish to have a graphical login screen to welcome users. `xdm` can be used, as described earlier. However, **KDE** includes an alternative, **kdm**, which is designed to look more attractive and include more login-time options. In particular, users can easily choose (via a menu) which desktop environment (**KDE**, **GNOME**, or something else) to run after logging on.

To begin with, run the **KDE** control panel, `kcontrol`, as `root`. It is generally considered unsafe to run the entire X environment as `root`. Instead, run the window manager as a normal user, open a terminal window (such as `xterm` or **KDE**'s `konsole`), become `root` with **`su`** (the user must be in the `wheel` group in `/etc/group` for this), and then type **`kcontrol`**.

Click on the icon on the left marked System, then on Login manager. On the right there are various configurable options, which the **KDE** manual will explain in greater detail. Click on sessions on the right. Click New type to add various window managers and desktop environments. These are just labels, so they can say **KDE** and **GNOME** rather than **startkde** or **gnome-session**. Include a label `failsafe`.

Play with the other menus as well, they are mainly cosmetic and self-explanatory. When you are done, click on Apply at the bottom, and quit the control center.

To make sure **kdm** understands what the labels (**KDE**, **GNOME** etc) mean, edit the files used by xdm.

> **Note:** In **KDE 2.2** this has changed: **kdm** now uses its own configuration files. Please see the **KDE 2.2** documentation for details.

In a terminal window, as `root`, edit the file `/usr/X11R6/lib/X11/xdm/Xsession`. There is a section in the middle like this:

```
case $# in
1)
        case $1 in
        failsafe)
                exec xterm -geometry 80x24-0-0
                ;;
        esac
esac
```

A few lines need to be added to this section. Assuming the labels from used were "KDE" and "GNOME", use the following:

```
case $# in
1)
        case $1 in
        kde)
```

```
                exec /usr/local/bin/startkde
                ;;
        GNOME)
                exec /usr/X11R6/bin/gnome-session
                ;;
        failsafe)
                exec xterm -geometry 80x24-0-0
                ;;
        esac
esac
```

For the **KDE** login-time desktop background to be honored, the following line needs to be added to `/usr/X11R6/lib/X11/xdm/Xsetup_0`:

```
/usr/local/bin/kdmdesktop
```

Now, make sure **kdm** is listed in `/etc/ttys` to be started at the next bootup. To do this, simply follow the instructions from the previous section on xdm and replace references to the `/usr/X11R6/bin/xdm` program with `/usr/local/bin/kdm`.

5.7.3.2 Anti-aliased Fonts

Starting with version 4.0.2, **XFree86** supports anti-aliasing via its "RENDER" extension, and starting with version 2.3, Qt (the toolkit used by **KDE**) supports this extension. Configuring this is described in Section 5.5.3 on antialiasing X11 fonts. So, with up-to-date software, anti-aliasing is possible on a **KDE** desktop. Just go to the KDE menu, go to Preferences⟶Look and Feel⟶Fonts, and click on the check box Use Anti-Aliasing for Fonts and Icons. For a Qt application which is not part of **KDE**, the environment variable `QT_XFT` needs to be set to `true` before starting the program.

5.7.4 XFce

5.7.4.1 About XFce

XFce is a desktop environment based on the GTK toolkit used by **GNOME**, but is much more lightweight and meant for those who want a simple, efficient desktop which is nevertheless easy to use and configure. Visually, it looks very much like **CDE**, found on commercial UNIX systems. Some of **XFce**'s features are:

- A simple, easy-to-handle desktop
- Fully configurable via mouse, with drag and drop, etc
- Main panel similar to **CDE**, with menus, applets and applications launchers
- Integrated window manager, file manager, sound manager, **GNOME** compliance module, and other things
- Themeable (since it uses GTK)
- Fast, light and efficient: ideal for older/slower machines or machines with memory limitations

More information on **XFce** can be found on the XFce website (http://www.xfce.org/).

5.7.4.2 Installing XFce

A binary package for **XFce** exists (at the time of writing). To install, simply type:

```
# pkg_add -r xfce
```

Alternatively, to build from source, use the ports collection:

```
# cd /usr/ports/x11-wm/xfce
# make install clean
```

Now, tell the X server to launch **XFce** the next time X is started. Simply type this:

```
% echo "/usr/X11R6/bin/startxfce" > ~/.xinitrc
```

The next time X is started, **XFce** will be the desktop. As before, if a display manager like `xdm` is being used, create an `.xsession`, as described in the section on GNOME, but with the `/usr/X11R6/bin/startxfce` command; or, configure the display manager to allow choosing a desktop at login time, as explained in the section on kdm.

II. System Administration

The remaining chapters of the FreeBSD Handbook cover all aspects of FreeBSD system administration. Each chapter starts by describing what you will learn as a result of reading the chapter, and also details what you are expected to know before tackling the material.

These chapters are designed to be read when you need the information. You do not have to read them in any particular order, nor do you need to read all of them before you can begin using FreeBSD.

Chapter 6 Configuration and Tuning

Written by Chern Lee. Based on a tutorial written by Mike Smith. Also based on tuning(7) written by Matt Dillon.

6.1 Synopsis

One of the important aspects of FreeBSD is system configuration. Correct system configuration will help prevent headaches during future upgrades. This chapter will explain much of the FreeBSD configuration process, including some of the parameters which can be set to tune a FreeBSD system.

After reading this chapter, you will know:

- How to efficiently work with file systems and swap partitions.
- The basics of `rc.conf` configuration and `/usr/local/etc/rc.d` startup systems.
- How to configure and test a network card.
- How to configure virtual hosts on your network devices.
- How to use the various configuration files in `/etc`.
- How to tune FreeBSD using `sysctl` variables.
- How to tune disk performance and modify kernel limitations.

Before reading this chapter, you should:

- Understand UNIX and FreeBSD basics (Chapter 3).
- Be familiar with keeping FreeBSD sources up to date (Chapter 21), and the basics of kernel configuration/compilation (Chapter 9).

6.2 Initial Configuration

6.2.1 Partition Layout

6.2.1.1 Base Partitions

When laying out file systems with disklabel(8) or sysinstall(8), remember that hard drives transfer data faster from the outer tracks to the inner. Thus smaller and heavier-accessed file systems should be closer to the outside of the drive While larger partitions like `/usr` should be placed toward the inner. It is a good idea to create partitions in a similar order to: root, swap, `/var`, `/usr`.

The size of `/var` reflects the intended machine usage. `/var` is used to hold mailboxes, log files, and printer spools. Mailboxes and log files can grow to unexpected sizes depending on how many users exist and how long log files are kept. Most users would never require a gigabyte, but remember that `/var/tmp` must be large enough to contain packages.

The `/usr` partition holds much of the files required to support the system, the ports(7) collection (recommended) and the source code (optional). Both of which are optional at install time. At least 2 gigabytes would be recommended for this partition.

When selecting partition sizes, keep the space requirements in mind. Running out of space in one partition while barely using another can be a hassle.

> **Note:** Some users have found that sysinstall(8)'s `Auto-defaults` partition sizer will sometimes select smaller than adequate `/var` and `/` partitions. Partition wisely and generously.

6.2.1.2 Swap Partition

As a rule of thumb, the swap partition should be about double the size of system memory (RAM). For example, if the machine has 128 megabytes of memory, the swap file should be 256 megabytes. Systems with less memory may perform better with more swap. Less than 256 megabytes of swap is not recommended and memory expansion should be considered. The kernel's VM paging algorithms are tuned to perform best when the swap partition is at least two times the size of main memory. Configuring too little swap can lead to inefficiencies in the VM page scanning code and might create issues later if more memory is added.

On larger systems with multiple SCSI disks (or multiple IDE disks operating on different controllers), it is recommend that a swap is configured on each drive (up to four drives). The swap partitions should be approximately the same size. The kernel can handle arbitrary sizes but internal data structures scale to 4 times the largest swap partition. Keeping the swap partitions near the same size will allow the kernel to optimally stripe swap space across disks. Large swap sizes are fine, even if swap is not used much. It might be easier to recover from a runaway program before being forced to reboot.

6.2.1.3 Why Partition?

Several users think a single large partition will be fine, but there are several reasons why this is a bad idea. First, each partition has different operational characteristics and separating them allows the file system to tune accordingly. For example, the root and `/usr` partitions are read-mostly, without much writing. While a lot of reading and writing could occur in `/var` and `/var/tmp`.

By properly partitioning a system, fragmentation introduced in the smaller write heavy partitions will not bleed over into the mostly-read partitions. Keeping the write-loaded partitions closer to the disk's edge, will increase I/O performance in the partitions where it occurs the most. Now while I/O performance in the larger partitions may be needed, shifting them more toward the edge of the disk will not lead to a significant performance improvement over moving `/var` to the edge. Finally, there are safety concerns. A smaller, neater root partition which is mostly read-only has a greater chance of surviving a bad crash.

6.3 Core Configuration

The principal location for system configuration information is within `/etc/rc.conf`. This file contains a wide range of configuration information, principally used at system startup to configure the system. Its name directly implies this; it is configuration information for the `rc*` files.

An administrator should make entries in the `rc.conf` file to override the default settings from `/etc/defaults/rc.conf`. The defaults file should not be copied verbatim to `/etc` - it contains default values, not examples. All system-specific changes should be made in the `rc.conf` file itself.

A number of strategies may be applied in clustered applications to separate site-wide configuration from system-specific configuration in order to keep administration overhead down. The recommended approach is to place site-wide configuration into another file, such as `/etc/rc.conf.site`, and then include this file into `/etc/rc.conf`, which will contain only system-specific information.

As `rc.conf` is read by sh(1) it is trivial to achieve this. For example:

- rc.conf:

  ```
  . rc.conf.site
  hostname="node15.example.com"
  network_interfaces="fxp0 lo0"
  ifconfig_fxp0="inet 10.1.1.1"
  ```

- rc.conf.site:

  ```
  defaultrouter="10.1.1.254"
  saver="daemon"
  blanktime="100"
  ```

The `rc.conf.site` file can then be distributed to every system using `rsync` or a similar program, while the `rc.conf` file remains unique.

Upgrading the system using sysinstall(8) or `make world` will not overwrite the `rc.conf` file, so system configuration information will not be lost.

6.4 Application Configuration

Typically, installed applications have their own configuration files, with their own syntax, etc. It is important that these files be kept separate from the base system, so that they may be easily located and managed by the package management tools.

Typically, these files are installed in `/usr/local/etc`. In the case where an application has a large number of configuration files, a subdirectory will be created to hold them.

Normally, when a port or package is installed, sample configuration files are also installed. These are usually identified with a `.default` suffix. If there are no existing configuration files for the application, they will be created by copying the `.default` files.

For example, consider the contents of the directory `/usr/local/etc/apache`:

```
-rw-r--r--  1 root  wheel   2184 May 20  1998 access.conf
-rw-r--r--  1 root  wheel   2184 May 20  1998 access.conf.default
-rw-r--r--  1 root  wheel   9555 May 20  1998 httpd.conf
-rw-r--r--  1 root  wheel   9555 May 20  1998 httpd.conf.default
-rw-r--r--  1 root  wheel  12205 May 20  1998 magic
-rw-r--r--  1 root  wheel  12205 May 20  1998 magic.default
-rw-r--r--  1 root  wheel   2700 May 20  1998 mime.types
```

```
-rw-r--r--  1 root  wheel   2700 May 20  1998 mime.types.default
-rw-r--r--  1 root  wheel   7980 May 20  1998 srm.conf
-rw-r--r--  1 root  wheel   7933 May 20  1998 srm.conf.default
```

The file sizes show that only the `srm.conf` file has been changed. A later update of the **Apache** port would not overwrite this changed file.

6.5 Starting Services

It is common for a system to host a number of services. These may be started in several different fashions, each having different advantages.

Software installed from a port or the packages collection will often place a script in `/usr/local/etc/rc.d` which is invoked at system startup with a `start` argument, and at system shutdown with a `stop` argument. This is the recommended way for starting system-wide services that are to be run as `root`, or that expect to be started as `root`. These scripts are registered as part of the installation of the package, and will be removed when the package is removed.

A generic startup script in `/usr/local/etc/rc.d` looks like:

```
#!/bin/sh
echo -n ' FooBar'

case "$1" in
start)
        /usr/local/bin/foobar
        ;;
stop)
        kill -9 `cat /var/run/foobar.pid`
        ;;
*)
        echo "Usage: `basename $0` {start|stop}" >&2
        exit 64
        ;;
esac

exit 0
```

The startup scripts of FreeBSD will look in `/usr/local/etc/rc.d` for scripts that have an `.sh` extension and are executable by `root`. Those scripts that are found are called with an option `start` at startup, and `stop` at shutdown to allow them to carry out their purpose. So if you wanted the above sample script to be picked up and run at the proper time during system startup, you should save it to a file called `FooBar.sh` in `/usr/local/etc/rc.d` and make sure it is executable. You can make a shell script executable with chmod(1) as shown below:

```
# chmod 755 FooBar.sh
```

Some services expect to be invoked by inetd(8) when a connection is received on a suitable port. This is common for mail reader servers (POP and IMAP, etc.). These services are enabled by editing the file `/etc/inetd.conf`. See inetd(8) for details on editing this file.

Some additional system services may not be covered by the toggles in `/etc/rc.conf`. These are traditionally enabled by placing the command(s) to invoke them in `/etc/rc.local`. As of FreeBSD 3.1 there is no default `/etc/rc.local`; if it is created by the administrator it will however be honored in the normal fashion. Note that `rc.local` is generally regarded as the location of last resort; if there is a better place to start a service, do it there.

> **Note:** Do *not* place any commands in `/etc/rc.conf`. To start daemons, or run any commands at boot time, place a script in `/usr/local/etc/rc.d` instead.

It is also possible to use the cron(8) daemon to start system services. This approach has a number of advantages, not least being that because cron(8) runs these processes as the owner of the `crontab`, services may be started and maintained by non-`root` users.

This takes advantage of a feature of cron(8): the time specification may be replaced by `@reboot`, which will cause the job to be run when cron(8) is started shortly after system boot.

6.6 Configuring the `cron` Utility

Contributed by Tom Rhodes.

One of the most useful utilities in FreeBSD is cron(8). The `cron` utility runs in the background and constantly checks the `/etc/crontab` file. The `cron` utility also checks the `/var/cron/tabs` directory, in search of new `crontab` files. These `crontab` files store information about specific functions which `cron` is supposed to perform at certain times.

Let us take a look at the `/etc/crontab` file:

```
# /etc/crontab - root's crontab for FreeBSD
#
# $FreeBSD: src/etc/crontab,v 1.32 2002/11/22 16:13:39 tom Exp $
# ❶
#
SHELL=/bin/sh
PATH=/etc:/bin:/sbin:/usr/bin:/usr/sbin ❷
HOME=/var/log
#
#
#minute hour mday month wday who command ❸
#
#
*/5 * * * * root /usr/libexec/atrun ❹
```

❶ Like most FreeBSD configuration files, the # character represents a comment. A comment can be placed in the file as a reminder of what and why a desired action is performed. Comments cannot be on the same line as a command or else they will be interpreted as part of the command; they must be on a new line. Blank lines are ignored.

❷ First, the environment must be defined. The equals (=) character is used to define any environment settings, as with this example where it is used for the `SHELL`, `PATH`, and `HOME` options. If the shell line is omitted, `cron` will use the default, which is sh. If the PATH variable is omitted, no default will be used and file locations will need to be absolute. If HOME is omitted, cron will use the invoking users home directory.

❸ This line defines a total of seven fields. Listed here are the values minute, hour, mday, month, wday, who, and command. These are almost all self explanatory. Minute is the time in minutes the command will be run. Hour is similar to the minute option, just in hours. Mday stands for day of the month. Month is similar to hour and minute, as it designates the month. The wday options stands for day of the week. All these fields must be numeric values, and follow the twenty-four hour clock. The "who" field is special, and only exists in the /etc/crontab file. This field specifies which user the command should be run as. When a user installs his or her crontab file, they will not have this option. Finally, the command option is listed. This is the last field, so naturally it should designate the command to be executed.

❹ This last line will define the values discussed above. Notice here we have a */5 listing, followed by several more * characters. These * characters mean "first-last", and can be interpreted as *every* time. So, judging by this line, it is apparent that the atrun command is to be invoked by root every five minutes regardless of what day or month it is. For more information on the atrun, see the atrun(8) manual page.

Commands can have any number of flags passed to them; however, commands which extend to multiple lines need to be broken with the backslash "\" continuation character.

This is the basic set up for every crontab file, although there is one thing different about this one. Field number six, where we specified the username, only exists in the system /etc/crontab file. This field should be omitted for individual user crontab files.

6.6.1 Installing a Crontab

To install your freshly written crontab, just use the crontab utility. The most common usage is:

```
# crontab crontab
```

There is also an option to list installed crontab files, just pass the -l to crontab and look over the output.

Users who wish to begin their own crontab file from scratch, without the use of a template, the crontab -e option is available. This will invoke the selected editor with an empty file. When the file is saved, it will be automatically installed by the crontab command.

6.7 Using rc under FreeBSD 5.X

Contributed by Tom Rhodes.

FreeBSD has recently integrated the NetBSD rc.d system for system initialization. Users should notice the files listed in the /etc/rc.d directory. Many of these files are for basic services which can be controlled with the start, stop, and restart options. For instance, sshd(8) can be restarted with the following command:

```
# /etc/rc.d/sshd restart
```

This procedure is similar for other services. Of course, services are usually started automatically as specified in rc.conf(5). For example, enabling the Network Address Translation daemon at startup is as simple as adding the following line to /etc/rc.conf:

```
natd_enable="YES"
```

If a `natd_enable="NO"` line is already present, then simply change the `NO` to `YES`. The rc scripts will automatically load any other dependent services during the next reboot, as described below.

Since the `rc.d` system is primarily intended to start/stop services at system startup/shutdown time; the standard `start`, `stop` and `restart` options will only perform their action if the appropriate `/etc/rc.conf` variables are set. For instance the above `sshd restart` command will only work if `sshd_enable` is set to `YES` in `/etc/rc.conf`. To `start`, `stop` or `restart` a service regardless of the settings in `/etc/rc.conf`, the commands should be prefixed with "force". For instance to restart `sshd` regardless of the current `/etc/rc.conf` setting, execute the following command:

```
# /etc/rc.d/sshd forcerestart
```

It is easy to check if a service is enabled in `/etc/rc.conf` by running the appropriate `rc.d` script with the option `rcvar`. Thus, an administrator can check that `sshd` is in fact enabled in `/etc/rc.conf` by running:

```
# /etc/rc.d/sshd rcvar
# sshd
$sshd_enable=YES
```

> **Note:** The second line (`# sshd`) is the output from the `sshd` command; not a `root` console.

To determine if a service is running, a `status` option is available. For instance to verify that `sshd` is actually started:

```
# /etc/rc.d/sshd status
sshd is running as pid 433.
```

It is also possible to `reload` a service. This will attempt to send a signal to an individual service, forcing the service to reload its configuration files. In most cases this means sending the service a `SIGHUP` signal.

The **rcNG** structure is not only used for network services, it also contributes to most of the system initialization. For instance, consider the `bgfsck` file. When this script is executed, it will print out the following message:

```
Starting background file system checks in 60 seconds.
```

Therefore this file is used for background file system checks, which are done only during system initialization.

Many system services depend on other services to function properly. For example, NIS and other RPC-based services may fail to start until after the `rpcbind` (portmapper) service has started. To resolve this issue, information about dependencies and other meta-data is included in the comments at the top of each startup script. The rcorder(8) program is then used to parse these comments during system initialization to determine the order in which system services should be invoked to satisfy the dependencies. The following words may be included at the top of each startup file:

- PROVIDE: Specifies the services this file provides.
- REQUIRE: Lists services which are required for this service. This file will run *after* the specified services.
- BEFORE: Lists services which depend on this service. This file will run *before* the specified services.
- KEYWORD: FreeBSD or NetBSD. This is used for *BSD dependent features.

By using this method, an administrator can easily control system services without the hassle of "runlevels" like some other UNIX operating systems.

Additional information about the FreeBSD 5.X `rc.d` system can be found in the rc(8) and rc.subr(8) manual pages.

6.8 Setting Up Network Interface Cards

Contributed by Marc Fonvieille.

Nowadays we can not think about a computer without thinking about a network connection. Adding and configuring a network card is a common task for any FreeBSD administrator.

6.8.1 Locating the Correct Driver

Before you begin, you should know the model of the card you have, the chip it uses, and whether it is a PCI or ISA card. FreeBSD supports a wide variety of both PCI and ISA cards. Check the Hardware Compatibility List for your release to see if your card is supported.

Once you are sure your card is supported, you need to determine the proper driver for the card. The file `/usr/src/sys/i386/conf/LINT` will give you the list of network interfaces drivers with some information about the supported chipsets/cards. If you have doubts about which driver is the correct one, read the manual page of the driver. The manual page will give you more information about the supported hardware and even the possible problems that could occur.

If you own a common card, most of the time you will not have to look very hard for a driver. Drivers for common network cards are present in the `GENERIC` kernel, so your card should show up during boot, like so:

```
dc0: <82c169 PNIC 10/100BaseTX> port 0xa000-0xa0ff mem 0xd3800000-0xd38
000ff irq 15 at device 11.0 on pci0
dc0: Ethernet address: 00:a0:cc:da:da:da
miibus0: <MII bus> on dc0
ukphy0: <Generic IEEE 802.3u media interface> on miibus0
ukphy0:  10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, auto
dc1: <82c169 PNIC 10/100BaseTX> port 0x9800-0x98ff mem 0xd3000000-0xd30
000ff irq 11 at device 12.0 on pci0
dc1: Ethernet address: 00:a0:cc:da:da:db
miibus1: <MII bus> on dc1
ukphy1: <Generic IEEE 802.3u media interface> on miibus1
ukphy1:  10baseT, 10baseT-FDX, 100baseTX, 100baseTX-FDX, auto
```

In this example, we see that two cards using the dc(4) driver are present on the system.

To use your network card, you will need to load the proper driver. This may be accomplished in one of two ways. The easiest way is to simply load a kernel module for your network card with kldload(8). A module is not available for all network card drivers (ISA cards and cards using the ed(4) driver, for example). Alternatively, you may statically compile the support for your card into your kernel. Check `/usr/src/sys/i386/conf/LINT` and the manual page of the driver to know what to add in your kernel configuration file. For more information about recompiling your kernel, please see Chapter 9. If your card was detected at boot by your kernel (`GENERIC`) you do not have to build a new kernel.

6.8.2 Configuring the Network Card

Once the right driver is loaded for the network card, the card needs to be configured. As with many other things, the network card may have been configured at installation time by **sysinstall**.

To display the configuration for the network interfaces on your system, enter the following command:

```
% ifconfig
dc0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet 192.168.1.3 netmask 0xffffff00 broadcast 192.168.1.255
        ether 00:a0:cc:da:da:da
        media: Ethernet autoselect (100baseTX <full-duplex>)
        status: active
dc1: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet 10.0.0.1 netmask 0xffffff00 broadcast 10.0.0.255
        ether 00:a0:cc:da:da:db
        media: Ethernet 10baseT/UTP
        status: no carrier
lp0: flags=8810<POINTOPOINT,SIMPLEX,MULTICAST> mtu 1500
lo0: flags=8049<UP,LOOPBACK,RUNNING,MULTICAST> mtu 16384
        inet 127.0.0.1 netmask 0xff000000
tun0: flags=8010<POINTOPOINT,MULTICAST> mtu 1500
```

> **Note:** Old versions of FreeBSD may require the `-a` option following ifconfig(8), for more details about the correct syntax of ifconfig(8), please refer to the manual page. Note also that entries concerning IPv6 (`inet6` etc.) were omitted in this example.

In this example, the following devices were displayed:

- `dc0`: The first Ethernet interface
- `dc1`: The second Ethernet interface
- `lp0`: The parallel port interface
- `lo0`: The loopback device
- `tun0`: The tunnel device used by **ppp**

FreeBSD uses the driver name followed by the order in which one the card is detected at the kernel boot to name the network card. For example `sis2` would be the third network card on the system using the sis(4) driver.

In this example, the `dc0` device is up and running. The key indicators are:

1. `UP` means that the card is configured and ready.
2. The card has an Internet (`inet`) address (in this case `192.168.1.3`).
3. It has a valid subnet mask (`netmask`; `0xffffff00` is the same as `255.255.255.0`).
4. It has a valid broadcast address (in this case, `192.168.1.255`).
5. The MAC address of the card (`ether`) is `00:a0:cc:da:da:da`

6. The physical media selection is on autoselection mode (`media: Ethernet autoselect (100baseTX <full-duplex>)`). We see that `dc1` was configured to run with `10baseT/UTP` media. For more information on available media types for a driver, please refer to its manual page.
7. The status of the link (`status`) is `active`, i.e. the carrier is detected. For `dc1`, we see `status: no carrier`. This is normal when an ethernet cable is not plugged into the card.

If the ifconfig(8) output had shown something similar to:

```
dc0: flags=8843<BROADCAST,SIMPLEX,MULTICAST> mtu 1500
        ether 00:a0:cc:da:da:da
```

it would indicate the card has not been configured.

To configure your card, you need `root` privileges. The network card configuration can be done from the command line with ifconfig(8) but you would have to do it after each reboot of the system. The file `/etc/rc.conf` is where to add the network card's configuration.

Open `/etc/rc.conf` in your favorite editor. You need to add a line for each network card present on the system, for example in our case, we added these lines:

```
ifconfig_dc0="inet 192.168.1.3 netmask 255.255.255.0"
ifconfig_dc1="inet 10.0.0.1 netmask 255.255.255.0 media 10baseT/UTP"
```

You have to replace `dc0`, `dc1`, and so on, with the correct device for your cards, and the addresses with the proper ones. You should read the card driver and ifconfig(8) manual pages for more details about the allowed options and also rc.conf(5) manual page for more information on the syntax of `/etc/rc.conf`.

If you configured the network during installation, some lines about the network card(s) may be already present. Double check `/etc/rc.conf` before adding any lines.

You will also have to edit the file `/etc/hosts` to add the names and the IP addresses of various machines of the LAN, if they are not already there. For more information please refer to hosts(5) and to `/usr/share/examples/etc/hosts`.

6.8.3 Testing and Troubleshooting

Once you have made the necessary changes in `/etc/rc.conf`, you should reboot your system. This will allow the change(s) to the interface(s) to be applied, and verify that the system restarts without any configuration errors.

Once the system has been rebooted, you should test the network interfaces.

6.8.3.1 Testing the Ethernet Card

To verify that an Ethernet card is configured correctly, you have to try two things. First, ping the interface itself, and then ping another machine on the LAN.

First test the local interface:

```
% ping -c5 192.168.1.3
PING 192.168.1.3 (192.168.1.3): 56 data bytes
64 bytes from 192.168.1.3: icmp_seq=0 ttl=64 time=0.082 ms
64 bytes from 192.168.1.3: icmp_seq=1 ttl=64 time=0.074 ms
64 bytes from 192.168.1.3: icmp_seq=2 ttl=64 time=0.076 ms
```

```
64 bytes from 192.168.1.3: icmp_seq=3 ttl=64 time=0.108 ms
64 bytes from 192.168.1.3: icmp_seq=4 ttl=64 time=0.076 ms

--- 192.168.1.3 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.074/0.083/0.108/0.013 ms
```

Now we have to ping another machine on the LAN:

```
% ping -c5 192.168.1.2
PING 192.168.1.2 (192.168.1.2): 56 data bytes
64 bytes from 192.168.1.2: icmp_seq=0 ttl=64 time=0.726 ms
64 bytes from 192.168.1.2: icmp_seq=1 ttl=64 time=0.766 ms
64 bytes from 192.168.1.2: icmp_seq=2 ttl=64 time=0.700 ms
64 bytes from 192.168.1.2: icmp_seq=3 ttl=64 time=0.747 ms
64 bytes from 192.168.1.2: icmp_seq=4 ttl=64 time=0.704 ms

--- 192.168.1.2 ping statistics ---
5 packets transmitted, 5 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.700/0.729/0.766/0.025 ms
```

You could also use the machine name instead of `192.168.1.2` if you have set up the `/etc/hosts` file.

6.8.3.2 Troubleshooting

Troubleshooting hardware and software configurations is always a pain, and a pain which can be alleviated by checking the simple things first. Is your network cable plugged in? Have you properly configured the network services? Did you configure the firewall correctly? Is the card you are using supported by FreeBSD? Always check the hardware notes before sending off a bug report. Update your version of FreeBSD to the latest STABLE version. Check the mailing list archives, or perhaps search the Internet.

If the card works, yet performance is poor, it would be worthwhile to read over the tuning(7) manual page. You can also check the network configuration as incorrect network settings can cause slow connections.

Some users experience one or two "device timeouts", which is normal for some cards. If they continue, or are bothersome, you may wish to be sure the device is not conflicting with another device. Double check the cable connections. Perhaps you may just need to get another card.

At times, users see a few `watchdog timeout` errors. The first thing to do here is to check your network cable. Many cards require a PCI slot which supports Bus Mastering. On some old motherboards, only one PCI slot allows it (usually slot 0). Check the network card and the motherboard documentation to determine if that may be the problem.

`No route to host` messages occur if the system is unable to route a packet to the destination host. This can happen if no default route is specified, or if a cable is unplugged. Check the output of `netstat -rn` and make sure there is a valid route to the host you are trying to reach. If there is not, read on to Chapter 19.

`ping: sendto: Permission denied` error messages are often caused by a misconfigured firewall. If `ipfw` is enabled in the kernel but no rules have been defined, then the default policy is to deny all traffic, even ping requests! Read on to Section 10.8 for more information.

Sometimes performance of the card is poor, or below average. In these cases it is best to set the media selection mode from `autoselect` to the correct media selection. While this usually works for most hardware, it may not resolve this issue for everyone. Again, check all the network settings, and read over the tuning(7) manual page.

6.9 Virtual Hosts

A very common use of FreeBSD is virtual site hosting, where one server appears to the network as many servers. This is achieved by assigning multiple network addresses to a single interface.

A given network interface has one "real" address, and may have any number of "alias" addresses. These aliases are normally added by placing alias entries in `/etc/rc.conf`.

An alias entry for the interface `fxp0` looks like:

```
ifconfig_fxp0_alias0="inet xxx.xxx.xxx.xxx netmask xxx.xxx.xxx.xxx"
```

Note that alias entries must start with alias0 and proceed upwards in order, (for example, _alias1, _alias2, and so on). The configuration process will stop at the first missing number.

The calculation of alias netmasks is important, but fortunately quite simple. For a given interface, there must be one address which correctly represents the network's netmask. Any other addresses which fall within this network must have a netmask of all `1`s.

For example, consider the case where the `fxp0` interface is connected to two networks, the `10.1.1.0` network with a netmask of `255.255.255.0` and the `202.0.75.16` network with a netmask of `255.255.255.240`. We want the system to appear at `10.1.1.1` through `10.1.1.5` and at `202.0.75.17` through `202.0.75.20`.

The following entries configure the adapter correctly for this arrangement:

```
ifconfig_fxp0="inet 10.1.1.1 netmask 255.255.255.0"
ifconfig_fxp0_alias0="inet 10.1.1.2 netmask 255.255.255.255"
ifconfig_fxp0_alias1="inet 10.1.1.3 netmask 255.255.255.255"
ifconfig_fxp0_alias2="inet 10.1.1.4 netmask 255.255.255.255"
ifconfig_fxp0_alias3="inet 10.1.1.5 netmask 255.255.255.255"
ifconfig_fxp0_alias4="inet 202.0.75.17 netmask 255.255.255.240"
ifconfig_fxp0_alias5="inet 202.0.75.18 netmask 255.255.255.255"
ifconfig_fxp0_alias6="inet 202.0.75.19 netmask 255.255.255.255"
ifconfig_fxp0_alias7="inet 202.0.75.20 netmask 255.255.255.255"
```

6.10 Configuration Files

6.10.1 `/etc` Layout

There are a number of directories in which configuration information is kept. These include:

`/etc`	Generic system configuration information; data here is system-specific.
`/etc/defaults`	Default versions of system configuration files.
`/etc/mail`	Extra sendmail(8) configuration, other MTA configuration files.
`/etc/ppp`	Configuration for both user- and kernel-ppp programs.
`/etc/namedb`	Default location for named(8) data. Normally `named.conf` and zone files are stored here.

`/usr/local/etc`	Configuration files for installed applications. May contain per-application subdirectories.
`/usr/local/etc/rc.d`	Start/stop scripts for installed applications.
`/var/db`	Automatically generated system-specific database files, such as the package database, the locate database, and so on

6.10.2 Hostnames

6.10.2.1 `/etc/resolv.conf`

`/etc/resolv.conf` dictates how FreeBSD's resolver accesses the Internet Domain Name System (DNS).

The most common entries to `resolv.conf` are:

`nameserver`	The IP address of a name server the resolver should query. The servers are queried in the order listed with a maximum of three.
`search`	Search list for hostname lookup. This is normally determined by the domain of the local hostname.
`domain`	The local domain name.

A typical `resolv.conf`:

```
search example.com
nameserver 147.11.1.11
nameserver 147.11.100.30
```

> **Note:** Only one of the `search` and `domain` options should be used.

If you are using DHCP, dhclient(8) usually rewrites `resolv.conf` with information received from the DHCP server.

6.10.2.2 `/etc/hosts`

`/etc/hosts` is a simple text database reminiscent of the old Internet. It works in conjunction with DNS and NIS providing name to IP address mappings. Local computers connected via a LAN can be placed in here for simplistic naming purposes instead of setting up a named(8) server. Additionally, `/etc/hosts` can be used to provide a local record of Internet names, reducing the need to query externally for commonly accessed names.

```
# $FreeBSD$
#
# Host Database
# This file should contain the addresses and aliases
# for local hosts that share this file.
# In the presence of the domain name service or NIS, this file may
```

```
# not be consulted at all; see /etc/nsswitch.conf for the resolution order.
#
#
::1                     localhost localhost.my.domain myname.my.domain
127.0.0.1               localhost localhost.my.domain myname.my.domain

#
# Imaginary network.
#10.0.0.2               myname.my.domain myname
#10.0.0.3               myfriend.my.domain myfriend
#
# According to RFC 1918, you can use the following IP networks for
# private nets which will never be connected to the Internet:
#
#       10.0.0.0        -   10.255.255.255
#       172.16.0.0      -   172.31.255.255
#       192.168.0.0     -   192.168.255.255
#
# In case you want to be able to connect to the Internet, you need
# real official assigned numbers.  PLEASE PLEASE PLEASE do not try
# to invent your own network numbers but instead get one from your
# network provider (if any) or from the Internet Registry (ftp to
# rs.internic.net, directory '/templates').
#
```

`/etc/hosts` takes on the simple format of:

```
[Internet address] [official hostname] [alias1] [alias2] ...
```

For example:

```
10.0.0.1 myRealHostname.example.com myRealHostname foobar1 foobar2
```

Consult hosts(5) for more information.

6.10.3 Log File Configuration

6.10.3.1 `syslog.conf`

`syslog.conf` is the configuration file for the syslogd(8) program. It indicates which types of `syslog` messages are logged to particular log files.

```
# $FreeBSD$
#
#       Spaces ARE valid field separators in this file. However,
#       other *nix-like systems still insist on using tabs as field
#       separators. If you are sharing this file between systems, you
#       may want to use only tabs as field separators here.
#       Consult the syslog.conf(5) manual page.
*.err;kern.debug;auth.notice;mail.crit          /dev/console
*.notice;kern.debug;lpr.info;mail.crit;news.err /var/log/messages
```

```
security.*                                      /var/log/security
mail.info                                       /var/log/maillog
lpr.info                                        /var/log/lpd-errs
cron.*                                          /var/log/cron
*.err                                           root
*.notice;news.err                               root
*.alert                                         root
*.emerg                                         *
# uncomment this to log all writes to /dev/console to /var/log/console.log
#console.info                                   /var/log/console.log
# uncomment this to enable logging of all log messages to /var/log/all.log
#*.*                                            /var/log/all.log
# uncomment this to enable logging to a remote log host named loghost
#*.*                                            @loghost
# uncomment these if you're running inn
# news.crit                                     /var/log/news/news.crit
# news.err                                      /var/log/news/news.err
# news.notice                                   /var/log/news/news.notice
!startslip
*.*                                             /var/log/slip.log
!ppp
*.*                                             /var/log/ppp.log
```

Consult the syslog.conf(5) manual page for more information.

6.10.3.2 `newsyslog.conf`

`newsyslog.conf` is the configuration file for newsyslog(8), a program that is normally scheduled to run by cron(8). newsyslog(8) determines when log files require archiving or rearranging. `logfile` is moved to `logfile.0`, `logfile.0` is moved to `logfile.1`, and so on. Alternatively, the log files may be archived in gzip(1) format causing them to be named: `logfile.0.gz`, `logfile.1.gz`, and so on.

`newsyslog.conf` indicates which log files are to be managed, how many are to be kept, and when they are to be touched. Log files can be rearranged and/or archived when they have either reached a certain size, or at a certain periodic time/date.

```
# configuration file for newsyslog
# $FreeBSD$
#
# filename          [owner:group]    mode count size when [ZB] [/pid_file] [sig_num]
/var/log/cron                           600  3     100  *     Z
/var/log/amd.log                        644  7     100  *     Z
/var/log/kerberos.log                   644  7     100  *     Z
/var/log/lpd-errs                       644  7     100  *     Z
/var/log/maillog                        644  7     *    @T00  Z
/var/log/sendmail.st                    644  10    *    168   B
/var/log/messages                       644  5     100  *     Z
/var/log/all.log                        600  7     *    @T00  Z
/var/log/slip.log                       600  3     100  *     Z
/var/log/ppp.log                        600  3     100  *     Z
/var/log/security                       600  10    100  *     Z
/var/log/wtmp                           644  3     *    @01T05 B
```

```
/var/log/daily.log                      640  7     *    @T00  Z
/var/log/weekly.log                     640  5     1    $W6D0 Z
/var/log/monthly.log                    640  12    *    $M1D0 Z
/var/log/console.log                    640  5     100  *     Z
```

Consult the newsyslog(8) manual page for more information.

6.10.4 `sysctl.conf`

`sysctl.conf` looks much like `rc.conf`. Values are set in a `variable=value` form. The specified values are set after the system goes into multi-user mode. Not all variables are settable in this mode.

A sample `sysctl.conf` turning off logging of fatal signal exits and letting Linux programs know they are really running under FreeBSD:

```
kern.logsigexit=0       # Do not log fatal signal exits (e.g. sig 11)
compat.linux.osname=FreeBSD
compat.linux.osrelease=4.3-STABLE
```

6.11 Tuning with sysctl

sysctl(8) is an interface that allows you to make changes to a running FreeBSD system. This includes many advanced options of the TCP/IP stack and virtual memory system that can dramatically improve performance for an experienced system administrator. Over five hundred system variables can be read and set using sysctl(8).

At its core, sysctl(8) serves two functions: to read and to modify system settings.

To view all readable variables:

```
% sysctl -a
```

To read a particular variable, for example, `kern.maxproc`:

```
% sysctl kern.maxproc
kern.maxproc: 1044
```

To set a particular variable, use the intuitive *`variable`*=*`value`* syntax:

```
# sysctl kern.maxfiles=5000
kern.maxfiles: 2088 -> 5000
```

Settings of sysctl variables are usually either strings, numbers, or booleans (a boolean being `1` for yes or a `0` for no).

6.11.1 sysctl(8) Read-only

Contributed by Tom Rhodes.

In some cases it may be desirable to modify read-only sysctl(8) values. While this is not recommended, it is also sometimes unavoidable.

For instance on some laptop models the cardbus(4) device will not probe memory ranges, and fail with errors which look similar to:

```
cbb0: Could not map register memory
```

```
device_probe_and_attach: cbb0 attach returned 12
```

Cases like the one above usually require the modification of some default sysctl(8) settings which are set read only. To overcome these situations a user can put sysctl(8) "OIDs" in their local `/boot/loader.conf.local`. Default settings are located in the `/boot/defaults/loader.conf` file.

Fixing the problem mentioned above would require a user to set `hw.pci.allow_unsupported_io_range=1` in the aforementioned file. Now cardbus(4) will work properly.

6.12 Tuning Disks

6.12.1 Sysctl Variables

6.12.1.1 `vfs.vmiodirenable`

The `vfs.vmiodirenable` sysctl variable may be set to either 0 (off) or 1 (on); it is 1 by default. This variable controls how directories are cached by the system. Most directories are small, using just a single fragment (typically 1 K) in the file system and less (typically 512 bytes) in the buffer cache. However, when operating in the default mode the buffer cache will only cache a fixed number of directories even if you have a huge amount of memory. Turning on this sysctl allows the buffer cache to use the VM Page Cache to cache the directories, making all the memory available for caching directories. However, the minimum in-core memory used to cache a directory is the physical page size (typically 4 K) rather than 512 bytes. We recommend turning this option on if you are running any services which manipulate large numbers of files. Such services can include web caches, large mail systems, and news systems. Turning on this option will generally not reduce performance even with the wasted memory but you should experiment to find out.

6.12.1.2 `vfs.write_behind`

The `vfs.write_behind` sysctl variable defaults to `1` (on). This tells the file system to issue media writes as full clusters are collected, which typically occurs when writing large sequential files. The idea is to avoid saturating the buffer cache with dirty buffers when it would not benefit I/O performance. However, this may stall processes and under certain circumstances you may wish to turn it off.

6.12.1.3 `vfs.hirunningspace`

The `vfs.hirunningspace` sysctl variable determines how much outstanding write I/O may be queued to disk controllers system-wide at any given instance. The default is usually sufficient but on machines with lots of disks you may want to bump it up to four or five *megabytes*. Note that setting too high a value (exceeding the buffer cache's write threshold) can lead to extremely bad clustering performance. Do not set this value arbitrarily high! Higher write values may add latency to reads occurring at the same time.

There are various other buffer-cache and VM page cache related sysctls. We do not recommend modifying these values. As of FreeBSD 4.3, the VM system does an extremely good job of automatically tuning itself.

6.12.1.4 vm.swap_idle_enabled

The vm.swap_idle_enabled sysctl variable is useful in large multi-user systems where you have lots of users entering and leaving the system and lots of idle processes. Such systems tend to generate a great deal of continuous pressure on free memory reserves. Turning this feature on and tweaking the swapout hysteresis (in idle seconds) via vm.swap_idle_threshold1 and vm.swap_idle_threshold2 allows you to depress the priority of memory pages associated with idle processes more quickly then the normal pageout algorithm. This gives a helping hand to the pageout daemon. Do not turn this option on unless you need it, because the tradeoff you are making is essentially pre-page memory sooner rather than later; thus eating more swap and disk bandwidth. In a small system this option will have a determinable effect but in a large system that is already doing moderate paging this option allows the VM system to stage whole processes into and out of memory easily.

6.12.1.5 hw.ata.wc

FreeBSD 4.3 flirted with turning off IDE write caching. This reduced write bandwidth to IDE disks but was considered necessary due to serious data consistency issues introduced by hard drive vendors. The problem is that IDE drives lie about when a write completes. With IDE write caching turned on, IDE hard drives not only write data to disk out of order, but will sometimes delay writing some blocks indefinitely when under heavy disk loads. A crash or power failure may cause serious file system corruption. FreeBSD's default was changed to be safe. Unfortunately, the result was such a huge performance loss that we changed write caching back to on by default after the release. You should check the default on your system by observing the hw.ata.wc sysctl variable. If IDE write caching is turned off, you can turn it back on by setting the kernel variable back to 1. This must be done from the boot loader at boot time. Attempting to do it after the kernel boots will have no effect.

For more information, please see ata(4).

6.12.1.6 SCSI_DELAY (kern.cam.scsi_delay)

The SCSI_DELAY kernel config may be used to reduce system boot times. The defaults are fairly high and can be responsible for 15+ seconds of delay in the boot process. Reducing it to 5 seconds usually works (especially with modern drives). Newer versions of FreeBSD (5.0+) should use the kern.cam.scsi_delay boot time tunable. The tunable, and kernel config option accept values in terms of *milliseconds* and *not seconds*.

6.12.2 Soft Updates

The tunefs(8) program can be used to fine-tune a file system. This program has many different options, but for now we are only concerned with toggling Soft Updates on and off, which is done by:

```
# tunefs -n enable /filesystem
# tunefs -n disable /filesystem
```

A filesystem cannot be modified with tunefs(8) while it is mounted. A good time to enable Soft Updates is before any partitions have been mounted, in single-user mode.

> **Note:** As of FreeBSD 4.5, it is possible to enable Soft Updates at filesystem creation time, through use of the `-U` option to newfs(8).

Soft Updates drastically improves meta-data performance, mainly file creation and deletion, through the use of a memory cache. We recommend to use Soft Updates on all of your file systems. There are two downsides to Soft Updates that you should be aware of: First, Soft Updates guarantees filesystem consistency in the case of a crash but could very easily be several seconds (even a minute!) behind updating the physical disk. If your system crashes you may lose more work than otherwise. Secondly, Soft Updates delays the freeing of filesystem blocks. If you have a filesystem (such as the root filesystem) which is almost full, performing a major update, such as `make installworld`, can cause the filesystem to run out of space and the update to fail.

6.12.2.1 More Details about Soft Updates

There are two traditional approaches to writing a file systems meta-data back to disk. (Meta-data updates are updates to non-content data like inodes or directories.)

Historically, the default behavior was to write out meta-data updates synchronously. If a directory had been changed, the system waited until the change was actually written to disk. The file data buffers (file contents) were passed through the buffer cache and backed up to disk later on asynchronously. The advantage of this implementation is that it operates safely. If there is a failure during an update, the meta-data are always in a consistent state. A file is either created completely or not at all. If the data blocks of a file did not find their way out of the buffer cache onto the disk by the time of the crash, fsck(8) is able to recognize this and repair the filesystem by setting the file length to 0. Additionally, the implementation is clear and simple. The disadvantage is that meta-data changes are slow. An `rm -r`, for instance, touches all the files in a directory sequentially, but each directory change (deletion of a file) will be written synchronously to the disk. This includes updates to the directory itself, to the inode table, and possibly to indirect blocks allocated by the file. Similar considerations apply for unrolling large hierarchies (`tar -x`).

The second case is asynchronous meta-data updates. This is the default for Linux/ext2fs and `mount -o async` for *BSD ufs. All meta-data updates are simply being passed through the buffer cache too, that is, they will be intermixed with the updates of the file content data. The advantage of this implementation is there is no need to wait until each meta-data update has been written to disk, so all operations which cause huge amounts of meta-data updates work much faster than in the synchronous case. Also, the implementation is still clear and simple, so there is a low risk for bugs creeping into the code. The disadvantage is that there is no guarantee at all for a consistent state of the filesystem. If there is a failure during an operation that updated large amounts of meta-data (like a power failure, or someone pressing the reset button), the filesystem will be left in an unpredictable state. There is no opportunity to examine the state of the filesystem when the system comes up again; the data blocks of a file could already have been written to the disk while the updates of the inode table or the associated directory were not. It is actually impossible to implement a `fsck` which is able to clean up the resulting chaos (because the necessary information is not available on the disk). If the filesystem has been damaged beyond repair, the only choice is to use newfs(8) on it and restore it from backup.

The usual solution for this problem was to implement *dirty region logging*, which is also referred to as *journaling*, although that term is not used consistently and is occasionally applied to other forms of transaction logging as well. Meta-data updates are still written synchronously, but only into a small region of the disk. Later on they will be moved to their proper location. Because the logging area is a small, contiguous region on the disk, there are no long distances for the disk heads to move, even during heavy operations, so these operations are quicker than synchronous updates. Additionally the complexity of the implementation is fairly limited, so the risk of bugs being present is low. A disadvantage is that all meta-data are written twice (once into the logging region and once to the proper location) so for normal work, a performance "pessimization" might result. On the other hand, in case of a crash, all pending meta-data operations can be quickly either rolled-back or completed from the logging area after the system comes up again, resulting in a fast filesystem startup.

Kirk McKusick, the developer of Berkeley FFS, solved this problem with Soft Updates: all pending meta-data updates are kept in memory and written out to disk in a sorted sequence ("ordered meta-data updates"). This has the effect that, in case of heavy meta-data operations, later updates to an item "catch" the earlier ones if the earlier ones are still in memory and have not already been written to disk. So all operations on, say, a directory are generally performed in memory before the update is written to disk (the data blocks are sorted according to their position so that they will not be on the disk ahead of their meta-data). If the system crashes, this causes an implicit "log rewind": all operations which did not find their way to the disk appear as if they had never happened. A consistent filesystem state is maintained that appears to be the one of 30 to 60 seconds earlier. The algorithm used guarantees that all resources in use are marked as such in their appropriate bitmaps: blocks and inodes. After a crash, the only resource allocation error that occurs is that resources are marked as "used" which are actually "free". fsck(8) recognizes this situation, and frees the resources that are no longer used. It is safe to ignore the dirty state of the filesystem after a crash by forcibly mounting it with `mount -f`. In order to free resources that may be unused, fsck(8) needs to be run at a later time. This is the idea behind the *background fsck*: at system startup time, only a *snapshot* of the filesystem is recorded. The `fsck` can be run later on. All file systems can then be mounted "dirty", so the system startup proceeds in multiuser mode. Then, background `fsck`s will be scheduled for all file systems where this is required, to free resources that may be unused. (File systems that do not use Soft Updates still need the usual foreground `fsck` though.)

The advantage is that meta-data operations are nearly as fast as asynchronous updates (i.e. faster than with *logging*, which has to write the meta-data twice). The disadvantages are the complexity of the code (implying a higher risk for bugs in an area that is highly sensitive regarding loss of user data), and a higher memory consumption. Additionally there are some idiosyncrasies one has to get used to. After a crash, the state of the filesystem appears to be somewhat "older". In situations where the standard synchronous approach would have caused some zero-length files to remain after the `fsck`, these files do not exist at all with a Soft Updates filesystem because neither the meta-data nor the file contents have ever been written to disk. Disk space is not released until the updates have been written to disk, which may take place some time after running `rm`. This may cause problems when installing large amounts of data on a filesystem that does not have enough free space to hold all the files twice.

6.13 Tuning Kernel Limits

6.13.1 File/Process Limits

6.13.1.1 `kern.maxfiles`

`kern.maxfiles` can be raised or lowered based upon your system requirements. This variable indicates the maximum number of file descriptors on your system. When the file descriptor table is full, `file: table is full` will show up repeatedly in the system message buffer, which can be viewed with the `dmesg` command.

Each open file, socket, or fifo uses one file descriptor. A large-scale production server may easily require many thousands of file descriptors, depending on the kind and number of services running concurrently.

`kern.maxfile`'s default value is dictated by the `MAXUSERS` option in your kernel configuration file. `kern.maxfiles` grows proportionally to the value of `MAXUSERS`. When compiling a custom kernel, it is a good idea to set this kernel configuration option according to the uses of your system. From this number, the kernel is given most of its pre-defined limits. Even though a production machine may not actually have 256 users connected at once, the resources needed may be similar to a high-scale web server.

> **Note:** As of FreeBSD 4.5, setting `MAXUSERS` to `0` in your kernel configuration file will choose a reasonable default value based on the amount of RAM present in your system.

6.13.1.2 `kern.ipc.somaxconn`

The `kern.ipc.somaxconn` sysctl variable limits the size of the listen queue for accepting new TCP connections. The default value of `128` is typically too low for robust handling of new connections in a heavily loaded web server environment. For such environments, it is recommended to increase this value to `1024` or higher. The service daemon may itself limit the listen queue size (e.g. sendmail(8), or **Apache**) but will often have a directive in its configuration file to adjust the queue size. Large listen queues also do a better job of avoiding Denial of Service (DoS) attacks.

6.13.2 Network Limits

The `NMBCLUSTERS` kernel configuration option dictates the amount of network Mbufs available to the system. A heavily-trafficked server with a low number of Mbufs will hinder FreeBSD's ability. Each cluster represents approximately 2 K of memory, so a value of 1024 represents 2 megabytes of kernel memory reserved for network buffers. A simple calculation can be done to figure out how many are needed. If you have a web server which maxes out at 1000 simultaneous connections, and each connection eats a 16 K receive and 16 K send buffer, you need approximately 32 MB worth of network buffers to cover the web server. A good rule of thumb is to multiply by 2, so 2x32 MB / 2 KB = 64 MB / 2 kB = 32768. We recommend values between 4096 and 32768 for machines with greater amounts of memory. Under no circumstances should you specify an arbitrarily high value for this parameter as it could lead to a boot time crash. The `-m` option to netstat(1) may be used to observe network cluster use.

`kern.ipc.nmbclusters` loader tunable should be used to tune this at boot time. Only older versions of FreeBSD will require you to use the `NMBCLUSTERS` kernel config(8) option.

For busy servers that make extensive use of the sendfile(2) system call, it may be necessary to increase the number of sendfile(2) buffers via the `NSFBUFS` kernel configuration option or by setting its value in `/boot/loader.conf` (see loader(8) for details). A common indicator that this parameter needs to be adjusted is when processes are seen in the `sfbufa` state. The sysctl variable `kern.ipc.nsfbufs` is a read-only glimpse at the kernel configured variable. This parameter nominally scales with `kern.maxusers`, however it may be necessary to tune accordingly.

> **Important:** Even though a socket has been marked as non-blocking, calling sendfile(2) on the non-blocking socket may result in the sendfile(2) call blocking until enough `struct sf_buf`'s are made available.

6.13.2.1 `net.inet.ip.portrange.*`

The `net.inet.ip.portrange.*` sysctl variables control the port number ranges automatically bound to TCP and UDP sockets. There are three ranges: a low range, a default range, and a high range. Most network programs use the default range which is controlled by the `net.inet.ip.portrange.first` and `net.inet.ip.portrange.last`, which default to 1024 and 5000, respectively. Bound port ranges are used for outgoing connections, and it is possible to run the system out of ports under certain circumstances. This most commonly occurs when you are running a heavily loaded web proxy. The port range is not an issue when running servers which handle mainly incoming connections, such as a normal web server, or has a limited number of outgoing connections, such as a mail relay. For situations where you may run yourself out of ports, it is recommended to increase `net.inet.ip.portrange.last` modestly. A value of `10000`, `20000` or `30000` may be reasonable. You should also consider firewall effects when changing the port range. Some firewalls may block large ranges of ports (usually low-numbered ports) and expect systems to use higher ranges of ports for outgoing connections — for this reason it is recommended that `net.inet.ip.portrange.first` be lowered.

6.13.2.2 TCP Bandwidth Delay Product

The TCP Bandwidth Delay Product Limiting is similar to TCP/Vegas in **NetBSD**. It can be enabled by setting `net.inet.tcp.inflight_enable` sysctl variable to `1`. The system will attempt to calculate the bandwidth delay product for each connection and limit the amount of data queued to the network to just the amount required to maintain optimum throughput.

This feature is useful if you are serving data over modems, Gigabit Ethernet, or even high speed WAN links (or any other link with a high bandwidth delay product), especially if you are also using window scaling or have configured a large send window. If you enable this option, you should also be sure to set `net.inet.tcp.inflight_debug` to `0` (disable debugging), and for production use setting `net.inet.tcp.inflight_min` to at least `6144` may be beneficial. However, note that setting high minimums may effectively disable bandwidth limiting depending on the link. The limiting feature reduces the amount of data built up in intermediate route and switch packet queues as well as reduces the amount of data built up in the local host's interface queue. With fewer packets queued up, interactive connections, especially over slow modems, will also be able to operate with lower *Round Trip Times*. However, note that this feature only effects data transmission (uploading / server side). It has no effect on data reception (downloading).

Adjusting `net.inet.tcp.inflight_stab` is *not* recommended. This parameter defaults to 20, representing 2 maximal packets added to the bandwidth delay product window calculation. The additional window is required to stabilize the algorithm and improve responsiveness to changing conditions, but it can also result in higher ping times over slow links (though still much lower than you would get without the inflight algorithm). In such cases, you may wish to try reducing this parameter to 15, 10, or 5; and may also have to reduce `net.inet.tcp.inflight_min` (for example, to 3500) to get the desired effect. Reducing these parameters should be done as a last resort only.

6.14 Adding Swap Space

No matter how well you plan, sometimes a system does not run as you expect. If you find you need more swap space, it is simple enough to add. You have three ways to increase swap space: adding a new hard drive, enabling swap over NFS, and creating a swap file on an existing partition.

6.14.1 Swap on a New Hard Drive

The best way to add swap, of course, is to use this as an excuse to add another hard drive. You can always use another hard drive, after all. If you can do this, go reread the discussion of swap space (configtuning-initial.html#SWAP-DESIGN) from the Initial Configuration (configtuning-initial.html) section of the Handbook for some suggestions on how to best arrange your swap.

6.14.2 Swapping over NFS

Swapping over NFS is only recommended if you do not have a local hard disk to swap to. Swapping over NFS is slow and inefficient in versions of FreeBSD prior to 4.X. It is reasonably fast and efficient in 4.0-RELEASE and newer. Even with newer versions of FreeBSD, NFS swapping will be limited by the available network bandwidth and puts an additional burden on the NFS server.

6.14.3 Swapfiles

You can create a file of a specified size to use as a swap file. In our example here we will use a 64MB file called `/usr/swap0`. You can use any name you want, of course.

Example 6-1. Creating a Swapfile on FreeBSD 4.X

1. Be certain that your kernel configuration includes the vnode driver. It is *not* in recent versions of `GENERIC`.
   ```
   pseudo-device   vn 1   #Vnode driver (turns a file into a device)
   ```
2. create a vn-device:
   ```
   # cd /dev
   # sh MAKEDEV vn0
   ```
3. create a swapfile (`/usr/swap0`):
   ```
   # dd if=/dev/zero of=/usr/swap0 bs=1024k count=64
   ```
4. set proper permissions on (`/usr/swap0`):
   ```
   # chmod 0600 /usr/swap0
   ```
5. enable the swap file in `/etc/rc.conf`:
   ```
   swapfile="/usr/swap0"   # Set to name of swapfile if aux swapfile desired.
   ```
6. Reboot the machine or to enable the swap file immediately, type:
   ```
   # vnconfig -e /dev/vn0b /usr/swap0 swap
   ```

Example 6-2. Creating a Swapfile on FreeBSD 5.X

1. Be certain that your kernel configuration includes the memory disk driver (md(4)). It is default in `GENERIC` kernel.
   ```
   device   md   # Memory "disks"
   ```
2. create a swapfile (`/usr/swap0`):
   ```
   # dd if=/dev/zero of=/usr/swap0 bs=1024k count=64
   ```
3. set proper permissions on (`/usr/swap0`):
   ```
   # chmod 0600 /usr/swap0
   ```
4. enable the swap file in `/etc/rc.conf`:
   ```
   swapfile="/usr/swap0"   # Set to name of swapfile if aux swapfile desired.
   ```
5. Reboot the machine or to enable the swap file immediately, type:
   ```
   # mdconfig -a -t vnode -f /usr/swap0 -u 0 && swapon /dev/md0
   ```

6.15 Power and Resource Management

Written by Hiten Pandya and Tom Rhodes.

It is very important to utilize hardware resources in an efficient manner. Before ACPI was introduced, it was very difficult and inflexible for operating systems to manage the power usage and thermal properties of a system. The hardware was controlled by some sort of BIOS embedded interface, such as *Plug and Play BIOS (PNPBIOS)*, or *Advanced Power Management (APM)* and so on. Power and Resource Management is one of the key components of a modern operating system. For example, you may want an operating system to monitor system limits (and possibly alert you) in case your system temperature increased unexpectedly.

In this section of the FreeBSD Handbook, we will provide comprehensive information about ACPI. References will be provided for further reading at the end. Please be aware that ACPI is available on FreeBSD 5.X and above systems as a default kernel module. For FreeBSD 4.9, ACPI can be enabled by adding the line `device acpi` to a kernel configuration and rebuilding.

6.15.1 What Is ACPI?

Advanced Configuration and Power Interface (ACPI) is a standard written by an alliance of vendors to provide a standard interface for hardware resources and power management (hence the name). It is a key element in *Operating System-directed configuration and Power Management*, i.e.: it provides more control and flexibility to the operating system (OS). Modern systems "stretched" the limits of the current Plug and Play interfaces (such as APM, which is used in FreeBSD 4.X), prior to the introduction of ACPI. ACPI is the direct successor to APM (Advanced Power Management).

6.15.2 Shortcomings of Advanced Power Management (APM)

The *Advanced Power Management (APM)* facility control's the power usage of a system based on its activity. The APM BIOS is supplied by the (system) vendor and it is specific to the hardware platform. An APM driver in the OS mediates access to the *APM Software Interface*, which allows management of power levels.

There are four major problems in APM. Firstly, power management is done by the (vendor-specific) BIOS, and the OS does not have any knowledge of it. One example of this, is when the user sets idle-time values for a hard drive in the APM BIOS, that when exceeded, it (BIOS) would spin down the hard drive, without the consent of the OS. Secondly, the APM logic is embedded in the BIOS, and it operates outside the scope of the OS. This means users can only fix problems in their APM BIOS by flashing a new one into the ROM; which, is a very dangerous procedure, and if it fails, it could leave the system in an unrecoverable state. Thirdly, APM is a vendor-specific technology, which, means that there is a lot or parity (duplication of efforts) and bugs found in one vendor's BIOS, may not be solved in others. Last but not the least, the APM BIOS did not have enough room to implement a sophisticated power policy, or one that can adapt very well to the purpose of the machine.

Plug and Play BIOS (PNPBIOS) was unreliable in many situations. PNPBIOS is 16-bit technology, so the OS has to use 16-bit emulation in order to "interface" with PNPBIOS methods.

The FreeBSD APM driver is documented in the apm(4) manual page.

6.15.3 Configuring ACPI

The `acpi.ko` driver is loaded by default at start up by the loader(8) and should *not* be compiled into the kernel. The reasoning behind this is that modules are easier to work with, say if switching to another `acpi.ko` without doing a kernel rebuild. This has the advantage of making testing easier. Another reason is that starting ACPI after a system has been brought up is not too useful, and in some cases can be fatal. In doubt, just disable ACPI all together. This driver should not and can not be unloaded because the system bus uses it for various hardware interactions. ACPI can be disabled with the acpiconf(8) utility. In fact most of the interaction with ACPI can be done via acpiconf(8). Basically this means, if anything about ACPI is in the dmesg(8) output, then most likely it is already running.

> **Note:** ACPI and APM cannot coexist and should be used separately. The last one to load will terminate if the driver notices the other running.

In the simplest form, ACPI can be used to put the system into a sleep mode with acpiconf(8), the `-s` flag, and a `1-5` option. Most users will only need `1`. Option `5` will do a soft-off which is the same action as:

```
# halt -p
```

The other options are available. Check out the acpiconf(8) manual page for more information.

6.15.4 Debugging and Disabling ACPI

Almost everything in ACPI is transparent, until it does not work. That is usually when you as a user will know there is something not working properly. The acpi(4) driver supports many debugging options, it is even possible to selectively disable some parts of the ACPI system. For more information about debugging facilities, read the acpi(4) manual page.

Sometimes for various reasons, the `acpi.ko` module must be unloaded. This can only be done at boot time by the loader(8). You can type at loader(8) prompt the command `unset acpi_load` each time you boot the system, or to stop the autoloading of the acpi(4) driver add the following line to the `/boot/loader.conf` file:

```
exec="unset acpi_load"
```

FreeBSD 5.1-RELEASE and later come with a boot-time menu that controls how FreeBSD is booted. One of the proposed options is to turn off ACPI. So to disable ACPI just select 2. Boot FreeBSD with ACPI disabled in the menu.

Chapter 7 The FreeBSD Booting Process

7.1 Synopsis

The process of starting a computer and loading the operating system is referred to as "the bootstrap process", or simply "booting". FreeBSD's boot process provides a great deal of flexibility in customizing what happens when you start the system, allowing you to select from different operating systems installed on the same computer, or even different versions of the same operating system or installed kernel.

This chapter details the configuration options you can set and how to customize the FreeBSD boot process. This includes everything that happens until the FreeBSD kernel has started, probed for devices, and started init(8). If you are not quite sure when this happens, it occurs when the text color changes from bright white to grey.

After reading this chapter, you will know:

- What the components of the FreeBSD bootstrap system are, and how they interact.
- The options you can give to the components in the FreeBSD bootstrap to control the boot process.
- The basics of device.hints(5).

> **x86 Only:** This chapter only describes the boot process for FreeBSD running on Intel x86 systems.

7.2 The Booting Problem

Turning on a computer and starting the operating system poses an interesting dilemma. By definition, the computer does not know how to do anything until the operating system is started. This includes running programs from the disk. So if the computer can not run a program from the disk without the operating system, and the operating system programs are on the disk, how is the operating system started?

This problem parallels one in the book *The Adventures of Baron Munchausen*. A character had fallen part way down a manhole, and pulled himself out by grabbing his bootstraps, and lifting. In the early days of computing the term *bootstrap* was applied to the mechanism used to load the operating system, which has become shortened to "booting".

On x86 hardware the Basic Input/Output System (BIOS) is responsible for loading the operating system. To do this, the BIOS looks on the hard disk for the Master Boot Record (MBR), which must be located on a specific place on the disk. The BIOS has enough knowledge to load and run the MBR, and assumes that the MBR can then carry out the rest of the tasks involved in loading the operating system.

If you only have one operating system installed on your disks then the standard MBR will suffice. This MBR searches for the first bootable slice on the disk, and then runs the code on that slice to load the remainder of the operating system.

If you have installed multiple operating systems on your disks then you can install a different MBR, one that can display a list of different operating systems, and allows you to choose the one to boot from. FreeBSD comes with one such MBR which can be installed, and other operating system vendors also provide alternative MBRs.

The remainder of the FreeBSD bootstrap system is divided into three stages. The first stage is run by the MBR, which knows just enough to get the computer into a specific state and run the second stage. The second stage can do a little bit more, before running the third stage. The third stage finishes the task of loading the operating system. The work is split into these three stages because the PC standards put limits on the size of the programs that can be run at stages one and two. Chaining the tasks together allows FreeBSD to provide a more flexible loader.

The kernel is then started and it begins to probe for devices and initialize them for use. Once the kernel boot process is finished, the kernel passes control to the user process init(8), which then makes sure the disks are in a usable state. init(8) then starts the user-level resource configuration which mounts file systems, sets up network cards to communicate on the network, and generally starts all the processes that usually are run on a FreeBSD system at startup.

7.3 The MBR, and Boot Stages One, Two, and Three

7.3.1 MBR, `/boot/boot0`

The FreeBSD MBR is located in `/boot/boot0`. This is a *copy* of the MBR, as the real MBR must be placed on a special part of the disk, outside the FreeBSD area.

`boot0` is very simple, since the program in the MBR can only be 512 bytes in size. If you have installed the FreeBSD MBR and have installed multiple operating systems on your hard disks then you will see a display similar to this one at boot time:

Example 7-1. `boot0` Screenshot

```
F1 DOS
F2 FreeBSD
F3 Linux
F4 ??
F5 Drive 1

Default: F2
```

Other operating systems, in particular Windows 95, have been known to overwrite an existing MBR with their own. If this happens to you, or you want to replace your existing MBR with the FreeBSD MBR then use the following command:

```
# fdisk -B -b /boot/boot0 device
```

Where *`device`* is the device that you boot from, such as `ad0` for the first IDE disk, `ad2` for the first IDE disk on a second IDE controller, `da0` for the first SCSI disk, and so on.

If you are a Linux user, however, and prefer that **LILO** control the boot process, you can edit the `/etc/lilo.conf` file for FreeBSD, or select `Leave The Master Boot Record Untouched` during the FreeBSD installation process. If you have installed the FreeBSD boot manager, you can boot back into Linux and modify the **LILO** configuration file `/etc/lilo.conf` and add the following option:

```
other=/dev/hdXY
table=/dev/hdb
loader=/boot/chain.b
```

```
label=FreeBSD
```

which will permit the booting of FreeBSD and Linux via **LILO**. In our example, we use *XY* to determine drive number and partition. If you are using a SCSI drive, you will want to change */dev/hdXY* to read something similar to */dev/sdXY*, which again uses the *XY* syntax. The `loader=/boot/chain.b` can be omitted if you have both operating systems on the same drive. You can now run `/sbin/lilo -v` to commit your new changes to the system, this should be verified with screen messages.

7.3.2 Stage One, /boot/boot1, and Stage Two, /boot/boot2

Conceptually the first and second stages are part of the same program, on the same area of the disk. Because of space constraints they have been split into two, but you would always install them together.

They are found on the boot sector of the boot slice, which is where boot0, or any other program on the MBR expects to find the program to run to continue the boot process. The files in the `/boot` directory are copies of the real files, which are stored outside of the FreeBSD file system.

`boot1` is very simple, since it too can only be 512 bytes in size, and knows just enough about the FreeBSD *disklabel*, which stores information about the slice, to find and execute `boot2`.

`boot2` is slightly more sophisticated, and understands the FreeBSD file system enough to find files on it, and can provide a simple interface to choose the kernel or loader to run.

Since the loader is much more sophisticated, and provides a nice easy-to-use boot configuration, `boot2` usually runs it, but previously it was tasked to run the kernel directly.

Example 7-2. `boot2` Screenshot

```
>> FreeBSD/i386 BOOT
Default: 0:ad(0,a)/kernel
boot:
```

If you ever need to replace the installed `boot1` and `boot2` use disklabel(8).

```
# disklabel -B diskslice
```

Where *diskslice* is the disk and slice you boot from, such as `ad0s1` for the first slice on the first IDE disk.

> **Dangerously Dedicated Mode:** If you use just the disk name, such as `ad0`, in the disklabel(8) command you will create a dangerously dedicated disk, without slices. This is almost certainly not what you want to do, so make sure you double check the disklabel(8) command before you press **Return**.

7.3.3 Stage Three, /boot/loader

The loader is the final stage of the three-stage bootstrap, and is located on the file system, usually as `/boot/loader`.

The loader is intended as a user-friendly method for configuration, using an easy-to-use built-in command set, backed up by a more powerful interpreter, with a more complex command set.

7.3.3.1 Loader Program Flow

During initialization, the loader will probe for a console and for disks, and figure out what disk it is booting from. It will set variables accordingly, and an interpreter is started where user commands can be passed from a script or interactively.

The loader will then read `/boot/loader.rc`, which by default reads in `/boot/defaults/loader.conf` which sets reasonable defaults for variables and reads `/boot/loader.conf` for local changes to those variables. `loader.rc` then acts on these variables, loading whichever modules and kernel are selected.

Finally, by default, the loader issues a 10 second wait for key presses, and boots the kernel if it is not interrupted. If interrupted, the user is presented with a prompt which understands the easy-to-use command set, where the user may adjust variables, unload all modules, load modules, and then finally boot or reboot.

7.3.3.2 Loader Built-In Commands

These are the most commonly used loader commands. For a complete discussion of all available commands, please see loader(8).

autoboot *`seconds`*

> Proceeds to boot the kernel if not interrupted within the time span given, in seconds. It displays a countdown, and the default time span is 10 seconds.

boot [*`-options`*] [*`kernelname`*]

> Immediately proceeds to boot the kernel, with the given options, if any, and with the kernel name given, if it is.

boot-conf

> Goes through the same automatic configuration of modules based on variables as what happens at boot. This only makes sense if you use `unload` first, and change some variables, most commonly `kernel`.

help [*`topic`*]

> Shows help messages read from `/boot/loader.help`. If the topic given is `index`, then the list of available topics is given.

include *`filename`* ...

> Processes the file with the given filename. The file is read in, and interpreted line by line. An error immediately stops the include command.

load [`-t` *`type`*] *`filename`*

> Loads the kernel, kernel module, or file of the type given, with the filename given. Any arguments after filename are passed to the file.

ls [`-l`] [*`path`*]

> Displays a listing of files in the given path, or the root directory, if the path is not specified. If `-l` is specified, file sizes will be shown too.

lsdev [`-v`]

Lists all of the devices from which it may be possible to load modules. If `-v` is specified, more details are printed.

lsmod [`-v`]

Displays loaded modules. If `-v` is specified, more details are shown.

more *`filename`*

Displays the files specified, with a pause at each `LINES` displayed.

reboot

Immediately reboots the system.

set *`variable`*
set *`variable`*`=`*`value`*

Sets the loader's environment variables.

unload

Removes all loaded modules.

7.3.3.3 Loader Examples

Here are some practical examples of loader usage:

- To simply boot your usual kernel, but in single-user mode:

  ```
  boot -s
  ```

- To unload your usual kernel and modules, and then load just your old (or another) kernel:

  ```
  unload
  load kernel.old
  ```

  You can use `kernel.GENERIC` to refer to the generic kernel that comes on the install disk, or `kernel.old` to refer to your previously installed kernel (when you have upgraded or configured your own kernel, for example).

  Note: Use the following to load your usual modules with another kernel:

  ```
  unload
  set kernel="kernel.old"
  boot-conf
  ```

- To load a kernel configuration script (an automated script which does the things you would normally do in the kernel boot-time configurator):

  ```
  load -t userconfig_script /boot/kernel.conf
  ```

7.4 Kernel Interaction During Boot

Once the kernel is loaded by either loader (as usual) or boot2 (bypassing the loader), it examines its boot flags, if any, and adjusts its behavior as necessary.

7.4.1 Kernel Boot Flags

Here are the more common boot flags:

`-a`

during kernel initialization, ask for the device to mount as the root file system.

`-C`

boot from CDROM.

`-c`

run UserConfig, the boot-time kernel configurator

`-s`

boot into single-user mode

`-v`

be more verbose during kernel startup

> **Note:** There are other boot flags, read boot(8) for more information on them.

7.5 Device Hints

Contributed by Tom Rhodes.

> **Note:** This is a FreeBSD 5.0 and later feature which does not exist in earlier versions.

During initial system startup, the boot loader(8) will read the device.hints(5) file. This file stores kernel boot information known as variables, sometimes referred to as "device hints". These "device hints" are used by device drivers for device configuration.

Device hints may also be specified at the Stage 3 boot loader prompt. Variables can be added using `set`, removed with `unset`, and viewed with the `show` commands. Variables set in the `/boot/device.hints` file can be overridden here also. Device hints entered at the boot loader are not permanent and will be forgotten on the next reboot.

Once the system is booted, the kenv(1) command can be used to dump all of the variables.

The syntax for the `/boot/device.hints` file is one variable per line, using the standard hash "`#`" as comment markers. Lines are constructed as follows:

`hint.driver.unit.keyword="`*`value`*`"`

The syntax for the Stage 3 boot loader is:

`set hint.driver.unit.keyword=`*`value`*

`driver` is the device driver name, `unit` is the device driver unit number, and `keyword` is the hint keyword. The keyword may consist of the following options:

- `at`: specifies the bus which the device is attached to.
- `port`: specifies the start address of the I/O to be used.
- `irq`: specifies the interrupt request number to be used.
- `drq`: specifies the DMA channel number.
- `maddr`: specifies the physical memory address occupied by the device.
- `flags`: sets various flag bits for the device.
- `disabled`: if set to `1` the device is disabled.

Device drivers may accept (or require) more hints not listed here, viewing their manual page is recommended. For more information, consult the device.hints(5), kenv(1), loader.conf(5), and loader(8) manual pages.

7.6 Init: Process Control Initialization

Once the kernel has finished booting, it passes control to the user process init(8), which is located at `/sbin/init`, or the program path specified in the `init_path` variable in `loader`.

7.6.1 Automatic Reboot Sequence

The automatic reboot sequence makes sure that the file systems available on the system are consistent. If they are not, and fsck(8) cannot fix the inconsistencies, init(8) drops the system into single-user mode for the system administrator to take care of the problems directly.

7.6.2 Single-User Mode

This mode can be reached through the automatic reboot sequence, or by the user booting with the `-s` option or setting the `boot_single` variable in `loader`.

It can also be reached by calling shutdown(8) without the reboot (`-r`) or halt (`-h`) options, from multi-user mode.

If the system `console` is set to `insecure` in `/etc/ttys`, then the system prompts for the `root` password before initiating single-user mode.

Example 7-3. An Insecure Console in `/etc/ttys`

```
# name  getty                           type    status          comments
#
# If console is marked "insecure", then init will ask for the root password
# when going to single-user mode.
console none                            unknown off insecure
```

> **Note:** An `insecure` console means that you consider your physical security to the console to be insecure, and want to make sure only someone who knows the `root` password may use single-user mode, and it does not mean that you want to run your console insecurely. Thus, if you want security, choose `insecure`, not `secure`.

7.6.3 Multi-User Mode

If init(8) finds your file systems to be in order, or once the user has finished in single-user mode, the system enters multi-user mode, in which it starts the resource configuration of the system.

7.6.3.1 Resource Configuration (rc)

The resource configuration system reads in configuration defaults from `/etc/defaults/rc.conf`, and system-specific details from `/etc/rc.conf`, and then proceeds to mount the system file systems mentioned in `/etc/fstab`, start up networking services, start up miscellaneous system daemons, and finally runs the startup scripts of locally installed packages.

The rc(8) manual page is a good reference to the resource configuration system, as is examining the scripts themselves.

7.7 Shutdown Sequence

Upon controlled shutdown, via shutdown(8), init(8) will attempt to run the script `/etc/rc.shutdown`, and then proceed to send all processes the `TERM` signal, and subsequently the `KILL` signal to any that do not terminate timely.

To power down a FreeBSD machine on architectures and systems that support power management, simply use the command `shutdown -p now` to turn the power off immediately. To just reboot a FreeBSD system, just use `shutdown -r now`. You need to be `root` or a member of `operator` group to run shutdown(8). The halt(8) and reboot(8) commands can also be used, please refer to their manual pages and to shutdown(8)'s one for more informations.

> **Note:** Power management requires acpi(4) support in the kernel or loaded as module for FreeBSD 5.X and apm(4) support for FreeBSD 4.X.

Chapter 8 Users and Basic Account Management

Contributed by Neil Blakey-Milner.

8.1 Synopsis

FreeBSD allows multiple users to use the computer at the same time. Obviously, only one of those users can be sitting in front of the screen and keyboard at any one time [1], but any number of users can log in through the network to get their work done. To use the system every user must have an account.

After reading this chapter, you will know:

- The differences between the various user accounts on a FreeBSD system.
- How to add user accounts.
- How to remove user accounts.
- How to change account details, such as the user's full name, or preferred shell.
- How to set limits on a per-account basis, to control the resources such as memory and CPU time that accounts and groups of accounts are allowed to access.
- How to use groups to make account management easier.

Before reading this chapter, you should:

- Understand the basics of UNIX and FreeBSD (Chapter 3).

8.2 Introduction

All access to the system is achieved via accounts, and all processes are run by users, so user and account management are of integral importance on FreeBSD systems.

Every account on a FreeBSD system has certain information associated with it to identify the account.

User name

The user name as it would be typed at the `login:` prompt. User names must be unique across the computer; you may not have two users with the same user name. There are a number of rules for creating valid user names, documented in passwd(5); you would typically use user names that consist of eight or fewer all lower case characters.

Password

Each account has a password associated with it. The password may be blank, in which case no password will be required to access the system. This is normally a very bad idea; every account should have a password.

User ID (UID)

The UID is a number from 0 to 65536 used to uniquely identify the user to the system. Internally, FreeBSD uses the UID to identify users—any FreeBSD commands that allow you to specify a user name will convert it to the UID before working with it. This means that you can have several accounts with different user names but the same UID. As far as FreeBSD is concerned these accounts are one user. It is unlikely you will ever need to do this.

Group ID (GID)

The GID is a number from 0 to 65536 used to uniquely identify the primary group that the user belongs to. Groups are a mechanism for controlling access to resources based on a user's GID rather than their UID. This can significantly reduce the size of some configuration files. A user may also be in more than one group.

Login class

Login classes are an extension to the group mechanism that provide additional flexibility when tailoring the system to different users.

Password change time

By default FreeBSD does not force users to change their passwords periodically. You can enforce this on a per-user basis, forcing some or all of your users to change their passwords after a certain amount of time has elapsed.

Account expiry time

By default FreeBSD does not expire accounts. If you are creating accounts that you know have a limited lifespan, for example, in a school where you have accounts for the students, then you can specify when the account expires. After the expiry time has elapsed the account cannot be used to log in to the system, although the account's directories and files will remain.

User's full name

The user name uniquely identifies the account to FreeBSD, but does not necessarily reflect the user's real name. This information can be associated with the account.

Home directory

The home directory is the full path to a directory on the system in which the user will start when logging on to the system. A common convention is to put all user home directories under `/home/username` or `/usr/home/username`. The user would store their personal files in their home directory, and any directories they may create in there.

User shell

The shell provides the default environment users use to interact with the system. There are many different kinds of shells, and experienced users will have their own preferences, which can be reflected in their account settings.

There are three main types of accounts: the Superuser, system users, and user accounts. The Superuser account, usually called `root`, is used to manage the system with no limitations on privileges. System users run services. Finally, user accounts are used by real people, who log on, read mail, and so forth.

8.3 The Superuser Account

The superuser account, usually called `root`, comes preconfigured to facilitate system administration, and should not be used for day-to-day tasks like sending and receiving mail, general exploration of the system, or programming.

This is because the superuser, unlike normal user accounts, can operate without limits, and misuse of the superuser account may result in spectacular disasters. User accounts are unable to destroy the system by mistake, so it is generally best to use normal user accounts whenever possible, unless you especially need the extra privilege.

You should always double and triple-check commands you issue as the superuser, since an extra space or missing character can mean irreparable data loss.

So, the first thing you should do after reading this chapter is to create an unprivileged user account for yourself for general usage if you have not already. This applies equally whether you are running a multi-user or single-user machine. Later in this chapter, we discuss how to create additional accounts, and how to change between the normal user and superuser.

8.4 System Accounts

System users are those used to run services such as DNS, mail, web servers, and so forth. The reason for this is security; if all services ran as the superuser, they could act without restriction.

Examples of system users are `daemon`, `operator`, `bind` (for the Domain Name Service), and `news`. Often sysadmins create `httpd` to run web servers they install.

`nobody` is the generic unprivileged system user. However, it is important to keep in mind that the more services that use `nobody`, the more files and processes that user will become associated with, and hence the more privileged that user becomes.

8.5 User Accounts

User accounts are the primary means of access for real people to the system, and these accounts insulate the user and the environment, preventing the users from damaging the system or other users, and allowing users to customize their environment without affecting others.

Every person accessing your system should have a unique user account. This allows you to find out who is doing what, prevent people from clobbering each others' settings or reading each others' mail, and so forth.

Each user can set up their own environment to accommodate their use of the system, by using alternate shells, editors, key bindings, and language.

8.6 Modifying Accounts

There are a variety of different commands available in the UNIX environment to manipulate user accounts. The most common commands are summarized below, followed by more detailed examples of their usage.

Command	Summary
adduser(8)	The recommended command-line application for adding new users.

Command	Summary
rmuser(8)	The recommended command-line application for removing users.
chpass(1)	A flexible tool to change user database information.
passwd(1)	The simple command-line tool to change user passwords.
pw(8)	A powerful and flexible tool to modify all aspects of user accounts.

8.6.1 adduser

adduser(8) is a simple program for adding new users. It creates entries in the system `passwd` and `group` files. It will also create a home directory for the new user, copy in the default configuration files ("dotfiles") from `/usr/share/skel`, and can optionally mail the new user a welcome message.

In FreeBSD 5.0, adduser(8) was rewritten from a Perl script to a shell script that acts as wrapper around pw(8), so its usage is slightly different on FreeBSD 4.X and FreeBSD 5.X.

To create the initial configuration file, use `adduser -s -config_create`. [2] Next, we configure adduser(8) defaults, and create our first user account, since using `root` for normal usage is evil and nasty.

Example 8-1. Configuring adduser and adding a user on FreeBSD 4.X

```
# adduser -v
Use option "-silent" if you don't want to see all warnings and questions.
Check /etc/shells
Check /etc/master.passwd
Check /etc/group
Enter your default shell: csh date no sh tcsh zsh [sh]: zsh
Your default shell is: zsh -> /usr/local/bin/zsh
Enter your default HOME partition: [/home]:
Copy dotfiles from: /usr/share/skel no [/usr/share/skel]:
Send message from file: /etc/adduser.message no
[/etc/adduser.message]: no
Do not send message
Use passwords (y/n) [y]: y

Write your changes to /etc/adduser.conf? (y/n) [n]: y

Ok, let's go.
Don't worry about mistakes. I will give you the chance later to correct any input.
Enter username [a-z0-9_-]: jru
Enter full name []: J. Random User
Enter shell csh date no sh tcsh zsh [zsh]:
Enter home directory (full path) [/home/jru]:
Uid [1001]:
Enter login class: default []:
Login group jru [jru]:
Login group is "jru". Invite jru into other groups: guest no
[no]: wheel
Enter password []:
Enter password again []:
```

```
Name:   jru
Password: ****
Fullname: J. Random User
Uid:   1001
Gid:   1001 (jru)
Class:
Groups:   jru wheel
HOME:     /home/jru
Shell:   /usr/local/bin/zsh
OK? (y/n) [y]: y
Added user “jru”
Copy files from /usr/share/skel to /home/jru
Add another user? (y/n) [y]: n
Goodbye!
#
```

In summary, we changed the default shell to **zsh** (an additional shell found in the Ports Collection), and turned off the sending of a welcome mail to added users. We then saved the configuration, created an account for `jru`, and made sure `jru` is in `wheel` group (so that she may assume the role of `root` with the su(1) command.)

> **Note:** The password you type in is not echoed, nor are asterisks displayed. Make sure you do not mistype the password twice.

> **Note:** Just use adduser(8) without arguments from now on, and you will not have to go through changing the defaults. If the program asks you to change the defaults, exit the program, and try the `-s` option.

Example 8-2. Adding a user on FreeBSD 5.X

```
# adduser
Username: jru
Full name: J. Random User
Uid (Leave empty for default):
Login group [jru]:
Login group is jru. Invite jru into other groups? []: wheel
Login class [default]:
Shell (sh csh tcsh zsh nologin) [sh]: zsh
Home directory [/home/jru]:
Use password-based authentication? [yes]:
Use an empty password? (yes/no) [no]:
Use a random password? (yes/no) [no]:
Enter password:
Enter password again:
Lock out the account after creation? [no]:
Username   : jru
Password   : ****
Full Name  : J. Random User
Uid        : 1001
```

```
Class      :
Groups     : jru wheel
Home       : /home/jru
Shell      : /usr/local/bin/zsh
Locked     : no
OK? (yes/no): yes
adduser: INFO: Successfully added (jru) to the user database.
Add another user? (yes/no): no
Goodbye!
#
```

8.6.2 `rmuser`

You can use rmuser(8) to completely remove a user from the system. rmuser(8) performs the following steps:

1. Removes the user's crontab(1) entry (if any).
2. Removes any at(1) jobs belonging to the user.
3. Kills all processes owned by the user.
4. Removes the user from the system's local password file.
5. Removes the user's home directory (if it is owned by the user).
6. Removes the incoming mail files belonging to the user from `/var/mail`.
7. Removes all files owned by the user from temporary file storage areas such as `/tmp`.
8. Finally, removes the username from all groups to which it belongs in `/etc/group`.

> **Note:** If a group becomes empty and the group name is the same as the username, the group is removed; this complements the per-user unique groups created by adduser(8).

rmuser(8) cannot be used to remove superuser accounts, since that is almost always an indication of massive destruction.

By default, an interactive mode is used, which attempts to make sure you know what you are doing.

Example 8-3. `rmuser` Interactive Account Removal

```
# rmuser jru
Matching password entry:
jru:*:1001:1001::0:0:J. Random User:/home/jru:/usr/local/bin/zsh
Is this the entry you wish to remove? y
Remove user's home directory (/home/jru)? y
Updating password file, updating databases, done.
Updating group file: trusted (removing group jru -- personal group is empty) done.
Removing user's incoming mail file /var/mail/jru: done.
Removing files belonging to jru from /tmp: done.
Removing files belonging to jru from /var/tmp: done.
```

```
Removing files belonging to jru from /var/tmp/vi.recover: done.
#
```

8.6.3 chpass

chpass(1) changes user database information such as passwords, shells, and personal information.

Only system administrators, as the superuser, may change other users' information and passwords with chpass(1).

When passed no options, aside from an optional username, chpass(1) displays an editor containing user information. When the user exists from the editor, the user database is updated with the new information.

> **Note:** In FreeBSD 5.X, you will be asked for your password after exiting the editor if you are not the superuser.

Example 8-4. Interactive chpass by Superuser

```
#Changing user database information for jru.
Login: jru
Password: *
Uid [#]: 1001
Gid [# or name]: 1001
Change [month day year]:
Expire [month day year]:
Class:
Home directory: /home/jru
Shell: /usr/local/bin/zsh
Full Name: J. Random User
Office Location:
Office Phone:
Home Phone:
Other information:
```

The normal user can change only a small subset of this information, and only for themselves.

Example 8-5. Interactive chpass by Normal User

```
#Changing user database information for jru.
Shell: /usr/local/bin/zsh
Full Name: J. Random User
Office Location:
Office Phone:
Home Phone:
Other information:
```

> **Note:** chfn(1) and chsh(1) are just links to chpass(1), as are ypchpass(1), ypchfn(1), and ypchsh(1). NIS support is automatic, so specifying the `yp` before the command is not necessary. If this is confusing to you, do not worry, NIS will be covered in Chapter 19.

8.6.4 passwd

passwd(1) is the usual way to change your own password as a user, or another user's password as the superuser.

> **Note:** Users must type in their original password before changing their password, to prevent an unauthorized person from changing their password when the user is away from their console.

Example 8-6. Changing Your Password

```
% passwd
Changing local password for jru.
Old password:
New password:
Retype new password:
passwd: updating the database...
passwd: done
```

Example 8-7. Changing Another User's Password as the Superuser

```
# passwd jru
Changing local password for jru.
New password:
Retype new password:
passwd: updating the database...
passwd: done
```

> **Note:** As with chpass(1), yppasswd(1) is just a link to passwd(1), so NIS works with either command.

8.6.5 pw

pw(8) is a command line utility to create, remove, modify, and display users and groups. It functions as a front end to the system user and group files. pw(8) has a very powerful set of command line options that make it suitable for use in shell scripts, but new users may find it more complicated than the other commands presented here.

8.7 Limiting Users

If you have users, the ability to limit their system use may have come to mind. FreeBSD provides several ways an administrator can limit the amount of system resources an individual may use. These limits are divided into two sections: disk quotas, and other resource limits.

Disk quotas limit disk usage to users, and they provide a way to quickly check that usage without calculating it every time. Quotas are discussed in Section 12.12.

The other resource limits include ways to limit the amount of CPU, memory, and other resources a user may consume. These are defined using login classes and are discussed here.

Login classes are defined in `/etc/login.conf`. The precise semantics are beyond the scope of this section, but are described in detail in the login.conf(5) manual page. It is sufficient to say that each user is assigned to a login class (`default` by default), and that each login class has a set of login capabilities associated with it. A login capability is a *`name=value`* pair, where *`name`* is a well-known identifier and *`value`* is an arbitrary string processed accordingly depending on the name. Setting up login classes and capabilities is rather straight-forward and is also described in login.conf(5).

Resource limits are different from plain vanilla login capabilities in two ways. First, for every limit, there is a soft (current) and hard limit. A soft limit may be adjusted by the user or application, but may be no higher than the hard limit. The latter may be lowered by the user, but never raised. Second, most resource limits apply per process to a specific user, not the user as a whole. Note, however, that these differences are mandated by the specific handling of the limits, not by the implementation of the login capability framework (i.e., they are not *really* a special case of login capabilities).

And so, without further ado, below are the most commonly used resource limits (the rest, along with all the other login capabilities, may be found in login.conf(5)).

`coredumpsize`

The limit on the size of a core file generated by a program is, for obvious reasons, subordinate to other limits on disk usage (e.g., `filesize`, or disk quotas). Nevertheless, it is often used as a less-severe method of controlling disk space consumption: since users do not generate core files themselves, and often do not delete them, setting this may save them from running out of disk space should a large program (e.g., **emacs**) crash.

`cputime`

This is the maximum amount of CPU time a user's process may consume. Offending processes will be killed by the kernel.

> **Note:** This is a limit on CPU *time* consumed, not percentage of the CPU as displayed in some fields by top(1) and ps(1). A limit on the latter is, at the time of this writing, not possible, and would be rather useless: a compiler—probably a legitimate task—can easily use almost 100% of a CPU for some time.

`filesize`

This is the maximum size of a file the user may possess. Unlike disk quotas, this limit is enforced on individual files, not the set of all files a user owns.

`maxproc`

This is the maximum number of processes a user may be running. This includes foreground and background processes alike. For obvious reasons, this may not be larger than the system limit specified by the `kern.maxproc` sysctl(8). Also note that setting this too small may hinder a user's productivity: it is often useful to be logged in multiple times or execute pipelines. Some tasks, such as compiling a large program, also spawn multiple processes (e.g., make(1), cc(1), and other intermediate preprocessors).

`memorylocked`

This is the maximum amount a memory a process may have requested to be locked into main memory (e.g., see mlock(2)). Some system-critical programs, such as amd(8), lock into main memory such that in the event of being swapped out, they do not contribute to a system's trashing in time of trouble.

`memoryuse`

This is the maximum amount of memory a process may consume at any given time. It includes both core memory and swap usage. This is not a catch-all limit for restricting memory consumption, but it is a good start.

`openfiles`

This is the maximum amount of files a process may have open. In FreeBSD, files are also used to represent sockets and IPC channels; thus, be careful not to set this too low. The system-wide limit for this is defined by the `kern.maxfiles` sysctl(8).

`sbsize`

This is the limit on the amount of network memory, and thus mbufs, a user may consume. This originated as a response to an old DoS attack by creating a lot of sockets, but can be generally used to limit network communications.

`stacksize`

This is the maximum size a process' stack may grow to. This alone is not sufficient to limit the amount of memory a program may use; consequently, it should be used in conjunction with other limits.

There are a few other things to remember when setting resource limits. Following are some general tips, suggestions, and miscellaneous comments.

- Processes started at system startup by `/etc/rc` are assigned to the `daemon` login class.
- Although the `/etc/login.conf` that comes with the system is a good source of reasonable values for most limits, only you, the administrator, can know what is appropriate for your system. Setting a limit too high may open your system up to abuse, while setting it too low may put a strain on productivity.
- Users of the X Window System (X11) should probably be granted more resources than other users. X11 by itself takes a lot of resources, but it also encourages users to run more programs simultaneously.
- Remember that many limits apply to individual processes, not the user as a whole. For example, setting `openfiles` to 50 means that each process the user runs may open up to 50 files. Thus, the gross amount of files a user may open is the value of `openfiles` multiplied by the value of `maxproc`. This also applies to memory consumption.

For further information on resource limits and login classes and capabilities in general, please consult the relevant manual pages: cap_mkdb(1), getrlimit(2), login.conf(5).

8.8 Personalizing Users

Localization is an environment set up by the system administrator or user to accommodate different languages, character sets, date and time standards, and so on. This is discussed in the localization chapter.

8.9 Groups

A group is simply a list of users. Groups are identified by their group name and GID (Group ID). In FreeBSD (and most other UNIX like systems), the two factors the kernel uses to decide whether a process is allowed to do something is its user ID and list of groups it belongs to. Unlike a user ID, a process has a list of groups associated with it. You may hear some things refer to the "group ID" of a user or process; most of the time, this just means the first group in the list.

The group name to group ID map is in `/etc/group`. This is a plain text file with four colon-delimited fields. The first field is the group name, the second is the encrypted password, the third the group ID, and the fourth the comma-delimited list of members. It can safely be edited by hand (assuming, of course, that you do not make any syntax errors!). For a more complete description of the syntax, see the group(5) manual page.

If you do not want to edit `/etc/group` manually, you can use the pw(8) command to add and edit groups. For example, to add a group called `teamtwo` and then confirm that it exists you can use:

Example 8-8. Adding a Group Using pw(8)

```
# pw groupadd teamtwo
# pw groupshow teamtwo
teamtwo:*:1100:
```

The number `1100` above is the group ID of the group `teamtwo`. Right now, `teamtwo` has no members, and is thus rather useless. Let's change that by inviting `jru` to the `teamtwo` group.

Example 8-9. Adding Somebody to a Group Using pw(8)

```
# pw groupmod teamtwo -M jru
# pw groupshow teamtwo
teamtwo:*:1100:jru
```

The argument to the `-M` option is a comma-delimited list of users who are members of the group. From the preceding sections, we know that the password file also contains a group for each user. The latter (the user) is automatically added to the group list by the system; the user will not show up as a member when using the `groupshow` command to pw(8), but will show up when the information is queried via id(1) or similar tool. In other words, pw(8) only manipulates the `/etc/group` file; it will never attempt to read additionally data from `/etc/passwd`.

Example 8-10. Using id(1) to Determine Group Membership

```
% id jru
uid=1001(jru) gid=1001(jru) groups=1001(jru), 1100(teamtwo)
```

As you can see, `jru` is a member of the groups `jru` and `teamtwo`.

For more information about pw(8), see its manual page, and for more information on the format of `/etc/group`, consult the group(5) manual page.

Notes

1. Well, unless you hook up multiple terminals, but we will save that for Chapter 17.
2. The `-s` makes adduser(8) default to quiet. We use `-v` later when we want to change defaults.

Chapter 9 Configuring the FreeBSD Kernel

Updated and restructured by Jim Mock. Originally contributed by Jake Hamby.

9.1 Synopsis

The kernel is the core of the FreeBSD operating system. It is responsible for managing memory, enforcing security controls, networking, disk access, and much more. While more and more of FreeBSD becomes dynamically configurable it is still occasionally necessary to reconfigure and recompile your kernel.

After reading this chapter, you will know:

- Why you might need to build a custom kernel.
- How to write a kernel configuration file, or alter an existing configuration file.
- How to use the kernel configuration file to create and build a new kernel.
- How to install the new kernel.
- How to create any entries in `/dev` that may be required.
- How to troubleshoot if things go wrong.

9.2 Why Build a Custom Kernel?

Traditionally, FreeBSD has had what is called a "monolithic" kernel. This means that the kernel was one large program, supported a fixed list of devices, and if you wanted to change the kernel's behavior then you had to compile a new kernel, and then reboot your computer with the new kernel.

Today, FreeBSD is rapidly moving to a model where much of the kernel's functionality is contained in modules which can be dynamically loaded and unloaded from the kernel as necessary. This allows the kernel to adapt to new hardware suddenly becoming available (such as PCMCIA cards in a laptop), or for new functionality to be brought into the kernel that was not necessary when the kernel was originally compiled. This is known as a modular kernel. Colloquially these are called KLDs.

Despite this, it is still necessary to carry out some static kernel configuration. In some cases this is because the functionality is so tied to the kernel that it can not be made dynamically loadable. In others it may simply be because no one has yet taken the time to write a dynamic loadable kernel module for that functionality yet.

Building a custom kernel is one of the most important rites of passage nearly every UNIX user must endure. This process, while time consuming, will provide many benefits to your FreeBSD system. Unlike the `GENERIC` kernel, which must support a wide range of hardware, a custom kernel only contains support for *your* PC's hardware. This has a number of benefits, such as:

- Faster boot time. Since the kernel will only probe the hardware you have on your system, the time it takes your system to boot will decrease dramatically.
- Less memory usage. A custom kernel often uses less memory than the `GENERIC` kernel, which is important because the kernel must always be present in real memory. For this reason, a custom kernel is especially useful on a system with a small amount of RAM.

- Additional hardware support. A custom kernel allows you to add in support for devices such as sound cards, which are not present in the `GENERIC` kernel.

9.3 Building and Installing a Custom Kernel

First, let us take a quick tour of the kernel build directory. All directories mentioned will be relative to the main `/usr/src/sys` directory, which is also accessible through `/sys`. There are a number of subdirectories here representing different parts of the kernel, but the most important, for our purposes, are *arch*`/conf`, where you will edit your custom kernel configuration, and `compile`, which is the staging area where your kernel will be built. *arch* represents either `i386`, `alpha`, or `pc98` (an alternative development branch of PC hardware, popular in Japan). Everything inside a particular architecture's directory deals with that architecture only; the rest of the code is common to all platforms to which FreeBSD could potentially be ported. Notice the logical organization of the directory structure, with each supported device, file system, and option in its own subdirectory. FreeBSD 5.X and up has support for `sparc64`, and a few other architectures under development.

> **Note:** If there is *not* a `/usr/src/sys` directory on your system, then the kernel source has not been installed. The easiest way to do this is by running `/stand/sysinstall` as `root`, choosing Configure, then Distributions, then src, then sys. If you have an aversion to **sysinstall** and you have access to an "official" FreeBSD CDROM, then you can also install the source from the command line:
>
> ```
> # mount /cdrom
> # mkdir -p /usr/src/sys
> # ln -s /usr/src/sys /sys
> # cat /cdrom/src/ssys.[a-d]* | tar -xzvf -
> ```

Next, move to the *arch*`/conf` directory and copy the `GENERIC` configuration file to the name you want to give your kernel. For example:

```
# cd /usr/src/sys/i386/conf
# cp GENERIC MYKERNEL
```

Traditionally, this name is in all capital letters and, if you are maintaining multiple FreeBSD machines with different hardware, it is a good idea to name it after your machine's hostname. We will call it `MYKERNEL` for the purpose of this example.

> **Tip:** Storing your kernel config file directly under `/usr/src` can be a bad idea. If you are experiencing problems it can be tempting to just delete `/usr/src` and start again. Five seconds after you do that you realize that you have deleted your custom kernel config file. Do not edit `GENERIC` directly, as it may get overwritten the next time you update your source tree, and your kernel modifications will be lost.
>
> You might want to keep your kernel config file elsewhere, and then create a symbolic link to the file in the `i386` directory.
>
> For example:
>
> ```
> # cd /usr/src/sys/i386/conf
> # mkdir /root/kernels
> # cp GENERIC /root/kernels/MYKERNEL
> # ln -s /root/kernels/MYKERNEL
> ```

> **Note:** You must execute these and all of the following commands under the `root` account or you will get permission denied errors.

Now, edit `MYKERNEL` with your favorite text editor. If you are just starting out, the only editor available will probably be **vi**, which is too complex to explain here, but is covered well in many books in the bibliography. However, FreeBSD does offer an easier editor called **ee** which, if you are a beginner, should be your editor of choice. Feel free to change the comment lines at the top to reflect your configuration or the changes you have made to differentiate it from `GENERIC`.

If you have built a kernel under SunOS or some other BSD operating system, much of this file will be very familiar to you. If you are coming from some other operating system such as DOS, on the other hand, the `GENERIC` configuration file might seem overwhelming to you, so follow the descriptions in the Configuration File section slowly and carefully.

> **Note:** Be sure to always check the file `/usr/src/UPDATING`, before you perform any update steps, in the case you sync your source tree with the latest sources of the FreeBSD project. In this file all important issues with updating FreeBSD are typed out. `/usr/src/UPDATING` always fits your version of the FreeBSD source, and is therefore more accurate for new information than the handbook.

You must now compile the source code for the kernel. There are two procedures you can use to do this, and the one you will use depends on why you are rebuilding the kernel, and the version of FreeBSD you are running.

- If you have installed *only* the kernel source code, use procedure 1.
- If you are running a FreeBSD version prior to 4.0, and you are *not* upgrading to FreeBSD 4.0 or higher using the `make world` procedure, use procedure 1.
- If you are building a new kernel without updating the source code (perhaps just to add a new option, such as `IPFIREWALL`) you can use either procedure.
- If you are rebuilding the kernel as part of a `make world` process, use procedure 2.

Procedure 1. Building a Kernel the "Traditional" Way

1. Run config(8) to generate the kernel source code.

   ```
   # /usr/sbin/config MYKERNEL
   ```

2. Change into the build directory. This is printed out after running the aforementioned command.

   ```
   # cd ../compile/MYKERNEL
   ```

   For FreeBSD version prior to 5.0, use instead:

   ```
   # cd ../../compile/MYKERNEL
   ```

3. Compile the kernel.

   ```
   # make depend
   # make
   ```

4. Install the new kernel.

   ```
   # make install
   ```

Procedure 2. Building a Kernel the "New" Way

1. Change to the `/usr/src` directory.

   ```
   # cd /usr/src
   ```

2. Compile the kernel.

   ```
   # make buildkernel KERNCONF=MYKERNEL
   ```

3. Install the new kernel.

   ```
   # make installkernel KERNCONF=MYKERNEL
   ```

> **Note:** In FreeBSD 4.2 and older you must replace `KERNCONF=` with `KERNEL=`. 4.2-STABLE that was fetched before Feb 2nd, 2001 does not recognize `KERNCONF=`.

If you have *not* upgraded your source tree in any way (you have not run **CVSup**, **CTM**, or used **anoncvs**), then you should use the `config`, `make depend`, `make`, `make install` sequence.

The new kernel will be copied to the root directory as `/kernel` and the old kernel will be moved to `/kernel.old`. Now, shutdown the system and reboot to use your new kernel. In case something goes wrong, there are some troubleshooting instructions at the end of this chapter. Be sure to read the section which explains how to recover in case your new kernel does not boot.

> **Note:** As of FreeBSD 5.0, kernels are installed along with their modules in `/boot/kernel`, and old kernels will be backed up in `/boot/kernel.old`. Other files relating to the boot process, such as the boot loader(8) and configuration are also stored in `/boot`. Third party or custom modules may be placed in `/boot/modules`, although users should be aware that keeping modules in sync with the compiled kernel is very important. Modules not intended to run with the compiled kernel may result in instability or incorrectness.

> **Note:** If you have added any new devices (such as sound cards) and you are running FreeBSD 4.X or previous versions, you may have to add some device nodes to your `/dev` directory before you can use them. For more information, take a look at Making Device Nodes section later on in this chapter.

9.4 The Configuration File

The general format of a configuration file is quite simple. Each line contains a keyword and one or more arguments. For simplicity, most lines only contain one argument. Anything following a `#` is considered a comment and ignored. The following sections describe each keyword, generally in the order they are listed in `GENERIC`, although some related keywords have been grouped together in a single section (such as Networking) even though they are actually scattered throughout the `GENERIC` file. An exhaustive list of options and more detailed explanations of the device lines is present in the LINT configuration file, located in the same directory as GENERIC. If you are in doubt as to the purpose or necessity of a line, check first in LINT.

> **Note:** In FreeBSD 5.X and above the LINT is non-existent. See the NOTES file for architecture dependent options. Some options, mainly architecture independent ones, are stored in the /usr/src/sys/conf/NOTES file. It is advisable to review the options in here also.

The following is an example GENERIC kernel configuration file with various additional comments where needed for clarity. This example should match your copy in /usr/src/sys/i386/conf/GENERIC fairly closely. For details of all the possible kernel options, see /usr/src/sys/i386/conf/LINT.

```
#
# GENERIC -- Generic kernel configuration file for FreeBSD/i386
#
# For more information on this file, please read the handbook section on
# Kernel Configuration Files:
#
#    http://www.FreeBSD.org/doc/en_US.ISO8859-1/books/handbook/kernelconfig-config.html
#
# The handbook is also available locally in /usr/share/doc/handbook
# if you've installed the doc distribution, otherwise always see the
# FreeBSD World Wide Web server (http://www.FreeBSD.org/) for the
# latest information.
#
# An exhaustive list of options and more detailed explanations of the
# device lines is also present in the ../../conf/NOTES and NOTES files.
# If you are in doubt as to the purpose or necessity of a line, check first
# in NOTES.
#
# $FreeBSD: src/sys/i386/conf/GENERIC,v 1.380 2003/03/29 13:36:41 mdodd Exp $
```

The following are the mandatory keywords required in *every* kernel you build:

```
machine i386
```

This is the machine architecture. It must be either i386, pc98, sparc64, alpha, ia64, amd64, or powerpc.

```
cpu          I486_CPU
cpu          I586_CPU
cpu          I686_CPU
```

The above option specifies the type of CPU you have in your system. You may have multiple instances of the CPU line (i.e., you are not sure whether you should use I586_CPU or I686_CPU), however, for a custom kernel, it is best to specify only the CPU you have. If you are unsure of your CPU type, you can check the /var/run/dmesg.boot file to view your boot up messages.

Support for I386_CPU is still provided in the source of FreeBSD, but it is disabled by default in both -STABLE and -CURRENT. This means that to install FreeBSD with a 386-class cpu, you now have the following options:

- Install an older FreeBSD release and rebuild from source as described in Section 9.3.

- Build the userland and kernel on a newer machine and install on the 386 using the precompiled `/usr/obj` files (see Section 21.5 for details).
- Roll your own release of FreeBSD which includes `I386_CPU` support in the kernels of the installation CD-ROM.

The first of these options is probably the easiest of all, but you will need a lot of disk space on a 386-class machine which may be difficult to find.

```
ident           GENERIC
```

This is the identification of the kernel. You should change this to whatever you named your kernel, i.e. `MYKERNEL` if you have followed the instructions of the previous examples. The value you put in the `ident` string will print when you boot up the kernel, so it is useful to give the new kernel a different name if you want to keep it separate from your usual kernel (i.e. you want to build an experimental kernel).

```
maxusers            n
```

The `maxusers` option sets the size of a number of important system tables. This number is supposed to be roughly equal to the number of simultaneous users you expect to have on your machine.

Starting with FreeBSD 4.5, the system will auto-tune this setting for you if you explicitly set it to `0`[1]. In FreeBSD 5.X, `maxusers` will default to `0` if not specified. If you are using an version of FreeBSD earlier than 4.5, or you want to manage it yourself you will want to set `maxusers` to at least 4, especially if you are using the X Window System or compiling software. The reason is that the most important table set by `maxusers` is the maximum number of processes, which is set to `20 + 16 * maxusers`, so if you set `maxusers` to 1, then you can only have 36 simultaneous processes, including the 18 or so that the system starts up at boot time, and the 15 or so you will probably create when you start the X Window System. Even a simple task like reading a manual page will start up nine processes to filter, decompress, and view it. Setting `maxusers` to 64 will allow you to have up to 1044 simultaneous processes, which should be enough for nearly all uses. If, however, you see the dreaded proc table full error when trying to start another program, or are running a server with a large number of simultaneous users (like `ftp.FreeBSD.org`), you can always increase the number and rebuild.

> **Note:** `maxusers` does *not* limit the number of users which can log into your machine. It simply sets various table sizes to reasonable values considering the maximum number of users you will likely have on your system and how many processes each of them will be running. One keyword which *does* limit the number of simultaneous *remote logins and X terminal windows* is `pseudo-device pty 16`.

```
# Floating point support - do not disable.
device          npx0     at nexus? port IO_NPX irq 13
```

`npx0` is the interface to the floating point math unit in FreeBSD, which is either the hardware co-processor or the software math emulator. This is *not* optional.

```
# Pseudo devices - the number indicates how many units to allocate.
pseudo-device   loop          # Network loopback
```

This is the generic loopback device for TCP/IP. If you telnet or FTP to `localhost` (a.k.a., `127.0.0.1`) it will come back at you through this pseudo-device. This is *mandatory*.

Everything that follows is more or less optional. See the notes underneath or next to each option for more information.

```
#To statically compile in device wiring instead of /boot/device.hints
#hints          "GENERIC.hints"         #Default places to look for devices.
```

In FreeBSD 5.X and newer versions the device.hints(5) is used to configure options of the device drivers. The default location that loader(8) will check at boot time is `/boot/device.hints`. Using the `hints` option you can compile these hints statically into your kernel. Then there is no need to create a `device.hints` file in `/boot`.

```
#makeoptions     DEBUG=-g          #Build kernel with gdb(1) debug symbols
```

The normal build process of the FreeBSD does not include debugging information when building the kernel and strips most symbols after the resulting kernel is linked, to save some space at the install location. If you are going to do tests of kernels in the -CURRENT branch or develop changes of your own for the FreeBSD kernel, you might want to uncomment this line. It will enable the use of the `-g` option which enables debugging information when passed to gcc(1). The same can be accomplished by the config(8) `-g` option, if you are using the "traditional" way for building your kernels (See the Section 9.3 for more informations.).

```
options          MATH_EMULATE      #Support for x87 emulation
```

This line allows the kernel to simulate a math co-processor if your computer does not have one (386 or 486SX). If you have a 486DX, or a 386 or 486SX (with a separate 387 or 487 chip), or higher (Pentium, Pentium II, etc.), you can comment this line out.

> **Note:** The normal math co-processor emulation routines that come with FreeBSD are *not* very accurate. If you do not have a math co-processor, and you need the best accuracy, it is recommended that you change this option to `GPL_MATH_EMULATE` to use the GNU math support, which is not included by default for licensing reasons.
>
> In FreeBSD 5.X, math emulation is disabled by default, as older CPUs that do not have native floating point math support are far less common, and in many cases not supported by the `GENERIC` kernel without other additional options.

```
options          INET          #InterNETworking
```

Networking support. Leave this in, even if you do not plan to be connected to a network. Most programs require at least loopback networking (i.e., making network connections within your PC), so this is essentially mandatory.

```
options          INET6          #IPv6 communications protocols
```

This enables the IPv6 communication protocols.

```
options          FFS          #Berkeley Fast Filesystem
options          FFS_ROOT     #FFS usable as root device [keep this!]
```

This is the basic hard drive Filesystem. Leave it in if you boot from the hard disk.

> **Note:** In FreeBSD 5.X, `FFS_ROOT` is no longer required.

```
options          UFS_ACL      #Support for access control lists
```

This option, present only in FreeBSD 5.X, enables kernel support for access control lists. This relies on the use of extended attributes and UFS2, and the feature is described in detail in the Section 10.13. ACLs are enabled by default, and should not be disabled in the kernel if they have been used previously on a file system, as this will remove the access control lists changing the way files are protected in unpredictable ways.

```
options         UFS_DIRHASH  #Improve performance on big directories
```

This option includes functionality to speed up disk operations on large directories, at the expense of using additional memory. You would normally keep this for a large server, or interactive workstation, and remove it if you are using FreeBSD on a smaller system where memory is at a premium and disk access speed is less important, such as a firewall.

```
options         SOFTUPDATES  #Enable FFS Soft Updates support
```

This option enables Soft Updates in the kernel, this will help speed up write access on the disks. Even when this functionality is provided by the kernel, it must be turned on for specific disks. Review the output from mount(8) to see if Soft Updates is enabled for your system disks. If you do not see the `soft-updates` option then you will need to activate it using the tunefs(8) (for existing filesystems) or newfs(8) (for new filesystems) commands.

```
options         MFS          #Memory Filesystem
options         MD_ROOT      #MD is a potential root device
```

This is the memory-mapped Filesystem. This is basically a RAM disk for fast storage of temporary files, useful if you have a lot of swap space that you want to take advantage of. A perfect place to mount an MFS partition is on the `/tmp` directory, since many programs store temporary data here. To mount an MFS RAM disk on `/tmp`, add the following line to `/etc/fstab`:

```
/dev/ad1s2b /tmp mfs rw 0 0
```

Now you simply need to either reboot, or run the command `mount /tmp`.

> **Note:** In FreeBSD 5.X, md(4)-backed UFS file systems are used for memory file systems rather than MFS. Information on configuring memory-backed file systems may be found in the manual pages for mdconfig(8) and mdmfs(8), and in Section 12.10. As a result, the `MFS` option is no longer supported.

```
options         NFS          #Network Filesystem
options         NFS_ROOT     #NFS usable as root device, NFS required
```

The network Filesystem. Unless you plan to mount partitions from a UNIX file server over TCP/IP, you can comment these out.

```
options         MSDOSFS      #MSDOS Filesystem
```

The MS-DOS Filesystem. Unless you plan to mount a DOS formatted hard drive partition at boot time, you can safely comment this out. It will be automatically loaded the first time you mount a DOS partition, as described above. Also, the excellent **mtools** software (in the ports collection) allows you to access DOS floppies without having to mount and unmount them (and does not require `MSDOSFS` at all).

```
options         CD9660       #ISO 9660 Filesystem
options         CD9660_ROOT  #CD-ROM usable as root, CD9660 required
```

The ISO 9660 Filesystem for CDROMs. Comment it out if you do not have a CDROM drive or only mount data CDs occasionally (since it will be dynamically loaded the first time you mount a data CD). Audio CDs do not need this Filesystem.

```
options         PROCFS      #Process filesystem
```

The process filesystem. This is a "pretend" filesystem mounted on `/proc` which allows programs like ps(1) to give you more information on what processes are running. In FreeBSD 5.X, use of `PROCFS` is not required under most circumstances, as most debugging and monitoring tools have been adapted to run without `PROCFS`. In addition, 5.X-CURRENT kernels making use of `PROCFS` must now also include support for `PSEUDOFS`:

```
options         PSEUDOFS    #Pseudo-filesystem framework
```

`PSEUDOFS` is not available in FreeBSD 4.X. Unlike in FreeBSD 4.X, new installations of FreeBSD 5.X will not mount the process file system by default.

```
options         COMPAT_43   #Compatible with BSD 4.3 [KEEP THIS!]
```

Compatibility with 4.3BSD. Leave this in; some programs will act strangely if you comment this out.

```
options         COMPAT_FREEBSD4     #Compatible with FreeBSD4
```

This option is required on FreeBSD 5.X i386 and Alpha systems to support applications compiled on older versions of FreeBSD that use older system call interfaces. It is recommended that this option be used on all i386 and Alpha systems that may run older applications; platforms that gained support only in 5.X, such as ia64 and Sparc64®, do not require this option.

```
options         SCSI_DELAY=15000    #Delay (in ms) before probing SCSI
```

This causes the kernel to pause for 15 seconds before probing each SCSI device in your system. If you only have IDE hard drives, you can ignore this, otherwise you will probably want to lower this number, perhaps to 5 seconds, to speed up booting. Of course, if you do this, and FreeBSD has trouble recognizing your SCSI devices, you will have to raise it back up.

```
options         UCONSOLE            #Allow users to grab the console
```

Allow users to grab the console, which is useful for X users. For example, you can create a console **xterm** by typing `xterm -C`, which will display any write(1), talk(1), and any other messages you receive, as well as any console messages sent by the kernel.

> **Note:** In FreeBSD 5.X, `UCONSOLE` is no longer required.

```
options         USERCONFIG          #boot -c editor
```

This option allows you to boot the configuration editor from the boot menu.

```
options         VISUAL_USERCONFIG   #visual boot -c editor
```

This option allows you to boot the visual configuration editor from the boot menu.

> **Note:** From FreeBSD versions 5.0 and later, the `USERCONFIG` options has been deprecated in favor of the new device.hints(5) method. For more information on device.hints(5) please visit Section 7.5.

```
options          KTRACE              #ktrace(1) support
```

This enables kernel process tracing, which is useful in debugging.

```
options          SYSVSHM             #SYSV-style shared memory
```

This option provides for System V shared memory. The most common use of this is the XSHM extension in X, which many graphics-intensive programs will automatically take advantage of for extra speed. If you use X, you will definitely want to include this.

```
options          SYSVSEM             #SYSV-style semaphores
```

Support for System V semaphores. Less commonly used but only adds a few hundred bytes to the kernel.

```
options          SYSVMSG             #SYSV-style message queues
```

Support for System V messages. Again, only adds a few hundred bytes to the kernel.

> **Note:** The ipcs(1) command will list any processes using each of these System V facilities.

```
options  P1003_1B #Posix P1003_1B real-time extensions
options  _KPOSIX_PRIORITY_SCHEDULING
```

Real-time extensions added in the 1993 POSIX®. Certain applications in the ports collection use these (such as **StarOffice**).

> **Note:** In FreeBSD 5.X, all of this functionality is now provided by the `_KPOSIX_PRIORITY_SCHEDULING` option, and `P1003_1B` is no longer required.

```
options ICMP_BANDLIM #Rate limit bad replies
```

This option enables ICMP error response bandwidth limiting. You typically want this option as it will help protect the machine from denial of service packet attacks.

> **Note:** In FreeBSD 5.X, this feature is enabled by default and the `ICMP_BANDLIM` option is not required.

```
# To make an SMP kernel, the next two are needed
#options        SMP                     # Symmetric MultiProcessor Kernel
#options        APIC_IO                 # Symmetric (APIC) I/O
```

The above are both required for SMP support.

```
device          isa
```

All PCs supported by FreeBSD have one of these. If you have an IBM PS/2 (Micro Channel Architecture), FreeBSD provides some limited support at this time. For more information about the MCA support, see `/usr/src/sys/i386/conf/LINT`.

```
device          eisa
```

Include this if you have an EISA motherboard. This enables auto-detection and configuration support for all devices on the EISA bus.

```
device          pci
```

Include this if you have a PCI motherboard. This enables auto-detection of PCI cards and gatewaying from the PCI to ISA bus.

```
device          agp
```

Include this if you have an AGP card in the system. This will enable support for AGP, and AGP GART for boards which have these features.

```
# Floppy drives
device          fdc0        at isa? port IO_FD1 irq 6 drq 2
device          fd0         at fdc0 drive 0
device          fd1         at fdc0 drive 1
```

This is the floppy drive controller. `fd0` is the `A:` floppy drive, and `fd1` is the `B:` drive.

```
device          ata
```

This driver supports all ATA and ATAPI devices. You only need one `device ata` line for the kernel to detect all PCI ATA/ATAPI devices on modern machines.

```
device          atadisk             # ATA disk drives
```

This is needed along with `device ata` for ATA disk drives.

```
device          atapicd             # ATAPI CDROM drives
```

This is needed along with `device ata` for ATAPI CDROM drives.

```
device          atapifd             # ATAPI floppy drives
```

This is needed along with `device ata` for ATAPI floppy drives.

```
device          atapist             # ATAPI tape drives
```

This is needed along with `device ata` for ATAPI tape drives.

```
options         ATA_STATIC_ID       #Static device numbering
```

This makes the controller number static (like the old driver) or else the device numbers are dynamically allocated.

```
# ATA and ATAPI devices
device          ata0        at isa? port IO_WD1 irq 14
device          ata1        at isa? port IO_WD2 irq 15
```

Use the above for older, non-PCI systems.

```
# SCSI Controllers
device          ahb        # EISA AHA1742 family
device          ahc        # AHA2940 and onboard AIC7xxx devices
device          amd        # AMD 53C974 (Teckram DC-390(T))
device          dpt        # DPT Smartcache - See LINT for options!
device          isp        # Qlogic family
device          ncr        # NCR/Symbios Logic
device          sym        # NCR/Symbios Logic (newer chipsets)

device          adv0       at isa?
device          adw
device          bt0        at isa?
device          aha0       at isa?
device          aic0       at isa?
```

SCSI controllers. Comment out any you do not have in your system. If you have an IDE only system, you can remove these altogether.

```
# SCSI peripherals
device          scbus      # SCSI bus (required)
device          da         # Direct Access (disks)
device          sa         # Sequential Access (tape etc)
device          cd         # CD
device          pass       # Passthrough device (direct SCSI
access)
```

SCSI peripherals. Again, comment out any you do not have, or if you have only IDE hardware, you can remove them completely.

```
# RAID controllers
device          ida        # Compaq Smart RAID
device          amr        # AMI MegaRAID
device          mlx        # Mylex DAC960 family
```

Supported RAID controllers. If you do not have any of these, you can comment them out or remove them.

```
# atkbdc0 controls both the keyboard and the PS/2 mouse
device          atkbdc0    at isa? port IO_KBD
```

The keyboard controller (`atkbdc`) provides I/O services for the AT keyboard and PS/2 style pointing devices. This controller is required by the keyboard driver (`atkbd`) and the PS/2 pointing device driver (`psm`).

```
device          atkbd0     at atkbdc? irq 1
```

The `atkbd` driver, together with `atkbdc` controller, provides access to the AT 84 keyboard or the AT enhanced keyboard which is connected to the AT keyboard controller.

```
device          psm0       at atkbdc? irq 12
```

Use this device if your mouse plugs into the PS/2 mouse port.

```
device          vga0        at isa?
```

The video card driver.

```
# splash screen/screen saver
pseudo-device          splash
```

Splash screen at start up! Screen savers require this too.

```
# syscons is the default console driver, resembling an SCO console
device          sc0          at isa?
```

`sc0` is the default console driver, which resembles a SCO console. Since most full-screen programs access the console through a terminal database library like `termcap`, it should not matter whether you use this or `vt0`, the `VT220` compatible console driver. When you log in, set your `TERM` variable to `scoansi` if full-screen programs have trouble running under this console.

```
# Enable this and PCVT_FREEBSD for pcvt vt220 compatible console driver
#device          vt0     at isa?
#options         XSERVER          # support for X server on a vt console
#options         FAT_CURSOR       # start with block cursor
# If you have a ThinkPAD, uncomment this along with the rest of the PCVT lines
#options         PCVT_SCANSET=2   # IBM keyboards are non-std
```

This is a VT220-compatible console driver, backward compatible to VT100/102. It works well on some laptops which have hardware incompatibilities with `sc0`. Also set your `TERM` variable to `vt100` or `vt220` when you log in. This driver might also prove useful when connecting to a large number of different machines over the network, where `termcap` or `terminfo` entries for the `sc0` device are often not available — `vt100` should be available on virtually any platform.

```
# Power management support (see LINT for more options)
device          apm0     at nexus? disable flags 0x20  # Advanced Power Management
```

Advanced Power Management support. Useful for laptops.

```
# PCCARD (PCMCIA) support
device          card
device          pcic0    at isa? irq 10 port 0x3e0 iomem 0xd0000
device          pcic1    at isa? irq 11 port 0x3e2 iomem 0xd4000 disable
```

PCMCIA support. You want this if you are using a laptop.

```
# Serial (COM) ports
device          sio0     at isa? port IO_COM1 flags 0x10 irq 4
device          sio1     at isa? port IO_COM2 irq 3
device          sio2     at isa? disable port IO_COM3 irq 5
device          sio3     at isa? disable port IO_COM4 irq 9
```

These are the four serial ports referred to as COM1 through COM4 in the MS-DOS/Windows world.

> **Note:** If you have an internal modem on COM4 and a serial port at COM2, you will have to change the IRQ of the modem to 2 (for obscure technical reasons, IRQ2 = IRQ 9) in order to access it from FreeBSD. If you have a multiport serial card, check the manual page for sio(4) for more information on the proper values for these lines. Some video cards (notably those based on S3 chips) use IO addresses in the form of `0x*2e8`, and since many

cheap serial cards do not fully decode the 16-bit IO address space, they clash with these cards making the COM4 port practically unavailable.

Each serial port is required to have a unique IRQ (unless you are using one of the multiport cards where shared interrupts are supported), so the default IRQs for COM3 and COM4 cannot be used.

```
# Parallel port
device          ppc0    at isa? irq 7
```

This is the ISA-bus parallel port interface.

```
device          ppbus      # Parallel port bus (required)
```

Provides support for the parallel port bus.

```
device          lpt        # Printer
```

Support for parallel port printers.

Note: All three of the above are required to enable parallel printer support.

```
device          plip       # TCP/IP over parallel
```

This is the driver for the parallel network interface.

```
device          ppi        # Parallel port interface device
```

The general-purpose I/O (“geek port”) + IEEE1284 I/O.

```
#device         vpo        # Requires scbus and da
```

This is for an Iomega Zip drive. It requires `scbus` and `da` support. Best performance is achieved with ports in EPP 1.9 mode.

```
# PCI Ethernet NICs.
device          de         # DEC/Intel DC21x4x (“Tulip”)
device          fxp        # Intel EtherExpress PRO/100B (82557, 82558)
device          tx         # SMC 9432TX (83c170 “EPIC”)
device          vx         # 3Com 3c590, 3c595 (“Vortex”)
device          wx         # Intel Gigabit Ethernet Card (“Wiseman”)
```

Various PCI network card drivers. Comment out or remove any of these not present in your system.

```
# PCI Ethernet NICs that use the common MII bus controller code.
device          miibus     # MII bus support
```

MII bus support is required for some PCI 10/100 Ethernet NICs, namely those which use MII-compliant transceivers or implement transceiver control interfaces that operate like an MII. Adding `device miibus` to the kernel config pulls in support for the generic miibus API and all of the PHY drivers, including a generic one for PHYs that are not specifically handled by an individual driver.

```
device          dc          # DEC/Intel 21143 and various workalikes
device          rl          # RealTek 8129/8139
device          sf          # Adaptec AIC-6915 (“Starfire”)
device          sis         # Silicon Integrated Systems SiS 900/SiS 7016
device          ste         # Sundance ST201 (D-Link DFE-550TX)
device          tl          # Texas Instruments ThunderLAN
device          vr          # VIA Rhine, Rhine II
device          wb          # Winbond W89C840F
device          xl          # 3Com 3c90x (“Boomerang”, “Cyclone”)
```

Drivers that use the MII bus controller code.

```
# ISA Ethernet NICs.
device          ed0    at isa? port 0x280 irq 10 iomem 0xd8000
device          ex
device          ep
# WaveLAN/IEEE 802.11 wireless NICs. Note: the WaveLAN/IEEE really
# exists only as a PCMCIA device, so there is no ISA attachment needed
# and resources will always be dynamically assigned by the pccard code.
device          wi
# Aironet 4500/4800 802.11 wireless NICs. Note: the declaration below will
# work for PCMCIA and PCI cards, as well as ISA cards set to ISA PnP
# mode (the factory default). If you set the switches on your ISA
# card for a manually chosen I/O address and IRQ, you must specify
# those parameters here.
device          an
# The probe order of these is presently determined by i386/isa/isa_compat.c.
device          ie0    at isa? port 0x300 irq 10 iomem 0xd0000
device          fe0    at isa? port 0x300
device          le0    at isa? port 0x300 irq 5 iomem 0xd0000
device          lnc0   at isa? port 0x280 irq 10 drq 0
device          cs0    at isa? port 0x300
device          sn0    at isa? port 0x300 irq 10
# requires PCCARD (PCMCIA) support to be activated
#device         xe0    at isa?
```

ISA Ethernet drivers. See `/usr/src/sys/i386/conf/LINT` for which cards are supported by which driver.

```
pseudo-device   ether         # Ethernet support
```

`ether` is only needed if you have an Ethernet card. It includes generic Ethernet protocol code.

```
pseudo-device   sl      1     # Kernel SLIP
```

`sl` is for SLIP support. This has been almost entirely supplanted by PPP, which is easier to set up, better suited for modem-to-modem connection, and more powerful. The *`number`* after `sl` specifies how many simultaneous SLIP sessions to support.

```
pseudo-device   ppp     1     # Kernel PPP
```

This is for kernel PPP support for dial-up connections. There is also a version of PPP implemented as a userland application that uses `tun` and offers more flexibility and features such as demand dialing. The *`number`* after `ppp` specifies how many simultaneous PPP connections to support.

```
pseudo-device   tun             # Packet tunnel.
```

This is used by the userland PPP software. A *number* after `tun` specifies the number of simultaneous PPP sessions to support. See the PPP section of this book for more information.

```
pseudo-device   pty             # Pseudo-ttys (telnet etc)
```

This is a "pseudo-terminal" or simulated login port. It is used by incoming `telnet` and `rlogin` sessions, **xterm**, and some other applications such as **Emacs**. A *number* after `pty` indicates the number of `pty`s to create. If you need more than the default of 16 simultaneous **xterm** windows and/or remote logins, be sure to increase this number accordingly, up to a maximum of 256.

```
pseudo-device   md              # Memory "disks"
```

Memory disk pseudo-devices.

```
pseudo-device   gif
```

or

```
pseudo-device   gif     4       # IPv6 and IPv4 tunneling
```

This implements IPv6 over IPv4 tunneling, IPv4 over IPv6 tunneling, IPv4 over IPv4 tunneling, and IPv6 over IPv6 tunneling. Beginning with FreeBSD 4.4 the `gif` device is "auto-cloning", and you should use the first example (without the number after `gif`). Earlier versions of FreeBSD require the number.

```
pseudo-device   faith   1       # IPv6-to-IPv4 relaying (translation)
```

This pseudo-device captures packets that are sent to it and diverts them to the IPv4/IPv6 translation daemon.

```
# The 'bpf' pseudo-device enables the Berkeley Packet Filter.
# Be aware of the administrative consequences of enabling this!
pseudo-device   bpf             # Berkeley packet filter
```

This is the Berkeley Packet Filter. This pseudo-device allows network interfaces to be placed in promiscuous mode, capturing every packet on a broadcast network (e.g., an Ethernet). These packets can be captured to disk and or examined with the tcpdump(1) program.

> **Note:** The `bpf pseudo-device` is also used by dhclient(8) to obtain the IP address of the default router (gateway) and so on. If you use DHCP, leave this uncommented.

```
# USB support
#device         uhci            # UHCI PCI->USB interface
#device         ohci            # OHCI PCI->USB interface
#device         usb             # USB Bus (required)
#device         ugen            # Generic
#device         uhid            # "Human Interface Devices"
#device         ukbd            # Keyboard
#device         ulpt            # Printer
#device         umass           # Disks/Mass storage - Requires scbus and da
#device         ums             # Mouse
# USB Ethernet, requires mii
```

```
#device         aue             # ADMtek USB ethernet
#device         cue             # CATC USB ethernet
#device         kue             # Kawasaki LSI USB ethernet
```

Support for various USB devices.

For more information and additional devices supported by FreeBSD, see `/usr/src/sys/i386/conf/LINT`.

9.4.1 Large Memory Configurations (PAE)

Large memory configuration machines require access to more than the 4 gigabyte limit on User+Kernel Virtual Address (KVA) space. Due to this limitation, Intel added support for 36-bit physical address space access in the Pentium Pro and later line of CPUs.

The Physical Address Extension (PAE) capability of the Intel Pentium Pro and later CPUs allows memory configurations of up to 64 gigabytes. FreeBSD provides support for this capability via the `PAE` kernel configuration option, available in the 4.X series of FreeBSD beginning with 4.9-RELEASE and in the 5.X series of FreeBSD beginning with 5.1-RELEASE. Due to the limitations of the Intel memory architecture, no distinction is made for memory above or below 4 gigabytes. Memory allocated above 4 gigabytes is simply added to the pool of available memory.

To enable PAE support in the kernel, simply add the following line to your kernel configuration file:

```
options     PAE
```

> **Note:** The PAE support in FreeBSD is only available for Intel IA-32 processors. It should also be noted, that the PAE support in FreeBSD has not received wide testing, and should be considered beta quality compared to other stable features of FreeBSD.

PAE support in FreeBSD has a few limitations:

- A process is not able to access more than 4 gigabytes of VM space.
- KLD modules cannot be loaded into a PAE enabled kernel, due to the differences in the build framework of a module and the kernel.
- Device drivers that do not use the bus_dma(9) interface will cause data corruption in a PAE enabled kernel and are not recommended for use. For this reason, the `PAE` kernel configuration file is provided in FreeBSD 5.X, which excludes all drivers not known to work in a PAE enabled kernel.
- Some system tunables determine memory resource usage by the amount of available physical memory. Such tunables can unnecessarily over-allocate due to the large memory nature of a PAE system. One such example is the `kern.maxvnodes` sysctl, which controls the maximum number of vnodes allowed in the kernel. It is advised to adjust this and other such tunables to a reasonable value.
- It might be necessary to increase the kernel virtual address (KVA) space or to reduce the amount of specific kernel resource that is heavily used (see above) in order to avoid KVA exhaustion. The `KVA_PAGES` kernel option can be used for increasing the KVA space.

For performance and stability concerns, it is advised to consult the tuning(7) manual page. The pae(4) manual page contains up-to-date information on FreeBSD's PAE support.

9.5 Making Device Nodes

> **Note:** If you are running FreeBSD 5.0 or later you can safely skip this section. These versions use devfs(5) to allocate device nodes transparently for the user.

Almost every device in the kernel has a corresponding "node" entry in the `/dev` directory. These nodes look like regular files, but are actually special entries into the kernel which programs use to access the device. The shell script `/dev/MAKEDEV`, which is executed when you first install the operating system, creates nearly all of the device nodes supported. However, it does not create *all* of them, so when you add support for a new device, it pays to make sure that the appropriate entries are in this directory, and if not, add them. Here is a simple example:

Suppose you add the IDE CD-ROM support to the kernel. The line to add is:

```
device acd0
```

This means that you should look for some entries that start with `acd0` in the `/dev` directory, possibly followed by a letter, such as `c`, or preceded by the letter `r`, which means a "raw" device. It turns out that those files are not there, so you must change to the `/dev` directory and type:

```
# sh MAKEDEV acd0
```

When this script finishes, you will find that there are now `acd0c` and `racd0c` entries in `/dev` so you know that it executed correctly.

For sound cards, the following command creates the appropriate entries:

```
# sh MAKEDEV snd0
```

> **Note:** When creating device nodes for devices such as sound cards, if other people have access to your machine, it may be desirable to protect the devices from outside access by adding them to the `/etc/fbtab` file. See fbtab(5) for more information.

Follow this simple procedure for any other non-`GENERIC` devices which do not have entries.

> **Note:** All SCSI controllers use the same set of `/dev` entries, so you do not need to create these. Also, network cards and SLIP/PPP pseudo-devices do not have entries in `/dev` at all, so you do not have to worry about these either.

9.6 If Something Goes Wrong

There are five categories of trouble that can occur when building a custom kernel. They are:

`config` fails:

If the config(8) command fails when you give it your kernel description, you have probably made a simple error somewhere. Fortunately, config(8) will print the line number that it had trouble with, so you can quickly skip to it with **vi**. For example, if you see:

```
config: line 17: syntax error
```

You can skip to the problem in **vi** by typing `17G` in command mode. Make sure the keyword is typed correctly, by comparing it to the `GENERIC` kernel or another reference.

`make` fails:

If the `make` command fails, it usually signals an error in your kernel description, but not severe enough for config(8) to catch it. Again, look over your configuration, and if you still cannot resolve the problem, send mail to the FreeBSD general questions mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-questions) with your kernel configuration, and it should be diagnosed very quickly.

Installing the new kernel fails:

If the kernel compiled fine, but failed to install (the `make install` or `make installkernel` command failed), the first thing to check is if your system is running at securelevel 1 or higher (see init(8)). The kernel installation tries to remove the immutable flag from your kernel and set the immutable flag on the new one. Since securelevel 1 or higher prevents unsetting the immutable flag for any files on the system, the kernel installation needs to be performed at securelevel 0 or lower.

The kernel does not boot:

If your new kernel does not boot, or fails to recognize your devices, do not panic! Fortunately, FreeBSD has an excellent mechanism for recovering from incompatible kernels. Simply choose the kernel you want to boot from at the FreeBSD boot loader. You can access this when the system counts down from 10. Hit any key except for the **Enter** key, type `unload` and then type `boot` *`kernel.old`*, or the filename of any other kernel that will boot properly. When reconfiguring a kernel, it is always a good idea to keep a kernel that is known to work on hand.

After booting with a good kernel you can check over your configuration file and try to build it again. One helpful resource is the `/var/log/messages` file which records, among other things, all of the kernel messages from every successful boot. Also, the dmesg(8) command will print the kernel messages from the current boot.

> **Note:** If you are having trouble building a kernel, make sure to keep a `GENERIC`, or some other kernel that is known to work on hand as a different name that will not get erased on the next build. You cannot rely on `kernel.old` because when installing a new kernel, `kernel.old` is overwritten with the last installed kernel which may be non-functional. Also, as soon as possible, move the working kernel to the proper `kernel` location or commands such as ps(1) will not work properly. The proper command to "unlock" the kernel file that `make` installs (in order to move another kernel back permanently) is:
>
> ```
> # chflags noschg /kernel
> ```
>
> If you find you cannot do this, you are probably running at a securelevel(8) greater than zero. Edit `kern_securelevel` in `/etc/rc.conf` and set it to `-1`, then reboot. You can change it back to its previous setting when you are happy with your new kernel.
>
> And, if you want to "lock" your new kernel into place, or any file for that matter, so that it cannot be moved or tampered with:
>
> ```
> # chflags schg /kernel
> ```

In FreeBSD 5.X, kernels are not installed with the system immutable flag, so this is unlikely to be the source of the problem you are experiencing.

The kernel works, but ps(1) does not work any more:

If you have installed a different version of the kernel from the one that the system utilities have been built with, for example, a 4.X kernel on a 3.X system, many system-status commands like ps(1) and vmstat(8) will not work any more. You must recompile the `libkvm` library as well as these utilities. This is one reason it is not normally a good idea to use a different version of the kernel from the rest of the operating system.

Notes

1. The auto-tuning algorithm sets `maxuser` equal to the amount of memory in the system, with a minimum of 32, and a maximum of 384.

Chapter 10 Security

Much of this chapter has been taken from the security(7) manual page by Matthew Dillon.

10.1 Synopsis

This chapter will provide a basic introduction to system security concepts, some general good rules of thumb, and some advanced topics under FreeBSD. A lot of the topics covered here can be applied to system and Internet security in general as well. The Internet is no longer a "friendly" place in which everyone wants to be your kind neighbor. Securing your system is imperative to protect your data, intellectual property, time, and much more from the hands of hackers and the like.

FreeBSD provides an array of utilities and mechanisms to ensure the integrity and security of your system and network.

After reading this chapter, you will know:

- Basic system security concepts, in respect to FreeBSD.
- About the various crypt mechanisms available in FreeBSD, such as DES and MD5.
- How to set up one-time password authentication.
- How to set up **KerberosIV** on FreeBSD releases prior to 5.0.
- How to set up **Kerberos5** on post FreeBSD 5.0 releases.
- How to create firewalls using IPFW.
- How to configure IPsec and create a VPN between FreeBSD/Windows machines.
- How to configure and use **OpenSSH**, FreeBSD's SSH implementation.
- How to configure and load access control extension modules using the TrustedBSD MAC Framework.
- What file system ACLs are and how to use them.
- How to utililize the FreeBSD security advisories publications.

Before reading this chapter, you should:

- Understand basic FreeBSD and Internet concepts.

10.2 Introduction

Security is a function that begins and ends with the system administrator. While all BSD UNIX multi-user systems have some inherent security, the job of building and maintaining additional security mechanisms to keep those users "honest" is probably one of the single largest undertakings of the sysadmin. Machines are only as secure as you make them, and security concerns are ever competing with the human necessity for convenience. UNIX systems, in general, are capable of running a huge number of simultaneous processes and many of these processes operate as servers – meaning that external entities can connect and talk to them. As yesterday's mini-computers and mainframes become today's desktops, and as computers become networked and internetworked, security becomes an even bigger issue.

Security is best implemented through a layered "onion" approach. In a nutshell, what you want to do is to create as many layers of security as are convenient and then carefully monitor the system for intrusions. You do not want to overbuild your security or you will interfere with the detection side, and detection is one of the single most important aspects of any security mechanism. For example, it makes little sense to set the `schg` flags (see chflags(1)) on every system binary because while this may temporarily protect the binaries, it prevents an attacker who has broken in from making an easily detectable change that may result in your security mechanisms not detecting the attacker at all.

System security also pertains to dealing with various forms of attack, including attacks that attempt to crash, or otherwise make a system unusable, but do not attempt to compromise the `root` account ("break root"). Security concerns can be split up into several categories:

1. Denial of service attacks.
2. User account compromises.
3. Root compromise through accessible servers.
4. Root compromise via user accounts.
5. Backdoor creation.

A denial of service attack is an action that deprives the machine of needed resources. Typically, DoS attacks are brute-force mechanisms that attempt to crash or otherwise make a machine unusable by overwhelming its servers or network stack. Some DoS attacks try to take advantage of bugs in the networking stack to crash a machine with a single packet. The latter can only be fixed by applying a bug fix to the kernel. Attacks on servers can often be fixed by properly specifying options to limit the load the servers incur on the system under adverse conditions. Brute-force network attacks are harder to deal with. A spoofed-packet attack, for example, is nearly impossible to stop, short of cutting your system off from the Internet. It may not be able to take your machine down, but it can saturate your Internet connection.

A user account compromise is even more common than a DoS attack. Many sysadmins still run standard **telnetd**, **rlogind**, **rshd**, and **ftpd** servers on their machines. These servers, by default, do not operate over encrypted connections. The result is that if you have any moderate-sized user base, one or more of your users logging into your system from a remote location (which is the most common and convenient way to login to a system) will have his or her password sniffed. The attentive system admin will analyze his remote access logs looking for suspicious source addresses even for successful logins.

One must always assume that once an attacker has access to a user account, the attacker can break `root`. However, the reality is that in a well secured and maintained system, access to a user account does not necessarily give the attacker access to `root`. The distinction is important because without access to `root` the attacker cannot generally hide his tracks and may, at best, be able to do nothing more than mess with the user's files, or crash the machine. User account compromises are very common because users tend not to take the precautions that sysadmins take.

System administrators must keep in mind that there are potentially many ways to break `root` on a machine. The attacker may know the `root` password, the attacker may find a bug in a root-run server and be able to break `root` over a network connection to that server, or the attacker may know of a bug in a suid-root program that allows the attacker to break `root` once he has broken into a user's account. If an attacker has found a way to break `root` on a machine, the attacker may not have a need to install a backdoor. Many of the `root` holes found and closed to date involve a considerable amount of work by the attacker to cleanup after himself, so most attackers install backdoors. A backdoor provides the attacker with a way to easily regain `root` access to the system, but it also gives the smart system administrator a convenient way to detect the intrusion. Making it impossible for an attacker to install a backdoor may actually be detrimental to your security, because it will not close off the hole the attacker found to break in the first place.

Security remedies should always be implemented with a multi-layered "onion peel" approach and can be categorized as follows:

1. Securing `root` and staff accounts.
2. Securing `root` – root-run servers and suid/sgid binaries.
3. Securing user accounts.
4. Securing the password file.
5. Securing the kernel core, raw devices, and filesystems.
6. Quick detection of inappropriate changes made to the system.
7. Paranoia.

The next section of this chapter will cover the above bullet items in greater depth.

10.3 Securing FreeBSD

> **Command vs. Protocol:** Throughout this document, we will use **bold** text to refer to a command or application. This is used for instances such as ssh, since it is a protocol as well as command.

The sections that follow will cover the methods of securing your FreeBSD system that were mentioned in the last section of this chapter.

10.3.1 Securing the `root` Account and Staff Accounts

First off, do not bother securing staff accounts if you have not secured the `root` account. Most systems have a password assigned to the `root` account. The first thing you do is assume that the password is *always* compromised. This does not mean that you should remove the password. The password is almost always necessary for console access to the machine. What it does mean is that you should not make it possible to use the password outside of the console or possibly even with the su(1) command. For example, make sure that your pty's are specified as being insecure in the `/etc/ttys` file so that direct `root` logins via `telnet` or `rlogin` are disallowed. If using other login services such as **sshd**, make sure that direct `root` logins are disabled there as well. You can do this by editing your `/etc/ssh/sshd_config` file, and making sure that `PermitRootLogin` is set to `NO`. Consider every access method – services such as FTP often fall through the cracks. Direct `root` logins should only be allowed via the system console.

Of course, as a sysadmin you have to be able to get to `root`, so we open up a few holes. But we make sure these holes require additional password verification to operate. One way to make `root` accessible is to add appropriate staff accounts to the `wheel` group (in `/etc/group`). The staff members placed in the `wheel` group are allowed to `su` to `root`. You should never give staff members native `wheel` access by putting them in the `wheel` group in their password entry. Staff accounts should be placed in a `staff` group, and then added to the `wheel` group via the `/etc/group` file. Only those staff members who actually need to have `root` access should be placed in the `wheel` group. It is also possible, when using an authentication method such as Kerberos, to use Kerberos' `.k5login` file in the `root` account to allow a ksu(1) to `root` without having to place anyone at all in the `wheel` group. This may be the better solution since the `wheel` mechanism still allows an intruder to break `root` if the intruder has gotten hold of your password file and can break into a staff account. While having the `wheel` mechanism is better than having nothing at all, it is not necessarily the safest option.

An indirect way to secure staff accounts, and ultimately `root` access is to use an alternative login access method and do what is known as "starring" out the encrypted password for the staff accounts. Using the vipw(8) command, one can replace each instance of an encrypted password with a single "`*`" character. This command will update the `/etc/master.passwd` file and user/password database to disable password-authenticated logins.

A staff account entry such as:

```
foobar:R9DT/Fa1/LV9U:1000:1000::0:0:Foo Bar:/home/foobar:/usr/local/bin/tcsh
```

Should be changed to this:

```
foobar:*:1000:1000::0:0:Foo Bar:/home/foobar:/usr/local/bin/tcsh
```

This change will prevent normal logins from occurring, since the encrypted password will never match "`*`". With this done, staff members must use another mechanism to authenticate themselves such as kerberos(1) or ssh(1) using a public/private key pair. When using something like Kerberos, one generally must secure the machines which run the Kerberos servers and your desktop workstation. When using a public/private key pair with ssh, one must generally secure the machine used to login *from* (typically one's workstation). An additional layer of protection can be added to the key pair by password protecting the key pair when creating it with ssh-keygen(1). Being able to "star" out the passwords for staff accounts also guarantees that staff members can only login through secure access methods that you have set up. This forces all staff members to use secure, encrypted connections for all of their sessions, which closes an important hole used by many intruders: sniffing the network from an unrelated, less secure machine.

The more indirect security mechanisms also assume that you are logging in from a more restrictive server to a less restrictive server. For example, if your main box is running all sorts of servers, your workstation should not be running any. In order for your workstation to be reasonably secure you should run as few servers as possible, up to and including no servers at all, and you should run a password-protected screen blanker. Of course, given physical access to a workstation an attacker can break any sort of security you put on it. This is definitely a problem that you should consider, but you should also consider the fact that the vast majority of break-ins occur remotely, over a network, from people who do not have physical access to your workstation or servers.

Using something like Kerberos also gives you the ability to disable or change the password for a staff account in one place, and have it immediately effect all the machines on which the staff member may have an account. If a staff member's account gets compromised, the ability to instantly change his password on all machines should not be underrated. With discrete passwords, changing a password on N machines can be a mess. You can also impose re-passwording restrictions with Kerberos: not only can a Kerberos ticket be made to timeout after a while, but the Kerberos system can require that the user choose a new password after a certain period of time (say, once a month).

10.3.2 Securing Root-run Servers and SUID/SGID Binaries

The prudent sysadmin only runs the servers he needs to, no more, no less. Be aware that third party servers are often the most bug-prone. For example, running an old version of **imapd** or **popper** is like giving a universal `root` ticket out to the entire world. Never run a server that you have not checked out carefully. Many servers do not need to be run as `root`. For example, the **ntalk**, **comsat**, and **finger** daemons can be run in special user *sandboxes*. A sandbox is not perfect, unless you go through a large amount of trouble, but the onion approach to security still stands: If someone is able to break in through a server running in a sandbox, they still have to break out of the sandbox. The more layers the attacker must break through, the lower the likelihood of his success. Root holes have historically been found in virtually every server ever run as `root`, including basic system servers. If you are running a machine through which people only login via **sshd** and never login via **telnetd** or **rshd** or **rlogind**, then turn off those services!

FreeBSD now defaults to running **ntalkd**, **comsat**, and **finger** in a sandbox. Another program which may be a candidate for running in a sandbox is named(8). `/etc/defaults/rc.conf` includes the arguments necessary to run **named** in a sandbox in a commented-out form. Depending on whether you are installing a new system or upgrading an existing system, the special user accounts used by these sandboxes may not be installed. The prudent sysadmin would research and implement sandboxes for servers whenever possible.

There are a number of other servers that typically do not run in sandboxes: **sendmail**, **popper**, **imapd**, **ftpd**, and others. There are alternatives to some of these, but installing them may require more work than you are willing to perform (the convenience factor strikes again). You may have to run these servers as `root` and rely on other mechanisms to detect break-ins that might occur through them.

The other big potential `root` holes in a system are the suid-root and sgid binaries installed on the system. Most of these binaries, such as **rlogin**, reside in `/bin`, `/sbin`, `/usr/bin`, or `/usr/sbin`. While nothing is 100% safe, the system-default suid and sgid binaries can be considered reasonably safe. Still, `root` holes are occasionally found in these binaries. A `root` hole was found in `Xlib` in 1998 that made **xterm** (which is typically suid) vulnerable. It is better to be safe than sorry and the prudent sysadmin will restrict suid binaries, that only staff should run, to a special group that only staff can access, and get rid of (`chmod 000`) any suid binaries that nobody uses. A server with no display generally does not need an **xterm** binary. Sgid binaries can be almost as dangerous. If an intruder can break an sgid-kmem binary, the intruder might be able to read `/dev/kmem` and thus read the encrypted password file, potentially compromising any passworded account. Alternatively an intruder who breaks group `kmem` can monitor keystrokes sent through pty's, including pty's used by users who login through secure methods. An intruder that breaks the `tty` group can write to almost any user's tty. If a user is running a terminal program or emulator with a keyboard-simulation feature, the intruder can potentially generate a data stream that causes the user's terminal to echo a command, which is then run as that user.

10.3.3 Securing User Accounts

User accounts are usually the most difficult to secure. While you can impose Draconian access restrictions on your staff and "star" out their passwords, you may not be able to do so with any general user accounts you might have. If you do have sufficient control, then you may win out and be able to secure the user accounts properly. If not, you simply have to be more vigilant in your monitoring of those accounts. Use of ssh and Kerberos for user accounts is more problematic, due to the extra administration and technical support required, but still a very good solution compared to a crypted password file.

10.3.4 Securing the Password File

The only sure fire way is to `*` out as many passwords as you can and use ssh or Kerberos for access to those accounts. Even though the encrypted password file (`/etc/spwd.db`) can only be read by `root`, it may be possible for an intruder to obtain read access to that file even if the attacker cannot obtain root-write access.

Your security scripts should always check for and report changes to the password file (see the Checking file integrity section below).

10.3.5 Securing the Kernel Core, Raw Devices, and Filesystems

If an attacker breaks `root` he can do just about anything, but there are certain conveniences. For example, most modern kernels have a packet sniffing device driver built in. Under FreeBSD it is called the `bpf` device. An intruder will commonly attempt to run a packet sniffer on a compromised machine. You do not need to give the intruder the capability and most systems do not have the need for the `bpf` device compiled in.

But even if you turn off the `bpf` device, you still have `/dev/mem` and `/dev/kmem` to worry about. For that matter, the intruder can still write to raw disk devices. Also, there is another kernel feature called the module loader, kldload(8). An enterprising intruder can use a KLD module to install his own `bpf` device, or other sniffing device, on a running kernel. To avoid these problems you have to run the kernel at a higher secure level, at least securelevel 1. The securelevel can be set with a `sysctl` on the `kern.securelevel` variable. Once you have set the securelevel to 1, write access to raw devices will be denied and special `chflags` flags, such as `schg`, will be enforced. You must also ensure that the `schg` flag is set on critical startup binaries, directories, and script files – everything that gets run up to the point where the securelevel is set. This might be overdoing it, and upgrading the system is much more difficult when you operate at a higher secure level. You may compromise and run the system at a higher secure level but not set the `schg` flag for every system file and directory under the sun. Another possibility is to simply mount `/` and `/usr` read-only. It should be noted that being too Draconian in what you attempt to protect may prevent the all-important detection of an intrusion.

10.3.6 Checking File Integrity: Binaries, Configuration Files, Etc.

When it comes right down to it, you can only protect your core system configuration and control files so much before the convenience factor rears its ugly head. For example, using `chflags` to set the `schg` bit on most of the files in `/` and `/usr` is probably counterproductive, because while it may protect the files, it also closes a detection window. The last layer of your security onion is perhaps the most important – detection. The rest of your security is pretty much useless (or, worse, presents you with a false sense of safety) if you cannot detect potential incursions. Half the job of the onion is to slow down the attacker, rather than stop him, in order to give the detection side of the equation a chance to catch him in the act.

The best way to detect an incursion is to look for modified, missing, or unexpected files. The best way to look for modified files is from another (often centralized) limited-access system. Writing your security scripts on the extra-secure limited-access system makes them mostly invisible to potential attackers, and this is important. In order to take maximum advantage you generally have to give the limited-access box significant access to the other machines in the business, usually either by doing a read-only NFS export of the other machines to the limited-access box, or by setting up ssh key-pairs to allow the limited-access box to ssh to the other machines. Except for its network traffic, NFS is the least visible method – allowing you to monitor the filesystems on each client box virtually undetected. If your limited-access server is connected to the client boxes through a switch, the NFS method is often the better choice. If your limited-access server is connected to the client boxes through a hub, or through several layers of routing, the NFS method may be too insecure (network-wise) and using ssh may be the better choice even with the audit-trail tracks that ssh lays.

Once you give a limited-access box, at least read access to the client systems it is supposed to monitor, you must write scripts to do the actual monitoring. Given an NFS mount, you can write scripts out of simple system utilities such as find(1) and md5(1). It is best to physically md5 the client-box files at least once a day, and to test control files such as those found in `/etc` and `/usr/local/etc` even more often. When mismatches are found, relative to the base md5 information the limited-access machine knows is valid, it should scream at a sysadmin to go check it out. A good security script will also check for inappropriate suid binaries and for new or deleted files on system partitions such as `/` and `/usr`.

When using ssh rather than NFS, writing the security script is much more difficult. You essentially have to `scp` the scripts to the client box in order to run them, making them visible, and for safety you also need to `scp` the binaries (such as find) that those scripts use. The **ssh** client on the client box may already be compromised. All in all, using ssh may be necessary when running over insecure links, but it is also a lot harder to deal with.

A good security script will also check for changes to user and staff members access configuration files: `.rhosts`, `.shosts`, `.ssh/authorized_keys` and so forth. . . files that might fall outside the purview of the `MD5` check.

If you have a huge amount of user disk space, it may take too long to run through every file on those partitions. In this case, setting mount flags to disallow suid binaries and devices on those partitions is a good idea. The `nodev` and `nosuid` options (see mount(8)) are what you want to look into. You should probably scan them anyway, at least once a week, since the object of this layer is to detect a break-in whether or not the break-in is effective.

Process accounting (see accton(8)) is a relatively low-overhead feature of the operating system which might help as a post-break-in evaluation mechanism. It is especially useful in tracking down how an intruder has actually broken into a system, assuming the file is still intact after the break-in occurs.

Finally, security scripts should process the log files, and the logs themselves should be generated in as secure a manner as possible – remote syslog can be very useful. An intruder tries to cover his tracks, and log files are critical to the sysadmin trying to track down the time and method of the initial break-in. One way to keep a permanent record of the log files is to run the system console to a serial port and collect the information on a continuing basis through a secure machine monitoring the consoles.

10.3.7 Paranoia

A little paranoia never hurts. As a rule, a sysadmin can add any number of security features, as long as they do not effect convenience, and can add security features that *do* effect convenience with some added thought. Even more importantly, a security administrator should mix it up a bit – if you use recommendations such as those given by this document verbatim, you give away your methodologies to the prospective attacker who also has access to this document.

10.3.8 Denial of Service Attacks

This section covers Denial of Service attacks. A DoS attack is typically a packet attack. While there is not much you can do about modern spoofed packet attacks that saturate your network, you can generally limit the damage by ensuring that the attacks cannot take down your servers.

1. Limiting server forks.
2. Limiting springboard attacks (ICMP response attacks, ping broadcast, etc.).
3. Kernel Route Cache.

A common DoS attack is against a forking server that attempts to cause the server to eat processes, file descriptors, and memory, until the machine dies. **inetd** (see inetd(8)) has several options to limit this sort of attack. It should be noted that while it is possible to prevent a machine from going down, it is not generally possible to prevent a service from being disrupted by the attack. Read the **inetd** manual page carefully and pay specific attention to the `-c`, `-C`, and `-R` options. Note that spoofed-IP attacks will circumvent the `-C` option to **inetd**, so typically a combination of options must be used. Some standalone servers have self-fork-limitation parameters.

Sendmail has its `-OMaxDaemonChildren` option, which tends to work much better than trying to use sendmail's load limiting options due to the load lag. You should specify a `MaxDaemonChildren` parameter, when you start **sendmail**, high enough to handle your expected load, but not so high that the computer cannot handle that number of **sendmails** without falling on its face. It is also prudent to run sendmail in queued mode (`-ODeliveryMode=queued`) and to run the daemon (`sendmail -bd`) separate from the queue-runs (`sendmail -q15m`). If you still want real-time delivery you can run the queue at a much lower interval, such as `-q1m`, but be sure to specify a reasonable `MaxDaemonChildren` option for *that* sendmail to prevent cascade failures.

Syslogd can be attacked directly and it is strongly recommended that you use the `-s` option whenever possible, and the `-a` option otherwise.

You should also be fairly careful with connect-back services such as **tcpwrapper**'s reverse-identd, which can be attacked directly. You generally do not want to use the reverse-ident feature of **tcpwrappers** for this reason.

It is a very good idea to protect internal services from external access by firewalling them off at your border routers. The idea here is to prevent saturation attacks from outside your LAN, not so much to protect internal services from network-based `root` compromise. Always configure an exclusive firewall, i.e., "firewall everything *except* ports A, B, C, D, and M-Z". This way you can firewall off all of your low ports except for certain specific services such as **named** (if you are primary for a zone), **ntalkd**, **sendmail**, and other Internet-accessible services. If you try to configure the firewall the other way – as an inclusive or permissive firewall, there is a good chance that you will forget to "close" a couple of services, or that you will add a new internal service and forget to update the firewall. You can still open up the high-numbered port range on the firewall, to allow permissive-like operation, without compromising your low ports. Also take note that FreeBSD allows you to control the range of port numbers used for dynamic binding, via the various `net.inet.ip.portrange` `sysctl`'s (`sysctl -a | fgrep portrange`), which can also ease the complexity of your firewall's configuration. For example, you might use a normal first/last range of 4000 to 5000, and a hiport range of 49152 to 65535, then block off everything under 4000 in your firewall (except for certain specific Internet-accessible ports, of course).

Another common DoS attack is called a springboard attack – to attack a server in a manner that causes the server to generate responses which overloads the server, the local network, or some other machine. The most common attack of this nature is the *ICMP ping broadcast attack*. The attacker spoofs ping packets sent to your LAN's broadcast address with the source IP address set to the actual machine they wish to attack. If your border routers are not configured to stomp on ping's to broadcast addresses, your LAN winds up generating sufficient responses to the spoofed source address to saturate the victim, especially when the attacker uses the same trick on several dozen broadcast addresses over several dozen different networks at once. Broadcast attacks of over a hundred and twenty megabits have been measured. A second common springboard attack is against the ICMP error reporting system. By constructing packets that generate ICMP error responses, an attacker can saturate a server's incoming network and cause the server to saturate its outgoing network with ICMP responses. This type of attack can also crash the server by running it out of mbuf's, especially if the server cannot drain the ICMP responses it generates fast enough. The FreeBSD kernel has a new kernel compile option called `ICMP_BANDLIM` which limits the effectiveness of these sorts of attacks. The last major class of springboard attacks is related to certain internal **inetd** services such as the udp echo service. An attacker simply spoofs a UDP packet with the source address being server A's echo port, and the destination address being server B's echo port, where server A and B are both on your LAN. The two servers then bounce this one packet back and forth between each other. The attacker can overload both servers and their LANs simply by injecting a few packets in this manner. Similar problems exist with the internal **chargen** port. A competent sysadmin will turn off all of these inetd-internal test services.

Spoofed packet attacks may also be used to overload the kernel route cache. Refer to the `net.inet.ip.rtexpire`, `rtminexpire`, and `rtmaxcache` `sysctl` parameters. A spoofed packet attack that uses a random source IP will cause the kernel to generate a temporary cached route in the route table, viewable with `netstat -rna | fgrep W3`. These routes typically timeout in 1600 seconds or so. If the kernel detects that the cached route table has gotten too big it will dynamically reduce the `rtexpire` but will never decrease it to less than `rtminexpire`. There are two problems:

1. The kernel does not react quickly enough when a lightly loaded server is suddenly attacked.
2. The `rtminexpire` is not low enough for the kernel to survive a sustained attack.

If your servers are connected to the Internet via a T3 or better, it may be prudent to manually override both `rtexpire` and `rtminexpire` via sysctl(8). Never set either parameter to zero (unless you want to crash the machine). Setting both parameters to 2 seconds should be sufficient to protect the route table from attack.

10.3.9 Access Issues with Kerberos and SSH

There are a few issues with both Kerberos and ssh that need to be addressed if you intend to use them. Kerberos V is an excellent authentication protocol, but there are bugs in the kerberized **telnet** and **rlogin** applications that make them unsuitable for dealing with binary streams. Also, by default Kerberos does not encrypt a session unless you use the `-x` option. **ssh** encrypts everything by default.

ssh works quite well in every respect except that it forwards encryption keys by default. What this means is that if you have a secure workstation holding keys that give you access to the rest of the system, and you ssh to an insecure machine, your keys are usable. The actual keys themselves are not exposed, but ssh installs a forwarding port for the duration of your login, and if an attacker has broken `root` on the insecure machine he can utilize that port to use your keys to gain access to any other machine that your keys unlock.

We recommend that you use ssh in combination with Kerberos whenever possible for staff logins. **ssh** can be compiled with Kerberos support. This reduces your reliance on potentially exposable ssh keys while at the same time protecting passwords via Kerberos. ssh keys should only be used for automated tasks from secure machines (something that Kerberos is unsuited to do). We also recommend that you either turn off key-forwarding in the ssh configuration, or that you make use of the `from=IP/DOMAIN` option that ssh allows in its `authorized_keys` file to make the key only usable to entities logging in from specific machines.

10.4 DES, MD5, and Crypt

Parts rewritten and updated by Bill Swingle.

Every user on a UNIX system has a password associated with their account. It seems obvious that these passwords need to be known only to the user and the actual operating system. In order to keep these passwords secret, they are encrypted with what is known as a "one-way hash", that is, they can only be easily encrypted but not decrypted. In other words, what we told you a moment ago was obvious is not even true: the operating system itself does not *really* know the password. It only knows the *encrypted* form of the password. The only way to get the "plain-text" password is by a brute force search of the space of possible passwords.

Unfortunately the only secure way to encrypt passwords when UNIX came into being was based on DES, the Data Encryption Standard. This was not such a problem for users resident in the US, but since the source code for DES could not be exported outside the US, FreeBSD had to find a way to both comply with US law and retain compatibility with all the other UNIX variants that still used DES.

The solution was to divide up the encryption libraries so that US users could install the DES libraries and use DES but international users still had an encryption method that could be exported abroad. This is how FreeBSD came to use MD5 as its default encryption method. MD5 is believed to be more secure than DES, so installing DES is offered primarily for compatibility reasons.

10.4.1 Recognizing Your Crypt Mechanism

Before FreeBSD 4.4 `libcrypt.a` was a symbolic link pointing to the library which was used for encryption. FreeBSD 4.4 changed `libcrypt.a` to provide a configurable password authentication hash library. Currently the library supports DES, MD5 and Blowfish hash functions. By default FreeBSD uses MD5 to encrypt passwords.

It is pretty easy to identify which encryption method FreeBSD is set up to use. Examining the encrypted passwords in the `/etc/master.passwd` file is one way. Passwords encrypted with the MD5 hash are longer than those encrypted with the DES hash and also begin with the characters `$1$`. Passwords starting with `$2$` are encrypted with the Blowfish hash function. DES password strings do not have any particular identifying characteristics, but they are shorter than MD5 passwords, and are coded in a 64-character alphabet which does not include the `$` character, so a relatively short string which does not begin with a dollar sign is very likely a DES password.

The password format used for new passwords is controlled by the `passwd_format` login capability in `/etc/login.conf`, which takes values of `des`, `md5` or `blf`. See the login.conf(5) manual page for more information about login capabilities.

10.5 One-time Passwords

S/Key is a one-time password scheme based on a one-way hash function. FreeBSD uses the MD4 hash for compatibility but other systems have used MD5 and DES-MAC. S/Key has been part of the FreeBSD base system since version 1.1.5 and is also used on a growing number of other operating systems. S/Key is a registered trademark of Bell Communications Research, Inc.

From version 5.0 of FreeBSD, S/Key has been replaced with the functionally equivalent OPIE (One-time Passwords In Everything). OPIE uses the MD5 hash by default.

There are three different sorts of passwords which we will discuss below. The first is your usual UNIX style or Kerberos password; we will call this a “UNIX password”. The second sort is the one-time password which is generated by the S/Key `key` program or the OPIE opiekey(1) program and accepted by the `keyinit` or opiepasswd(1) programs and the login prompt; we will call this a “one-time password”. The final sort of password is the secret password which you give to the `key`/`opiekey` programs (and sometimes the `keyinit`/`opiepasswd` programs) which it uses to generate one-time passwords; we will call it a “secret password” or just unqualified “password”.

The secret password does not have anything to do with your UNIX password; they can be the same but this is not recommended. S/Key and OPIE secret passwords are not limited to 8 characters like old UNIX passwords[1], they can be as long as you like. Passwords of six or seven word long phrases are fairly common. For the most part, the S/Key or OPIE system operates completely independently of the UNIX password system.

Besides the password, there are two other pieces of data that are important to S/Key and OPIE. One is what is known as the “seed” or “key”, consisting of two letters and five digits. The other is what is called the “iteration count”, a number between 1 and 100. S/Key creates the one-time password by concatenating the seed and the secret password, then applying the MD4/MD5 hash as many times as specified by the iteration count and turning the result into six short English words. These six English words are your one-time password. The authentication system (primarily PAM) keeps track of the last one-time password used, and the user is authenticated if the hash of the user-provided password is equal to the previous password. Because a one-way hash is used it is impossible to generate future one-time passwords if a successfully used password is captured; the iteration count is decremented after each successful login to keep the user and the login program in sync. When the iteration count gets down to 1, S/Key and OPIE must be reinitialized.

There are three programs involved in each system which we will discuss below. The `key` and `opiekey` programs accept an iteration count, a seed, and a secret password, and generate a one-time password or a consecutive list of one-time passwords. The `keyinit` and `opiepasswd` programs are used to initialize S/Key and OPIE respectively, and to change passwords, iteration counts, or seeds; they take either a secret passphrase, or an iteration count, seed, and one-time password. The `keyinfo` and `opieinfo` programs examine the relevant credentials files (`/etc/skeykeys` or `/etc/opiekeys`) and print out the invoking user's current iteration count and seed.

There are four different sorts of operations we will cover. The first is using `keyinit` or `opiepasswd` over a secure connection to set up one-time-passwords for the first time, or to change your password or seed. The second operation is using `keyinit` or `opiepasswd` over an insecure connection, in conjunction with `key` or `opiekey` over a secure connection, to do the same. The third is using `key`/`opiekey` to log in over an insecure connection. The fourth is using `key` or `opiekey` to generate a number of keys which can be written down or printed out to carry with you when going to some location without secure connections to anywhere.

10.5.1 Secure Connection Initialization

To initialize S/Key for the first time, change your password, or change your seed while logged in over a secure connection (e.g., on the console of a machine or via **ssh**), use the `keyinit` command without any parameters while logged in as yourself:

```
% keyinit
Adding unfurl:
Reminder - Only use this method if you are directly connected.
If you are using telnet or rlogin exit with no password and use keyinit -s.
Enter secret password:
Again secret password:

ID unfurl s/key is 99 to17757
DEFY CLUB PRO NASH LACE SOFT
```

For OPIE, `opiepasswd` is used instead:

```
% opiepasswd -c
[grimreaper] ~ $ opiepasswd -f -c
Adding unfurl:
Only use this method from the console; NEVER from remote. If you are using
telnet, xterm, or a dial-in, type ^C now or exit with no password.
Then run opiepasswd without the -c parameter.
Using MD5 to compute responses.
Enter new secret pass phrase:
Again new secret pass phrase:
ID unfurl OTP key is 499 to4268
MOS MALL GOAT ARM AVID COED
```

At the `Enter new secret pass phrase:` or `Enter secret password:` prompts, you should enter a password or phrase. Remember, this is not the password that you will use to login with, this is used to generate your one-time login keys. The "ID" line gives the parameters of your particular instance: your login name, the iteration count, and seed. When logging in the system will remember these parameters and present them back to you so you do not have to remember them. The last line gives the particular one-time password which corresponds to those parameters and your secret password; if you were to re-login immediately, this one-time password is the one you would use.

10.5.2 Insecure Connection Initialization

To initialize or change your secret password over an insecure connection, you will need to already have a secure connection to some place where you can run `key` or `opiekey`; this might be in the form of a desk accessory on a Macintosh, or a shell prompt on a machine you trust. You will also need to make up an iteration count (100 is probably a good value), and you may make up your own seed or use a randomly-generated one. Over on the insecure connection (to the machine you are initializing), use the `keyinit -s` command:

```
% keyinit -s
Updating unfurl:
Old key: to17758
Reminder you need the 6 English words from the key command.
Enter sequence count from 1 to 9999: 100
Enter new key [default to17759]:
s/key 100 to 17759
s/key access password:
s/key access password:CURE MIKE BANE HIM RACY GORE
```

For OPIE, you need to use `opiepasswd`:

```
% opiepasswd

Updating unfurl:
You need the response from an OTP generator.
Old secret pass phrase:
        otp-md5 498 to4268 ext
        Response: GAME GAG WELT OUT DOWN CHAT
New secret pass phrase:
        otp-md5 499 to4269
        Response: LINE PAP MILK NELL BUOY TROY

ID mark OTP key is 499 gr4269
LINE PAP MILK NELL BUOY TROY
```

To accept the default seed (which the `keyinit` program confusingly calls a `key`), press **Return**. Then before entering an access password, move over to your secure connection or S/Key desk accessory, and give it the same parameters:

```
% key 100 to17759
Reminder - Do not use this program while logged in via telnet or rlogin.
Enter secret password: <secret password>
CURE MIKE BANE HIM RACY GORE
```

Or for OPIE:

```
% opiekey 498 to4268
Using the MD5 algorithm to compute response.
Reminder: Don’t use opiekey from telnet or dial-in sessions.
Enter secret pass phrase:
```

```
GAME GAG WELT OUT DOWN CHAT
```

Now switch back over to the insecure connection, and copy the one-time password generated over to the relevant program.

10.5.3 Generating a Single One-time Password

Once you have initialized S/Key or OPIE, when you login you will be presented with a prompt like this:

```
% telnet example.com
Trying 10.0.0.1...
Connected to example.com
Escape character is '^]'.

FreeBSD/i386 (example.com) (ttypa)

login: <username>
s/key 97 fw13894
Password:
```

Or for OPIE:

```
% telnet example.com
Trying 10.0.0.1...
Connected to example.com
Escape character is '^]'.

FreeBSD/i386 (example.com) (ttypa)

login: <username>
otp-md5 498 gr4269 ext
Password:
```

As a side note, the S/Key and OPIE prompts have a useful feature (not shown here): if you press **Return** at the password prompt, the prompter will turn echo on, so you can see what you are typing. This can be extremely useful if you are attempting to type in a password by hand, such as from a printout.

At this point you need to generate your one-time password to answer this login prompt. This must be done on a trusted system that you can run `key` or `opiekey` on. (There are versions of these for DOS, Windows and Mac OS as well.) They need both the iteration count and the seed as command line options. You can cut-and-paste these right from the login prompt on the machine that you are logging in to.

On the trusted system:

```
% key 97 fw13894
Reminder - Do not use this program while logged in via telnet or rlogin.
Enter secret password:
WELD LIP ACTS ENDS ME HAAG
```

For OPIE:

```
% opiekey 498 to4268
Using the MD5 algorithm to compute response.
```

```
Reminder: Don't use opiekey from telnet or dial-in sessions.
Enter secret pass phrase:
GAME GAG WELT OUT DOWN CHAT
```

Now that you have your one-time password you can continue logging in:

```
login: <username>
s/key 97 fw13894
Password: <return to enable echo>
s/key 97 fw13894
Password [echo on]: WELD LIP ACTS ENDS ME HAAG
Last login: Tue Mar 21 11:56:41 from 10.0.0.2 ...
```

10.5.4 Generating Multiple One-time Passwords

Sometimes you have to go places where you do not have access to a trusted machine or secure connection. In this case, it is possible to use the `key` and `opiekey` commands to generate a number of one-time passwords beforehand to be printed out and taken with you. For example:

```
% key -n 5 30 zz99999
Reminder - Do not use this program while logged in via telnet or rlogin.
Enter secret password: <secret password>
26: SODA RUDE LEA LIND BUDD SILT
27: JILT SPY DUTY GLOW COWL ROT
28: THEM OW COLA RUNT BONG SCOT
29: COT MASH BARR BRIM NAN FLAG
30: CAN KNEE CAST NAME FOLK BILK
```

Or for OPIE:

```
% opiekey -n 5 30 zz99999
Using the MD5 algorithm to compute response.
Reminder: Don't use opiekey from telnet or dial-in sessions.
Enter secret pass phrase: <secret password>
26: JOAN BORE FOSS DES NAY QUIT
27: LATE BIAS SLAY FOLK MUCH TRIG
28: SALT TIN ANTI LOON NEAL USE
29: RIO ODIN GO BYE FURY TIC
30: GREW JIVE SAN GIRD BOIL PHI
```

The `-n 5` requests five keys in sequence, the `30` specifies what the last iteration number should be. Note that these are printed out in *reverse* order of eventual use. If you are really paranoid, you might want to write the results down by hand; otherwise you can cut-and-paste into `lpr`. Note that each line shows both the iteration count and the one-time password; you may still find it handy to scratch off passwords as you use them.

10.5.5 Restricting Use of UNIX® Passwords

S/Key can place restrictions on the use of UNIX passwords based on the host name, user name, terminal port, or IP address of a login session. These restrictions can be found in the configuration file `/etc/skey.access`. The skey.access(5) manual page has more information on the complete format of the file and also details some security cautions to be aware of before depending on this file for security.

If there is no `/etc/skey.access` file (this is the default on FreeBSD 4.X systems), then all users will be allowed to use UNIX passwords. If the file exists, however, then all users will be required to use S/Key unless explicitly permitted to do otherwise by configuration statements in the `skey.access` file. In all cases, UNIX passwords are permitted on the console.

Here is a sample `skey.access` configuration file which illustrates the three most common sorts of configuration statements:

```
permit internet 192.168.0.0 255.255.0.0
permit user fnord
permit port ttyd0
```

The first line (`permit internet`) allows users whose IP source address (which is vulnerable to spoofing) matches the specified value and mask, to use UNIX passwords. This should not be considered a security mechanism, but rather, a means to remind authorized users that they are using an insecure network and need to use S/Key for authentication.

The second line (`permit user`) allows the specified username, in this case `fnord`, to use UNIX passwords at any time. Generally speaking, this should only be used for people who are either unable to use the `key` program, like those with dumb terminals, or those who are uneducable.

The third line (`permit port`) allows all users logging in on the specified terminal line to use UNIX passwords; this would be used for dial-ups.

OPIE can restrict the use of UNIX passwords based on the IP address of a login session just like S/Key does. The relevant file is `/etc/opieaccess`, which is present by default on FreeBSD 5.0 and newer systems. Please check opieaccess(5) for more information on this file and which security considerations you should be aware of when using it.

Here is a sample `opieaccess` file:

```
permit 192.168.0.0 255.255.0.0
```

This line allows users whose IP source address (which is vulnerable to spoofing) matches the specified value and mask, to use UNIX passwords at any time.

If no rules in `opieaccess` are matched, the default is to deny non-OPIE logins.

10.6 KerberosIV

Contributed by Mark Murray. Based on a contribution by Mark Dapoz.

Kerberos is a network add-on system/protocol that allows users to authenticate themselves through the services of a secure server. Services such as remote login, remote copy, secure inter-system file copying and other high-risk tasks are made considerably safer and more controllable.

The following instructions can be used as a guide on how to set up Kerberos as distributed for FreeBSD. However, you should refer to the relevant manual pages for a complete description.

10.6.1 Installing KerberosIV

Kerberos is an optional component of FreeBSD. The easiest way to install this software is by selecting the `krb4` or `krb5` distribution in **sysinstall** during the initial installation of FreeBSD. This will install the "eBones" (KerberosIV) or "Heimdal" (Kerberos5) implementation of Kerberos. These implementations are included because they are developed outside the USA/Canada and were thus available to system owners outside those countries during the era of restrictive export controls on cryptographic code from the USA.

Alternatively, the MIT implementation of Kerberos is available from the ports collection as `security/krb5`.

10.6.2 Creating the Initial Database

This is done on the Kerberos server only. First make sure that you do not have any old Kerberos databases around. You should change to the directory `/etc/kerberosIV` and check that only the following files are present:

```
# cd /etc/kerberosIV
# ls
README krb.conf        krb.realms
```

If any additional files (such as `principal.*` or `master_key`) exist, then use the `kdb_destroy` command to destroy the old Kerberos database, or if Kerberos is not running, simply delete the extra files.

You should now edit the `krb.conf` and `krb.realms` files to define your Kerberos realm. In this case the realm will be `EXAMPLE.COM` and the server is `grunt.example.com`. We edit or create the `krb.conf` file:

```
# cat krb.conf
EXAMPLE.COM
EXAMPLE.COM grunt.example.com admin server
CS.BERKELEY.EDU okeeffe.berkeley.edu
ATHENA.MIT.EDU kerberos.mit.edu
ATHENA.MIT.EDU kerberos-1.mit.edu
ATHENA.MIT.EDU kerberos-2.mit.edu
ATHENA.MIT.EDU kerberos-3.mit.edu
LCS.MIT.EDU kerberos.lcs.mit.edu
TELECOM.MIT.EDU bitsy.mit.edu
ARC.NASA.GOV trident.arc.nasa.gov
```

In this case, the other realms do not need to be there. They are here as an example of how a machine may be made aware of multiple realms. You may wish to not include them for simplicity.

The first line names the realm in which this system works. The other lines contain realm/host entries. The first item on a line is a realm, and the second is a host in that realm that is acting as a "key distribution center". The words `admin server` following a host's name means that host also provides an administrative database server. For further explanation of these terms, please consult the Kerberos manual pages.

Now we have to add `grunt.example.com` to the `EXAMPLE.COM` realm and also add an entry to put all hosts in the `.example.com` domain in the `EXAMPLE.COM` realm. The `krb.realms` file would be updated as follows:

```
# cat krb.realms
grunt.example.com EXAMPLE.COM
.example.com EXAMPLE.COM
.berkeley.edu CS.BERKELEY.EDU
.MIT.EDU ATHENA.MIT.EDU
```

```
.mit.edu ATHENA.MIT.EDU
```

Again, the other realms do not need to be there. They are here as an example of how a machine may be made aware of multiple realms. You may wish to remove them to simplify things.

The first line puts the *specific* system into the named realm. The rest of the lines show how to default systems of a particular subdomain to a named realm.

Now we are ready to create the database. This only needs to run on the Kerberos server (or Key Distribution Center). Issue the `kdb_init` command to do this:

```
# kdb_init
Realm name [default  ATHENA.MIT.EDU ]: EXAMPLE.COM
You will be prompted for the database Master Password.
It is important that you NOT FORGET this password.

Enter Kerberos master key:
```

Now we have to save the key so that servers on the local machine can pick it up. Use the `kstash` command to do this:

```
# kstash

Enter Kerberos master key:

Current Kerberos master key version is 1.

Master key entered. BEWARE!
```

This saves the encrypted master password in `/etc/kerberosIV/master_key`.

10.6.3 Making It All Run

Two principals need to be added to the database for *each* system that will be secured with Kerberos. Their names are `kpasswd` and `rcmd`. These two principals are made for each system, with the instance being the name of the individual system.

These daemons, **kpasswd** and **rcmd** allow other systems to change Kerberos passwords and run commands like rcp(1), rlogin(1) and rsh(1).

Now let us add these entries:

```
# kdb_edit
Opening database...

Enter Kerberos master key:

Current Kerberos master key version is 1.

Master key entered.  BEWARE!
Previous or default values are in [brackets] ,
enter return to leave the same, or new value.

Principal name: passwd
Instance: grunt
```

```
<Not found>, Create [y] ? y

Principal: passwd, Instance: grunt, kdc_key_ver: 1
New Password:                    <---- enter RANDOM here
Verifying password

New Password: <---- enter RANDOM here

Random password [y] ? y

Principal's new key version = 1
Expiration date (enter yyyy-mm-dd) [ 2000-01-01 ] ?
Max ticket lifetime (*5 minutes) [ 255 ] ?
Attributes [ 0 ] ?
Edit O.K.
Principal name: rcmd
Instance: grunt

<Not found>, Create [y] ?

Principal: rcmd, Instance: grunt, kdc_key_ver: 1
New Password: <---- enter RANDOM here
Verifying password

New Password:           <---- enter RANDOM here

Random password [y] ?

Principal's new key version = 1
Expiration date (enter yyyy-mm-dd) [ 2000-01-01 ] ?
Max ticket lifetime (*5 minutes) [ 255 ] ?
Attributes [ 0 ] ?
Edit O.K.
Principal name:         <---- null entry here will cause an exit
```

10.6.4 Creating the Server File

We now have to extract all the instances which define the services on each machine. For this we use the `ext_srvtab` command. This will create a file which must be copied or moved *by secure means* to each Kerberos client's `/etc/kerberosIV` directory. This file must be present on each server and client, and is crucial to the operation of Kerberos.

```
# ext_srvtab grunt
Enter Kerberos master key:

Current Kerberos master key version is 1.

Master key entered. BEWARE!
Generating 'grunt-new-srvtab'....
```

Now, this command only generates a temporary file which must be renamed to `srvtab` so that all the servers can pick it up. Use the mv(1) command to move it into place on the original system:

```
# mv grunt-new-srvtab srvtab
```

If the file is for a client system, and the network is not deemed safe, then copy the *`client`*`-new-srvtab` to removable media and transport it by secure physical means. Be sure to rename it to `srvtab` in the client's `/etc/kerberosIV` directory, and make sure it is mode 600:

```
# mv grumble-new-srvtab srvtab
# chmod 600 srvtab
```

10.6.5 Populating the Database

We now have to add some user entries into the database. First let us create an entry for the user `jane`. Use the `kdb_edit` command to do this:

```
# kdb_edit
Opening database...

Enter Kerberos master key:

Current Kerberos master key version is 1.

Master key entered.  BEWARE!
Previous or default values are in [brackets] ,
enter return to leave the same, or new value.

Principal name: jane
Instance:

<Not found>, Create [y] ? y

Principal: jane, Instance: , kdc_key_ver: 1
New Password:                <---- enter a secure password here
Verifying password

New Password:                <---- re-enter the password here
Principal's new key version = 1
Expiration date (enter yyyy-mm-dd) [ 2000-01-01 ] ?
Max ticket lifetime (*5 minutes) [ 255 ] ?
Attributes [ 0 ] ?
Edit O.K.
Principal name:    <---- null entry here will cause an exit
```

10.6.6 Testing It All Out

First we have to start the Kerberos daemons. Note that if you have correctly edited your `/etc/rc.conf` then this will happen automatically when you reboot. This is only necessary on the Kerberos server. Kerberos clients will automatically get what they need from the `/etc/kerberosIV` directory.

```
# kerberos &
Kerberos server starting
Sleep forever on error
Log file is /var/log/kerberos.log
Current Kerberos master key version is 1.

Master key entered. BEWARE!

Current Kerberos master key version is 1
Local realm: EXAMPLE.COM
# kadmind -n &
KADM Server KADM0.0A initializing
Please do not use 'kill -9' to kill this job, use a
regular kill instead

Current Kerberos master key version is 1.

Master key entered.  BEWARE!
```

Now we can try using the `kinit` command to get a ticket for the ID `jane` that we created above:

```
% kinit jane
MIT Project Athena (grunt.example.com)
Kerberos Initialization for "jane"
Password:
```

Try listing the tokens using `klist` to see if we really have them:

```
% klist
Ticket file:    /tmp/tkt245
Principal:      jane@EXAMPLE.COM

  Issued           Expires          Principal
Apr 30 11:23:22  Apr 30 19:23:22  krbtgt.EXAMPLE.COM@EXAMPLE.COM
```

Now try changing the password using passwd(1) to check if the **kpasswd** daemon can get authorization to the Kerberos database:

```
% passwd
realm EXAMPLE.COM
Old password for jane:
New Password for jane:
Verifying password
New Password for jane:
Password changed.
```

10.6.7 Adding su Privileges

Kerberos allows us to give *each* user who needs `root` privileges their own *separate* su(1) password. We could now add an ID which is authorized to su(1) to `root`. This is controlled by having an instance of `root` associated with a principal. Using `kdb_edit` we can create the entry `jane.root` in the Kerberos database:

```
# kdb_edit
Opening database...

Enter Kerberos master key:

Current Kerberos master key version is 1.

Master key entered.  BEWARE!
Previous or default values are in [brackets] ,
enter return to leave the same, or new value.

Principal name: jane
Instance: root

<Not found>, Create [y] ? y

Principal: jane, Instance: root, kdc_key_ver: 1
New Password:                    <---- enter a SECURE password here
Verifying password

New Password:          <---- re-enter the password here

Principal's new key version = 1
Expiration date (enter yyyy-mm-dd) [ 2000-01-01 ] ?
Max ticket lifetime (*5 minutes) [ 255 ] ? 12 <--- Keep this short!
Attributes [ 0 ] ?
Edit O.K.
Principal name:           <---- null entry here will cause an exit
```

Now try getting tokens for it to make sure it works:

```
# kinit jane.root
MIT Project Athena (grunt.example.com)
Kerberos Initialization for "jane.root"
Password:
```

Now we need to add the user to `root`'s `.klogin` file:

```
# cat /root/.klogin
jane.root@EXAMPLE.COM
```

Now try doing the su(1):

```
% su
Password:
```

and take a look at what tokens we have:

```
# klist
Ticket file: /tmp/tkt_root_245
Principal:      jane.root@EXAMPLE.COM

  Issued           Expires          Principal
May  2 20:43:12  May  3 04:43:12  krbtgt.EXAMPLE.COM@EXAMPLE.COM
```

10.6.8 Using Other Commands

In an earlier example, we created a principal called `jane` with an instance `root`. This was based on a user with the same name as the principal, and this is a Kerberos default; that a `<principal>.<instance>` of the form `<username>.root` will allow that `<username>` to su(1) to `root` if the necessary entries are in the `.klogin` file in `root`'s home directory:

```
# cat /root/.klogin
jane.root@EXAMPLE.COM
```

Likewise, if a user has in their own home directory lines of the form:

```
% cat ~/.klogin
jane@EXAMPLE.COM
jack@EXAMPLE.COM
```

This allows anyone in the `EXAMPLE.COM` realm who has authenticated themselves as `jane` or `jack` (via `kinit`, see above) to access to `jane`'s account or files on this system (`grunt`) via rlogin(1), rsh(1) or rcp(1).

For example, `jane` now logs into another system using Kerberos:

```
% kinit
MIT Project Athena (grunt.example.com)
Password:
% rlogin grunt
Last login: Mon May  1 21:14:47 from grumble
Copyright (c) 1980, 1983, 1986, 1988, 1990, 1991, 1993, 1994
        The Regents of the University of California.   All rights reserved.

FreeBSD BUILT-19950429 (GR386) #0: Sat Apr 29 17:50:09 SAT 1995
```

Or `jack` logs into `jane`'s account on the same machine (`jane` having set up the `.klogin` file as above, and the person in charge of Kerberos having set up principal *jack* with a null instance):

```
% kinit
% rlogin grunt -l jane
MIT Project Athena (grunt.example.com)
Password:
Last login: Mon May  1 21:16:55 from grumble
Copyright (c) 1980, 1983, 1986, 1988, 1990, 1991, 1993, 1994
        The Regents of the University of California.   All rights reserved.
FreeBSD BUILT-19950429 (GR386) #0: Sat Apr 29 17:50:09 SAT 1995
```

10.7 Kerberos5

Contributed by Tillman Hodgson. Based on a contribution by Mark Murray.

Every FreeBSD release beyond FreeBSD-5.1 includes support only for **Kerberos5**. Hence **Kerberos5** is the only version included, and its configuration is similar in many aspects to that of **KerberosIV**. The following information only applies to **Kerberos5** in post FreeBSD-5.0 releases. Users who wish to use the **KerberosIV** package may install the `security/krb4` port.

Kerberos is a network add-on system/protocol that allows users to authenticate themselves through the services of a secure server. Services such as remote login, remote copy, secure inter-system file copying and other high-risk tasks are made considerably safer and more controllable.

Kerberos can be described as an identity-verifying proxy system. It can also be described as a trusted third-party authentication system. **Kerberos** provides only one function — the secure authentication of users on the network. It does not provide authorization functions (what users are allowed to do) or auditing functions (what those users did). After a client and server have used **Kerberos** to prove their identity, they can also encrypt all of their communications to assure privacy and data integrity as they go about their business.

Therefore it is highly recommended that **Kerberos** be used with other security methods which provide authorization and audit services.

The following instructions can be used as a guide on how to set up **Kerberos** as distributed for FreeBSD. However, you should refer to the relevant manual pages for a complete description.

For purposes of demonstrating a **Kerberos** installation, the various namespaces will be handled as follows:

- The DNS domain ("zone") will be example.org.
- The **Kerberos** realm will be EXAMPLE.ORG.

> **Note:** Please use real domain names when setting up **Kerberos** even if you intend to run it internally. This avoids DNS problems and assures inter-operation with other **Kerberos** realms.

10.7.1 History

Kerberos was created by MIT as a solution to network security problems. The **Kerberos** protocol uses strong cryptography so that a client can prove its identity to a server (and vice versa) across an insecure network connection.

Kerberos is both the name of a network authentication protocol and an adjective to describe programs that implement the program (**Kerberos** telnet, for example). The current version of the protocol is version 5, described in RFC 1510.

Several free implementations of this protocol are available, covering a wide range of operating systems. The Massachusetts Institute of Technology (MIT), where **Kerberos** was originally developed, continues to develop their **Kerberos** package. It is commonly used in the US as a cryptography product, as such it has historically been affected by US export regulations. The MIT **Kerberos** is available as a port (`security/krb5`). Heimdal **Kerberos** is another version 5 implementation, and was explicitly developed outside of the US to avoid export regulations (and is thus often included in non-commercial UNIX variants). The Heimdal **Kerberos** distribution is available as a port (`security/heimdal`), and a minimal installation of it is included in the base FreeBSD install.

In order to reach the widest audience, these instructions assume the use of the Heimdal distribution included in FreeBSD.

10.7.2 Setting up a Heimdal KDC

The Key Distribution Center (KDC) is the centralized authentication service that **Kerberos** provides — it is the computer that issues **Kerberos** tickets. The KDC is considered "trusted" by all other computers in the **Kerberos** realm, and thus has heightened security concerns.

Note that while running the **Kerberos** server requires very few computing resources, a dedicated machine acting only as a KDC is recommended for security reasons.

To begin setting up a KDC, ensure that your `/etc/rc.conf` file contains the correct settings to act as a KDC (you may need to adjust paths to reflect your own system):

```
kerberos5_server_enable="YES"
kadmind5_server_enable="YES"
kerberos_stash="YES"
```

> **Note:** The `kerberos_stash` is only available in FreeBSD 4.X.

Next we will set up your **Kerberos** config file, `/etc/krb5.conf`:

```
[libdefaults]
    default_realm = EXAMPLE.ORG
[realms]
    EXAMPLE.ORG = {
        kdc = kerberos.example.org
    }
[domain_realm]
    .example.org = EXAMPLE.ORG
```

Note that this `/etc/krb5.conf` file implies that your KDC will have the fully-qualified hostname of `kerberos.example.org`. You will need to add a CNAME (alias) entry to your zone file to accomplish this if your KDC has a different hostname.

> **Note:** For large networks with a properly configured BIND DNS server, the above example could be trimmed to:
>
> ```
> [libdefaults]
>       default_realm = EXAMPLE.ORG
> ```
>
> With the following lines being appended to the `example.org` zonefile:
>
> ```
> _kerberos._udp      IN  SRV     01 00 88 kerberos.example.org.
> _kerberos._tcp      IN  SRV     01 00 88 kerberos.example.org.
> _kpasswd._udp       IN  SRV     01 00 464 kerberos.example.org.
> _kerberos-adm._tcp  IN  SRV     01 00 749 kerberos.example.org.
> _kerberos           IN  TXT     EXAMPLE.ORG.
> ```

Next we will create the **Kerberos** database. This database contains the keys of all principals encrypted with a master password. You are not required to remember this password, it will be stored in a file (`/var/heimdal/m-key`). To create the master key, run `kstash` and enter a password.

Once the master key has been created, you can initialize the database using the `kadmin` program with the `-l` option (standing for "local"). This option instructs `kadmin` to modify the database files directly rather than going through the `kadmind` network service. This handles the chicken-and-egg problem of trying to connect to the database before it is created. Once you have the `kadmin` prompt, use the `init` command to create your realms initial database.

Lastly, while still in `kadmin`, create your first principal using the `add` command. Stick to the defaults options for the principal for now, you can always change them later with the `modify` command. Note that you can use the `?` command at any prompt to see the available options.

A sample database creation session is shown below:

```
# kstash
      Master key: xxxxxxxx
      Verifying password - Master key: xxxxxxxx

      # kadmin -l
      kadmin> init EXAMPLE.ORG
      Realm max ticket life [unlimited]:
      kadmin> add tillman
      Max ticket life [unlimited]:
      Max renewable life [unlimited]:
      Attributes []:
      Password: xxxxxxxx
      Verifying password - Password: xxxxxxxx
```

Now it is time to start up the KDC services. Run `/etc/rc.d/kerberos start` and `/etc/rc.d/kadmind start` to bring up the services. Note that you won't have any kerberized daemons running at this point but you should be able to confirm the that the KDC is functioning by obtaining and listing a ticket for the principal (user) that you just created from the command-line of the KDC itself:

```
%k5init tillman
      tillman@EXAMPLE.ORG's Password:

      %k5list
      Credentials cache: FILE:/tmp/krb5cc_500
      Principal: tillman@EXAMPLE.ORG

              Issued           Expires          Principal
              Aug 27 15:37:58  Aug 28 01:37:58  krbtgt/EXAMPLE.ORG@EXAMPLE.ORG
              Aug 27 15:37:58  Aug 28 01:37:58  krbtgt/EXAMPLE.ORG@EXAMPLE.ORG

      v4-ticket file: /tmp/tkt500
      k5list: No ticket file (tf_util)
```

10.7.3 Kerberos enabling a server with Heimdal services

First, we need a copy of the **Kerberos** configuration file, `/etc/krb5.conf`. To do so, simply copy it over to the client computer from the KDC in a secure fashion (using network utilities, such as scp(1), or physically via a floppy disk).

Next you need a `/etc/krb5.keytab` file. This is the major difference between a server providing **Kerberos** enabled daemons and a workstation — the server must have a `keytab` file. This file contains the servers host key, which allows it and the KDC to verify each others identity. It must be transmitted to the server in a secure fashion, as the security of the server can be broken if the key is made public. This explicitly means that transferring it via a clear text channel, such as FTP, is a very bad idea.

Typically, you transfer to the `keytab` to the server using the `kadmin` program. This is handy because you also need to create the host principal (the KDC end of the `krb5.keytab`) using `kadmin`.

Note that you must have already obtained a ticket and that this ticket must be allowed to use the `kadmin` interface in the `kadmind.acl`. See the section titled "Remote administration" in the Heimdal info pages (`info heimdal`) for details on designing access control lists. If you do not want to enable remote `kadmin` access, you can simply securely connect to the KDC (via local console, ssh(1) or **Kerberos** telnet(1)) and perform administration locally using `kadmin -l`.

After installing the `/etc/krb5.conf` file, you can use `kadmin` from the **Kerberos** server. The `add --random-key` command will let you add the servers host principal, and the `ext` command will allow you to extract the servers host principal to its own keytab. For example:

```
# kadmin
kadmin> add --random-key host/myserver.EXAMPLE.ORG
Max ticket life [unlimited]:
Max renewable life [unlimited]:
Attributes []:
kadmin> ext host/myserver.EXAMPLE.ORG
kadmin> exit
```

Note that the `ext` command (short for "extract") stores the extracted key in `/etc/krb5.keytab` by default.

If you do not have `kadmind` running on the KDC (possibly for security reasons) and thus do not have access to `kadmin` remotely, you can add the host principal (`host/myserver.EXAMPLE.ORG`) directly on the KDC and then extract it to a temporary file (to avoid over-writing the `/etc/krb5.keytab` on the KDC) using something like this:

```
# kadmin
kadmin> ext --keytab=/tmp/example.keytab host/myserver.example.org
kadmin> exit
```

You can then securely copy the keytab to the server computer (using `scp` or a floppy, for example). Be sure to specify a non-default keytab name to avoid over-writing the keytab on the KDC.

At this point your server can communicate with the KDC (due to its `krb5.conf` file) and it can prove its own identity (due to the `krb5.keytab` file). It is now ready for you to enable some **Kerberos** services. For this example we will enable the `telnet` service by putting a line like this into your `/etc/inetd.conf` and then restarting the inetd(8) service with `/etc/rc.d/inetd restart`:

```
telnet    stream  tcp     nowait  root    /usr/libexec/telnetd  telnetd -a user
```

The critical bit is that the `-a` (for authentication) type is set to user. Consult the telnetd(8) manual page for more details.

10.7.4 Kerberos enabling a client with Heimdal

Setting up a client computer is almost trivially easy. As far as **Kerberos** configuration goes, you only need the **Kerberos** configuration file, located at `/etc/krb5.conf`. Simply securely copy it over to the client computer from the KDC.

Test your client computer by attempting to use `kinit`, `klist`, and `kdestroy` from the client to obtain, show, and then delete a ticket for the principal you created above. You should also be able to use **Kerberos** applications to connect to **Kerberos** enabled servers, though if that does not work and obtaining a ticket does the problem is likely with the server and not with the client or the KDC.

When testing an application like `telnet`, try using a packet sniffer (such as tcpdump(1)) to confirm that your password is not sent in the clear. Try using `telnet` with the `-x` option, which encrypts the entire data stream (similar to `ssh`).

The core **Kerberos** client applications (traditionally named `kinit`, `klist`, `kdestroy`, and `kpasswd`) are installed in the base FreeBSD install. Note that FreeBSD versions prior to 5.0 renamed them to `k5init`, `k5list`, `k5destroy`, `k5passwd`, and `k5stash` (though it is typically only used once).

Various non-core **Kerberos** client applications are also installed by default. This is where the "minimal" nature of the base Heimdal installation is felt: `telnet` is the only **Kerberos** enabled service.

The Heimdal port adds some of the missing client applications: **Kerberos** enabled versions of `ftp`, `rsh`, `rcp`, `rlogin`, and a few other less common programs. The MIT port also contains a full suite of **Kerberos** client applications.

10.7.5 User configuration files: `.k5login` and `.k5users`

Users within a realm typically have their **Kerberos** principal (such as `tillman@EXAMPLE.ORG`) mapped to a local user account (such as a local account named `tillman`). Client applications such as `telnet` usually do not require a user name or a principal.

Occasionally, however, you want to grant access to a local user account to someone who does not have a matching **Kerberos** principal. For example, `tillman@EXAMPLE.ORG` may need access to the local user account `webdevelopers`. Other principals may also need access to that local account.

The `.k5login` and `.k5users` files, placed in a users home directory, can be used similar to a powerful combination of `.hosts` and `.rhosts`, solving this problem. For example, if a `.k5login` with the following contents:

```
tillman@example.org
jdoe@example.org
```

Were to be placed into the home directory of the local user `webdevelopers` then both principals listed would have access to that account without requiring a shared password.

Reading the man pages for these commands is recommended. Note that the `ksu` man page covers `.k5users`.

10.7.6 Kerberos Tips, Tricks, and Troubleshooting

- When using either the Heimdal or MIT **Kerberos** ports ensure that your `PATH` environment variable lists the **Kerberos** versions of the client applications before the system versions.
- Is your time in sync? Are you sure? If the time is not in sync (typically within five minutes) authentication will fail.
- MIT and Heimdal inter-operate nicely. Except for `kadmin`, the protocol for which is not standardized.
- If you change your hostname, you also need to change your `host/` principal and update your keytab. This also applies to special keytab entries like the `www/` principal used for Apache's `www/mod_auth_kerb`.
- All hosts in your realm must be resolvable (both forwards and reverse) in DNS (or `/etc/hosts` as a minimum). CNAMEs will work, but the A and PTR records must be correct and in place. The error message isn't very

intuitive: `Kerberos5 refuses authentication because Read req failed: Key table entry not found`.

- Some operating systems that may being acting as clients to your KDC do not set the permissions for `ksu` to be setuid `root`. This means that `ksu` does not work, which is a good security idea but annoying. This is not a KDC error.
- With MIT **Kerberos**, if you want to allow a principal to have a ticket life longer than the default ten hours, you must use `modify_principal` in `kadmin` to change the maxlife of both the principal in question and the `krbtgt` principal. Then the principal can use the `-l` option with `kinit` to request a ticket with a longer lifetime.
-

  Note: If you run a packet sniffer on your KDC to add in troubleshooting and then run `kinit` from a workstation, you will notice that your TGT is sent immediately upon running `kinit` — even before you type your password! The explanation is that the **Kerberos** server freely transmits a TGT (Ticket Granting Ticket) to any unauthorized request; however, every TGT is encrypted in a key derived from the user's password. Therefore, when a user types their password it is not being sent to the KDC, it is being used to decrypt the TGT that `kinit` already obtained. If the decryption process results in a valid ticket with a valid time stamp, the user has valid **Kerberos** credentials. These credentials include a session key for establishing secure communications with the **Kerberos** server in the future, as well as the actual ticket-granting ticket, which is actually encrypted with the **Kerberos** server's own key. This second layer of encryption is unknown to the user, but it is what allows the **Kerberos** server to verify the authenticity of each TGT.

- You have to keep the time in sync between all the computers in your realm. NTP is perfect for this. For more information on NTP, see Section 19.12.
- If you want to use long ticket lifetimes (a week, for example) and you are using **OpenSSH** to connect to the machine where your ticket is stored, make sure that **Kerberos** `TicketCleanup` is set to `no` in your `sshd_config` or else your tickets will be deleted when you log out.
- Remember that host principals can have a longer ticket lifetime as well. If your user principal has a lifetime of a week but the host you are connecting to has a lifetime of nine hours, you will have an expired host principal in your cache and the ticket cache will not work as expected.
- When setting up a `krb5.dict` file to prevent specific bad passwords from being used (the manual page for `kadmind` covers this briefly), remember that it only applies to principals that have a password policy assigned to them. The `krb5.dict` files format is simple: one string per line. Creating a symbolic link to `/usr/share/dict/words` might be useful.

10.7.7 Differences with the MIT port

The major difference between the MIT and Heimdal installs relates to the `kadmin` program which has a different (but equivalent) set of commands and uses a different protocol. This has a large implications if your KDC is MIT as you will not be able to use the Heimdal `kadmin` program to administer your KDC remotely (or vice versa, for that matter).

The client applications may also take slightly different command line options to accomplish the same tasks. Following the instructions on the MIT **Kerberos** web site (http://web.mit.edu/Kerberos/www/) is recommended. Be careful of path issues: the MIT port installs into `/usr/local/` by default, and the "normal" system applications may be run instead of MIT if your `PATH` environment variable lists the system directories first.

> **Note:** With the MIT `security/krb5` port that is provided by FreeBSD, be sure to read the `/usr/local/share/doc/krb5/README.FreeBSD` file installed by the port if you want to understand why logins via `telnetd` and `klogind` behave somewhat oddly. Most importantly, correcting the "incorrect permissions on cache file" behavior requires that the `login.krb5` binary be used for authentication so that it can properly change ownership for the forwarded credentials.

10.7.8 Mitigating limitations found in Kerberos

10.7.8.1 Kerberos is an all-or-nothing approach

Every service enabled on the network must be modified to work with **Kerberos** (or be otherwise secured against network attacks) or else the users credentials could be stolen and re-used. An example of this would be **Kerberos** enabling all remote shells (via `rsh` and `telnet`, for example) but not converting the POP3 mail server which sends passwords in plaintext.

10.7.8.2 Kerberos is intended for single-user workstations

In a multi-user environment, **Kerberos** is less secure. This is because it stores the tickets in the `/tmp` directory, which is readable by all users. If a user is sharing a computer with several other people simultaneously (i.e. multi-user), it is possible that the user's tickets can be stolen (copied) by another user.

This can be overcome with the `-c` filename command-line option or (preferably) the `KRB5CCNAME` environment variable, but this is rarely done. In principal, storing the ticket in the users home directory and using simple file permissions can mitigate this problem.

10.7.8.3 The KDC is a single point of failure

By design, the KDC must be as secure as the master password database is contained on it. The KDC should have absolutely no other services running on it and should be physically secured. The danger is high because **Kerberos** stores all passwords encrypted with the same key (the "master" key), which in turn is stored as a file on the KDC.

As a side note, a compromised master key is not quite as bad as one might normally fear. The master key is only used to encrypt the **Kerberos** database and as a seed for the random number generator. As long as access to your KDC is secure, an attacker cannot do much with the master key.

Additionally, if the KDC is unavailable (perhaps due to a denial of service attack or network problems) the network services are unusable as authentication can not be performed, a recipe for a denial-of-service attack. This can alleviated with multiple KDCs (a single master and one or more slaves) and with careful implementation of secondary or fall-back authentication (PAM is excellent for this).

10.7.8.4 Kerberos Shortcomings

Kerberos allows users, hosts and services to authenticate between themselves. It does not have a mechanism to authenticate the KDC to the users, hosts or services. This means that a trojanned `kinit` (for example) could record all user names and passwords. Something like `security/tripwire` or other file system integrity checking tools can alleviate this.

10.7.9 Resources and further information

- The Kerberos FAQ (http://www.faqs.org/faqs/Kerberos-faq/general/preamble.html)
- Designing an Authentication System: a Dialogue in Four Scenes (http://web.mit.edu/Kerberos/www/dialogue.html)
- RFC 1510, The **Kerberos** Network Authentication Service (V5) (http://www.ietf.org/rfc/rfc1510.txt?number=1510)
- MIT **Kerberos** home page (http://web.mit.edu/Kerberos/www/)
- Heimdal **Kerberos** home page (http://www.pdc.kth.se/heimdal/)

10.8 Firewalls

Contributed by Gary Palmer and Alex Nash.

Firewalls are an area of increasing interest for people who are connected to the Internet, and are even finding applications on private networks to provide enhanced security. This section will hopefully explain what firewalls are, how to use them, and how to use the facilities provided in the FreeBSD kernel to implement them.

> **Note:** People often think that having a firewall between your internal network and the "Big Bad Internet" will solve all your security problems. It may help, but a poorly set up firewall system is more of a security risk than not having one at all. A firewall can add another layer of security to your systems, but it cannot stop a really determined cracker from penetrating your internal network. If you let internal security lapse because you believe your firewall to be impenetrable, you have just made the crackers job that much easier.

10.8.1 What Is a Firewall?

There are currently two distinct types of firewalls in common use on the Internet today. The first type is more properly called a *packet filtering router*. This type of firewall utilizes a multi-homed machine and a set of rules to determine whether to forward or block individual packets. A multi-homed machine is simply a device with multiple network interfaces. The second type, known as a *proxy server*, relies on daemons to provide authentication and to forward packets, possibly on a multi-homed machine which has kernel packet forwarding disabled.

Sometimes sites combine the two types of firewalls, so that only a certain machine (known as a *bastion host*) is allowed to send packets through a packet filtering router onto an internal network. Proxy services are run on the bastion host, which are generally more secure than normal authentication mechanisms.

FreeBSD comes with a kernel packet filter (known as IPFW), which is what the rest of this section will concentrate on. Proxy servers can be built on FreeBSD from third party software, but there is such a variety of proxy servers available that it would be impossible to cover them in this section.

10.8.1.1 Packet Filtering Routers

A router is a machine which forwards packets between two or more networks. A packet filtering router is programmed to compare each packet to a list of rules before deciding if it should be forwarded or not. Most modern IP routing software includes packet filtering functionality that defaults to forwarding all packets. To enable the filters, you need to define a set of rules.

To decide whether a packet should be passed on, the firewall looks through its set of rules for a rule which matches the contents of the packet's headers. Once a match is found, the rule action is obeyed. The rule action could be to drop the packet, to forward the packet, or even to send an ICMP message back to the originator. Only the first match counts, as the rules are searched in order. Hence, the list of rules can be referred to as a "rule chain".

The packet-matching criteria varies depending on the software used, but typically you can specify rules which depend on the source IP address of the packet, the destination IP address, the source port number, the destination port number (for protocols which support ports), or even the packet type (UDP, TCP, ICMP, etc).

10.8.1.2 Proxy Servers

Proxy servers are machines which have had the normal system daemons (**telnetd**, **ftpd**, etc) replaced with special servers. These servers are called *proxy servers*, as they normally only allow onward connections to be made. This enables you to run (for example) a proxy **telnet** server on your firewall host, and people can **telnet** in to your firewall from the outside, go through some authentication mechanism, and then gain access to the internal network (alternatively, proxy servers can be used for signals coming from the internal network and heading out).

Proxy servers are normally more secure than normal servers, and often have a wider variety of authentication mechanisms available, including "one-shot" password systems so that even if someone manages to discover what password you used, they will not be able to use it to gain access to your systems as the password expires immediately after the first use. As they do not actually give users access to the host machine, it becomes a lot more difficult for someone to install backdoors around your security system.

Proxy servers often have ways of restricting access further, so that only certain hosts can gain access to the servers. Most will also allow the administrator to specify which users can talk to which destination machines. Again, what facilities are available depends largely on what proxy software you choose.

10.8.2 What Does IPFW Allow Me to Do?

IPFW, the software supplied with FreeBSD, is a packet filtering and accounting system which resides in the kernel, and has a user-land control utility, ipfw(8). Together, they allow you to define and query the rules used by the kernel in its routing decisions.

There are two related parts to IPFW. The firewall section performs packet filtering. There is also an IP accounting section which tracks usage of the router, based on rules similar to those used in the firewall section. This allows the administrator to monitor how much traffic the router is getting from a certain machine, or how much WWW traffic it is forwarding, for example.

As a result of the way that IPFW is designed, you can use IPFW on non-router machines to perform packet filtering on incoming and outgoing connections. This is a special case of the more general use of IPFW, and the same commands and techniques should be used in this situation.

10.8.3 Enabling IPFW on FreeBSD

As the main part of the IPFW system lives in the kernel, you will need to add one or more options to your kernel configuration file, depending on what facilities you want, and recompile your kernel. See "Reconfiguring your Kernel" (Chapter 9) for more details on how to recompile your kernel.

> **Warning:** IPFW defaults to a policy of `deny ip from any to any`. If you do not add other rules during startup to allow access, *you will lock yourself out* of the server upon rebooting into a firewall-enabled kernel. We suggest that you set `firewall_type=open` in your `/etc/rc.conf` file when first enabling this feature, then refining the firewall rules in `/etc/rc.firewall` after you have tested that the new kernel feature works properly. To be on the safe side, you may wish to consider performing the initial firewall configuration from the local console rather than via **ssh**. Another option is to build a kernel using both the `IPFIREWALL` and `IPFIREWALL_DEFAULT_TO_ACCEPT` options. This will change the default rule of IPFW to `allow ip from any to any` and avoid the possibility of a lockout.

There are currently four kernel configuration options relevant to IPFW:

`options IPFIREWALL`

Compiles into the kernel the code for packet filtering.

`options IPFIREWALL_VERBOSE`

Enables code to allow logging of packets through syslogd(8). Without this option, even if you specify that packets should be logged in the filter rules, nothing will happen.

`options IPFIREWALL_VERBOSE_LIMIT=10`

Limits the number of packets logged through syslogd(8) on a per entry basis. You may wish to use this option in hostile environments in which you want to log firewall activity, but do not want to be open to a denial of service attack via syslog flooding.

When a chain entry reaches the packet limit specified, logging is turned off for that particular entry. To resume logging, you will need to reset the associated counter using the ipfw(8) utility:

```
# ipfw zero 4500
```

Where 4500 is the chain entry you wish to continue logging.

`options IPFIREWALL_DEFAULT_TO_ACCEPT`

This changes the default rule action from "deny" to "allow". This avoids the possibility of locking yourself out if you happen to boot a kernel with `IPFIREWALL` support but have not configured your firewall yet. It is also very useful if you often use ipfw(8) as a filter for specific problems as they arise. Use with care though, as this opens up the firewall and changes the way it works.

Note: Previous versions of FreeBSD contained an `IPFIREWALL_ACCT` option. This is now obsolete as the firewall code automatically includes accounting facilities.

10.8.4 Configuring IPFW

The configuration of the IPFW software is done through the ipfw(8) utility. The syntax for this command looks quite complicated, but it is relatively simple once you understand its structure.

There are currently four different command categories used by the utility: addition/deletion, listing, flushing, and clearing. Addition/deletion is used to build the rules that control how packets are accepted, rejected, and logged. Listing is used to examine the contents of your rule set (otherwise known as the chain) and packet counters (accounting). Flushing is used to remove all entries from the chain. Clearing is used to zero out one or more accounting entries.

10.8.4.1 Altering the IPFW Rules

The syntax for this form of the command is:

`ipfw` [-N] command [index] action [log] protocol addresses [options]

There is one valid flag when using this form of the command:

-N

Resolve addresses and service names in output.

The *command* given can be shortened to the shortest unique form. The valid *commands* are:

add

Add an entry to the firewall/accounting rule list

delete

Delete an entry from the firewall/accounting rule list

Previous versions of IPFW used separate firewall and accounting entries. The present version provides packet accounting with each firewall entry.

If an *index* value is supplied, it is used to place the entry at a specific point in the chain. Otherwise, the entry is placed at the end of the chain at an index 100 greater than the last chain entry (this does not include the default policy, rule 65535, deny).

The `log` option causes matching rules to be output to the system console if the kernel was compiled with `IPFIREWALL_VERBOSE`.

Valid *actions* are:

reject

Drop the packet, and send an ICMP host or port unreachable (as appropriate) packet to the source.

allow

Pass the packet on as normal. (aliases: `pass`, `permit`, and `accept`)

deny

Drop the packet. The source is not notified via an ICMP message (thus it appears that the packet never arrived at the destination).

count

Update packet counters but do not allow/deny the packet based on this rule. The search continues with the next chain entry.

Each *action* will be recognized by the shortest unambiguous prefix.

The *protocols* which can be specified are:

all

Matches any IP packet

icmp

Matches ICMP packets

tcp

Matches TCP packets

udp

Matches UDP packets

The *address* specification is:

from *`address/mask`* [*`port`*] to *`address/mask`* [*`port`*] [via *`interface`*]

You can only specify *`port`* in conjunction with *protocols* which support ports (UDP and TCP).

The `via` is optional and may specify the IP address or domain name of a local IP interface, or an interface name (e.g. `ed0`) to match only packets coming through this interface. Interface unit numbers can be specified with an optional wildcard. For example, `ppp*` would match all kernel PPP interfaces.

The syntax used to specify an *`address/mask`* is:

`address`

or

`address/mask-bits`

or

`address:mask-pattern`

A valid hostname may be specified in place of the IP address. *`mask-bits`* is a decimal number representing how many bits in the address mask should be set. e.g. specifying `192.216.222.1/24` will create a mask which will allow any address in a class C subnet (in this case, `192.216.222`) to be matched. *`mask-pattern`* is an IP address which will be logically AND'ed with the address given. The keyword `any` may be used to specify "any IP address".

The port numbers to be blocked are specified as:

`port` [,*`port`* [,*`port`* [. . .]]]

to specify either a single port or a list of ports, or

`port-port`

to specify a range of ports. You may also combine a single range with a list, but the range must always be specified first.

The *options* available are:

frag

Matches if the packet is not the first fragment of the datagram.

in

Matches if the packet is on the way in.

out

Matches if the packet is on the way out.

ipoptions *`spec`*

Matches if the IP header contains the comma separated list of options specified in *`spec`*. The supported IP options are: `ssrr` (strict source route), `lsrr` (loose source route), `rr` (record packet route), and `ts` (time stamp). The absence of a particular option may be specified with a leading `!`.

established

Matches if the packet is part of an already established TCP connection (i.e. it has the RST or ACK bits set). You can optimize the performance of the firewall by placing *established* rules early in the chain.

setup

Matches if the packet is an attempt to establish a TCP connection (the SYN bit is set but the ACK bit is not).

tcpflags *`flags`*

Matches if the TCP header contains the comma separated list of *`flags`*. The supported flags are `fin`, `syn`, `rst`, `psh`, `ack`, and `urg`. The absence of a particular flag may be indicated by a leading `!`.

icmptypes *types*

Matches if the ICMP type is present in the list *types*. The list may be specified as any combination of ranges and/or individual types separated by commas. Commonly used ICMP types are: `0` echo reply (ping reply), `3` destination unreachable, `5` redirect, `8` echo request (ping request), and `11` time exceeded (used to indicate TTL expiration as with traceroute(8)).

10.8.4.2 Listing the IPFW Rules

The syntax for this form of the command is:

`ipfw` [-a] [-c] [-d] [-e] [-t] [-N] [-S] list

There are seven valid flags when using this form of the command:

-a

While listing, show counter values. This option is the only way to see accounting counters.

-c

List rules in compact form.

-d

Show dynamic rules in addition to static rules.

-e

If `-d` was specified, also show expired dynamic rules.

-t

Display the last match times for each chain entry. The time listing is incompatible with the input syntax used by the ipfw(8) utility.

-N

Attempt to resolve given addresses and service names.

-S

Show the set each rule belongs to. If this flag is not specified, disabled rules will not be listed.

10.8.4.3 Flushing the IPFW Rules

The syntax for flushing the chain is:

`ipfw` flush

This causes all entries in the firewall chain to be removed except the fixed default policy enforced by the kernel (index 65535). Use caution when flushing rules; the default deny policy will leave your system cut off from the network until allow entries are added to the chain.

10.8.4.4 Clearing the IPFW Packet Counters

The syntax for clearing one or more packet counters is:

`ipfw` zero [*`index`*]

When used without an *`index`* argument, all packet counters are cleared. If an *`index`* is supplied, the clearing operation only affects a specific chain entry.

10.8.5 Example Commands for ipfw

This command will deny all packets from the host `evil.crackers.org` to the telnet port of the host `nice.people.org`:

```
# ipfw add deny tcp from evil.crackers.org to nice.people.org 23
```

The next example denies and logs any TCP traffic from the entire `crackers.org` network (a class C) to the `nice.people.org` machine (any port).

```
# ipfw add deny log tcp from evil.crackers.org/24 to nice.people.org
```

If you do not want people sending X sessions to your internal network (a subnet of a class C), the following command will do the necessary filtering:

```
# ipfw add deny tcp from any to my.org/28 6000 setup
```

To see the accounting records:

```
# ipfw -a list
```

or in the short form

```
# ipfw -a l
```

You can also see the last time a chain entry was matched with:

```
# ipfw -at l
```

10.8.6 Building a Packet Filtering Firewall

> **Note:** The following suggestions are just that: suggestions. The requirements of each firewall are different and we cannot tell you how to build a firewall to meet your particular requirements.

When initially setting up your firewall, unless you have a test bench setup where you can configure your firewall host in a controlled environment, it is strongly recommend you use the logging version of the commands and enable logging in the kernel. This will allow you to quickly identify problem areas and cure them without too much disruption. Even after the initial setup phase is complete, I recommend using the logging for 'deny' as it allows tracing of possible attacks and also modification of the firewall rules if your requirements alter.

> **Note:** If you use the logging versions of the `accept` command, be aware that it can generate *large* amounts of log data. One log entry will be generated for every packet that passes through the firewall, so large FTP/http transfers, etc, will really slow the system down. It also increases the latencies on those packets as it requires more work to be done by the kernel before the packet can be passed on. **syslogd** will also start using up a lot more processor time as it logs all the extra data to disk, and it could quite easily fill the partition `/var/log` is located on.

You should enable your firewall from `/etc/rc.conf.local` or `/etc/rc.conf`. The associated manual page explains which knobs to fiddle and lists some preset firewall configurations. If you do not use a preset configuration, `ipfw list` will output the current ruleset into a file that you can pass to `rc.conf`. If you do not use `/etc/rc.conf.local` or `/etc/rc.conf` to enable your firewall, it is important to make sure your firewall is enabled before any IP interfaces are configured.

The next problem is what your firewall should actually *do*! This is largely dependent on what access to your network you want to allow from the outside, and how much access to the outside world you want to allow from the inside. Some general rules are:

- Block all incoming access to ports below 1024 for TCP. This is where most of the security sensitive services are, like finger, SMTP (mail) and telnet.
- Block *all* incoming UDP traffic. There are very few useful services that travel over UDP, and what useful traffic there is, is normally a security threat (e.g. Suns RPC and NFS protocols). This has its disadvantages also, since UDP is a connectionless protocol, denying incoming UDP traffic also blocks the replies to outgoing UDP traffic. This can cause a problem for people (on the inside) using external archie (prospero) servers. If you want to allow access to archie, you will have to allow packets coming from ports 191 and 1525 to any internal UDP port through the firewall. **ntp** is another service you may consider allowing through, which comes from port 123.
- Block traffic to port 6000 from the outside. Port 6000 is the port used for access to X11 servers, and can be a security threat (especially if people are in the habit of doing `xhost +` on their workstations). X11 can actually use a range of ports starting at 6000, the upper limit being how many X displays you can run on the machine. The upper limit as defined by RFC 1700 (Assigned Numbers) is 6063.
- Check what ports any internal servers use (e.g. SQL servers, etc). It is probably a good idea to block those as well, as they normally fall outside the 1-1024 range specified above.

Another checklist for firewall configuration is available from CERT at
http://www.cert.org/tech_tips/packet_filtering.html

As stated above, these are only *guidelines*. You will have to decide what filter rules you want to use on your firewall yourself. We cannot accept ANY responsibility if someone breaks into your network, even if you follow the advice given above.

10.8.7 IPFW Overhead and Optimization

Many people want to know how much overhead IPFW adds to a system. The answer to this depends mostly on your rule set and processor speed. For most applications dealing with Ethernet and small rule sets, the answer is "negligible". For those of you that need actual measurements to satisfy your curiosity, read on.

The following measurements were made using 2.2.5-STABLE on a 486-66. (While IPFW has changed slightly in later releases of FreeBSD, it still performs with similar speed.) IPFW was modified to measure the time spent within the `ip_fw_chk` routine, displaying the results to the console every 1000 packets.

Two rule sets, each with 1000 rules, were tested. The first set was designed to demonstrate a worst case scenario by repeating the rule:

```
# ipfw add deny tcp from any to any 55555
```

This demonstrates a worst case scenario by causing most of IPFW's packet check routine to be executed before finally deciding that the packet does not match the rule (by virtue of the port number). Following the 999th iteration of this rule was an `allow ip from any to any`.

The second set of rules were designed to abort the rule check quickly:

```
# ipfw add deny ip from 1.2.3.4 to 1.2.3.4
```

The non-matching source IP address for the above rule causes these rules to be skipped very quickly. As before, the 1000th rule was an `allow ip from any to any`.

The per-packet processing overhead in the former case was approximately 2.703 ms/packet, or roughly 2.7 microseconds per rule. Thus the theoretical packet processing limit with these rules is around 370 packets per second. Assuming 10 Mbps Ethernet and a ~1500 byte packet size, we would only be able to achieve 55.5% bandwidth utilization.

For the latter case each packet was processed in approximately 1.172 ms, or roughly 1.2 microseconds per rule. The theoretical packet processing limit here would be about 853 packets per second, which could consume 10 Mbps Ethernet bandwidth.

The excessive number of rules tested and the nature of those rules do not provide a real-world scenario -- they were used only to generate the timing information presented here. Here are a few things to keep in mind when building an efficient rule set:

- Place an `established` rule early on to handle the majority of TCP traffic. Do not put any `allow tcp` statements before this rule.
- Place heavily triggered rules earlier in the rule set than those rarely used (*without changing the permissiveness of the firewall*, of course). You can see which rules are used most often by examining the packet counting statistics with `ipfw -a l`.

10.9 OpenSSL

As of FreeBSD 4.0, the OpenSSL toolkit is a part of the base system. OpenSSL (http://www.openssl.org/) provides a general-purpose cryptography library, as well as the Secure Sockets Layer v2/v3 (SSLv2/SSLv3) and Transport Layer Security v1 (TLSv1) network security protocols.

However, one of the algorithms (specifically IDEA) included in OpenSSL is protected by patents in the USA and elsewhere, and is not available for unrestricted use. IDEA is included in the OpenSSL sources in FreeBSD, but it is not built by default. If you wish to use it, and you comply with the license terms, enable the `MAKE_IDEA` switch in `/etc/make.conf` and rebuild your sources using `make world`.

Today, the RSA algorithm is free for use in USA and other countries. In the past it was protected by a patent.

10.9.1 Source Code Installations

OpenSSL is part of the `src-crypto` and `src-secure` **CVSup** collections. See the Obtaining FreeBSD section for more information about obtaining and updating FreeBSD source code.

10.10 VPN over IPsec

Written by Nik Clayton.

Creating a VPN between two networks, separated by the Internet, using FreeBSD gateways.

10.10.1 Understanding IPsec

Written by Hiten M. Pandya.

This section will guide you through the process of setting up IPsec, and to use it in an environment which consists of FreeBSD and **Microsoft Windows 2000/XP** machines, to make them communicate securely. In order to set up IPsec, it is necessary that you are familiar with the concepts of building a custom kernel (see Chapter 9).

IPsec is a protocol which sits on top of the Internet Protocol (IP) layer. It allows two or more hosts to communicate in a secure manner (hence the name). The FreeBSD IPsec "network stack" is based on the KAME (http://www.kame.net/) implementation, which has support for both protocol families, IPv4 and IPv6.

> **Note:** FreeBSD 5.X contains a "hardware accelerated" IPsec stack, known as "Fast IPsec", that was obtained from OpenBSD. It employs cryptographic hardware (whenever possible) via the crypto(4) subsystem to optimize the performance of IPsec. This subsystem is new, and does not support all the features that are available in the KAME version of IPsec. However, in order to enable hardware-accelerated IPsec, the following kernel option has to be added to your kernel configuration file:
>
> ```
> options   FAST_IPSEC  # new IPsec (cannot define w/ IPSEC)
> ```
>
> Note, that it is not currently possible to use the "Fast IPsec" subsystem in lue with the KAME implementation of IPsec. Consult the fast_ipsec(4) manual page for more information.

IPsec consists of two sub-protocols:

- *Encapsulated Security Payload (ESP)*, protects the IP packet data from third party interference, by encrypting the contents using symmetric cryptography algorithms (like Blowfish, 3DES).
- *Authentication Header (AH)*, protects the IP packet header from third party interference and spoofing, by computing a cryptographic checksum and hashing the IP packet header fields with a secure hashing function. This is then followed by an additional header that contains the hash, to allow the information in the packet to be authenticated.

ESP and AH can either be used together or separately, depending on the environment.

IPsec can either be used to directly encrypt the traffic between two hosts (known as *Transport Mode*); or to build "virtual tunnels" between two subnets, which could be used for secure communication between two corporate networks (known as *Tunnel Mode*). The latter is more commonly known as a *Virtual Private Network (VPN)*. The ipsec(4) manual page should be consulted for detailed information on the IPsec subsystem in FreeBSD.

To add IPsec support to your kernel, add the following options to your kernel configuration file:

```
options   IPSEC        #IP security
options   IPSEC_ESP    #IP security (crypto; define w/ IPSEC)
```

If IPsec debugging support is desired, the following kernel option should also be added:

```
options   IPSEC_DEBUG  #debug for IP security
```

10.10.2 The Problem

There's no standard for what constitutes a VPN. VPNs can be implemented using a number of different technologies, each of which have their own strengths and weaknesses. This article presents a number of scenarios, and strategies for implementing a VPN for each scenario.

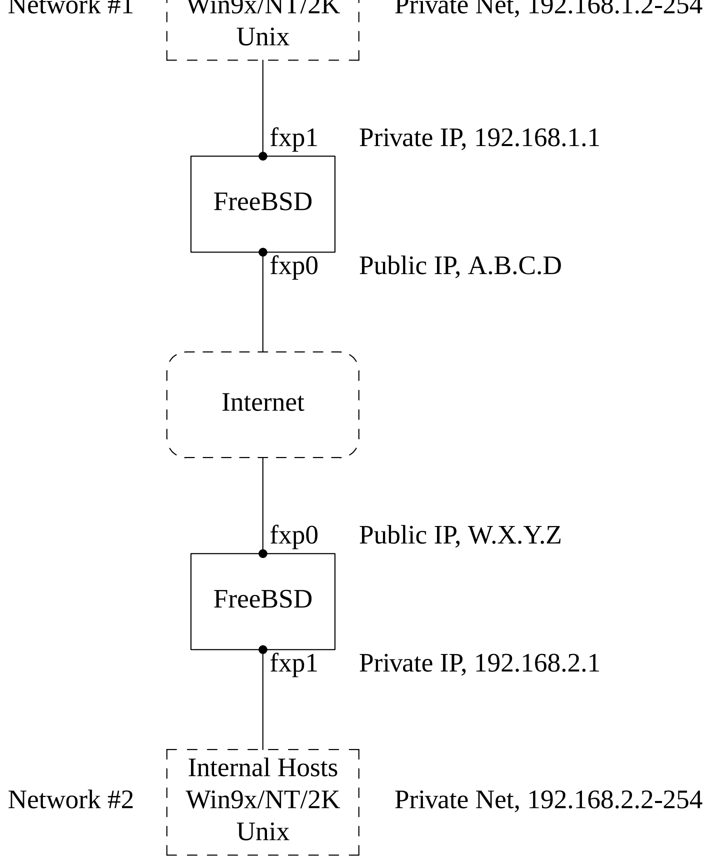
10.10.3 Scenario #1: Two networks, connected to the Internet, to behave as one

This is the scenario that caused me to first investigating VPNs. The premise is as follows:

- You have at least two sites
- Both sites are using IP internally
- Both sites are connected to the Internet, through a gateway that is running FreeBSD.
- The gateway on each network has at least one public IP address.
- The internal addresses of the two networks can be public or private IP addresses, it doesn't matter. You can be running NAT on the gateway machine if necessary.
- The internal IP addresses of the two networks *do not collide*. While I expect it is theoretically possible to use a combination of VPN technology and NAT to get this to work, I expect it to be a configuration nightmare.

If you find that you are trying to connect two networks, both of which, internally, use the same private IP address range (e.g., both of them use `192.168.1.x`), then one of the networks will have to be renumbered.

The network topology might look something like this:



Notice the two public IP addresses. I'll use the letters to refer to them in the rest of this article. Anywhere you see those letters in this article, replace them with your own public IP addresses. Note also that that internally, the two gateway machines have `.1` IP addresses, and that the two networks have different private IP address (`192.168.1.x` and `192.168.2.x` respectively). All the machines on the private networks have been configured to use the `.1` machine as their default gateway.

The intention is that, from a network point of view, each network should view the machines on the other network as though they were directly attached the same router -- albeit a slightly slow router with an occasional tendency to drop packets.

This means that (for example), machine `192.168.1.20` should be able to run

```
ping 192.168.2.34
```

and have it work, transparently. Windows machines should be able to see the machines on the other network, browse file shares, and so on, in exactly the same way that they can browse machines on the local network.

And the whole thing has to be secure. This means that traffic between the two networks has to be encrypted.

Creating a VPN between these two networks is a multi-step process. The stages are as follows:

1. Create a "virtual" network link between the two networks, across the Internet. Test it, using tools like ping(8), to make sure it works.
2. Apply security policies to ensure that traffic between the two networks is transparently encrypted and decrypted as necessary. Test this, using tools like tcpdump(1), to ensure that traffic is encrypted.

3. Configure additional software on the FreeBSD gateways, to allow Windows machines to see one another across the VPN.

10.10.3.1 Step 1: Creating and testing a "virtual" network link

Suppose that you were logged in to the gateway machine on network #1 (with public IP address `A.B.C.D`, private IP address `192.168.1.1`), and you ran `ping 192.168.2.1`, which is the private address of the machine with IP address `W.X.Y.Z`. What needs to happen in order for this to work?

1. The gateway machine needs to know how to reach `192.168.2.1`. In other words, it needs to have a route to `192.168.2.1`.
2. Private IP addresses, such as those in the `192.168.x` range are not supposed to appear on the Internet at large. Instead, each packet you send to `192.168.2.1` will need to be wrapped up inside another packet. This packet will need to appear to be from `A.B.C.D`, and it will have to be sent to `W.X.Y.Z`. This process is called *encapsulation*.
3. Once this packet arrives at `W.X.Y.Z` it will need to "unencapsulated", and delivered to `192.168.2.1`.

You can think of this as requiring a "tunnel" between the two networks. The two "tunnel mouths" are the IP addresses `A.B.C.D` and `W.X.Y.Z`, and the tunnel must be told the addresses of the private IP addresses that will be allowed to pass through it. The tunnel is used to transfer traffic with private IP addresses across the public Internet.

This tunnel is created by using the generic interface, or `gif` devices on FreeBSD. As you can imagine, the `gif` interface on each gateway host must be configured with four IP addresses; two for the public IP addresses, and two for the private IP addresses.

Support for the gif device must be compiled in to the FreeBSD kernel on both machines. You can do this by adding the line:

```
pseudo-device gif
```

to the kernel configuration files on both machines, and then compile, install, and reboot as normal.

Configuring the tunnel is a two step process. First the tunnel must be told what the outside (or public) IP addresses are, using gifconfig(8). Then the private IP addresses must be configured using ifconfig(8).

On the gateway machine on network #1 you would run the following two commands to configure the tunnel.

```
gifconfig gif0 A.B.C.D W.X.Y.Z
ifconfig gif0 inet 192.168.1.1 192.168.2.1 netmask 0xffffffff
```

On the other gateway machine you run the same commands, but with the order of the IP addresses reversed.

```
gifconfig gif0 W.X.Y.Z A.B.C.D
ifconfig gif0 inet 192.168.2.1 192.168.1.1 netmask 0xffffffff
```

You can then run:

```
gifconfig gif0
```

to see the configuration. For example, on the network #1 gateway, you would see this:

```
# gifconfig gif0
gif0: flags=8011<UP,POINTTOPOINT,MULTICAST> mtu 1280
inet 192.168.1.1 --> 192.168.2.1 netmask 0xffffffff
physical address inet A.B.C.D --> W.X.Y.Z
```

As you can see, a tunnel has been created between the physical addresses `A.B.C.D` and `W.X.Y.Z`, and the traffic allowed through the tunnel is that between `192.168.1.1` and `192.168.2.1`.

This will also have added an entry to the routing table on both machines, which you can examine with the command `netstat -rn`. This output is from the gateway host on network #1.

```
# netstat -rn
Routing tables

Internet:
Destination      Gateway       Flags    Refs    Use    Netif  Expire
...
192.168.2.1      192.168.1.1   UH         0       0    gif0
...
```

As the "Flags" value indicates, this is a host route, which means that each gateway knows how to reach the other gateway, but they do not know how to reach the rest of their respective networks. That problem will be fixed shortly.

It is likely that you are running a firewall on both machines. This will need to be circumvented for your VPN traffic. You might want to allow all traffic between both networks, or you might want to include firewall rules that protect both ends of the VPN from one another.

It greatly simplifies testing if you configure the firewall to allow all traffic through the VPN. You can always tighten things up later. If you are using ipfw(8) on the gateway machines then a command like

```
ipfw add 1 allow ip from any to any via gif0
```

will allow all traffic between the two end points of the VPN, without affecting your other firewall rules. Obviously you will need to run this command on both gateway hosts.

This is sufficient to allow each gateway machine to ping the other. On `192.168.1.1`, you should be able to run

```
ping 192.168.2.1
```

and get a response, and you should be able to do the same thing on the other gateway machine.

However, you will not be able to reach internal machines on either network yet. This is because of the routing -- although the gateway machines know how to reach one another, they do not know how to reach the network behind each one.

To solve this problem you must add a static route on each gateway machine. The command to do this on the first gateway would be:

```
route add 192.168.2.0 192.168.2.1 netmask 0xffffff00
```

This says "In order to reach the hosts on the network `192.168.2.0`, send the packets to the host `192.168.2.1`". You will need to run a similar command on the other gateway, but with the `192.168.1.x` addresses instead.

IP traffic from hosts on one network will now be able to reach hosts on the other network.

That has now created two thirds of a VPN between the two networks, in as much as it is “virtual” and it is a “network”. It is not private yet. You can test this using ping(8) and tcpdump(1). Log in to the gateway host and run

```
tcpdump dst host 192.168.2.1
```

In another log in session on the same host run

```
ping 192.168.2.1
```

You will see output that looks something like this:

```
16:10:24.018080 192.168.1.1 > 192.168.2.1: icmp: echo request
16:10:24.018109 192.168.1.1 > 192.168.2.1: icmp: echo reply
16:10:25.018814 192.168.1.1 > 192.168.2.1: icmp: echo request
16:10:25.018847 192.168.1.1 > 192.168.2.1: icmp: echo reply
16:10:26.028896 192.168.1.1 > 192.168.2.1: icmp: echo request
16:10:26.029112 192.168.1.1 > 192.168.2.1: icmp: echo reply
```

As you can see, the ICMP messages are going back and forth unencrypted. If you had used the `-s` parameter to tcpdump(1) to grab more bytes of data from the packets you would see more information.

Obviously this is unacceptable. The next section will discuss securing the link between the two networks so that it all traffic is automatically encrypted.

Summary:

- Configure both kernels with “pseudo-device gif”.
- Edit `/etc/rc.conf` on gateway host #1 and add the following lines (replacing IP addresses as necessary).

  ```
  gifconfig_gif0="A.B.C.D W.X.Y.Z"
  ifconfig_gif0="inet 192.168.1.1 192.168.2.1 netmask 0xffffffff"
  static_routes="vpn"
  route_vpn="192.168.2.0 192.168.2.1 netmask 0xffffff00"
  ```

- Edit your firewall script (`/etc/rc.firewall`, or similar) on both hosts, and add

  ```
  ipfw add 1 allow ip from any to any via gif0
  ```

- Make similar changes to `/etc/rc.conf` on gateway host #2, reversing the order of IP addresses.

10.10.3.2 Step 2: Securing the link

To secure the link we will be using IPsec. IPsec provides a mechanism for two hosts to agree on an encryption key, and to then use this key in order to encrypt data between the two hosts.

The are two areas of configuration to be considered here.

1. There must be a mechanism for two hosts to agree on the encryption mechanism to use. Once two hosts have agreed on this mechanism there is said to be a "security association" between them.
2. There must be a mechanism for specifying which traffic should be encrypted. Obviously, you don't want to encrypt all your outgoing traffic -- you only want to encrypt the traffic that is part of the VPN. The rules that you put in place to determine what traffic will be encrypted are called "security policies".

Security associations and security policies are both maintained by the kernel, and can be modified by userland programs. However, before you can do this you must configure the kernel to support IPsec and the Encapsulated Security Payload (ESP) protocol. This is done by configuring a kernel with:

```
options IPSEC
options IPSEC_ESP
```

and recompiling, reinstalling, and rebooting. As before you will need to do this to the kernels on both of the gateway hosts.

You have two choices when it comes to setting up security associations. You can configure them by hand between two hosts, which entails choosing the encryption algorithm, encryption keys, and so forth, or you can use daemons that implement the Internet Key Exchange protocol (IKE) to do this for you.

I recommend the latter. Apart from anything else, it is easier to set up.

Editing and displaying security policies is carried out using setkey(8). By analogy, `setkey` is to the kernel's security policy tables as route(8) is to the kernel's routing tables. `setkey` can also display the current security associations, and to continue the analogy further, is akin to `netstat -r` in that respect.

There are a number of choices for daemons to manage security associations with FreeBSD. This article will describe how to use one of these, racoon. racoon is in the FreeBSD ports collection, in the security/ category, and is installed in the usual way.

racoon must be run on both gateway hosts. On each host it is configured with the IP address of the other end of the VPN, and a secret key (which you choose, and must be the same on both gateways).

The two daemons then contact one another, confirm that they are who they say they are (by using the secret key that you configured). The daemons then generate a new secret key, and use this to encrypt the traffic over the VPN. They periodically change this secret, so that even if an attacker were to crack one of the keys (which is as theoretically close to unfeasible as it gets) it won't do them much good -- by the time they've cracked the key the two daemons have chosen another one.

racoon's configuration is stored in `${PREFIX}/etc/racoon`. You should find a configuration file there, which should not need to be changed too much. The other component of racoon's configuration, which you will need to change, is the "pre-shared key".

The default racoon configuration expects to find this in the file `${PREFIX}/etc/racoon/psk.txt`. It is important to note that the pre-shared key is *not* the key that will be used to encrypt your traffic across the VPN link, it is simply a token that allows the key management daemons to trust one another.

`psk.txt` contains a line for each remote site you are dealing with. In this example, where there are two sites, each `psk.txt` file will contain one line (because each end of the VPN is only dealing with one other end).

On gateway host #1 this line should look like this:

```
W.X.Y.Z            secret
```

That is, the *public* IP address of the remote end, whitespace, and a text string that provides the secret. Obviously, you shouldn't use "secret" as your key -- the normal rules for choosing a password apply.

On gateway host #2 the line would look like this

```
A.B.C.D            secret
```

That is, the public IP address of the remote end, and the same secret key. `psk.txt` must be mode `0600` (i.e., only read/write to `root`) before racoon will run.

You must run racoon on both gateway machines. You will also need to add some firewall rules to allow the IKE traffic, which is carried over UDP to the ISAKMP (Internet Security Association Key Management Protocol) port. Again, this should be fairly early in your firewall ruleset.

```
ipfw add 1 allow udp from A.B.C.D to W.X.Y.Z isakmp
ipfw add 1 allow udp from W.X.Y.Z to A.B.C.D isakmp
```

Once racoon is running you can try pinging one gateway host from the other. The connection is still not encrypted, but racoon will then set up the security associations between the two hosts -- this might take a moment, and you may see this as a short delay before the ping commands start responding.

Once the security association has been set up you can view it using setkey(8). Run

```
setkey -D
```

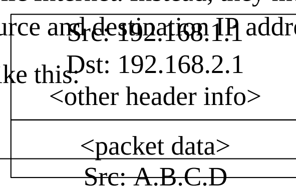
on either host to view the security association information.

That's one half of the problem. They other half is setting your security policies.

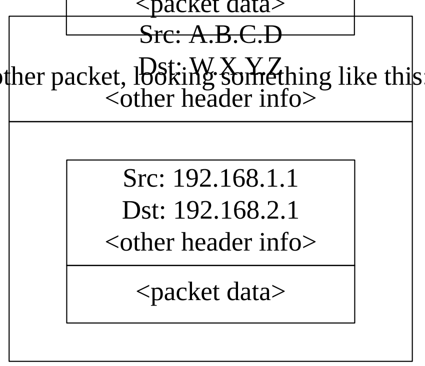
To create a sensible security policy, let's review what's been set up so far. This discussions hold for both ends of the link.

Each IP packet that you send out has a header that contains data about the packet. The header includes the IP addresses of both the source and destination. As we already know, private IP addresses, such as the `192.168.x.y` range are not supposed to appear on the public Internet. Instead, they must first be encapsulated inside another packet. This packet must have the public source and destination IP addresses substituted for the private addresses.

So if your outgoing packet started looking like this:



Then it will be encapsulated inside another packet, looking something like this:



This encapsulation is carried out by the `gif` device. As you can see, the packet now has real IP addresses on the outside, and our original packet has been wrapped up as data inside the packet that will be put out on the Internet.

Obviously, we want all traffic between the VPNs to be encrypted. You might try putting this in to words, as:

"If a packet leaves from `A.B.C.D`, and it is destined for `W.X.Y.Z`, then encrypt it, using the necessary security associations."

"If a packet arrives from `W.X.Y.Z`, and it is destined for `A.B.C.D`, then decrypt it, using the necessary security associations."

That's close, but not quite right. If you did this, all traffic to and from `W.X.Y.Z`, even traffic that was not part of the VPN, would be encrypted. That's not quite what you want. The correct policy is as follows

"If a packet leaves from `A.B.C.D`, and that packet is encapsulating another packet, and it is destined for `W.X.Y.Z`, then encrypt it, using the necessary security associations."

"If a packet arrives from `W.X.Y.Z`, and that packet is encapsulating another packet, and it is destined for `A.B.C.D`, then encrypt it, using the necessary security associations."

A subtle change, but a necessary one.

Security policies are also set using setkey(8). setkey(8) features a configuration language for defining the policy. You can either enter configuration instructions via stdin, or you can use the `-f` option to specify a filename that contains configuration instructions.

The configuration on gateway host #1 (which has the public IP address `A.B.C.D`) to force all outbound traffic to `W.X.Y.Z` to be encrypted is:

```
spdadd A.B.C.D/32 W.X.Y.Z/32 ipencap -P out ipsec esp/tunnel/A.B.C.D-W.X.Y.Z/require;
```

Put these commands in a file (e.g., `/etc/ipsec.conf`) and then run

```
# setkey -f /etc/ipsec.conf
```

`spdadd` tells setkey(8) that we want to add a rule to the secure policy database. The rest of this line specifies which packets will match this policy. `A.B.C.D/32` and `W.X.Y.Z/32` are the IP addresses and netmasks that identify the network or hosts that this policy will apply to. In this case, we want it to apply to traffic between these two hosts. `ipencap` tells the kernel that this policy should only apply to packets that encapsulate other packets. `-P out` says that this policy applies to outgoing packets, and `ipsec` says that the packet will be secured.

The second line specifies how this packet will be encrypted. `esp` is the protocol that will be used, while `tunnel` indicates that the packet will be further encapsulated in an IPsec packet. The repeated use of `A.B.C.D` and `W.X.Y.Z` is used to select the security association to use, and the final `require` mandates that packets must be encrypted if they match this rule.

This rule only matches outgoing packets. You will need a similar rule to match incoming packets.

```
spdadd W.X.Y.Z/32 A.B.C.D/32 ipencap -P in ipsec esp/tunnel/W.X.Y.Z-A.B.C.D/require;
```

Note the `in` instead of `out` in this case, and the necessary reversal of the IP addresses.

The other gateway host (which has the public IP address `W.X.Y.Z`) will need similar rules.

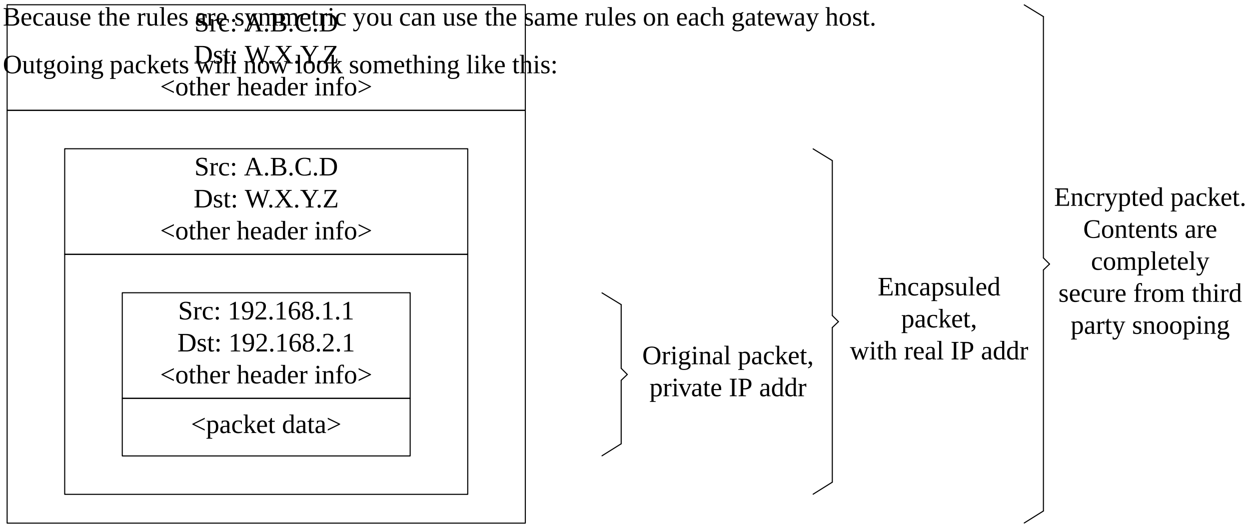
```
spdadd W.X.Y.Z/32 A.B.C.D/32 ipencap -P out ipsec esp/tunnel/W.X.Y.Z-A.B.C.D/require;
       spdadd A.B.C.D/32 W.X.Y.Z/32 ipencap -P in ipsec esp/tunnel/A.B.C.D-W.X.Y.Z/require;
```

Finally, you need to add firewall rules to allow ESP and IPENCAP packets back and forth. These rules will need to be added to both hosts.

```
ipfw add 1 allow esp from A.B.C.D to W.X.Y.Z
ipfw add 1 allow esp from W.X.Y.Z to A.B.C.D
ipfw add 1 allow ipencap from A.B.C.D to W.X.Y.Z
ipfw add 1 allow ipencap from W.X.Y.Z to A.B.C.D
```

Because the rules are symmetric you can use the same rules on each gateway host.

Outgoing packets will now look something like this:



When they are received by the far end of the VPN they will first be decrypted (using the security associations that have been negotiated by racoon). Then they will enter the `gif` interface, which will unwrap the second layer, until you are left with the innermost packet, which can then travel in to the inner network.

You can check the security using the same ping(8) test from earlier. First, log in to the `A.B.C.D` gateway machine, and run:

```
tcpdump dst host 192.168.2.1
```

In another log in session on the same host run

```
ping 192.168.2.1
```

This time you should see output like the following:

```
XXX tcpdump output
```

Now, as you can see, tcpdump(1) shows the ESP packets. If you try and examine them with the `-s` option you will see (apparently) gibberish, because of the encryption.

Congratulations. You have just set up a VPN between two remote sites.

Summary

- Configure both kernels with:

  ```
  options IPSEC
  options IPSEC_ESP
  ```

- Install `security/racoon`. Edit `${PREFIX}/etc/racoon/psk.txt` on both gateway hosts, adding an entry for the remote host's IP address and a secret key that they both know. Make sure this file is mode 0600.
- Add the following lines to `/etc/rc.conf` on each host:

  ```
  ipsec_enable="YES"
  ipsec_file="/etc/ipsec.conf"
  ```

- Create an `/etc/ipsec.conf` on each host that contains the necessary spdadd lines. On gateway host #1 this would be:

  ```
  spdadd A.B.C.D/32 W.X.Y.Z/32 ipencap -P out ipsec
    esp/tunnel/A.B.C.D-W.X.Y.Z/require;
  spdadd W.X.Y.Z/32 A.B.C.D/32 ipencap -P in ipsec
    esp/tunnel/W.X.Y.Z-A.B.C.D/require;
  ```

  On gateway host #2 this would be:

  ```
  spdadd W.X.Y.Z/32 A.B.C.D/32 ipencap -P out ipsec
    esp/tunnel/W.X.Y.Z-A.B.C.D/require;
  spdadd A.B.C.D/32 W.X.Y.Z/32 ipencap -P in ipsec
    esp/tunnel/A.B.C.D-W.X.Y.Z/require;
  ```

- Add firewall rules to allow IKE, ESP, and IPENCAP traffic to both hosts:

  ```
  ipfw add 1 allow udp from A.B.C.D to W.X.Y.Z isakmp
  ipfw add 1 allow udp from W.X.Y.Z to A.B.C.D isakmp
  ipfw add 1 allow esp from A.B.C.D to W.X.Y.Z
  ipfw add 1 allow esp from W.X.Y.Z to A.B.C.D
  ipfw add 1 allow ipencap from A.B.C.D to W.X.Y.Z
  ipfw add 1 allow ipencap from W.X.Y.Z to A.B.C.D
  ```

The previous two steps should suffice to get the VPN up and running. Machines on each network will be able to refer to one another using IP addresses, and all traffic across the link will be automatically and securely encrypted.

10.11 OpenSSH

Contributed by Chern Lee.

OpenSSH is a set of network connectivity tools used to access remote machines securely. It can be used as a direct replacement for `rlogin`, `rsh`, `rcp`, and `telnet`. Additionally, any other TCP/IP connections can be tunneled/forwarded securely through SSH. **OpenSSH** encrypts all traffic to effectively eliminate eavesdropping, connection hijacking, and other network-level attacks.

OpenSSH is maintained by the OpenBSD project, and is based upon SSH v1.2.12 with all the recent bug fixes and updates. It is compatible with both SSH protocols 1 and 2. **OpenSSH** has been in the base system since FreeBSD 4.0.

10.11.1 Advantages of Using OpenSSH

Normally, when using telnet(1) or rlogin(1), data is sent over the network in an clear, un-encrypted form. Network sniffers anywhere in between the client and server can steal your user/password information or data transferred in your session. **OpenSSH** offers a variety of authentication and encryption methods to prevent this from happening.

10.11.2 Enabling sshd

Be sure to make the following addition to your `rc.conf` file:

```
sshd_enable="YES"
```

This will load sshd(8), the daemon program for **OpenSSH**, the next time your system initializes. Alternatively, you can simply run directly the **sshd** daemon by typing `sshd` on the command line.

10.11.3 SSH Client

The ssh(1) utility works similarly to rlogin(1).

```
# ssh user@example.com
Host key not found from the list of known hosts.
Are you sure you want to continue connecting (yes/no)? yes
Host 'example.com' added to the list of known hosts.
user@example.com's password: *******
```

The login will continue just as it would have if a session was created using `rlogin` or `telnet`. SSH utilizes a key fingerprint system for verifying the authenticity of the server when the client connects. The user is prompted to enter `yes` only when connecting for the first time. Future attempts to login are all verified against the saved fingerprint key. The SSH client will alert you if the saved fingerprint differs from the received fingerprint on future login attempts. The fingerprints are saved in `~/.ssh/known_hosts`, or `~/.ssh/known_hosts2` for SSH v2 fingerprints.

By default, **OpenSSH** servers are configured to accept both SSH v1 and SSH v2 connections. The client, however, can choose between the two. Version 2 is known to be more robust and secure than its predecessor.

The ssh(1) command can be forced to use either protocol by passing it the `-1` or `-2` argument for v1 and v2, respectively.

10.11.4 Secure Copy

The scp(1) command works similarly to rcp(1); it copies a file to or from a remote machine, except in a secure fashion.

```
#  scp user@example.com:/COPYRIGHT COPYRIGHT
user@example.com's password: *******
COPYRIGHT            100% |*****************************|  4735
00:00
#
```

Since the fingerprint was already saved for this host in the previous example, it is verified when using scp(1) here.

The arguments passed to scp(1) are similar to cp(1), with the file or files in the first argument, and the destination in the second. Since the file is fetched over the network, through SSH, one or more of the file arguments takes on the form `user@host:<path_to_remote_file>`.

10.11.5 Configuration

The system-wide configuration files for both the **OpenSSH** daemon and client reside within the `/etc/ssh` directory.

`ssh_config` configures the client settings, while `sshd_config` configures the daemon.

Additionally, the `sshd_program` (`/usr/sbin/sshd` by default), and `sshd_flags` `rc.conf` options can provide more levels of configuration.

10.11.6 ssh-keygen

Instead of using passwords, ssh-keygen(1) can be used to generate RSA keys to authenticate a user:

```
% ssh-keygen -t rsa1
Initializing random number generator...
Generating p:  .++ (distance 66)
Generating q:  ..............................++ (distance 498)
Computing the keys...
Key generation complete.
Enter file in which to save the key (/home/user/.ssh/identity):
Enter passphrase:
Enter the same passphrase again:
Your identification has been saved in /home/user/.ssh/identity.
...
```

ssh-keygen(1) will create a public and private key pair for use in authentication. The private key is stored in `~/.ssh/identity`, whereas the public key is stored in `~/.ssh/identity.pub`. The public key must be placed in `~/.ssh/authorized_keys` of the remote machine in order for the setup to work.

This will allow connection to the remote machine based upon RSA authentication instead of passwords.

> **Note:** The `-t rsa1` option will create RSA keys for use by SSH protocol version 1. If you want to use RSA keys with the SSH protocol version 2, you have to use the command `ssh-keygen -t rsa`.

If a passphrase is used in ssh-keygen(1), the user will be prompted for a password each time in order to use the private key.

A SSH protocol version 2 DSA key can be created for the same purpose by using the `ssh-keygen -t dsa` command. This will create a public/private DSA key for use in SSH protocol version 2 sessions only. The public key is stored in `~/.ssh/id_dsa.pub`, while the private key is in `~/.ssh/id_dsa`.

DSA public keys are also placed in `~/.ssh/authorized_keys` on the remote machine.

ssh-agent(1) and ssh-add(1) are utilities used in managing multiple passworded private keys.

> **Warning:** The various options and files can be different according to the **OpenSSH** version you have on your system, to avoid problems you should consult the ssh-keygen(1) manual page.

10.11.7 SSH Tunneling

OpenSSH has the ability to create a tunnel to encapsulate another protocol in an encrypted session.

The following command tells ssh(1) to create a tunnel for **telnet**:

```
% ssh -2 -N -f -L 5023:localhost:23 user@foo.example.com
%
```

The `ssh` command is used with the following options:

`-2`

Forces `ssh` to use version 2 of the protocol. (Do not use if you are working with older SSH servers)

`-N`

Indicates no command, or tunnel only. If omitted, `ssh` would initiate a normal session.

`-f`

Forces `ssh` to run in the background.

`-L`

Indicates a local tunnel in *`localport:remotehost:remoteport`* fashion.

`user@foo.example.com`

The remote SSH server.

An SSH tunnel works by creating a listen socket on `localhost` on the specified port. It then forwards any connection received on the local host/port via the SSH connection to the specified remote host and port.

In the example, port *`5023`* on `localhost` is being forwarded to port *`23`* on `localhost` of the remote machine. Since *`23`* is **telnet**, this would create a secure **telnet** session through an SSH tunnel.

This can be used to wrap any number of insecure TCP protocols such as SMTP, POP3, FTP, etc.

Example 10-1. Using SSH to Create a Secure Tunnel for SMTP

```
% ssh -2 -N -f -L 5025:localhost:25 user@mailserver.example.com
user@mailserver.example.com's password: *****
% telnet localhost 5025
Trying 127.0.0.1...
Connected to localhost.
Escape character is '^]'.
220 mailserver.example.com ESMTP
```

This can be used in conjunction with an ssh-keygen(1) and additional user accounts to create a more seamless/hassle-free SSH tunneling environment. Keys can be used in place of typing a password, and the tunnels can be run as a separate user.

10.11.7.1 Practical SSH Tunneling Examples

10.11.7.1.1 Secure Access of a POP3 Server

At work, there is an SSH server that accepts connections from the outside. On the same office network resides a mail server running a POP3 server. The network, or network path between your home and office may or may not be completely trustable. Because of this, you need to check your e-mail in a secure manner. The solution is to create an SSH connection to your office's SSH server, and tunnel through to the mail server.

```
% ssh -2 -N -f -L 2110:mail.example.com:110 user@ssh-server.example.com
user@ssh-server.example.com's password: ******
```

When the tunnel is up and running, you can point your mail client to send POP3 requests to `localhost` port 2110. A connection here will be forwarded securely across the tunnel to `mail.example.com`.

10.11.7.1.2 Bypassing a Draconian Firewall

Some network administrators impose extremely draconian firewall rules, filtering not only incoming connections, but outgoing connections. You may be only given access to contact remote machines on ports 22 and 80 for SSH and web surfing.

You may wish to access another (perhaps non-work related) service, such as an Ogg Vorbis server to stream music. If this Ogg Vorbis server is streaming on some other port than 22 or 80, you will not be able to access it.

The solution is to create an SSH connection to a machine outside of your network's firewall, and use it to tunnel to the Ogg Vorbis server.

```
% ssh -2 -N -f -L 8888:music.example.com:8000 user@unfirewalled-system.example.org
user@unfirewalled-system.example.org's password: *******
```

Your streaming client can now be pointed to `localhost` port 8888, which will be forwarded over to `music.example.com` port 8000, successfully evading the firewall.

10.11.8 Further Reading

OpenSSH (http://www.openssh.com/)

ssh(1) scp(1) ssh-keygen(1) ssh-agent(1) ssh-add(1)

sshd(8) sftp-server(8)

10.12 Mandatory Access Control (MAC)

Sponsored by DARPA and Network Associates Laboratories. Contributed by Robert Watson.

FreeBSD 5.0 includes a new kernel security framework, the TrustedBSD MAC Framework. The MAC Framework permits compile-time, boot-time, and run-time extension of the kernel access control policy, and can be used to load support for Mandatory Access Control (MAC), and custom security modules such as hardening modules. The MAC

Framework is currently considered to be an experimental feature, and should not yet be used in production environments without careful consideration. It is anticipated that the MAC Framework will be appropriate for more widespread production use by FreeBSD 5.2.

When configured into a kernel, the MAC Framework permits security modules to augment the existing kernel access control model, restricting access to system services and objects. For example, the mac_bsdextended(4) module augments file system access control, permitting administrators to provide a firewall-like ruleset constraining access to file system objects based on user ids and group membership. Some modules require little or no configuration, such as mac_seeotheruids(4), whereas others perform ubiquitous object labeling, such as mac_biba(4) and mac_mls(4), and require extensive configuration.

To enable the MAC Framework in your system kernel, you must add the following entry to your kernel configuration:

```
options MAC
```

Security policy modules shipped with the base system may be loaded using kldload(8) or in the boot loader(8) They may also be compiled directly into the kernel using the following options, if the use of modules is not desired.

Different MAC policies may be configured in different ways; frequently, MAC policy modules export configuration parameters using the sysctl(8) MIB using the `security.mac` namespace. Policies relying on file system or other labels may require a configuration step that involves assigning initial labels to system objects or creating a policy configuration file. For information on how to configure and use each policy module, see its man page.

A variety of tools are available to configure the MAC Framework and labels maintained by various policies. Extensions have been made to the login and credential management mechanisms (setusercontext(3)) to support initial user labeling using login.conf(5). In addition, modifications have been made to su(1), ps(1), ls(1), and ifconfig(8) to inspect and set labels on processes, files, and interfaces. In addition, several new tools have been added to manage labels on objects, including getfmac(8), setfmac(8), and setfsmac(8) to manage labels on files, and getpmac(8) and setpmac(8).

What follows is a list of policy modules shipped with FreeBSD 5.0.

10.12.1 Biba Integrity Policy (mac_biba)

Vendor: TrustedBSD Project

Module name: mac_biba.ko

Kernel option: `MAC_BIBA`

The Biba Integrity Policy (mac_biba(4)) provides for hierarchical and non-hierarchical labeling of all system objects with integrity data, and the strict enforcement of an information flow policy to prevent corruption of high integrity subjects and data by low-integrity subjects. Integrity is enforced by preventing high integrity subjects (generally processes) from reading low integrity objects (often files), and preventing low integrity subjects from writing to high integrity objects. This security policy is frequently used in commercial trusted systems to provide strong protection for the Trusted Code Base (TCB). Because it provides ubiquitous labeling, the Biba integrity policy must be compiled into the kernel or loaded at boot.

10.12.2 File System Firewall Policy (mac_bsdextended)

Vendor: TrustedBSD Project

Module name: mac_bsdextended.ko

Kernel option: `MAC_BSDEXTENDED`

The File System Firewall Policy (mac_bsdextended(4)) provides an extension to the BSD file system permission model, permitting the administrator to define a set of firewall-like rules for limiting access to file system objects owned by other users and groups. Managed using ugidfw(8), rules may limit access to files and directories based on the uid and gids of the process attempting the access, and the owner and group of the target of the access attempt. All rules are restrictive, so they may be placed in any order. This policy requires no prior configuration or labeling, and may be appropriate in multi-user environments where mandatory limits on inter-user data exchange are required. Caution should be exercised in limiting access to files owned by the super-user or other system user ids, as many useful programs and directories are owned by these users. As with a network firewall, improper application of file system firewall rules may render the system unusable. New tools to manage the rule set may be easily written using the libugidfw(3) library.

10.12.3 Interface Silencing Policy (mac_ifoff)

Vendor: TrustedBSD Project

Module name: mac_ifoff.ko

Kernel option: `MAC_IFOFF`

The interface silencing policy (mac_ifoff(4)) prohibits the use of network interfaces during the boot until explicitly enabled, preventing spurious stack output stack response to incoming packets. This is appropriate for use in environments where the monitoring of packets is required, but no traffic may be generated.

10.12.4 Low-Watermark Mandatory Access Control (LOMAC) (mac_lomac)

Vendor: Network Associates Laboratories

Module name: mac_lomac.ko

Kernel option: `MAC_LOMAC`

Similar to the Biba Integrity Policy, the LOMAC policy (mac_lomac(4)) relies on the ubiquitous labeling of all system objects with integrity labels. Unlike Biba, LOMAC permits high integrity subjects to read from low integrity objects, but then downgrades the label on the subject to prevent future writes to high integrity objects. This policy may provide for greater compatibility, as well as require less initial configuration than Biba. However, as with Biba, it ubiquitously labels objects and must therefore be compiled into the kernel or loaded at boot.

10.12.5 Multi-Level Security Policy (MLS) (mac_mls)

Vendor: TrustedBSD Project

Module name: mac_mls.ko

Kernel option: `MAC_MLS`

Multi-Level Security (MLS) (mac_mls(4)) provides for hierarchical and non-hierarchical labeling of all system objects with sensitivity data, and the strict enforcement of an information flow policy to prevent the leakage of confidential data to untrusted parties. The logical conjugate of the Biba Integrity Policy, MLS is frequently shipped in commercial trusted operating systems to protect data secrecy in multi-user environments. Hierarchal labels provide support for the notion of clearances and classifications in traditional parlance; non-hierarchical labels provide support for "need-to-know." As with Biba, ubiquitous labeling of objects occurs, and it must therefore be compiled into the kernel or loaded at boot. As with Biba, extensive initial configuration may be required.

10.12.6 MAC Stub Policy (mac_none)

Vendor: TrustedBSD Project

Module name: mac_none.ko

Kernel option: `MAC_NONE`

The None policy (mac_none(4)) provides a stub sample policy for developers, implementing all entry points, but not changing the system access control policy. Running this on a production system would not be highly beneficial.

10.12.7 Process Partition Policy (mac_partition)

Vendor: TrustedBSD Project

Module name: mac_partition.ko

Kernel option: `MAC_PARTITION`

The Partition policy (mac_partition(4)) provides for a simple process visibility limitation, assigning labels to processes identifying what numeric system partition they are present in. If none, all other processes are visible using standard monitoring tools; if a partition identifier is present, then only other processes in the same partition are visible. This policy may be compiled into the kernel, loaded at boot, or loaded at run-time.

10.12.8 See Other Uids Policy (mac_seeotheruids)

Vendor: TrustedBSD Project

Module name: mac_seeotheruids.ko

Kernel option: `MAC_SEEOTHERUIDS`

The See Other Uids policy (mac_seeotheruids(4)) implements a similar process visibility model to mac_partition, except that it relies on process credentials to control visibility of processes, rather than partition labels. This policy may be configured to exempt certain users and groups, including permitting system operators to view all processes without special privilege. This policy may be compiled into the kernel, loaded at boot, or loaded at run-time.

10.12.9 MAC Framework Test Policy (mac_test)

Vendor: TrustedBSD Project

Module name: mac_test.ko

Kernel option: `MAC_TEST`

The Test policy (mac_test(4)) provides a regression test environment for the MAC Framework, and will cause a fail-stop in the event that internal MAC Framework assertions about proper data labeling fail. This module can be used to detect failures to properly label system objects in the kernel implementation. This policy may be compiled into the kernel, loaded at boot, or loaded at run-time.

10.13 File System Access Control Lists

Contributed by Tom Rhodes.

In conjunction with file system enhancements like snapshots, FreeBSD 5.0 and later offers the security of File System Access Control Lists (ACLs).

Access Control Lists extend the standard UNIX permission model in a highly compatible (POSIX.1e) way. This feature permits an administrator to make use of and take advantage of a more sophisticated security model.

To enable ACL support for UFS file systems, the following:

```
options UFS_ACL
```

must be compiled into the kernel. If this option has not been compiled in, a warning message will be displayed when attempting to mount a file system supporting ACLs. This option is included in the `GENERIC` kernel. ACLs rely on extended attributes being enabled on the file system. Extended attributes are natively supported in the next generation UNIX file system, UFS2.

> **Note:** A higher level of administrative overhead is required to configure extended attributes on UFS1 than on UFS2. The performance of extended attributes on UFS2 is also substantially higher. As a result, UFS2 is generally recommended in preference to UFS1 for use with access control lists.

ACLs are enabled by the mount-time administrative flag, `acls`, which may be added to `/etc/fstab`. The mount-time flag can also be automatically set in a persistent manner using tunefs(8) to modify a superblock ACLs flag in the file system header. In general, it is preferred to use the superblock flag for several reasons:

- The mount-time ACLs flag cannot be changed by a remount (mount(8) `-u`), only by means of a complete umount(8) and fresh mount(8). This means that ACLs cannot be enabled on the root file system after boot. It also means that you cannot change the disposition of a file system once it is in use.
- Setting the superblock flag will cause the file system to always be mounted with ACLs enabled even if there is not an `fstab` entry or if the devices re-order. This prevents accidental mounting of the file system without ACLs enabled, which can result in ACLs being improperly enforced, and hence security problems.

> **Note:** We may change the ACLs behavior to allow the flag to be enabled without a complete fresh mount(8), but we consider it desirable to discourage accidental mounting without ACLs enabled, because you can shoot your feet quite nastily if you enable ACLs, then disable them, then re-enable them without flushing the extended attributes. In general, once you have enabled ACLs on a file system, they should not be disabled, as the resulting file protections may not be compatible with those intended by the users of the system, and re-enabling ACLs may re-attach the previous ACLs to files that have since had their permissions changed, resulting in other unpredictable behavior.

File systems with ACLs enabled will show a `+` (plus) sign in their permission settings when viewed. For example:

```
drwx------  2 robert  robert  512 Dec 27 11:54 private
drwxrwx---+ 2 robert  robert  512 Dec 23 10:57 directory1
drwxrwx---+ 2 robert  robert  512 Dec 22 10:20 directory2
drwxrwx---+ 2 robert  robert  512 Dec 27 11:57 directory3
drwxr-xr-x  2 robert  robert  512 Nov 10 11:54 public_html
```

Here we see that the `directory1`, `directory2`, and `directory3` directories are all taking advantage of ACLs. The `public_html` directory is not.

10.13.1 Making Use of ACLs

The file system ACLs can be viewed by the getfacl(1) utility. For instance, to view the ACL settings on the `test` file, one would use the command:

```
%getfacl test
#file:test
#owner:1001
#group:1001
user::rw-
group::r--
other::r--
```

To change the ACL settings on this file, invoke the setfacl(1) utility. Observe:

```
%setfacl -k test
```

The `-k` flag will remove all of the currently defined ACLs from a file or file system. The more preferable method would be to use `-b` as it leaves the basic fields required for ACLs to work.

```
%-m u:trhodes:rwx,group:web:r--,o::--- test
```

In the aforementioned command, the `-m` option was used to modify the default ACL entries. Since there were no pre-defined entries, as they were removed by the previous command, this will restore the default options and assign the options listed. Take care to notice that if you add a user or group which does not exist on the system, an `Invalid argument` error will be printed to `stdout`.

10.14 FreeBSD Security Advisories

Contributed by Tom Rhodes.

Like many production quality operating systems, FreeBSD publishes "Security Advisories". These advisories are usually mailed to the security lists and noted in the Errata only after the appropriate releases have been patched. This section will work to explain what an advisory is, how to understand them, and what measures to take in order to patch a system.

10.14.1 What does an advisory look like?

The FreeBSD security advisories look similar to the one below, taken from the security mailing list.

```
=============================================================================
FreeBSD-SA-XX:XX.UTIL                                     Security Advisory
                                                          The FreeBSD Project

Topic:          denial of service due to some problem❶
```

```
Category:       core❷
Module:         sys❸
Announced:      2003-09-23❹
Credits:        Person@EMAIL-ADDRESS❺
Affects:        All releases of FreeBSD❻
                FreeBSD 4-STABLE prior to the correction date
Corrected:      2003-09-23 16:42:59 UTC (RELENG_4, 4.9-PRERELEASE)
                2003-09-23 20:08:42 UTC (RELENG_5_1, 5.1-RELEASE-p6)
                2003-09-23 20:07:06 UTC (RELENG_5_0, 5.0-RELEASE-p15)
                2003-09-23 16:44:58 UTC (RELENG_4_8, 4.8-RELEASE-p8)
                2003-09-23 16:47:34 UTC (RELENG_4_7, 4.7-RELEASE-p18)
                2003-09-23 16:49:46 UTC (RELENG_4_6, 4.6-RELEASE-p21)
                2003-09-23 16:51:24 UTC (RELENG_4_5, 4.5-RELEASE-p33)
                2003-09-23 16:52:45 UTC (RELENG_4_4, 4.4-RELEASE-p43)
                2003-09-23 16:54:39 UTC (RELENG_4_3, 4.3-RELEASE-p39)❼
FreeBSD only:   NO❽

For general information regarding FreeBSD Security Advisories,
including descriptions of the fields above, security branches, and the
following sections, please visit
http://www.freebsd.org/security/.

I.   Background❾


II.  Problem Description(10)


III. Impact(11)


IV.  Workaround(12)


V.   Solution(13)


VI.  Correction details(14)


VII. References(15)
```

❶ The topic field indicates exactly what the problem is. It is basically an introduction to the current security advisory and notes the utility with the vulnerability.

❷ The Category refers to the affected part of the system which may be one of core, contrib, or ports. The core category means that the vulnerability affects a core component of the FreeBSD operating system. The contrib category means that the vulnerability affects software contributed to the FreeBSD Project, such as **Sendmail**. Finally the ports category indicates that the vulnerability affects add on software available as part of the ports collection.

❸ The Module field refers to the component location, for instance sys. In this example, we see that the module, sys, is affected; therefore, this vulnerability affects a component used within the kernel.

❹ The Announced field reflects the date said security advisory was published, or announced to the world. This means that the security team has verified that the problem does exist and that a patch has been committed to the FreeBSD source code repository.

❺ The Credits field gives credit to the individual or organization who noticed the vulnerability and reported it.

❻ The Affects field explains which releases of FreeBSD are affected by this vulnerability. For the kernel, a quick look over the output from `ident` on the affected files will help in determining the revision. For ports, the version number is listed after the port name in `/var/db/pkg`. If the system does not sync with the FreeBSD CVS repository and rebuild daily, chances are that it is affected.

❼ The Corrected field indicates the date, time, time offset, and release that was corrected.

❽ The FreeBSD only field indicates whether this vulnerability affects just FreeBSD, or if it affects other operating systems as well.

❾ The background field gives information on exactly what the affected utility is. Most of the time this is why the utility exists in FreeBSD, what it is used for, and a bit of information on how the utility came to be.

(10) The Problem Description field explains the security hole in depth. This can include information on flawed code, or even how the utility could be maliciously used to open a security hole.

(11) The Impact field describes what type of impact the problem could have on a system. For example, this could be anything from a denial of service attack, to extra privileges available to users, or even giving the attacker superuser access.

(12) The Workaround field offers a feasible workaround to system administrators who may be incapable of upgrading the system. This may be due to time constraints, network availability, or a slew of other reasons. Regardless, security should not be taken lightly, and an affected system should either be patched or the security hole workaround should be implemented.

(13) The Solution field offers instructions on patching the affected system. This is a step by step tested and verified method for getting a system patched and working securely.

(14) The Correction Details field displays the CVS branch or release name with the periods changed to underscore characters. It also shows the revision number of the affected files within each branch.

(15) The References field usually offers sources of other information. This can included web URLs, books, mailing lists, and newsgroups.

Notes

1. Under FreeBSD the standard login password may be up to 128 characters in length.

Chapter 11 Printing

Contributed by Sean Kelly. Restructured and updated by Jim Mock.

11.1 Synopsis

FreeBSD can be used to print to a wide variety of printers, from the oldest impact printer to the latest laser printers, and everything in between, allowing you to produce high quality printed output from the applications you run.

FreeBSD can also be configured to act as a print server on a network; in this capacity FreeBSD can receive print jobs from a variety of other computers, including other FreeBSD computers, Windows and Mac OS hosts. FreeBSD will ensure that one job at a time is printed, and can keep statistics on which users and machines are doing the most printing, produce "banner" pages showing who's printout is who's, and more.

After reading this chapter, you will know:

- How to configure the FreeBSD print spooler.
- How to install print filters, to handle special print jobs differently, including converting incoming documents to print formats that your printers understand.
- How to enable header, or banner pages on your printout.
- How to print to printers connected to other computers.
- How to print to printers connected directly to the network.
- How to control printer restrictions, including limiting the size of print jobs, and preventing certain users from printing.
- How to keep printer statistics, and account for printer usage.
- How to troubleshoot printing problems.

Before reading this chapter, you should:

- Know how to configure and install a new kernel (Chapter 9).

11.2 Introduction

In order to use printers with FreeBSD, you will need to set them up to work with the Berkeley line printer spooling system, also known as the **LPD** spooling system. It is the standard printer control system in FreeBSD. This chapter introduces the **LPD** spooling system, often simply called **LPD**, and will guide you through its configuration.

If you are already familiar with **LPD** or another printer spooling system, you may wish to skip to section Setting up the spooling system.

LPD controls everything about a host's printers. It is responsible for a number of things:

- It controls access to attached printers and printers attached to other hosts on the network.
- It enables users to submit files to be printed; these submissions are known as *jobs*.
- It prevents multiple users from accessing a printer at the same time by maintaining a *queue* for each printer.

- It can print *header pages* (also known as *banner* or *burst* pages) so users can easily find jobs they have printed in a stack of printouts.
- It takes care of communications parameters for printers connected on serial ports.
- It can send jobs over the network to a **LPD** spooler on another host.
- It can run special filters to format jobs to be printed for various printer languages or printer capabilities.
- It can account for printer usage.

Through a configuration file (`/etc/printcap`), and by providing the special filter programs, you can enable the **LPD** system to do all or some subset of the above for a great variety of printer hardware.

11.2.1 Why You Should Use the Spooler

If you are the sole user of your system, you may be wondering why you should bother with the spooler when you do not need access control, header pages, or printer accounting. While it is possible to enable direct access to a printer, you should use the spooler anyway since:

- **LPD** prints jobs in the background; you do not have to wait for data to be copied to the printer.
- **LPD** can conveniently run a job to be printed through filters to add date/time headers or convert a special file format (such as a TeX DVI file) into a format the printer will understand. You will not have to do these steps manually.
- Many free and commercial programs that provide a print feature usually expect to talk to the spooler on your system. By setting up the spooling system, you will more easily support other software you may later add or already have.

11.3 Basic Setup

To use printers with the **LPD** spooling system, you will need to set up both your printer hardware and the **LPD** software. This document describes two levels of setup:

- See section Simple Printer Setup to learn how to connect a printer, tell **LPD** how to communicate with it, and print plain text files to the printer.
- See section Advanced Printer Setup to find out how to print a variety of special file formats, to print header pages, to print across a network, to control access to printers, and to do printer accounting.

11.3.1 Simple Printer Setup

This section tells how to configure printer hardware and the **LPD** software to use the printer. It teaches the basics:

- Section Hardware Setup gives some hints on connecting the printer to a port on your computer.
- Section Software Setup shows how to set up the **LPD** spooler configuration file (`/etc/printcap`).

If you are setting up a printer that uses a network protocol to accept data to print instead of a serial or parallel interface, see Printers With Networked Data Stream Interfaces.

Although this section is called "Simple Printer Setup", it is actually fairly complex. Getting the printer to work with your computer and the **LPD** spooler is the hardest part. The advanced options like header pages and accounting are fairly easy once you get the printer working.

11.3.1.1 Hardware Setup

This section tells about the various ways you can connect a printer to your PC. It talks about the kinds of ports and cables, and also the kernel configuration you may need to enable FreeBSD to speak to the printer.

If you have already connected your printer and have successfully printed with it under another operating system, you can probably skip to section Software Setup.

11.3.1.1.1 Ports and Cables

Nearly all printers you can get for a PC today support one or both of the following interfaces:

- *Serial* interfaces use a serial port on your computer to send data to the printer. Serial interfaces are common in the computer industry and cables are readily available and also easy to construct. Serial interfaces sometimes need special cables and might require you to configure somewhat complex communications options.
- *Parallel* interfaces use a parallel port on your computer to send data to the printer. Parallel interfaces are common in the PC market. Cables are readily available but more difficult to construct by hand. There are usually no communications options with parallel interfaces, making their configuration exceedingly simple.

  Parallel interfaces are sometimes known as "Centronics" interfaces, named after the connector type on the printer.

In general, serial interfaces are slower than parallel interfaces. Parallel interfaces usually offer just one-way communication (computer to printer) while serial gives you two-way. Newer parallel ports (EPP and ECP) and printers can communicate in both directions under FreeBSD when a IEEE1284 compliant cable is used.

Usually, the only time you need two-way communication with the printer is if the printer speaks PostScript. PostScript printers can be very verbose. In fact, PostScript jobs are actually programs sent to the printer; they need not produce paper at all and may return results directly to the computer. PostScript also uses two-way communication to tell the computer about problems, such as errors in the PostScript program or paper jams. Your users may be appreciative of such information. Furthermore, the best way to do effective accounting with a PostScript printer requires two-way communication: you ask the printer for its page count (how many pages it has printed in its lifetime), then send the user's job, then ask again for its page count. Subtract the two values and you know how much paper to charge the user.

11.3.1.1.2 Parallel Ports

To hook up a printer using a parallel interface, connect the Centronics cable between the printer and the computer. The instructions that came with the printer, the computer, or both should give you complete guidance.

Remember which parallel port you used on the computer. The first parallel port is `/dev/ppc0` to FreeBSD; the second is `/dev/ppc1`, and so on. The printer device name uses the same scheme: `/dev/lpt0` for the printer on the first parallel ports etc.

11.3.1.1.3 Serial Ports

To hook up a printer using a serial interface, connect the proper serial cable between the printer and the computer. The instructions that came with the printer, the computer, or both should give you complete guidance.

If you are unsure what the "proper serial cable" is, you may wish to try one of the following alternatives:

- A *modem* cable connects each pin of the connector on one end of the cable straight through to its corresponding pin of the connector on the other end. This type of cable is also known as a "DTE-to-DCE" cable.
- A *null-modem* cable connects some pins straight through, swaps others (send data to receive data, for example), and shorts some internally in each connector hood. This type of cable is also known as a "DTE-to-DTE" cable.
- A *serial printer* cable, required for some unusual printers, is like the null-modem cable, but sends some signals to their counterparts instead of being internally shorted.

You should also set up the communications parameters for the printer, usually through front-panel controls or DIP switches on the printer. Choose the highest `bps` (bits per second, sometimes *baud rate*) rate that both your computer and the printer can support. Choose 7 or 8 data bits; none, even, or odd parity; and 1 or 2 stop bits. Also choose a flow control protocol: either none, or XON/XOFF (also known as "in-band" or "software") flow control. Remember these settings for the software configuration that follows.

11.3.1.2 Software Setup

This section describes the software setup necessary to print with the **LPD** spooling system in FreeBSD.

Here is an outline of the steps involved:

1. Configure your kernel, if necessary, for the port you are using for the printer; section Kernel Configuration tells you what you need to do.
2. Set the communications mode for the parallel port, if you are using a parallel port; section Setting the Communication Mode for the Parallel Port gives details.
3. Test if the operating system can send data to the printer. Section Checking Printer Communications gives some suggestions on how to do this.
4. Set up **LPD** for the printer by modifying the file `/etc/printcap`. You will find out how to do this later in this chapter.

11.3.1.2.1 Kernel Configuration

The operating system kernel is compiled to work with a specific set of devices. The serial or parallel interface for your printer is a part of that set. Therefore, it might be necessary to add support for an additional serial or parallel port if your kernel is not already configured for one.

To find out if the kernel you are currently using supports a serial interface, type:

```
# grep sioN /var/run/dmesg.boot
```

Where `N` is the number of the serial port, starting from zero. If you see output similar to the following:

```
sio2 at port 0x3e8-0x3ef irq 5 on isa
sio2: type 16550A
```

then the kernel supports the port.

To find out if the kernel supports a parallel interface, type:

```
# grep ppcN /var/run/dmesg.boot
```

Where `N` is the number of the parallel port, starting from zero. If you see output similar to the following:

```
ppc0: <Parallel port> at port 0x378-0x37f irq 7 on isa0
ppc0: SMC-like chipset (ECP/EPP/PS2/NIBBLE) in COMPATIBLE mode
ppc0: FIFO with 16/16/8 bytes threshold
```

then the kernel supports the port.

You might have to reconfigure your kernel in order for the operating system to recognize and use the parallel or serial port you are using for the printer.

To add support for a serial port, see the section on kernel configuration. To add support for a parallel port, see that section *and* the section that follows.

11.3.1.3 Adding `/dev` Entries for the Ports

> **Note:** FreeBSD 5.0 includes the `devfs` filesystem which automatically creates device nodes as needed. If you are running a version of FreeBSD with `devfs` enabled then you can safely skip this section.

Even though the kernel may support communication along a serial or parallel port, you will still need a software interface through which programs running on the system can send and receive data. That is what entries in the `/dev` directory are for.

To add a `/dev` entry for a port:

1. Become `root` with the su(1) command. Enter the `root` password when prompted.
2. Change to the `/dev` directory:

   ```
   # cd /dev
   ```
3. Type:

   ```
   # ./MAKEDEV port
   ```

   Where *`port`* is the device entry for the port you want to make. Use `lpt0` for the printer on the first parallel port, `lpt1` for the printer on the second port, and so on; use `ttyd0` for the first serial port, `ttyd1` for the second, and so on.
4. Type:

   ```
   # ls -l port
   ```

   to make sure the device entry got created.

11.3.1.3.1 Setting the Communication Mode for the Parallel Port

When you are using the parallel interface, you can choose whether FreeBSD should use interrupt-driven or polled communication with the printer. The generic printer device driver (lpt(4)) on FreeBSD 4.X and 5.X uses the ppbus(4) system, which controls the port chipset with the ppc(4) driver.

- The *interrupt-driven* method is the default with the GENERIC kernel. With this method, the operating system uses an IRQ line to determine when the printer is ready for data.
- The *polled* method directs the operating system to repeatedly ask the printer if it is ready for more data. When it responds ready, the kernel sends more data.

The interrupt-driven method is usually somewhat faster but uses up a precious IRQ line. Some newer HP printers are claimed not to work correctly in interrupt mode, apparently due to some (not yet exactly understood) timing problem. These printers need polled mode. You should use whichever one works. Some printers will work in both modes, but are painfully slow in interrupt mode.

You can set the communications mode in two ways: by configuring the kernel or by using the lptcontrol(8) program.

To set the communications mode by configuring the kernel:

1. Edit your kernel configuration file. Look for an `ppc0` entry. If you are setting up the second parallel port, use `ppc1` instead. Use `ppc2` for the third port, and so on.
   - If you want interrupt-driven mode, for FreeBSD 4.X add the `irq` specifier:

     ```
     device ppc0 at isa? irq N
     ```

     Where *N* is the IRQ number for your computer's parallel port.

     For FreeBSD 5.X, edit the following line:

     ```
     hint.ppc.0.irq="N"
     ```

     in the `/boot/device.hints` file and replace *N* with the right IRQ number. The kernel configuration file must also contain the ppc(4) driver:

     ```
     device ppc
     ```

   - If you want polled mode, do not add the `irq` specifier:

     For FreeBSD 4.X, use the following line in your kernel configuration file:

     ```
     device ppc0 at isa?
     ```

     For FreeBSD 5.X, simply remove in your `/boot/device.hints` file, the following line:

     ```
     hint.ppc.0.irq="N"
     ```

     In some cases, this is not enough to put the port in polled mode under FreeBSD 5.X. Most of time it comes from acpi(4) driver, this latter is able to probe and attach devices, and therefore, control the access mode to the printer port. You should check your acpi(4) configuration to correct this problem.

2. Save the file. Then configure, build, and install the kernel, then reboot. See kernel configuration for more details.

To set the communications mode with lptcontrol(8):

1. Type:

   `# lptcontrol -i -d /dev/lptN`

   to set interrupt-driven mode for `lptN`.

2. Type:

   `# lptcontrol -p -d /dev/lptN`

   to set polled-mode for `lptN`.

You could put these commands in your `/etc/rc.local` file to set the mode each time your system boots. See lptcontrol(8) for more information.

11.3.1.3.2 Checking Printer Communications

Before proceeding to configure the spooling system, you should make sure the operating system can successfully send data to your printer. It is a lot easier to debug printer communication and the spooling system separately.

To test the printer, we will send some text to it. For printers that can immediately print characters sent to them, the program lptest(1) is perfect: it generates all 96 printable ASCII characters in 96 lines.

For a PostScript (or other language-based) printer, we will need a more sophisticated test. A small PostScript program, such as the following, will suffice:

```
%!PS
100 100 moveto 300 300 lineto stroke
310 310 moveto /Helvetica findfont 12 scalefont setfont
(Is this thing working?) show
showpage
```

The above PostScript code can be placed into a file and used as shown in the examples appearing in the following sections.

> **Note:** When this document refers to a printer language, it is assuming a language like PostScript, and not Hewlett Packard's PCL. Although PCL has great functionality, you can intermingle plain text with its escape sequences. PostScript cannot directly print plain text, and that is the kind of printer language for which we must make special accommodations.

11.3.1.3.2.1 Checking a Parallel Printer

This section tells you how to check if FreeBSD can communicate with a printer connected to a parallel port.

To test a printer on a parallel port:

1. Become `root` with su(1).
2. Send data to the printer.
   - If the printer can print plain text, then use lptest(1). Type:

     `# lptest > /dev/lptN`

     Where *N* is the number of the parallel port, starting from zero.

- If the printer understands PostScript or other printer language, then send a small program to the printer. Type:

  ```
  # cat > /dev/lptN
  ```

  Then, line by line, type the program *carefully* as you cannot edit a line once you have pressed `RETURN` or `ENTER`. When you have finished entering the program, press `CONTROL+D`, or whatever your end of file key is.

  Alternatively, you can put the program in a file and type:

  ```
  # cat file > /dev/lptN
  ```

  Where *`file`* is the name of the file containing the program you want to send to the printer.

You should see something print. Do not worry if the text does not look right; we will fix such things later.

11.3.1.3.2.2 Checking a Serial Printer

This section tells you how to check if FreeBSD can communicate with a printer on a serial port.

To test a printer on a serial port:

1. Become `root` with su(1).
2. Edit the file `/etc/remote`. Add the following entry:

   ```
   printer:dv=/dev/port:br#bps-rate:pa=parity
   ```

   Where *`port`* is the device entry for the serial port (`ttyd0`, `ttyd1`, etc.), *`bps-rate`* is the bits-per-second rate at which the printer communicates, and *`parity`* is the parity required by the printer (either `even`, `odd`, `none`, or `zero`).

   Here is a sample entry for a printer connected via a serial line to the third serial port at 19200 bps with no parity:

   ```
   printer:dv=/dev/ttyd2:br#19200:pa=none
   ```

3. Connect to the printer with tip(1). Type:

   ```
   # tip printer
   ```

   If this step does not work, edit the file `/etc/remote` again and try using `/dev/cuaaN` instead of `/dev/ttydN`.

4. Send data to the printer.

   - If the printer can print plain text, then use lptest(1). Type:

     ```
     % $lptest
     ```

   - If the printer understands PostScript or other printer language, then send a small program to the printer. Type the program, line by line, *very carefully* as backspacing or other editing keys may be significant to the printer. You may also need to type a special end-of-file key for the printer so it knows it received the whole program. For PostScript printers, press `CONTROL+D`.

     Alternatively, you can put the program in a file and type:

     ```
     % >file
     ```

Where *`file`* is the name of the file containing the program. After tip(1) sends the file, press any required end-of-file key.

You should see something print. Do not worry if the text does not look right; we will fix that later.

11.3.1.4 Enabling the Spooler: the `/etc/printcap` File

At this point, your printer should be hooked up, your kernel configured to communicate with it (if necessary), and you have been able to send some simple data to the printer. Now, we are ready to configure **LPD** to control access to your printer.

You configure **LPD** by editing the file `/etc/printcap`. The **LPD** spooling system reads this file each time the spooler is used, so updates to the file take immediate effect.

The format of the printcap(5) file is straightforward. Use your favorite text editor to make changes to `/etc/printcap`. The format is identical to other capability files like `/usr/share/misc/termcap` and `/etc/remote`. For complete information about the format, see the cgetent(3).

The simple spooler configuration consists of the following steps:

1. Pick a name (and a few convenient aliases) for the printer, and put them in the `/etc/printcap` file; see the Naming the Printer section for more information on naming.
2. Turn off header pages (which are on by default) by inserting the `sh` capability; see the Suppressing Header Pages section for more information.
3. Make a spooling directory, and specify its location with the `sd` capability; see the Making the Spooling Directory section for more information.
4. Set the `/dev` entry to use for the printer, and note it in `/etc/printcap` with the `lp` capability; see the Identifying the Printer Device for more information. Also, if the printer is on a serial port, set up the communication parameters with the `ms#` capability which is discussed in the Configuring Spooler Communications Parameters section.
5. Install a plain text input filter; see the Installing the Text Filter section for details.
6. Test the setup by printing something with the lpr(1) command. More details are available in the Trying It Out and Troubleshooting sections.

Note: Language-based printers, such as PostScript printers, cannot directly print plain text. The simple setup outlined above and described in the following sections assumes that if you are installing such a printer you will print only files that the printer can understand.

Users often expect that they can print plain text to any of the printers installed on your system. Programs that interface to **LPD** to do their printing usually make the same assumption. If you are installing such a printer and want to be able to print jobs in the printer language *and* print plain text jobs, you are strongly urged to add an additional step to the simple setup outlined above: install an automatic plain-text-to-PostScript (or other printer language) conversion program. The section entitled Accommodating Plain Text Jobs on PostScript Printers tells how to do this.

11.3.1.4.1 Naming the Printer

The first (easy) step is to pick a name for your printer It really does not matter whether you choose functional or whimsical names since you can also provide a number of aliases for the printer.

At least one of the printers specified in the `/etc/printcap` should have the alias `lp`. This is the default printer's name. If users do not have the `PRINTER` environment variable nor specify a printer name on the command line of any of the **LPD** commands, then `lp` will be the default printer they get to use.

Also, it is common practice to make the last alias for a printer be a full description of the printer, including make and model.

Once you have picked a name and some common aliases, put them in the `/etc/printcap` file. The name of the printer should start in the leftmost column. Separate each alias with a vertical bar and put a colon after the last alias.

In the following example, we start with a skeletal `/etc/printcap` that defines two printers (a Diablo 630 line printer and a Panasonic KX-P4455 PostScript laser printer):

```
#
#  /etc/printcap for host rose
#
rattan|line|diablo|lp|Diablo 630 Line Printer:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:
```

In this example, the first printer is named `rattan` and has as aliases `line`, `diablo`, `lp`, and `Diablo 630 Line Printer`. Since it has the alias `lp`, it is also the default printer. The second is named `bamboo`, and has as aliases `ps`, `PS`, `S`, `panasonic`, and `Panasonic KX-P4455 PostScript v51.4`.

11.3.1.4.2 Suppressing Header Pages

The **LPD** spooling system will by default print a *header page* for each job. The header page contains the user name who requested the job, the host from which the job came, and the name of the job, in nice large letters. Unfortunately, all this extra text gets in the way of debugging the simple printer setup, so we will suppress header pages.

To suppress header pages, add the `sh` capability to the entry for the printer in `/etc/printcap`. Here is an example `/etc/printcap` with `sh` added:

```
#
#  /etc/printcap for host rose - no header pages anywhere
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
	:sh:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
	:sh:
```

Note how we used the correct format: the first line starts in the leftmost column, and subsequent lines are indented with a single TAB. Every line in an entry except the last ends in a backslash character.

11.3.1.4.3 Making the Spooling Directory

The next step in the simple spooler setup is to make a *spooling directory*, a directory where print jobs reside until they are printed, and where a number of other spooler support files live.

Because of the variable nature of spooling directories, it is customary to put these directories under `/var/spool`. It is not necessary to backup the contents of spooling directories, either. Recreating them is as simple as running mkdir(1).

It is also customary to make the directory with a name that is identical to the name of the printer, as shown below:

```
# mkdir /var/spool/printer-name
```

However, if you have a lot of printers on your network, you might want to put the spooling directories under a single directory that you reserve just for printing with **LPD**. We will do this for our two example printers `rattan` and `bamboo`:

```
# mkdir /var/spool/lpd
# mkdir /var/spool/lpd/rattan
# mkdir /var/spool/lpd/bamboo
```

> **Note:** If you are concerned about the privacy of jobs that users print, you might want to protect the spooling directory so it is not publicly accessible. Spooling directories should be owned and be readable, writable, and searchable by user daemon and group daemon, and no one else. We will do this for our example printers:
>
> ```
> # chown daemon:daemon /var/spool/lpd/rattan
> # chown daemon:daemon /var/spool/lpd/bamboo
> # chmod 770 /var/spool/lpd/rattan
> # chmod 770 /var/spool/lpd/bamboo
> ```

Finally, you need to tell **LPD** about these directories using the `/etc/printcap` file. You specify the pathname of the spooling directory with the `sd` capability:

```
#
#  /etc/printcap for host rose - added spooling directories
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:
```

Note that the name of the printer starts in the first column but all other entries describing the printer should be indented with a tab and each line escaped with a backslash.

If you do not specify a spooling directory with `sd`, the spooling system will use `/var/spool/lpd` as a default.

11.3.1.4.4 Identifying the Printer Device

In the Adding `/dev` Entries for the Ports section, we identified which entry in the `/dev` directory FreeBSD will use to communicate with the printer. Now, we tell **LPD** that information. When the spooling system has a job to print, it will open the specified device on behalf of the filter program (which is responsible for passing data to the printer).

List the `/dev` entry pathname in the `/etc/printcap` file using the `lp` capability.

In our running example, let us assume that `rattan` is on the first parallel port, and `bamboo` is on a sixth serial port; here are the additions to `/etc/printcap`:

```
#
#  /etc/printcap for host rose - identified what devices to use
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:\
        :lp=/dev/ttyd5:
```

If you do not specify the `lp` capability for a printer in your `/etc/printcap` file, **LPD** uses `/dev/lp` as a default. `/dev/lp` currently does not exist in FreeBSD.

If the printer you are installing is connected to a parallel port, skip to the section entitled, Installing the Text Filter. Otherwise, be sure to follow the instructions in the next section.

11.3.1.4.5 Configuring Spooler Communication Parameters

For printers on serial ports, **LPD** can set up the bps rate, parity, and other serial communication parameters on behalf of the filter program that sends data to the printer. This is advantageous since:

- It lets you try different communication parameters by simply editing the `/etc/printcap` file; you do not have to recompile the filter program.
- It enables the spooling system to use the same filter program for multiple printers which may have different serial communication settings.

The following `/etc/printcap` capabilities control serial communication parameters of the device listed in the `lp` capability:

`br#`*`bps-rate`*

Sets the communications speed of the device to *`bps-rate`*, where *`bps-rate`* can be 50, 75, 110, 134, 150, 200, 300, 600, 1200, 1800, 2400, 4800, 9600, 19200, 38400, 57600, or 115200 bits-per-second.

`ms#`*`stty-mode`*

Sets the options for the terminal device after opening the device. stty(1) explains the available options.

When **LPD** opens the device specified by the `lp` capability, it sets the characteristics of the device to those specified with the `ms#` capability. Of particular interest will be the `parenb`, `parodd`, `cs5`, `cs6`, `cs7`, `cs8`, `cstopb`, `crtscts`, and `ixon` modes, which are explained in the stty(1) manual page.

Let us add to our example printer on the sixth serial port. We will set the bps rate to 38400. For the mode, we will set no parity with `-parenb`, 8-bit characters with `cs8`, no modem control with `clocal` and hardware flow control with `crtscts`:

```
bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:
```

11.3.1.4.6 Installing the Text Filter

We are now ready to tell **LPD** what text filter to use to send jobs to the printer. A *text filter*, also known as an *input filter*, is a program that **LPD** runs when it has a job to print. When **LPD** runs the text filter for a printer, it sets the filter's standard input to the job to print, and its standard output to the printer device specified with the `lp` capability. The filter is expected to read the job from standard input, perform any necessary translation for the printer, and write the results to standard output, which will get printed. For more information on the text filter, see the Filters section.

For our simple printer setup, the text filter can be a small shell script that just executes `/bin/cat` to send the job to the printer. FreeBSD comes with another filter called `lpf` that handles backspacing and underlining for printers that might not deal with such character streams well. And, of course, you can use any other filter program you want. The filter `lpf` is described in detail in section entitled lpf: a Text Filter.

First, let us make the shell script `/usr/local/libexec/if-simple` be a simple text filter. Put the following text into that file with your favorite text editor:

```
#!/bin/sh
#
# if-simple - Simple text input filter for lpd
# Installed in /usr/local/libexec/if-simple
#
# Simply copies stdin to stdout.  Ignores all filter arguments.

/bin/cat && exit 0
exit 2
```

Make the file executable:

```
# chmod 555 /usr/local/libexec/if-simple
```

And then tell LPD to use it by specifying it with the `if` capability in `/etc/printcap`. We will add it to the two printers we have so far in the example `/etc/printcap`:

```
#
#  /etc/printcap for host rose - added text filter
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\ :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:\
        :if=/usr/local/libexec/if-simple:
```

11.3.1.4.7 Turn on **LPD**

lpd(8) is run from `/etc/rc`, controlled by the `lpd_enable` variable. This variable defaults to `NO`. If you have not done so already, add the line:

```
lpd_enable="YES"
```

to `/etc/rc.conf`, and then either restart your machine, or just run lpd(8).

```
# lpd
```

11.3.1.4.8 Trying It Out

You have reached the end of the simple **LPD** setup. Unfortunately, congratulations are not quite yet in order, since we still have to test the setup and correct any problems. To test the setup, try printing something. To print with the **LPD** system, you use the command lpr(1), which submits a job for printing.

You can combine lpr(1) with the lptest(1) program, introduced in section Checking Printer Communications to generate some test text.

*To test the simple **LPD** setup:*

Type:

```
# lptest 20 5 | lpr -Pprinter-name
```

Where *`printer-name`* is a the name of a printer (or an alias) specified in `/etc/printcap`. To test the default printer, type lpr(1) without any `-P` argument. Again, if you are testing a printer that expects PostScript, send a PostScript program in that language instead of using lptest(1). You can do so by putting the program in a file and typing `lpr file`.

For a PostScript printer, you should get the results of the program. If you are using lptest(1), then your results should look like the following:

```
!"#$%&'()*+,-./01234
"#$%&'()*+,-./012345
#$%&'()*+,-./0123456
$%&'()*+,-./01234567
%&'()*+,-./012345678
```

To further test the printer, try downloading larger programs (for language-based printers) or running lptest(1) with different arguments. For example, `lptest 80 60` will produce 60 lines of 80 characters each.

If the printer did not work, see the Troubleshooting section.

11.4 Advanced Printer Setup

This section describes filters for printing specially formatted files, header pages, printing across networks, and restricting and accounting for printer usage.

11.4.1 Filters

Although **LPD** handles network protocols, queuing, access control, and other aspects of printing, most of the *real* work happens in the *filters*. Filters are programs that communicate with the printer and handle its device dependencies and special requirements. In the simple printer setup, we installed a plain text filter—an extremely simple one that should work with most printers (section Installing the Text Filter).

However, in order to take advantage of format conversion, printer accounting, specific printer quirks, and so on, you should understand how filters work. It will ultimately be the filter's responsibility to handle these aspects. And the bad news is that most of the time *you* have to provide filters yourself. The good news is that many are generally available; when they are not, they are usually easy to write.

Also, FreeBSD comes with one, `/usr/libexec/lpr/lpf`, that works with many printers that can print plain text. (It handles backspacing and tabs in the file, and does accounting, but that is about all it does.) There are also several filters and filter components in the FreeBSD Ports Collection.

Here is what you will find in this section:

- Section How Filters Work, tries to give an overview of a filter's role in the printing process. You should read this section to get an understanding of what is happening "under the hood" when **LPD** uses filters. This knowledge could help you anticipate and debug problems you might encounter as you install more and more filters on each of your printers.
- **LPD** expects every printer to be able to print plain text by default. This presents a problem for PostScript (or other language-based printers) which cannot directly print plain text. Section Accommodating Plain Text Jobs on PostScript Printers tells you what you should do to overcome this problem. You should read this section if you have a PostScript printer.
- PostScript is a popular output format for many programs. Even some people (myself included) write PostScript code directly. But PostScript printers are expensive. Section Simulating PostScript on Non PostScript Printers tells how you can further modify a printer's text filter to accept and print PostScript data on a *non PostScript* printer. You should read this section if you do not have a PostScript printer.
- Section Conversion Filters tells about a way you can automate the conversion of specific file formats, such as graphic or typesetting data, into formats your printer can understand. After reading this section, you should be able to set up your printers such that users can type `lpr -t` to print troff data, or `lpr -d` to print TeX DVI data, or `lpr -v` to print raster image data, and so forth. I recommend reading this section.
- Section Output Filters tells all about a not often used feature of **LPD**: output filters. Unless you are printing header pages (see Header Pages), you can probably skip that section altogether.
- Section lpf: a Text Filter describes `lpf`, a fairly complete if simple text filter for line printers (and laser printers that act like line printers) that comes with FreeBSD. If you need a quick way to get printer accounting working for plain text, or if you have a printer which emits smoke when it sees backspace characters, you should definitely consider `lpf`.

11.4.1.1 How Filters Work

As mentioned before, a filter is an executable program started by **LPD** to handle the device-dependent part of communicating with the printer.

When **LPD** wants to print a file in a job, it starts a filter program. It sets the filter's standard input to the file to print, its standard output to the printer, and its standard error to the error logging file (specified in the `lf` capability in `/etc/printcap`, or `/dev/console` by default).

Which filter **LPD** starts and the filter's arguments depend on what is listed in the `/etc/printcap` file and what arguments the user specified for the job on the lpr(1) command line. For example, if the user typed `lpr -t`, **LPD** would start the troff filter, listed in the `tf` capability for the destination printer. If the user wanted to print plain text, it would start the `if` filter (this is mostly true: see Output Filters for details).

There are three kinds of filters you can specify in `/etc/printcap`:

- The *text filter*, confusingly called the *input filter* in **LPD** documentation, handles regular text printing. Think of it as the default filter. **LPD** expects every printer to be able to print plain text by default, and it is the text filter's job to make sure backspaces, tabs, or other special characters do not confuse the printer. If you are in an environment where you have to account for printer usage, the text filter must also account for pages printed, usually by counting the number of lines printed and comparing that to the number of lines per page the printer supports. The text filter is started with the following argument list:

`filter-name` [-c] -w*`width`* -l*`length`* -i*`indent`* -n *`login`* -h *`host acct-file`*

where

`-c`

: appears if the job is submitted with `lpr -l`

`width`

: is the value from the `pw` (page width) capability specified in `/etc/printcap`, default 132

`length`

: is the value from the `pl` (page length) capability, default 66

`indent`

: is the amount of the indentation from `lpr -i`, default 0

`login`

: is the account name of the user printing the file

`host`

: is the host name from which the job was submitted

`acct-file`

: is the name of the accounting file from the `af` capability.

- A *conversion filter* converts a specific file format into one the printer can render onto paper. For example, ditroff typesetting data cannot be directly printed, but you can install a conversion filter for ditroff files to convert the ditroff data into a form the printer can digest and print. Section Conversion Filters tells all about them. Conversion filters also need to do accounting, if you need printer accounting. Conversion filters are started with the following arguments:

`filter-name` -x*`pixel-width`* -y*`pixel-height`* -n *`login`* -h *`host acct-file`* where `pixel-width` is the value from the `px` capability (default 0) and `pixel-height` is the value from the `py` capability (default 0).

- The *output filter* is used only if there is no text filter, or if header pages are enabled. In my experience, output filters are rarely used. Section Output Filters describe them. There are only two arguments to an output filter:

`filter-name` -w*width* -l*length*

which are identical to the text filters `-w` and `-l` arguments.

Filters should also *exit* with the following exit status:

exit 0

If the filter printed the file successfully.

exit 1

If the filter failed to print the file but wants **LPD** to try to print the file again. **LPD** will restart a filter if it exits with this status.

exit 2

If the filter failed to print the file and does not want **LPD** to try again. **LPD** will throw out the file.

The text filter that comes with the FreeBSD release, `/usr/libexec/lpr/lpf`, takes advantage of the page width and length arguments to determine when to send a form feed and how to account for printer usage. It uses the login, host, and accounting file arguments to make the accounting entries.

If you are shopping for filters, see if they are LPD-compatible. If they are, they must support the argument lists described above. If you plan on writing filters for general use, then have them support the same argument lists and exit codes.

11.4.1.2 Accommodating Plain Text Jobs on PostScript® Printers

If you are the only user of your computer and PostScript (or other language-based) printer, and you promise to never send plain text to your printer and to never use features of various programs that will want to send plain text to your printer, then you do not need to worry about this section at all.

But, if you would like to send both PostScript and plain text jobs to the printer, then you are urged to augment your printer setup. To do so, we have the text filter detect if the arriving job is plain text or PostScript. All PostScript jobs must start with `%!` (for other printer languages, see your printer documentation). If those are the first two characters in the job, we have PostScript, and can pass the rest of the job directly. If those are not the first two characters in the file, then the filter will convert the text into PostScript and print the result.

How do we do this?

If you have got a serial printer, a great way to do it is to install `lprps`. `lprps` is a PostScript printer filter which performs two-way communication with the printer. It updates the printer's status file with verbose information from the printer, so users and administrators can see exactly what the state of the printer is (such as `toner low` or `paper jam`). But more importantly, it includes a program called `psif` which detects whether the incoming job is plain text and calls `textps` (another program that comes with `lprps`) to convert it to PostScript. It then uses `lprps` to send the job to the printer.

`lprps` is part of the FreeBSD Ports Collection (see The Ports Collection). You can fetch, build and install it yourself, of course. After installing `lprps`, just specify the pathname to the `psif` program that is part of `lprps`. If you installed `lprps` from the ports collection, use the following in the serial PostScript printer's entry in `/etc/printcap`:

```
:if=/usr/local/libexec/psif:
```

You should also specify the `rw` capability; that tells **LPD** to open the printer in read-write mode.

If you have a parallel PostScript printer (and therefore cannot use two-way communication with the printer, which `lprps` needs), you can use the following shell script as the text filter:

```
#!/bin/sh
#
#  psif - Print PostScript or plain text on a PostScript printer
#  Script version; NOT the version that comes with lprps
#  Installed in /usr/local/libexec/psif
#

IFS="" read -r first_line
first_two_chars=‘expr "$first_line" : ’\(..\)’‘

if [ "$first_two_chars" = "%!" ]; then
    #
    #  PostScript job, print it.
    #
    echo "$first_line" && cat && printf "\004" && exit 0
    exit 2
else
    #
    #  Plain text, convert it, then print it.
    #
    ( echo "$first_line"; cat ) | /usr/local/bin/textps && printf "\004" && exit 0
    exit 2
fi
```

In the above script, `textps` is a program we installed separately to convert plain text to PostScript. You can use any text-to-PostScript program you wish. The FreeBSD Ports Collection (see The Ports Collection) includes a full featured text-to-PostScript program called `a2ps` that you might want to investigate.

11.4.1.3 Simulating PostScript on Non PostScript Printers

PostScript is the *de facto* standard for high quality typesetting and printing. PostScript is, however, an *expensive* standard. Thankfully, Aladdin Enterprises has a free PostScript work-alike called **Ghostscript** that runs with FreeBSD. Ghostscript can read most PostScript files and can render their pages onto a variety of devices, including many brands of non-PostScript printers. By installing Ghostscript and using a special text filter for your printer, you can make your non PostScript printer act like a real PostScript printer.

Ghostscript is in the FreeBSD Ports Collection, if you would like to install it from there. You can fetch, build, and install it quite easily yourself, as well.

To simulate PostScript, we have the text filter detect if it is printing a PostScript file. If it is not, then the filter will pass the file directly to the printer; otherwise, it will use Ghostscript to first convert the file into a format the printer will understand.

Here is an example: the following script is a text filter for Hewlett Packard DeskJet 500 printers. For other printers, substitute the `-sDEVICE` argument to the `gs` (Ghostscript) command. (Type `gs -h` to get a list of devices the current installation of Ghostscript supports.)

```
#!/bin/sh
#
#  ifhp - Print Ghostscript-simulated PostScript on a DeskJet 500
#  Installed in /usr/local/libexec/ifhp

#
#  Treat LF as CR+LF:
#
printf "\033&k2G" || exit 2

#
#  Read first two characters of the file
#
IFS="" read -r first_line
first_two_chars=‘expr "$first_line" : ’\(..\)’‘

if [ "$first_two_chars" = "%!" ]; then
    #
    #  It is PostScript; use Ghostscript to scan-convert and print it.
    #
    #  Note that PostScript files are actually interpreted programs,
    #  and those programs are allowed to write to stdout, which will
    #  mess up the printed output.  So, we redirect stdout to stderr
    #  and then make descriptor 3 go to stdout, and have Ghostscript
    #  write its output there.  Exercise for the clever reader:
    #  capture the stderr output from Ghostscript and mail it back to
    #  the user originating the print job.
    #
    exec 3>&1 1>&2
    /usr/local/bin/gs -dSAFER -dNOPAUSE -q -sDEVICE=djet500 \
        -sOutputFile=/dev/fd/3 - && exit 0
else
    #
    #  Plain text or HP/PCL, so just print it directly; print a form feed
    #  at the end to eject the last page.
    #
    echo "$first_line" && cat && printf "\033&l0H" &&
exit 0
fi

exit 2
```

Finally, you need to notify **LPD** of the filter via the `if` capability:

```
:if=/usr/local/libexec/ifhp:
```

That is it. You can type `lpr plain.text` and `lpr whatever.ps` and both should print successfully.

11.4.1.4 Conversion Filters

After completing the simple setup described in Simple Printer Setup, the first thing you will probably want to do is install conversion filters for your favorite file formats (besides plain ASCII text).

11.4.1.4.1 Why Install Conversion Filters?

Conversion filters make printing various kinds of files easy. As an example, suppose we do a lot of work with the TeX typesetting system, and we have a PostScript printer. Every time we generate a DVI file from TeX, we cannot print it directly until we convert the DVI file into PostScript. The command sequence goes like this:

```
% dvips seaweed-analysis.dvi
% lpr seaweed-analysis.ps
```

By installing a conversion filter for DVI files, we can skip the hand conversion step each time by having **LPD** do it for us. Now, each time we get a DVI file, we are just one step away from printing it:

```
% lpr -d seaweed-analysis.dvi
```

We got **LPD** to do the DVI file conversion for us by specifying the `-d` option. Section Formatting and Conversion Options lists the conversion options.

For each of the conversion options you want a printer to support, install a *conversion filter* and specify its pathname in `/etc/printcap`. A conversion filter is like the text filter for the simple printer setup (see section Installing the Text Filter) except that instead of printing plain text, the filter converts the file into a format the printer can understand.

11.4.1.4.2 Which Conversions Filters Should I Install?

You should install the conversion filters you expect to use. If you print a lot of DVI data, then a DVI conversion filter is in order. If you have got plenty of troff to print out, then you probably want a troff filter.

The following table summarizes the filters that **LPD** works with, their capability entries for the `/etc/printcap` file, and how to invoke them with the `lpr` command:

File type	`/etc/printcap` capability	`lpr` option
cifplot	`cf`	`-c`
DVI	`df`	`-d`
plot	`gf`	`-g`
ditroff	`nf`	`-n`
FORTRAN text	`rf`	`-f`
troff	`tf`	`-f`
raster	`vf`	`-v`
plain text	`if`	none, `-p`, or `-l`

In our example, using `lpr -d` means the printer needs a `df` capability in its entry in `/etc/printcap`.

Despite what others might contend, formats like FORTRAN text and plot are probably obsolete. At your site, you can give new meanings to these or any of the formatting options just by installing custom filters. For example, suppose you would like to directly print Printerleaf files (files from the Interleaf desktop publishing program), but will never print plot files. You could install a Printerleaf conversion filter under the `gf` capability and then educate your users that `lpr -g` mean "print Printerleaf files."

11.4.1.4.3 Installing Conversion Filters

Since conversion filters are programs you install outside of the base FreeBSD installation, they should probably go under `/usr/local`. The directory `/usr/local/libexec` is a popular location, since they are specialized programs that only **LPD** will run; regular users should not ever need to run them.

To enable a conversion filter, specify its pathname under the appropriate capability for the destination printer in `/etc/printcap`.

In our example, we will add the DVI conversion filter to the entry for the printer named `bamboo`. Here is the example `/etc/printcap` file again, with the new `df` capability for the printer `bamboo`.

```
#
#  /etc/printcap for host rose - added df filter for bamboo
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:rw:\
        :if=/usr/local/libexec/psif:\
        :df=/usr/local/libexec/psdf:
```

The DVI filter is a shell script named `/usr/local/libexec/psdf`. Here is that script:

```
#!/bin/sh
#
#  psdf - DVI to PostScript printer filter
#  Installed in /usr/local/libexec/psdf
#
# Invoked by lpd when user runs lpr -d
#
exec /usr/local/bin/dvips -f | /usr/local/libexec/lprps "$@"
```

This script runs `dvips` in filter mode (the `-f` argument) on standard input, which is the job to print. It then starts the PostScript printer filter `lprps` (see section Accommodating Plain Text Jobs on PostScript Printers) with the arguments **LPD** passed to this script. `lprps` will use those arguments to account for the pages printed.

11.4.1.4.4 More Conversion Filter Examples

Since there is no fixed set of steps to install conversion filters, let me instead provide more examples. Use these as guidance to making your own filters. Use them directly, if appropriate.

This example script is a raster (well, GIF file, actually) conversion filter for a Hewlett Packard LaserJet III-Si printer:

```
#!/bin/sh
#
#  hpvf - Convert GIF files into HP/PCL, then print
#  Installed in /usr/local/libexec/hpvf

PATH=/usr/X11R6/bin:$PATH; export PATH
giftopnm | ppmtopgm | pgmtopbm | pbmtolj -resolution 300 \
    && exit 0 \
    || exit 2
```

It works by converting the GIF file into a portable anymap, converting that into a portable graymap, converting that into a portable bitmap, and converting that into LaserJet/PCL-compatible data.

Here is the `/etc/printcap` file with an entry for a printer using the above filter:

```
#
#  /etc/printcap for host orchid
#
teak|hp|laserjet|Hewlett Packard LaserJet 3Si:\
        :lp=/dev/lpt0:sh:sd=/var/spool/lpd/teak:mx#0:\
        :if=/usr/local/libexec/hpif:\
        :vf=/usr/local/libexec/hpvf:
```

The following script is a conversion filter for troff data from the groff typesetting system for the PostScript printer named `bamboo`:

```
#!/bin/sh
#
#  pstf - Convert groff's troff data into PS, then print.
#  Installed in /usr/local/libexec/pstf
#
exec grops | /usr/local/libexec/lprps "$@"
```

The above script makes use of `lprps` again to handle the communication with the printer. If the printer were on a parallel port, we would use this script instead:

```
#!/bin/sh
#
#  pstf - Convert groff's troff data into PS, then print.
#  Installed in /usr/local/libexec/pstf
#
exec grops
```

That is it. Here is the entry we need to add to `/etc/printcap` to enable the filter:

```
:tf=/usr/local/libexec/pstf:
```

Here is an example that might make old hands at FORTRAN blush. It is a FORTRAN-text filter for any printer that can directly print plain text. We will install it for the printer `teak`:

```
#!/bin/sh
#
```

```
# hprf - FORTRAN text filter for LaserJet 3si:
# Installed in /usr/local/libexec/hprf
#

printf "\033&k2G" && fpr && printf "\033&l0H" &&
 exit 0
exit 2
```

And we will add this line to the `/etc/printcap` for the printer `teak` to enable this filter:

```
:rf=/usr/local/libexec/hprf:
```

Here is one final, somewhat complex example. We will add a DVI filter to the LaserJet printer `teak` introduced earlier. First, the easy part: updating `/etc/printcap` with the location of the DVI filter:

```
:df=/usr/local/libexec/hpdf:
```

Now, for the hard part: making the filter. For that, we need a DVI-to-LaserJet/PCL conversion program. The FreeBSD Ports Collection (see The Ports Collection) has one: `dvi2xx` is the name of the package. Installing this package gives us the program we need, `dvilj2p`, which converts DVI into LaserJet IIp, LaserJet III, and LaserJet 2000 compatible codes.

`dvilj2p` makes the filter `hpdf` quite complex since `dvilj2p` cannot read from standard input. It wants to work with a filename. What is worse, the filename has to end in `.dvi` so using `/dev/fd/0` for standard input is problematic. We can get around that problem by linking (symbolically) a temporary file name (one that ends in `.dvi`) to `/dev/fd/0`, thereby forcing `dvilj2p` to read from standard input.

The only other fly in the ointment is the fact that we cannot use `/tmp` for the temporary link. Symbolic links are owned by user and group `bin`. The filter runs as user `daemon`. And the `/tmp` directory has the sticky bit set. The filter can create the link, but it will not be able clean up when done and remove it since the link will belong to a different user.

Instead, the filter will make the symbolic link in the current working directory, which is the spooling directory (specified by the `sd` capability in `/etc/printcap`). This is a perfect place for filters to do their work, especially since there is (sometimes) more free disk space in the spooling directory than under `/tmp`.

Here, finally, is the filter:

```
#!/bin/sh
#
#  hpdf - Print DVI data on HP/PCL printer
#  Installed in /usr/local/libexec/hpdf

PATH=/usr/local/bin:$PATH; export PATH

#
#  Define a function to clean up our temporary files.  These exist
#  in the current directory, which will be the spooling directory
#  for the printer.
#
cleanup() {
   rm -f hpdf$$.dvi
}
```

```
#
#  Define a function to handle fatal errors: print the given message
#  and exit 2.  Exiting with 2 tells LPD to do not try to reprint the
#  job.
#
fatal() {
    echo "$@" 1>&2
    cleanup
    exit 2
}

#
#  If user removes the job, LPD will send SIGINT, so trap SIGINT
#  (and a few other signals) to clean up after ourselves.
#
trap cleanup 1 2 15

#
#  Make sure we are not colliding with any existing files.
#
cleanup

#
#  Link the DVI input file to standard input (the file to print).
#
ln -s /dev/fd/0 hpdf$$.dvi || fatal "Cannot symlink /dev/fd/0"

#
#  Make LF = CR+LF
#
printf "\033&k2G" || fatal "Cannot initialize printer"

#
#  Convert and print.  Return value from dvilj2p does not seem to be
#  reliable, so we ignore it.
#
dvilj2p -M1 -q -e- dfhp$$.dvi

#
#  Clean up and exit
#
cleanup
exit 0
```

11.4.1.4.5 Automated Conversion: an Alternative to Conversion Filters

All these conversion filters accomplish a lot for your printing environment, but at the cost forcing the user to specify (on the lpr(1) command line) which one to use. If your users are not particularly computer literate, having to specify a filter option will become annoying. What is worse, though, is that an incorrectly specified filter option may run a filter on the wrong type of file and cause your printer to spew out hundreds of sheets of paper.

Rather than install conversion filters at all, you might want to try having the text filter (since it is the default filter) detect the type of file it has been asked to print and then automatically run the right conversion filter. Tools such as `file` can be of help here. Of course, it will be hard to determine the differences between *some* file types—and, of course, you can still provide conversion filters just for them.

The FreeBSD Ports Collection has a text filter that performs automatic conversion called `apsfilter`. It can detect plain text, PostScript, and DVI files, run the proper conversions, and print.

11.4.1.5 Output Filters

The **LPD** spooling system supports one other type of filter that we have not yet explored: an output filter. An output filter is intended for printing plain text only, like the text filter, but with many simplifications. If you are using an output filter but no text filter, then:

- **LPD** starts an output filter once for the entire job instead of once for each file in the job.
- **LPD** does not make any provision to identify the start or the end of files within the job for the output filter.
- **LPD** does not pass the user's login or host to the filter, so it is not intended to do accounting. In fact, it gets only two arguments:

  `filter-name` -w*`width`* -l*`length`*

  Where *`width`* is from the `pw` capability and *`length`* is from the `pl` capability for the printer in question.

Do not be seduced by an output filter's simplicity. If you would like each file in a job to start on a different page an output filter *will not work*. Use a text filter (also known as an input filter); see section Installing the Text Filter. Furthermore, an output filter is actually *more complex* in that it has to examine the byte stream being sent to it for special flag characters and must send signals to itself on behalf of **LPD**.

However, an output filter is *necessary* if you want header pages and need to send escape sequences or other initialization strings to be able to print the header page. (But it is also *futile* if you want to charge header pages to the requesting user's account, since **LPD** does not give any user or host information to the output filter.)

On a single printer, **LPD** allows both an output filter and text or other filters. In such cases, **LPD** will start the output filter to print the header page (see section Header Pages) only. **LPD** then expects the output filter to *stop itself* by sending two bytes to the filter: ASCII 031 followed by ASCII 001. When an output filter sees these two bytes (031, 001), it should stop by sending `SIGSTOP` to itself. When **LPD**'s done running other filters, it will restart the output filter by sending `SIGCONT` to it.

If there is an output filter but *no* text filter and **LPD** is working on a plain text job, **LPD** uses the output filter to do the job. As stated before, the output filter will print each file of the job in sequence with no intervening form feeds or other paper advancement, and this is probably *not* what you want. In almost all cases, you need a text filter.

The program `lpf`, which we introduced earlier as a text filter, can also run as an output filter. If you need a quick-and-dirty output filter but do not want to write the byte detection and signal sending code, try `lpf`. You can also wrap `lpf` in a shell script to handle any initialization codes the printer might require.

11.4.1.6 `lpf`: a Text Filter

The program `/usr/libexec/lpr/lpf` that comes with FreeBSD binary distribution is a text filter (input filter) that can indent output (job submitted with `lpr -i`), allow literal characters to pass (job submitted with `lpr -l`), adjust the printing position for backspaces and tabs in the job, and account for pages printed. It can also act like an output filter.

`lpf` is suitable for many printing environments. And although it has no capability to send initialization sequences to a printer, it is easy to write a shell script to do the needed initialization and then execute `lpf`.

In order for `lpf` to do page accounting correctly, it needs correct values filled in for the `pw` and `pl` capabilities in the `/etc/printcap` file. It uses these values to determine how much text can fit on a page and how many pages were in a user's job. For more information on printer accounting, see Accounting for Printer Usage.

11.4.2 Header Pages

If you have *lots* of users, all of them using various printers, then you probably want to consider *header pages* as a necessary evil.

Header pages, also known as *banner* or *burst pages* identify to whom jobs belong after they are printed. They are usually printed in large, bold letters, perhaps with decorative borders, so that in a stack of printouts they stand out from the real documents that comprise users' jobs. They enable users to locate their jobs quickly. The obvious drawback to a header page is that it is yet one more sheet that has to be printed for every job, their ephemeral usefulness lasting not more than a few minutes, ultimately finding themselves in a recycling bin or rubbish heap. (Note that header pages go with each job, not each file in a job, so the paper waste might not be that bad.)

The **LPD** system can provide header pages automatically for your printouts *if* your printer can directly print plain text. If you have a PostScript printer, you will need an external program to generate the header page; see Header Pages on PostScript Printers.

11.4.2.1 Enabling Header Pages

In the Simple Printer Setup section, we turned off header pages by specifying `sh` (meaning "suppress header") in the `/etc/printcap` file. To enable header pages for a printer, just remove the `sh` capability.

Sounds too easy, right?

You are right. You *might* have to provide an output filter to send initialization strings to the printer. Here is an example output filter for Hewlett Packard PCL-compatible printers:

```
#!/bin/sh
#
#  hpof - Output filter for Hewlett Packard PCL-compatible printers
#  Installed in /usr/local/libexec/hpof

printf "\033&k2G" || exit 2
exec /usr/libexec/lpr/lpf
```

Specify the path to the output filter in the `of` capability. See the Output Filters section for more information.

Here is an example `/etc/printcap` file for the printer `teak` that we introduced earlier; we enabled header pages and added the above output filter:

```
#
#  /etc/printcap for host orchid
#
teak|hp|laserjet|Hewlett Packard LaserJet 3Si:\
        :lp=/dev/lpt0:sd=/var/spool/lpd/teak:mx#0:\
        :if=/usr/local/libexec/hpif:\
        :vf=/usr/local/libexec/hpvf:\
        :of=/usr/local/libexec/hpof:
```

Now, when users print jobs to `teak`, they get a header page with each job. If users want to spend time searching for their printouts, they can suppress header pages by submitting the job with `lpr -h`; see the Header Page Options section for more lpr(1) options.

> **Note: LPD** prints a form feed character after the header page. If your printer uses a different character or sequence of characters to eject a page, specify them with the `ff` capability in `/etc/printcap`.

11.4.2.2 Controlling Header Pages

By enabling header pages, **LPD** will produce a *long header*, a full page of large letters identifying the user, host, and job. Here is an example (kelly printed the job named outline from host `rose`):

```
k                   ll       ll
k                    l        l
k                    l        l
k   k     eeee       l        l     y    y
k  k     e    e      l        l     y    y
k k      eeeeee      l        l     y    y
kk k     e           l        l     y    y
k   k    e    e      l        l     y   yy
k    k    eeee      lll      lll     yyy y
                                         y
                                    y    y
                                     yyyy


                             ll
                    t         l        i
                    t         l
 oooo    u    u   ttttt       l       ii     n nnn     eeee
o    o   u    u     t         l        i     nn   n   e    e
o    o   u    u     t         l        i     n    n   eeeeee
o    o   u    u     t         l        i     n    n   e
o    o   u  uu      t  t      l        i     n    n   e    e
 oooo     uuu u      tt      lll      iii    n    n    eeee
```

```
r rrr     oooo     ssss     eeee
rr   r   o    o   s    s   e    e
r        o    o    ss      eeeeee
r        o    o      ss    e
r        o    o   s    s   e    e
r         oooo     ssss     eeee







                                                            Job:  outline
                                                            Date: Sun Sep 17 11:04:58 1995
```

LPD appends a form feed after this text so the job starts on a new page (unless you have `sf` (suppress form feeds) in the destination printer's entry in `/etc/printcap`).

If you prefer, **LPD** can make a *short header*; specify `sb` (short banner) in the `/etc/printcap` file. The header page will look like this:

```
rose:kelly  Job: outline  Date: Sun Sep 17 11:07:51 1995
```

Also by default, **LPD** prints the header page first, then the job. To reverse that, specify `hl` (header last) in `/etc/printcap`.

11.4.2.3 Accounting for Header Pages

Using **LPD**'s built-in header pages enforces a particular paradigm when it comes to printer accounting: header pages must be *free of charge*.

Why?

Because the output filter is the only external program that will have control when the header page is printed that could do accounting, and it is not provided with any *user or host* information or an accounting file, so it has no idea whom to charge for printer use. It is also not enough to just "add one page" to the text filter or any of the conversion filters (which do have user and host information) since users can suppress header pages with `lpr -h`. They could still be charged for header pages they did not print. Basically, `lpr -h` will be the preferred option of environmentally-minded users, but you cannot offer any incentive to use it.

It is *still not enough* to have each of the filters generate their own header pages (thereby being able to charge for them). If users wanted the option of suppressing the header pages with `lpr -h`, they will still get them and be charged for them since **LPD** does not pass any knowledge of the `-h` option to any of the filters.

So, what are your options?

You can:

- Accept **LPD**'s paradigm and make header pages free.

- Install an alternative to **LPD**, such as **LPRng**. Section Alternatives to the Standard Spooler tells more about other spooling software you can substitute for **LPD**.
- Write a *smart* output filter. Normally, an output filter is not meant to do anything more than initialize a printer or do some simple character conversion. It is suited for header pages and plain text jobs (when there is no text (input) filter). But, if there is a text filter for the plain text jobs, then **LPD** will start the output filter only for the header pages. And the output filter can parse the header page text that **LPD** generates to determine what user and host to charge for the header page. The only other problem with this method is that the output filter still does not know what accounting file to use (it is not passed the name of the file from the `af` capability), but if you have a well-known accounting file, you can hard-code that into the output filter. To facilitate the parsing step, use the `sh` (short header) capability in `/etc/printcap`. Then again, all that might be too much trouble, and users will certainly appreciate the more generous system administrator who makes header pages free.

11.4.2.4 Header Pages on PostScript Printers

As described above, **LPD** can generate a plain text header page suitable for many printers. Of course, PostScript cannot directly print plain text, so the header page feature of **LPD** is useless—or mostly so.

One obvious way to get header pages is to have every conversion filter and the text filter generate the header page. The filters should use the user and host arguments to generate a suitable header page. The drawback of this method is that users will always get a header page, even if they submit jobs with `lpr -h`.

Let us explore this method. The following script takes three arguments (user login name, host name, and job name) and makes a simple PostScript header page:

```
#!/bin/sh
#
#  make-ps-header - make a PostScript header page on stdout
#  Installed in /usr/local/libexec/make-ps-header
#

#
#  These are PostScript units (72 to the inch).  Modify for A4 or
#  whatever size paper you are using:
#
page_width=612
page_height=792
border=72

#
#  Check arguments
#
if [ $# -ne 3 ]; then
    echo "Usage: ‘basename $0‘ <user> <host> <job>" 1>&2
    exit 1
fi

#
#  Save these, mostly for readability in the PostScript, below.
#
user=$1
host=$2
```

```
job=$3
date=‘date‘

#
#  Send the PostScript code to stdout.
#
exec cat <<EOF
%!PS

%
%  Make sure we do not interfere with user’s job that will follow
%
save

%
%  Make a thick, unpleasant border around the edge of the paper.
%
$border $border moveto
$page_width $border 2 mul sub 0 rlineto
0 $page_height $border 2 mul sub rlineto
currentscreen 3 -1 roll pop 100 3 1 roll setscreen
$border 2 mul $page_width sub 0 rlineto closepath
0.8 setgray 10 setlinewidth stroke 0 setgray

%
%  Display user’s login name, nice and large and prominent
%
/Helvetica-Bold findfont 64 scalefont setfont
$page_width ($user) stringwidth pop sub 2 div $page_height 200 sub moveto
($user) show

%
%  Now show the boring particulars
%
/Helvetica findfont 14 scalefont setfont
/y 200 def
[ (Job:) (Host:) (Date:) ] {
200 y moveto show /y y 18 sub def }
forall

/Helvetica-Bold findfont 14 scalefont setfont
/y 200 def
[ ($job) ($host) ($date) ] {
        270 y moveto show /y y 18 sub def
} forall

%
% That is it
%
restore
showpage
EOF
```

Now, each of the conversion filters and the text filter can call this script to first generate the header page, and then print the user's job. Here is the DVI conversion filter from earlier in this document, modified to make a header page:

```
#!/bin/sh
#
#  psdf - DVI to PostScript printer filter
#  Installed in /usr/local/libexec/psdf
#
#  Invoked by lpd when user runs lpr -d
#

orig_args="$@"

fail() {
    echo "$@" 1>&2
    exit 2
}

while getopts "x:y:n:h:" option; do
    case $option in
        x|y)  ;; # Ignore
        n)    login=$OPTARG ;;
        h)    host=$OPTARG ;;
        *)    echo "LPD started `basename $0` wrong." 1>&2
              exit 2
              ;;
    esac
done

[ "$login" ] || fail "No login name"
[ "$host" ] || fail "No host name"

( /usr/local/libexec/make-ps-header $login $host "DVI File"
  /usr/local/bin/dvips -f ) | eval /usr/local/libexec/lprps $orig_args
```

Notice how the filter has to parse the argument list in order to determine the user and host name. The parsing for the other conversion filters is identical. The text filter takes a slightly different set of arguments, though (see section How Filters Work).

As we have mentioned before, the above scheme, though fairly simple, disables the "suppress header page" option (the `-h` option) to `lpr`. If users wanted to save a tree (or a few pennies, if you charge for header pages), they would not be able to do so, since every filter's going to print a header page with every job.

To allow users to shut off header pages on a per-job basis, you will need to use the trick introduced in section Accounting for Header Pages: write an output filter that parses the LPD-generated header page and produces a PostScript version. If the user submits the job with `lpr -h`, then **LPD** will not generate a header page, and neither will your output filter. Otherwise, your output filter will read the text from **LPD** and send the appropriate header page PostScript code to the printer.

If you have a PostScript printer on a serial line, you can make use of `lprps`, which comes with an output filter, `psof`, which does the above. Note that `psof` does not charge for header pages.

11.4.3 Networked Printing

FreeBSD supports networked printing: sending jobs to remote printers. Networked printing generally refers to two different things:

- Accessing a printer attached to a remote host. You install a printer that has a conventional serial or parallel interface on one host. Then, you set up **LPD** to enable access to the printer from other hosts on the network. Section Printers Installed on Remote Hosts tells how to do this.
- Accessing a printer attached directly to a network. The printer has a network interface in addition (or in place of) a more conventional serial or parallel interface. Such a printer might work as follows:
  - It might understand the **LPD** protocol and can even queue jobs from remote hosts. In this case, it acts just like a regular host running **LPD**. Follow the same procedure in section Printers Installed on Remote Hosts to set up such a printer.
  - It might support a data stream network connection. In this case, you "attach" the printer to one host on the network by making that host responsible for spooling jobs and sending them to the printer. Section Printers with Networked Data Stream Interfaces gives some suggestions on installing such printers.

11.4.3.1 Printers Installed on Remote Hosts

The **LPD** spooling system has built-in support for sending jobs to other hosts also running **LPD** (or are compatible with **LPD**). This feature enables you to install a printer on one host and make it accessible from other hosts. It also works with printers that have network interfaces that understand the **LPD** protocol.

To enable this kind of remote printing, first install a printer on one host, the *printer host*, using the simple printer setup described in the Simple Printer Setup section. Do any advanced setup in Advanced Printer Setup that you need. Make sure to test the printer and see if it works with the features of **LPD** you have enabled. Also ensure that the *local host* has authorization to use the **LPD** service in the *remote host* (see Restricting Jobs from Remote Printers).

If you are using a printer with a network interface that is compatible with **LPD**, then the *printer host* in the discussion below is the printer itself, and the *printer name* is the name you configured for the printer. See the documentation that accompanied your printer and/or printer-network interface.

> **Tip:** If you are using a Hewlett Packard Laserjet then the printer name `text` will automatically perform the LF to CRLF conversion for you, so you will not require the `hpif` script.

Then, on the other hosts you want to have access to the printer, make an entry in their `/etc/printcap` files with the following:

1. Name the entry anything you want. For simplicity, though, you probably want to use the same name and aliases as on the printer host.
2. Leave the `lp` capability blank, explicitly (`:lp=:`).
3. Make a spooling directory and specify its location in the `sd` capability. **LPD** will store jobs here before they get sent to the printer host.
4. Place the name of the printer host in the `rm` capability.

5. Place the printer name on the *printer host* in the `rp` capability.

That is it. You do not need to list conversion filters, page dimensions, or anything else in the `/etc/printcap` file.

Here is an example. The host `rose` has two printers, `bamboo` and `rattan`. We will enable users on the host `orchid` to print to those printers. Here is the `/etc/printcap` file for `orchid` (back from section Enabling Header Pages). It already had the entry for the printer `teak`; we have added entries for the two printers on the host `rose`:

```
#
#  /etc/printcap for host orchid - added (remote) printers on rose
#

#
#  teak is local; it is connected directly to orchid:
#
teak|hp|laserjet|Hewlett Packard LaserJet 3Si:\
        :lp=/dev/lpt0:sd=/var/spool/lpd/teak:mx#0:\
        :if=/usr/local/libexec/ifhp:\
        :vf=/usr/local/libexec/vfhp:\
        :of=/usr/local/libexec/ofhp:

#
#  rattan is connected to rose; send jobs for rattan to rose:
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :lp=:rm=rose:rp=rattan:sd=/var/spool/lpd/rattan:

#
#  bamboo is connected to rose as well:
#
bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :lp=:rm=rose:rp=bamboo:sd=/var/spool/lpd/bamboo:
```

Then, we just need to make spooling directories on `orchid`:

```
# mkdir -p /var/spool/lpd/rattan /var/spool/lpd/bamboo
# chmod 770 /var/spool/lpd/rattan /var/spool/lpd/bamboo
# chown daemon:daemon /var/spool/lpd/rattan /var/spool/lpd/bamboo
```

Now, users on `orchid` can print to `rattan` and `bamboo`. If, for example, a user on `orchid` typed

```
% lpr -P bamboo -d sushi-review.dvi
```

the **LPD** system on `orchid` would copy the job to the spooling directory `/var/spool/lpd/bamboo` and note that it was a DVI job. As soon as the host `rose` has room in its `bamboo` spooling directory, the two **LPDs** would transfer the file to `rose`. The file would wait in `rose`'s queue until it was finally printed. It would be converted from DVI to PostScript (since `bamboo` is a PostScript printer) on `rose`.

11.4.3.2 Printers with Networked Data Stream Interfaces

Often, when you buy a network interface card for a printer, you can get two versions: one which emulates a spooler (the more expensive version), or one which just lets you send data to it as if you were using a serial or parallel port (the cheaper version). This section tells how to use the cheaper version. For the more expensive one, see the previous section Printers Installed on Remote Hosts.

The format of the `/etc/printcap` file lets you specify what serial or parallel interface to use, and (if you are using a serial interface), what baud rate, whether to use flow control, delays for tabs, conversion of newlines, and more. But there is no way to specify a connection to a printer that is listening on a TCP/IP or other network port.

To send data to a networked printer, you need to develop a communications program that can be called by the text and conversion filters. Here is one such example: the script `netprint` takes all data on standard input and sends it to a network-attached printer. We specify the hostname of the printer as the first argument and the port number to which to connect as the second argument to `netprint`. Note that this supports one-way communication only (FreeBSD to printer); many network printers support two-way communication, and you might want to take advantage of that (to get printer status, perform accounting, etc.).

```
#!/usr/bin/perl
#
#  netprint - Text filter for printer attached to network
#  Installed in /usr/local/libexec/netprint
#
$#ARGV eq 1 || die "Usage: $0 <printer-hostname> <port-number>";

$printer_host = $ARGV[0];
$printer_port = $ARGV[1];

require 'sys/socket.ph';

($ignore, $ignore, $protocol) = getprotobyname('tcp');
($ignore, $ignore, $ignore, $ignore, $address)
    = gethostbyname($printer_host);

$sockaddr = pack('S n a4 x8', &AF_INET, $printer_port, $address);

socket(PRINTER, &PF_INET, &SOCK_STREAM, $protocol)
    || die "Can't create TCP/IP stream socket: $!";
connect(PRINTER, $sockaddr) || die "Can't contact $printer_host: $!";
while (<STDIN>) { print PRINTER; }
exit 0;
```

We can then use this script in various filters. Suppose we had a Diablo 750-N line printer connected to the network. The printer accepts data to print on port number 5100. The host name of the printer is scrivener. Here is the text filter for the printer:

```
#!/bin/sh
#
#  diablo-if-net - Text filter for Diablo printer 'scrivener' listening
#  on port 5100.   Installed in /usr/local/libexec/diablo-if-net
#
exec /usr/libexec/lpr/lpf "$@" | /usr/local/libexec/netprint scrivener 5100
```

11.4.4 Restricting Printer Usage

This section gives information on restricting printer usage. The **LPD** system lets you control who can access a printer, both locally or remotely, whether they can print multiple copies, how large their jobs can be, and how large the printer queues can get.

11.4.4.1 Restricting Multiple Copies

The **LPD** system makes it easy for users to print multiple copies of a file. Users can print jobs with `lpr -#5` (for example) and get five copies of each file in the job. Whether this is a good thing is up to you.

If you feel multiple copies cause unnecessary wear and tear on your printers, you can disable the `-#` option to lpr(1) by adding the `sc` capability to the `/etc/printcap` file. When users submit jobs with the `-#` option, they will see:

```
lpr: multiple copies are not allowed
```

Note that if you have set up access to a printer remotely (see section Printers Installed on Remote Hosts), you need the `sc` capability on the remote `/etc/printcap` files as well, or else users will still be able to submit multiple-copy jobs by using another host.

Here is an example. This is the `/etc/printcap` file for the host `rose`. The printer `rattan` is quite hearty, so we will allow multiple copies, but the laser printer `bamboo` is a bit more delicate, so we will disable multiple copies by adding the `sc` capability:

```
#
#  /etc/printcap for host rose - restrict multiple copies on bamboo
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:sc:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:rw:\
        :if=/usr/local/libexec/psif:\
        :df=/usr/local/libexec/psdf:
```

Now, we also need to add the `sc` capability on the host `orchid`'s `/etc/printcap` (and while we are at it, let us disable multiple copies for the printer `teak`):

```
#
#  /etc/printcap for host orchid - no multiple copies for local
#  printer teak or remote printer bamboo
teak|hp|laserjet|Hewlett Packard LaserJet 3Si:\
        :lp=/dev/lpt0:sd=/var/spool/lpd/teak:mx#0:sc:\
        :if=/usr/local/libexec/ifhp:\
        :vf=/usr/local/libexec/vfhp:\
        :of=/usr/local/libexec/ofhp:

rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :lp=:rm=rose:rp=rattan:sd=/var/spool/lpd/rattan:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
```

```
        :lp=:rm=rose:rp=bamboo:sd=/var/spool/lpd/bamboo:sc:
```

By using the `sc` capability, we prevent the use of `lpr -#`, but that still does not prevent users from running lpr(1) multiple times, or from submitting the same file multiple times in one job like this:

```
% lpr forsale.sign forsale.sign forsale.sign forsale.sign forsale.sign
```

There are many ways to prevent this abuse (including ignoring it) which you are free to explore.

11.4.4.2 Restricting Access to Printers

You can control who can print to what printers by using the UNIX group mechanism and the `rg` capability in `/etc/printcap`. Just place the users you want to have access to a printer in a certain group, and then name that group in the `rg` capability.

Users outside the group (including `root`) will be greeted with `lpr: Not a member of the restricted group` if they try to print to the controlled printer.

As with the `sc` (suppress multiple copies) capability, you need to specify `rg` on remote hosts that also have access to your printers, if you feel it is appropriate (see section Printers Installed on Remote Hosts).

For example, we will let anyone access the printer `rattan`, but only those in group `artists` can use `bamboo`. Here is the familiar `/etc/printcap` for host `rose`:

```
#
#  /etc/printcap for host rose - restricted group for bamboo
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:

bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:sc:rg=artists:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:rw:\
        :if=/usr/local/libexec/psif:\
        :df=/usr/local/libexec/psdf:
```

Let us leave the other example `/etc/printcap` file (for the host `orchid`) alone. Of course, anyone on `orchid` can print to `bamboo`. It might be the case that we only allow certain logins on `orchid` anyway, and want them to have access to the printer. Or not.

> **Note:** There can be only one restricted group per printer.

11.4.4.3 Controlling Sizes of Jobs Submitted

If you have many users accessing the printers, you probably need to put an upper limit on the sizes of the files users can submit to print. After all, there is only so much free space on the filesystem that houses the spooling directories, and you also need to make sure there is room for the jobs of other users.

LPD enables you to limit the maximum byte size a file in a job can be with the `mx` capability. The units are in `BUFSIZ` blocks, which are 1024 bytes. If you put a zero for this capability, there will be no limit on file size; however, if no `mx` capability is specified, then a default limit of 1000 blocks will be used.

> **Note:** The limit applies to *fi les* in a job, and*not* the total job size.

LPD will not refuse a file that is larger than the limit you place on a printer. Instead, it will queue as much of the file up to the limit, which will then get printed. The rest will be discarded. Whether this is correct behavior is up for debate.

Let us add limits to our example printers `rattan` and `bamboo`. Since those artists' PostScript files tend to be large, we will limit them to five megabytes. We will put no limit on the plain text line printer:

```
#
#  /etc/printcap for host rose
#

#
#  No limit on job size:
#
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:mx#0:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:

#
#  Limit of five megabytes:
#
bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:sc:rg=artists:mx#5000:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:rw:\
        :if=/usr/local/libexec/psif:\
        :df=/usr/local/libexec/psdf:
```

Again, the limits apply to the local users only. If you have set up access to your printers remotely, remote users will not get those limits. You will need to specify the `mx` capability in the remote `/etc/printcap` files as well. See section Printers Installed on Remote Hosts for more information on remote printing.

There is another specialized way to limit job sizes from remote printers; see section Restricting Jobs from Remote Printers.

11.4.4.4 Restricting Jobs from Remote Printers

The **LPD** spooling system provides several ways to restrict print jobs submitted from remote hosts:

Host restrictions

> You can control from which remote hosts a local **LPD** accepts requests with the files `/etc/hosts.equiv` and `/etc/hosts.lpd`. **LPD** checks to see if an incoming request is from a host listed in either one of these files. If not, **LPD** refuses the request.

The format of these files is simple: one host name per line. Note that the file `/etc/hosts.equiv` is also used by the ruserok(3) protocol, and affects programs like rsh(1) and rcp(1), so be careful.

For example, here is the `/etc/hosts.lpd` file on the host `rose`:

```
orchid
violet
madrigal.fishbaum.de
```

This means `rose` will accept requests from the hosts `orchid`, `violet`, and `madrigal.fishbaum.de`. If any other host tries to access `rose`'s **LPD**, the job will be refused.

Size restrictions

You can control how much free space there needs to remain on the filesystem where a spooling directory resides. Make a file called `minfree` in the spooling directory for the local printer. Insert in that file a number representing how many disk blocks (512 bytes) of free space there has to be for a remote job to be accepted.

This lets you insure that remote users will not fill your filesystem. You can also use it to give a certain priority to local users: they will be able to queue jobs long after the free disk space has fallen below the amount specified in the `minfree` file.

For example, let us add a `minfree` file for the printer `bamboo`. We examine `/etc/printcap` to find the spooling directory for this printer; here is `bamboo`'s entry:

```
bamboo|ps|PS|S|panasonic|Panasonic KX-P4455 PostScript v51.4:\
        :sh:sd=/var/spool/lpd/bamboo:sc:rg=artists:mx#5000:\
        :lp=/dev/ttyd5:ms#-parenb cs8 clocal crtscts:rw:mx#5000:\
        :if=/usr/local/libexec/psif:\
        :df=/usr/local/libexec/psdf:
```

The spooling directory is given in the `sd` capability. We will make three megabytes (which is 6144 disk blocks) the amount of free disk space that must exist on the filesystem for **LPD** to accept remote jobs:

```
# echo 6144 > /var/spool/lpd/bamboo/minfree
```

User restrictions

You can control which remote users can print to local printers by specifying the `rs` capability in `/etc/printcap`. When `rs` appears in the entry for a locally-attached printer, **LPD** will accept jobs from remote hosts *if* the user submitting the job also has an account of the same login name on the local host. Otherwise, **LPD** refuses the job.

This capability is particularly useful in an environment where there are (for example) different departments sharing a network, and some users transcend departmental boundaries. By giving them accounts on your systems, they can use your printers from their own departmental systems. If you would rather allow them to use *only* your printers and not your computer resources, you can give them "token" accounts, with no home directory and a useless shell like `/usr/bin/false`.

11.4.5 Accounting for Printer Usage

So, you need to charge for printouts. And why not? Paper and ink cost money. And then there are maintenance costs—printers are loaded with moving parts and tend to break down. You have examined your printers, usage patterns, and maintenance fees and have come up with a per-page (or per-foot, per-meter, or per-whatever) cost. Now, how do you actually start accounting for printouts?

Well, the bad news is the **LPD** spooling system does not provide much help in this department. Accounting is highly dependent on the kind of printer in use, the formats being printed, and *your* requirements in charging for printer usage.

To implement accounting, you have to modify a printer's text filter (to charge for plain text jobs) and the conversion filters (to charge for other file formats), to count pages or query the printer for pages printed. You cannot get away with using the simple output filter, since it cannot do accounting. See section Filters.

Generally, there are two ways to do accounting:

- *Periodic accounting* is the more common way, possibly because it is easier. Whenever someone prints a job, the filter logs the user, host, and number of pages to an accounting file. Every month, semester, year, or whatever time period you prefer, you collect the accounting files for the various printers, tally up the pages printed by users, and charge for usage. Then you truncate all the logging files, starting with a clean slate for the next period.
- *Timely accounting* is less common, probably because it is more difficult. This method has the filters charge users for printouts as soon as they use the printers. Like disk quotas, the accounting is immediate. You can prevent users from printing when their account goes in the red, and might provide a way for users to check and adjust their "print quotas." But this method requires some database code to track users and their quotas.

The **LPD** spooling system supports both methods easily: since you have to provide the filters (well, most of the time), you also have to provide the accounting code. But there is a bright side: you have enormous flexibility in your accounting methods. For example, you choose whether to use periodic or timely accounting. You choose what information to log: user names, host names, job types, pages printed, square footage of paper used, how long the job took to print, and so forth. And you do so by modifying the filters to save this information.

11.4.5.1 Quick and Dirty Printer Accounting

FreeBSD comes with two programs that can get you set up with simple periodic accounting right away. They are the text filter `lpf`, described in section lpf: a Text Filter, and pac(8), a program to gather and total entries from printer accounting files.

As mentioned in the section on filters (Filters), **LPD** starts the text and the conversion filters with the name of the accounting file to use on the filter command line. The filters can use this argument to know where to write an accounting file entry. The name of this file comes from the `af` capability in `/etc/printcap`, and if not specified as an absolute path, is relative to the spooling directory.

LPD starts `lpf` with page width and length arguments (from the `pw` and `pl` capabilities). `lpf` uses these arguments to determine how much paper will be used. After sending the file to the printer, it then writes an accounting entry in the accounting file. The entries look like this:

```
2.00 rose:andy
3.00 rose:kelly
3.00 orchid:mary
5.00 orchid:mary
2.00 orchid:zhang
```

You should use a separate accounting file for each printer, as `lpf` has no file locking logic built into it, and two `lpf`s might corrupt each other's entries if they were to write to the same file at the same time. An easy way to insure a separate accounting file for each printer is to use `af=acct` in `/etc/printcap`. Then, each accounting file will be in the spooling directory for a printer, in a file named `acct`.

When you are ready to charge users for printouts, run the pac(8) program. Just change to the spooling directory for the printer you want to collect on and type `pac`. You will get a dollar-centric summary like the following:

```
  Login               pages/feet   runs    price
orchid:kelly                5.00    1   $  0.10
orchid:mary                31.00    3   $  0.62
orchid:zhang                9.00    1   $  0.18
rose:andy                   2.00    1   $  0.04
rose:kelly                177.00  104   $  3.54
rose:mary                  87.00   32   $  1.74
rose:root                  26.00   12   $  0.52

total                     337.00  154   $  6.74
```

These are the arguments pac(8) expects:

`-P`*`printer`*

Which *`printer`* to summarize. This option works only if there is an absolute path in the `af` capability in `/etc/printcap`.

`-c`

Sort the output by cost instead of alphabetically by user name.

`-m`

Ignore host name in the accounting files. With this option, user `smith` on host `alpha` is the same user `smith` on host `gamma`. Without, they are different users.

`-p`*`price`*

Compute charges with *`price`* dollars per page or per foot instead of the price from the `pc` capability in `/etc/printcap`, or two cents (the default). You can specify *`price`* as a floating point number.

`-r`

Reverse the sort order.

`-s`

Make an accounting summary file and truncate the accounting file.

`name ...`

Print accounting information for the given user *`names`* only.

In the default summary that pac(8) produces, you see the number of pages printed by each user from various hosts. If, at your site, host does not matter (because users can use any host), run `pac -m`, to produce the following summary:

```
  Login               pages/feet   runs    price
```

```
andy                     2.00    1   $  0.04
kelly                  182.00  105   $  3.64
mary                   118.00   35   $  2.36
root                    26.00   12   $  0.52
zhang                    9.00    1   $  0.18

total                  337.00  154   $  6.74
```

To compute the dollar amount due, pac(8) uses the `pc` capability in the `/etc/printcap` file (default of 200, or 2 cents per page). Specify, in hundredths of cents, the price per page or per foot you want to charge for printouts in this capability. You can override this value when you run pac(8) with the `-p` option. The units for the `-p` option are in dollars, though, not hundredths of cents. For example,

```
# pac -p1.50
```

makes each page cost one dollar and fifty cents. You can really rake in the profits by using this option.

Finally, running `pac -s` will save the summary information in a summary accounting file, which is named the same as the printer's accounting file, but with `_sum` appended to the name. It then truncates the accounting file. When you run pac(8) again, it rereads the summary file to get starting totals, then adds information from the regular accounting file.

11.4.5.2 How Can You Count Pages Printed?

In order to perform even remotely accurate accounting, you need to be able to determine how much paper a job uses. This is the essential problem of printer accounting.

For plain text jobs, the problem is not that hard to solve: you count how many lines are in a job and compare it to how many lines per page your printer supports. Do not forget to take into account backspaces in the file which overprint lines, or long logical lines that wrap onto one or more additional physical lines.

The text filter `lpf` (introduced in lpf: a Text Filter) takes into account these things when it does accounting. If you are writing a text filter which needs to do accounting, you might want to examine `lpf`'s source code.

How do you handle other file formats, though?

Well, for DVI-to-LaserJet or DVI-to-PostScript conversion, you can have your filter parse the diagnostic output of `dvilj` or `dvips` and look to see how many pages were converted. You might be able to do similar things with other file formats and conversion programs.

But these methods suffer from the fact that the printer may not actually print all those pages. For example, it could jam, run out of toner, or explode—and the user would still get charged.

So, what can you do?

There is only one *sure* way to do *accurate* accounting. Get a printer that can tell you how much paper it uses, and attach it via a serial line or a network connection. Nearly all PostScript printers support this notion. Other makes and models do as well (networked Imagen laser printers, for example). Modify the filters for these printers to get the page usage after they print each job and have them log accounting information based on that value *only*. There is no line counting nor error-prone file examination required.

Of course, you can always be generous and make all printouts free.

11.5 Using Printers

This section tells you how to use printers you have set up with FreeBSD. Here is an overview of the user-level commands:

lpr(1)

Print jobs

lpq(1)

Check printer queues

lprm(1)

Remove jobs from a printer's queue

There is also an administrative command, lpc(8), described in the section Administering the **LPD** Spooler, used to control printers and their queues.

All three of the commands lpr(1), lprm(1), and lpq(1) accept an option `-P` *`printer-name`* to specify on which printer/queue to operate, as listed in the `/etc/printcap` file. This enables you to submit, remove, and check on jobs for various printers. If you do not use the `-P` option, then these commands use the printer specified in the `PRINTER` environment variable. Finally, if you do not have a `PRINTER` environment variable, these commands default to the printer named `lp`.

Hereafter, the terminology *default printer* means the printer named in the `PRINTER` environment variable, or the printer named `lp` when there is no `PRINTER` environment variable.

11.5.1 Printing Jobs

To print files, type:

```
% lpr filename ...
```

This prints each of the listed files to the default printer. If you list no files, lpr(1) reads data to print from standard input. For example, this command prints some important system files:

```
% lpr /etc/host.conf /etc/hosts.equiv
```

To select a specific printer, type:

```
% lpr -P printer-name filename ...
```

This example prints a long listing of the current directory to the printer named `rattan`:

```
% ls -l | lpr -P rattan
```

Because no files were listed for the lpr(1) command, `lpr` read the data to print from standard input, which was the output of the `ls -l` command.

The lpr(1) command can also accept a wide variety of options to control formatting, apply file conversions, generate multiple copies, and so forth. For more information, see the section Printing Options.

11.5.2 Checking Jobs

When you print with lpr(1), the data you wish to print is put together in a package called a "print job", which is sent to the **LPD** spooling system. Each printer has a queue of jobs, and your job waits in that queue along with other jobs from yourself and from other users. The printer prints those jobs in a first-come, first-served order.

To display the queue for the default printer, type lpq(1). For a specific printer, use the `-P` option. For example, the command

```
% lpq -P bamboo
```

shows the queue for the printer named `bamboo`. Here is an example of the output of the `lpq` command:

```
bamboo is ready and printing
Rank   Owner    Job  Files                              Total Size
active kelly    9    /etc/host.conf, /etc/hosts.equiv   88 bytes
2nd    kelly    10   (standard input)                   1635 bytes
3rd    mary     11   ...                                78519 bytes
```

This shows three jobs in the queue for `bamboo`. The first job, submitted by user kelly, got assigned "job number" 9. Every job for a printer gets a unique job number. Most of the time you can ignore the job number, but you will need it if you want to cancel the job; see section Removing Jobs for details.

Job number nine consists of two files; multiple files given on the lpr(1) command line are treated as part of a single job. It is the currently active job (note the word `active` under the "Rank" column), which means the printer should be currently printing that job. The second job consists of data passed as the standard input to the lpr(1) command. The third job came from user `mary`; it is a much larger job. The pathname of the file she is trying to print is too long to fit, so the lpq(1) command just shows three dots.

The very first line of the output from lpq(1) is also useful: it tells what the printer is currently doing (or at least what **LPD** thinks the printer is doing).

The lpq(1) command also support a `-l` option to generate a detailed long listing. Here is an example of `lpq -l`:

```
waiting for bamboo to become ready (offline ?)
kelly: 1st  [job 009rose]
       /etc/host.conf                    73 bytes
       /etc/hosts.equiv                  15 bytes

kelly: 2nd  [job 010rose]
       (standard input)                  1635 bytes

mary: 3rd                                [job 011rose]
      /home/orchid/mary/research/venus/alpha-regio/mapping 78519 bytes
```

11.5.3 Removing Jobs

If you change your mind about printing a job, you can remove the job from the queue with the lprm(1) command. Often, you can even use lprm(1) to remove an active job, but some or all of the job might still get printed.

To remove a job from the default printer, first use lpq(1) to find the job number. Then type:

```
% lprm job-number
```

To remove the job from a specific printer, add the `-P` option. The following command removes job number 10 from the queue for the printer `bamboo`:

```
% lprm -P bamboo 10
```

The lprm(1) command has a few shortcuts:

lprm -

Removes all jobs (for the default printer) belonging to you.

lprm *user*

Removes all jobs (for the default printer) belonging to *user*. The superuser can remove other users' jobs; you can remove only your own jobs.

lprm

With no job number, user name, or `-` appearing on the command line, lprm(1) removes the currently active job on the default printer, if it belongs to you. The superuser can remove any active job.

Just use the `-P` option with the above shortcuts to operate on a specific printer instead of the default. For example, the following command removes all jobs for the current user in the queue for the printer named `rattan`:

```
% lprm -P rattan -
```

Note: If you are working in a networked environment, lprm(1) will let you remove jobs only from the host from which the jobs were submitted, even if the same printer is available from other hosts. The following command sequence demonstrates this:

```
% lpr -P rattan myfile
% rlogin orchid
% lpq -P rattan
Rank   Owner   Job  Files                          Total Size
active seeyan   12 ...                            49123 bytes
2nd    kelly      13   myfile                         12 bytes
% lprm -P rattan 13
rose: Permission denied
% logout
% lprm -P rattan 13
dfA013rose dequeued
cfA013rose dequeued
```

11.5.4 Beyond Plain Text: Printing Options

The lpr(1) command supports a number of options that control formatting text, converting graphic and other file formats, producing multiple copies, handling of the job, and more. This section describes the options.

11.5.4.1 Formatting and Conversion Options

The following lpr(1) options control formatting of the files in the job. Use these options if the job does not contain plain text or if you want plain text formatted through the pr(1) utility.

For example, the following command prints a DVI file (from the TeX typesetting system) named `fish-report.dvi` to the printer named `bamboo`:

```
% lpr -P bamboo -d fish-report.dvi
```

These options apply to every file in the job, so you cannot mix (say) DVI and ditroff files together in a job. Instead, submit the files as separate jobs, using a different conversion option for each job.

> **Note:** All of these options except `-p` and `-T` require conversion filters installed for the destination printer. For example, the `-d` option requires the DVI conversion filter. Section Conversion Filters gives details.

`-c`

Print cifplot files.

`-d`

Print DVI files.

`-f`

Print FORTRAN text files.

`-g`

Print plot data.

`-i` *`number`*

Indent the output by *`number`* columns; if you omit *`number`*, indent by 8 columns. This option works only with certain conversion filters.

> **Note:** Do not put any space between the `-i` and the number.

`-l`

Print literal text data, including control characters.

`-n`

Print ditroff (device independent troff) data.

-p

Format plain text with pr(1) before printing. See pr(1) for more information.

`-T` *`title`*

Use *`title`* on the pr(1) header instead of the file name. This option has effect only when used with the `-p` option.

`-t`

Print troff data.

`-v`

Print raster data.

Here is an example: this command prints a nicely formatted version of the ls(1) manual page on the default printer:

```
% zcat /usr/share/man/man1/ls.1.gz | troff -t -man | lpr -t
```

The zcat(1) command uncompresses the source of the ls(1) manual page and passes it to the troff(1) command, which formats that source and makes GNU troff output and passes it to lpr(1), which submits the job to the **LPD** spooler. Because we used the `-t` option to lpr(1), the spooler will convert the GNU troff output into a format the default printer can understand when it prints the job.

11.5.4.2 Job Handling Options

The following options to lpr(1) tell **LPD** to handle the job specially:

-# *`copies`*

Produce a number of *`copies`* of each file in the job instead of just one copy. An administrator may disable this option to reduce printer wear-and-tear and encourage photocopier usage. See section Restricting Multiple Copies.

This example prints three copies of `parser.c` followed by three copies of `parser.h` to the default printer:

```
% lpr -#3 parser.c parser.h
```

-m

Send mail after completing the print job. With this option, the **LPD** system will send mail to your account when it finishes handling your job. In its message, it will tell you if the job completed successfully or if there was an error, and (often) what the error was.

-s

Do not copy the files to the spooling directory, but make symbolic links to them instead.

If you are printing a large job, you probably want to use this option. It saves space in the spooling directory (your job might overflow the free space on the filesystem where the spooling directory resides). It saves time as well since **LPD** will not have to copy each and every byte of your job to the spooling directory.

There is a drawback, though: since **LPD** will refer to the original files directly, you cannot modify or remove them until they have been printed.

> **Note:** If you are printing to a remote printer, **LPD** will eventually have to copy files from the local host to the remote host, so the `-s` option will save space only on the local spooling directory, not the remote. It is still useful, though.

-r

Remove the files in the job after copying them to the spooling directory, or after printing them with the `-s` option. Be careful with this option!

11.5.4.3 Header Page Options

These options to lpr(1) adjust the text that normally appears on a job's header page. If header pages are suppressed for the destination printer, these options have no effect. See section Header Pages for information about setting up header pages.

-C *`text`*

Replace the hostname on the header page with *`text`*. The hostname is normally the name of the host from which the job was submitted.

-J *`text`*

Replace the job name on the header page with *`text`*. The job name is normally the name of the first file of the job, or `stdin` if you are printing standard input.

-h

Do not print any header page.

> **Note:** At some sites, this option may have no effect due to the way header pages are generated. See Header Pages for details.

11.5.5 Administering Printers

As an administrator for your printers, you have had to install, set up, and test them. Using the lpc(8) command, you can interact with your printers in yet more ways. With lpc(8), you can

- Start and stop the printers
- Enable and disable their queues
- Rearrange the order of the jobs in each queue.

First, a note about terminology: if a printer is *stopped*, it will not print anything in its queue. Users can still submit jobs, which will wait in the queue until the printer is *started* or the queue is cleared.

If a queue is *disabled*, no user (except `root`) can submit jobs for the printer. An *enabled* queue allows jobs to be submitted. A printer can be *started* for a disabled queue, in which case it will continue to print jobs in the queue until the queue is empty.

In general, you have to have `root` privileges to use the lpc(8) command. Ordinary users can use the lpc(8) command to get printer status and to restart a hung printer only.

Here is a summary of the lpc(8) commands. Most of the commands take a *`printer-name`* argument to tell on which printer to operate. You can use `all` for the *`printer-name`* to mean all printers listed in `/etc/printcap`.

`abort` *`printer-name`*

Cancel the current job and stop the printer. Users can still submit jobs if the queue is enabled.

`clean` *`printer-name`*

Remove old files from the printer's spooling directory. Occasionally, the files that make up a job are not properly removed by **LPD**, particularly if there have been errors during printing or a lot of administrative activity. This command finds files that do not belong in the spooling directory and removes them.

`disable` *`printer-name`*

Disable queuing of new jobs. If the printer is running, it will continue to print any jobs remaining in the queue. The superuser (`root`) can always submit jobs, even to a disabled queue.

This command is useful while you are testing a new printer or filter installation: disable the queue and submit jobs as `root`. Other users will not be able to submit jobs until you complete your testing and re-enable the queue with the `enable` command.

`down` *`printer-name message`*

Take a printer down. Equivalent to `disable` followed by `stop`. The *`message`* appears as the printer's status whenever a user checks the printer's queue with lpq(1) or status with `lpc status`.

`enable` *`printer-name`*

Enable the queue for a printer. Users can submit jobs but the printer will not print anything until it is started.

`help` *`command-name`*

Print help on the command *`command-name`*. With no *`command-name`*, print a summary of the commands available.

`restart` *`printer-name`*

Start the printer. Ordinary users can use this command if some extraordinary circumstance hangs **LPD**, but they cannot start a printer stopped with either the `stop` or `down` commands. The `restart` command is equivalent to `abort` followed by `start`.

`start` *`printer-name`*

Start the printer. The printer will print jobs in its queue.

`stop` *`printer-name`*

Stop the printer. The printer will finish the current job and will not print anything else in its queue. Even though the printer is stopped, users can still submit jobs to an enabled queue.

`topq` *`printer-name job-or-username`*

Rearrange the queue for *`printer-name`* by placing the jobs with the listed *`job`* numbers or the jobs belonging to *`username`* at the top of the queue. For this command, you cannot use `all` as the *`printer-name`*.

`up` *`printer-name`*

Bring a printer up; the opposite of the `down` command. Equivalent to `start` followed by `enable`.

lpc(8) accepts the above commands on the command line. If you do not enter any commands, lpc(8) enters an interactive mode, where you can enter commands until you type `exit`, `quit`, or end-of-file.

11.6 Alternatives to the Standard Spooler

If you have been reading straight through this manual, by now you have learned just about everything there is to know about the **LPD** spooling system that comes with FreeBSD. You can probably appreciate many of its shortcomings, which naturally leads to the question: "What other spooling systems are out there (and work with FreeBSD)?"

LPRng

LPRng, which purportedly means "LPR: the Next Generation" is a complete rewrite of PLP. Patrick Powell and Justin Mason (the principal maintainer of PLP) collaborated to make **LPRng**. The main site for **LPRng** is http://www.lprng.org/.

CUPS

CUPS, the Common UNIX Printing System, provides a portable printing layer for UNIX-based operating systems. It has been developed by Easy Software Products to promote a standard printing solution for all UNIX vendors and users.

CUPS uses the Internet Printing Protocol (IPP) as the basis for managing print jobs and queues. The Line Printer Daemon (LPD) Server Message Block (SMB), and AppSocket (a.k.a. JetDirect) protocols are also supported with reduced functionality. CUPS adds network printer browsing and PostScript Printer Description (PPD) based printing options to support real-world printing under UNIX.

The main site for **CUPS** is http://www.cups.org/.

11.7 Troubleshooting

After performing the simple test with lptest(1), you might have gotten one of the following results instead of the correct printout:

It worked, after awhile; or, it did not eject a full sheet.

The printer printed the above, but it sat for awhile and did nothing. In fact, you might have needed to press a PRINT REMAINING or FORM FEED button on the printer to get any results to appear.

If this is the case, the printer was probably waiting to see if there was any more data for your job before it printed anything. To fix this problem, you can have the text filter send a FORM FEED character (or whatever is necessary) to the printer. This is usually sufficient to have the printer immediately print any text remaining in its internal buffer. It is also useful to make sure each print job ends on a full sheet, so the next job does not start somewhere on the middle of the last page of the previous job.

The following replacement for the shell script `/usr/local/libexec/if-simple` prints a form feed after it sends the job to the printer:

```
#!/bin/sh
#
# if-simple - Simple text input filter for lpd
# Installed in /usr/local/libexec/if-simple
#
# Simply copies stdin to stdout.  Ignores all filter arguments.
# Writes a form feed character (\f) after printing job.

/bin/cat && printf "\f" && exit 0
exit 2
```

It produced the "staircase effect."

You got the following on paper:

```
!"#$%&'()*+,-./01234
                "#$%&'()*+,-./012345
                                 #$%&'()*+,-./0123456
```

You have become another victim of the *staircase effect*, caused by conflicting interpretations of what characters should indicate a new line. UNIX style operating systems use a single character: ASCII code 10, the line feed (LF). MS-DOS, OS/2®, and others uses a pair of characters, ASCII code 10 *and* ASCII code 13 (the carriage return or CR). Many printers use the MS-DOS convention for representing new-lines.

When you print with FreeBSD, your text used just the line feed character. The printer, upon seeing a line feed character, advanced the paper one line, but maintained the same horizontal position on the page for the next character to print. That is what the carriage return is for: to move the location of the next character to print to the left edge of the paper.

Here is what FreeBSD wants your printer to do:

Printer received CR	Printer prints CR
Printer received LF	Printer prints CR + LF

Here are some ways to achieve this:

- Use the printer's configuration switches or control panel to alter its interpretation of these characters. Check your printer's manual to find out how to do this.

Note: If you boot your system into other operating systems besides FreeBSD, you may have to *reconfigure* the printer to use a an interpretation for CR and LF characters that those other operating systems use. You might prefer one of the other solutions, below.

- Have FreeBSD's serial line driver automatically convert LF to CR+LF. Of course, this works with printers on serial ports *only*. To enable this feature, use the `ms#` capability and set the `onlcr` mode in the `/etc/printcap` file for the printer.
- Send an *escape code* to the printer to have it temporarily treat LF characters differently. Consult your printer's manual for escape codes that your printer might support. When you find the proper escape code, modify the text filter to send the code first, then send the print job.

  Here is an example text filter for printers that understand the Hewlett-Packard PCL escape codes. This filter makes the printer treat LF characters as a LF and CR; then it sends the job; then it sends a form feed to eject the last page of the job. It should work with nearly all Hewlett Packard printers.

```
#!/bin/sh
#
# hpif - Simple text input filter for lpd for HP-PCL based printers
# Installed in /usr/local/libexec/hpif
#
# Simply copies stdin to stdout.  Ignores all filter arguments.
# Tells printer to treat LF as CR+LF.  Ejects the page when done.

printf "\033&k2G" && cat && printf "\033&l0H" && exit 0
exit 2
```

  Here is an example `/etc/printcap` from a host called `orchid`. It has a single printer attached to its first parallel port, a Hewlett Packard LaserJet 3Si named `teak`. It is using the above script as its text filter:

```
#
#  /etc/printcap for host orchid
#
teak|hp|laserjet|Hewlett Packard LaserJet 3Si:\
        :lp=/dev/lpt0:sh:sd=/var/spool/lpd/teak:mx#0:\
        :if=/usr/local/libexec/hpif:
```

It overprinted each line.

The printer never advanced a line. All of the lines of text were printed on top of each other on one line.

This problem is the "opposite" of the staircase effect, described above, and is much rarer. Somewhere, the LF characters that FreeBSD uses to end a line are being treated as CR characters to return the print location to the left edge of the paper, but not also down a line.

Use the printer's configuration switches or control panel to enforce the following interpretation of LF and CR characters:

Printer receives	Printer prints

Printer receives	Printer prints
CR	CR
LF	CR + LF

The printer lost characters.

While printing, the printer did not print a few characters in each line. The problem might have gotten worse as the printer ran, losing more and more characters.

The problem is that the printer cannot keep up with the speed at which the computer sends data over a serial line (this problem should not occur with printers on parallel ports). There are two ways to overcome the problem:

- If the printer supports XON/XOFF flow control, have FreeBSD use it by specifying the `ixon` mode in the `ms#` capability.
- If the printer supports carrier flow control, specify the `crtscts` mode in the `ms#` capability. Make sure the cable connecting the printer to the computer is correctly wired for carrier flow control.

It printed garbage.

The printer printed what appeared to be random garbage, but not the desired text.

This is usually another symptom of incorrect communications parameters with a serial printer. Double-check the bps rate in the `br` capability, and the parity setting in the `ms#` capability; make sure the printer is using the same settings as specified in the `/etc/printcap` file.

Nothing happened.

If nothing happened, the problem is probably within FreeBSD and not the hardware. Add the log file (`lf`) capability to the entry for the printer you are debugging in the `/etc/printcap` file. For example, here is the entry for `rattan`, with the `lf` capability:

```
rattan|line|diablo|lp|Diablo 630 Line Printer:\
        :sh:sd=/var/spool/lpd/rattan:\
        :lp=/dev/lpt0:\
        :if=/usr/local/libexec/if-simple:\
        :lf=/var/log/rattan.log
```

Then, try printing again. Check the log file (in our example, `/var/log/rattan.log`) to see any error messages that might appear. Based on the messages you see, try to correct the problem.

If you do not specify a `lf` capability, **LPD** uses `/dev/console` as a default.

Chapter 12 Storage

12.1 Synopsis

This chapter covers the use of disks in FreeBSD. This includes memory-backed disks, network-attached disks, and standard SCSI/IDE storage devices.

After reading this chapter, you will know:

- The terminology FreeBSD uses to describe the organization of data on a physical disk (partitions and slices).
- How to add additional hard disks to your system.
- How to set up virtual file systems, such as memory disks.
- How to use quotas to limit disk space usage.
- How to encrypt disks to secure them against attackers.
- How to create and burn CDs and DVDs on FreeBSD.
- The various storage media options for backups.
- How to use backup programs available under FreeBSD.
- How to backup to floppy disks.
- What snapshots are and how to use them efficiently.

12.2 Device Names

The following is a list of physical storage devices supported in FreeBSD, and the device names associated with them.

Table 12-1. Physical Disk Naming Conventions

Drive type	Drive device name
IDE hard drives	`ad`
IDE CDROM drives	`acd`
SCSI hard drives and USB Mass storage devices	`da`
SCSI CDROM drives	`cd`
Assorted non-standard CDROM drives	`mcd` for Mitsumi CD-ROM, `scd` for Sony CD-ROM, `matcd` for Matsushita/Panasonic CD-ROM [a]
Floppy drives	`fd`
SCSI tape drives	`sa`
IDE tape drives	`ast`
Flash drives	`fla` for DiskOnChip® Flash device
RAID drives	`aacd` for Adaptec® AdvancedRAID, `mlxd` and `mlyd` for Mylex®, `amrd` for AMI MegaRAID®, `idad` for Compaq Smart RAID, `twed` for 3ware® RAID.

Drive type	Drive device name
Notes: a. The matcd(4) driver has been removed in FreeBSD 4.X branch since October 5th, 2002 and does not exist in FreeBSD 5.0 ar	

12.3 Adding Disks

Originally contributed by David O'Brien.

Lets say we want to add a new SCSI disk to a machine that currently only has a single drive. First turn off the computer and install the drive in the computer following the instructions of the computer, controller, and drive manufacturer. Due to the wide variations of procedures to do this, the details are beyond the scope of this document.

Login as user `root`. After you have installed the drive, inspect `/var/run/dmesg.boot` to ensure the new disk was found. Continuing with our example, the newly added drive will be `da1` and we want to mount it on `/1` (if you are adding an IDE drive, the device name will be `wd1` in pre-4.0 systems, or `ad1` in most 4.X systems).

Because FreeBSD runs on IBM-PC compatible computers, it must take into account the PC BIOS partitions. These are different from the traditional BSD partitions. A PC disk has up to four BIOS partition entries. If the disk is going to be truly dedicated to FreeBSD, you can use the *dedicated* mode. Otherwise, FreeBSD will have to live within one of the PC BIOS partitions. FreeBSD calls the PC BIOS partitions *slices* so as not to confuse them with traditional BSD partitions. You may also use slices on a disk that is dedicated to FreeBSD, but used in a computer that also has another operating system installed. This is to not confuse the `fdisk` utility of the other operating system.

In the slice case the drive will be added as `/dev/da1s1e`. This is read as: SCSI disk, unit number 1 (second SCSI disk), slice 1 (PC BIOS partition 1), and `e` BSD partition. In the dedicated case, the drive will be added simply as `/dev/da1e`.

12.3.1 Using sysinstall(8)

1. Navigating **Sysinstall**

   You may use `/stand/sysinstall` to partition and label a new disk using its easy to use menus. Either login as user `root` or use the `su` command. Run `/stand/sysinstall` and enter the `Configure` menu. Within the `FreeBSD Configuration Menu`, scroll down and select the `Fdisk` option.

2. **fdisk** Partition Editor

   Once inside **fdisk**, we can type **`A`** to use the entire disk for FreeBSD. When asked if you want to "remain cooperative with any future possible operating systems", answer `YES`. Write the changes to the disk using **`W`**. Now exit the FDISK editor by typing **`q`**. Next you will be asked about the Master Boot Record. Since you are adding a disk to an already running system, choose `None`.

3. Disk Label Editor

   Next, you need to exit **sysinstall** and start it again. Follow the directions above, although this time choose the `Label` option. This will enter the `Disk Label Editor`. This is where you will create the traditional BSD partitions. A disk can have up to eight partitions, labeled `a-h`. A few of the partition labels have special uses. The `a` partition is used for the root partition (`/`). Thus only your system disk (e.g, the disk you boot from) should have an `a` partition. The `b` partition is used for swap partitions, and you may have many disks with swap partitions. The `c` partition addresses the entire disk in dedicated mode, or the entire FreeBSD slice in slice mode. The other partitions are for general use.

sysinstall's Label editor favors the `e` partition for non-root, non-swap partitions. Within the Label editor, create a single file system by typing **C**. When prompted if this will be a FS (file system) or swap, choose `FS` and type in a mount point (e.g, `/mnt`). When adding a disk in post-install mode, **sysinstall** will not create entries in `/etc/fstab` for you, so the mount point you specify is not important.

You are now ready to write the new label to the disk and create a file system on it. Do this by typing **W**. Ignore any errors from **sysinstall** that it could not mount the new partition. Exit the Label Editor and **sysinstall** completely.

4. Finish

   The last step is to edit `/etc/fstab` to add an entry for your new disk.

12.3.2 Using Command Line Utilities

12.3.2.1 Using Slices

This setup will allow your disk to work correctly with other operating systems that might be installed on your computer and will not confuse other operating systems' `fdisk` utilities. It is recommended to use this method for new disk installs. Only use `dedicated` mode if you have a good reason to do so!

```
# dd if=/dev/zero of=/dev/da1 bs=1k count=1
# fdisk -BI da1 #Initialize your new disk
# disklabel -B -w -r da1s1 auto #Label it.
# disklabel -e da1s1 # Edit the disklabel just created and add any partitions.
# mkdir -p /1
# newfs /dev/da1s1e # Repeat this for every partition you created.
# mount /dev/da1s1e /1 # Mount the partition(s)
# vi /etc/fstab # Add the appropriate entry/entries to your /etc/fstab.
```

If you have an IDE disk, substitute `ad` for `da`. On pre-4.X systems use `wd`.

12.3.2.2 Dedicated

If you will not be sharing the new drive with another operating system, you may use the `dedicated` mode. Remember this mode can confuse Microsoft operating systems; however, no damage will be done by them. IBM's OS/2 however, will "appropriate" any partition it finds which it does not understand.

```
# dd if=/dev/zero of=/dev/da1 bs=1k count=1
# disklabel -Brw da1 auto
# disklabel -e da1 # create the 'e' partition
# newfs -d0 /dev/da1e
# mkdir -p /1
# vi /etc/fstab # add an entry for /dev/da1e
# mount /1
```

An alternate method is:

```
# dd if=/dev/zero of=/dev/da1 count=2
# disklabel /dev/da1 | disklabel -BrR da1 /dev/stdin
# newfs /dev/da1e
```

```
# mkdir -p /1
# vi /etc/fstab # add an entry for /dev/da1e
# mount /1
```

> **Note:** Since FreeBSD 5.1-RELEASE, the bsdlabel(8) utility replaces the old disklabel(8) program. With bsdlabel(8) a number of obsolete options and parameters have been retired; in the examples above the option `-r` should be removed with bsdlabel(8). For more information, please refer to the bsdlabel(8) manual page.

12.4 RAID

12.4.1 Software RAID

12.4.1.1 Concatenated Disk Driver (CCD) Configuration

Original work by Christopher Shumway. Revised by Jim Brown.

When choosing a mass storage solution the most important factors to consider are speed, reliability, and cost. It is rare to have all three in balance; normally a fast, reliable mass storage device is expensive, and to cut back on cost either speed or reliability must be sacrificed.

In designing the system described below, cost was chosen as the most important factor, followed by speed, then reliability. Data transfer speed for this system is ultimately constrained by the network. And while reliability is very important, the CCD drive described below serves online data that is already fully backed up on CD-R's and can easily be replaced.

Defining your own requirements is the first step in choosing a mass storage solution. If your requirements prefer speed or reliability over cost, your solution will differ from the system described in this section.

12.4.1.1.1 Installing the Hardware

In addition to the IDE system disk, three Western Digital 30GB, 5400 RPM IDE disks form the core of the CCD disk described below providing approximately 90GB of online storage. Ideally, each IDE disk would have its own IDE controller and cable, but to minimize cost, additional IDE controllers were not used. Instead the disks were configured with jumpers so that each IDE controller has one master, and one slave.

Upon reboot, the system BIOS was configured to automatically detect the disks attached. More importantly, FreeBSD detected them on reboot:

```
ad0: 19574MB <WDC WD205BA> [39770/16/63] at ata0-master UDMA33
ad1: 29333MB <WDC WD307AA> [59598/16/63] at ata0-slave UDMA33
ad2: 29333MB <WDC WD307AA> [59598/16/63] at ata1-master UDMA33
ad3: 29333MB <WDC WD307AA> [59598/16/63] at ata1-slave UDMA33
```

> **Note:** If FreeBSD does not detect all the disks, ensure that you have jumpered them correctly. Most IDE drives also have a "Cable Select" jumper. This is *not* the jumper for the master/slave relationship. Consult the drive documentation for help in identifying the correct jumper.

Next, consider how to attach them as part of the file system. You should research both vinum(8) (Chapter 13) and ccd(4). In this particular configuration, ccd(4) was chosen.

12.4.1.1.2 Setting Up the CCD

The driver ccd(4) allows you to take several identical disks and concatenate them into one logical file system. In order to use ccd(4), you need a kernel with ccd(4) support built in. Add this line to your kernel configuration file, rebuild, and reinstall the kernel:

```
pseudo-device   ccd     4
```

On 5.X systems, you have to use instead the following line:

```
device   ccd
```

> **Note:** In FreeBSD 5.X, it is not necessary to specify a number of ccd(4) devices, as the ccd(4) device driver is now self-cloning — new device instances will automatically be created on demand.

The ccd(4) support can also be loaded as a kernel loadable module in FreeBSD 3.0 or later.

To set up ccd(4), you must first use disklabel(8) to label the disks:

```
disklabel -r -w ad1 auto
disklabel -r -w ad2 auto
disklabel -r -w ad3 auto
```

This creates a disklabel for `ad1c`, `ad2c` and `ad3c` that spans the entire disk.

> **Note:** Since FreeBSD 5.1-RELEASE, the bsdlabel(8) utility replaces the old disklabel(8) program. With bsdlabel(8) a number of obsolete options and parameters have been retired; in the examples above the option `-r` should be removed. For more information, please refer to the bsdlabel(8) manual page.

The next step is to change the disk label type. You can use disklabel(8) to edit the disks:

```
disklabel -e ad1
disklabel -e ad2
disklabel -e ad3
```

This opens up the current disk label on each disk with the editor specified by the `EDITOR` environment variable, typically vi(1).

An unmodified disk label will look something like this:

```
8 partitions:
#        size   offset    fstype   [fsize bsize bps/cpg]
  c: 60074784        0    unused        0     0     0   # (Cyl.    0 - 59597)
```

Add a new `e` partition for ccd(4) to use. This can usually be copied from the `c` partition, but the `fstype` *must* be **`4.2BSD`**. The disk label should now look something like this:

```
8 partitions:
#        size   offset    fstype   [fsize bsize bps/cpg]
  c: 60074784        0    unused        0     0     0   # (Cyl.    0 - 59597)
  e: 60074784        0    4.2BSD        0     0     0   # (Cyl.    0 - 59597)
```

12.4.1.1.3 Building the File System

The device node for `ccd0c` may not exist yet, so to create it, perform the following commands:

```
cd /dev
sh MAKEDEV ccd0
```

> **Note:** In FreeBSD 5.0, devfs(5) will automatically manage device nodes in `/dev`, so use of `MAKEDEV` is not necessary.

Now that you have all of the disks labeled, you must build the ccd(4). To do that, use ccdconfig(8), with options similar to the following:

```
ccdconfig ccd0❶ 32❷ 0❸ /dev/ad1e❹ /dev/ad2e /dev/ad3e
```

The use and meaning of each option is shown below:

❶ The first argument is the device to configure, in this case, `/dev/ccd0c`. The `/dev/` portion is optional.

❷ The interleave for the file system. The interleave defines the size of a stripe in disk blocks, each normally 512 bytes. So, an interleave of 32 would be 16,384 bytes.

❸ Flags for ccdconfig(8). If you want to enable drive mirroring, you can specify a flag here. This configuration does not provide mirroring for ccd(4), so it is set at 0 (zero).

❹ The final arguments to ccdconfig(8) are the devices to place into the array. Use the complete pathname for each device.

After running ccdconfig(8) the ccd(4) is configured. A file system can be installed. Refer to newfs(8) for options, or simply run:

```
newfs /dev/ccd0c
```

12.4.1.1.4 Making it All Automatic

Generally, you will want to mount the ccd(4) upon each reboot. To do this, you must configure it first. Write out your current configuration to `/etc/ccd.conf` using the following command:

```
ccdconfig -g > /etc/ccd.conf
```

During reboot, the script `/etc/rc` runs `ccdconfig -C` if `/etc/ccd.conf` exists. This automatically configures the ccd(4) so it can be mounted.

Note: If you are booting into single user mode, before you can mount(8) the ccd(4), you need to issue the following command to configure the array:

```
ccdconfig -C
```

To automatically mount the ccd(4), place an entry for the ccd(4) in `/etc/fstab` so it will be mounted at boot time:

```
/dev/ccd0c              /media       ufs     rw      2       2
```

12.4.1.2 The Vinum Volume Manager

The Vinum Volume Manager is a block device driver which implements virtual disk drives. It isolates disk hardware from the block device interface and maps data in ways which result in an increase in flexibility, performance and reliability compared to the traditional slice view of disk storage. vinum(8) implements the RAID-0, RAID-1 and RAID-5 models, both individually and in combination.

See Chapter 13 for more information about vinum(8).

12.4.2 Hardware RAID

FreeBSD also supports a variety of hardware RAID controllers. These devices control a RAID subsystem without the need for FreeBSD specific software to manage the array.

Using an on-card BIOS, the card controls most of the disk operations itself. The following is a brief setup description using a Promise IDE RAID controller. When this card is installed and the system is started up, it displays a prompt requesting information. Follow the instructions to enter the card's setup screen. From here, you have the ability to combine all the attached drives. After doing so, the disk(s) will look like a single drive to FreeBSD. Other RAID levels can be set up accordingly.

12.4.3 Rebuilding ATA RAID1 Arrays

FreeBSD allows you to hot-replace a failed disk in an array. This requires that you catch it before you reboot.

You will probably see something like the following in `/var/log/messages` or in the dmesg(8) output:

```
ad6 on monster1 suffered a hard error.
ad6: READ command timeout tag=0 serv=0 - resetting
ad6: trying fallback to PIO mode
ata3: resetting devices .. done
ad6: hard error reading fsbn 1116119 of 0-7 (ad6 bn 1116119; cn 1107 tn 4 sn 11) status=59 error=40
ar0: WARNING - mirror lost
```

Using atacontrol(8), check for further information:

```
# atacontrol list
ATA channel 0:
Master:      no device present
```

```
Slave:   acd0 <HL-DT-ST CD-ROM GCR-8520B/1.00> ATA/ATAPI rev 0

ATA channel 1:
Master:      no device present
Slave:       no device present

ATA channel 2:
Master:  ad4 <MAXTOR 6L080J4/A93.0500> ATA/ATAPI rev 5
Slave:       no device present

ATA channel 3:
Master:  ad6 <MAXTOR 6L080J4/A93.0500> ATA/ATAPI rev 5
Slave:       no device present

# atacontrol status ar0
ar0: ATA RAID1 subdisks: ad4 ad6 status: DEGRADED
```

1. You will first need to detach the disk from the array so that you can safely remove it:

   ```
   # atacontrol detach 3
   ```

2. Replace the disk.
3. Reattach the disk as a spare:

   ```
   # atacontrol attach 3
   Master:  ad6 <MAXTOR 6L080J4/A93.0500> ATA/ATAPI rev 5
   Slave:   no device present
   ```

4. Rebuild the array:

   ```
   # atacontrol rebuild ar0
   ```

5. The rebuild command hangs until complete. However, it is possible to open another terminal (using **Alt**+**F*n***) and check on the progress by issuing the following command:

   ```
   # dmesg | tail -10
   [output removed]
   ad6: removed from configuration
   ad6: deleted from ar0 disk1
   ad6: inserted into ar0 disk1 as spare

   # atacontrol status ar0
   ar0: ATA RAID1 subdisks: ad4 ad6 status: REBUILDING 0% completed
   ```

6. Wait until this operation completes.

12.5 Creating and Using Optical Media (CDs & DVDs)

Contributed by Mike Meyer.

12.5.1 Introduction

CDs have a number of features that differentiate them from conventional disks. Initially, they were not writable by the user. They are designed so that they can be read continuously without delays to move the head between tracks. They are also much easier to transport between systems than similarly sized media were at the time.

CDs do have tracks, but this refers to a section of data to be read continuously and not a physical property of the disk. To produce a CD on FreeBSD, you prepare the data files that are going to make up the tracks on the CD, then write the tracks to the CD.

The ISO 9660 file system was designed to deal with these differences. It unfortunately codifies file system limits that were common then. Fortunately, it provides an extension mechanism that allows properly written CDs to exceed those limits while still working with systems that do not support those extensions.

The `sysutils/mkisofs` program is used to produce a data file containing an ISO 9660 file system. It has options that support various extensions, and is described below. You can install it with the `sysutils/mkisofs` port.

Which tool to use to burn the CD depends on whether your CD burner is ATAPI or something else. ATAPI CD burners use the `burncd` program that is part of the base system. SCSI and USB CD burners should use `cdrecord` from the `sysutils/cdrtools` port.

`burncd` has a limited number of supported drives. To find out if a drive is supported, see the CD-R/RW supported drives (http://www.freebsd.dk/ata/) list.

> **Note:** If you run FreeBSD 5.X, FreeBSD 4.8-RELEASE version or higher, it will be possible to use `cdrecord` and other tools for SCSI drives on an ATAPI hardware with the ATAPI/CAM module.

12.5.2 mkisofs

`sysutils/mkisofs` produces an ISO 9660 file system that is an image of a directory tree in the UNIX file system name space. The simplest usage is:

```
# mkisofs -o imagefile.iso /path/to/tree
```

This command will create an *`imagefile.iso`* containing an ISO 9660 file system that is a copy of the tree at *`/path/to/tree`*. In the process, it will map the file names to names that fit the limitations of the standard ISO 9660 file system, and will exclude files that have names uncharacteristic of ISO file systems.

A number of options are available to overcome those restrictions. In particular, `-R` enables the Rock Ridge extensions common to UNIX systems, `-J` enables Joliet extensions used by Microsoft systems, and `-hfs` can be used to create HFS file systems used by Mac OS.

For CDs that are going to be used only on FreeBSD systems, `-U` can be used to disable all filename restrictions. When used with `-R`, it produces a file system image that is identical to the FreeBSD tree you started from, though it may violate the ISO 9660 standard in a number of ways.

The last option of general use is `-b`. This is used to specify the location of the boot image for use in producing an "El Torito" bootable CD. This option takes an argument which is the path to a boot image from the top of the tree being written to the CD. So, given that `/tmp/myboot` holds a bootable FreeBSD system with the boot image in `/tmp/myboot/boot/cdboot`, you could produce the image of an ISO 9660 file system in `/tmp/bootable.iso` like so:

```
# mkisofs -U -R -b boot/cdboot -o /tmp/bootable.iso /tmp/myboot
```

Having done that, if you have `vn` (FreeBSD 4.X), or `md` (FreeBSD 5.X) configured in your kernel, you can mount the file system with:

```
# vnconfig -e vn0c /tmp/bootable.iso
# mount -t cd9660 /dev/vn0c /mnt
```

for FreeBSD 4.X, and for FreeBSD 5.X:

```
# mdconfig -a -t vnode -f /tmp/bootable.iso -u 0
# mount -t cd9660 /dev/md0 /mnt
```

At which point you can verify that `/mnt` and `/tmp/myboot` are identical.

There are many other options you can use with `sysutils/mkisofs` to fine-tune its behavior. In particular: modifications to an ISO 9660 layout and the creation of Joliet and HFS discs. See the mkisofs(8) manual page for details.

12.5.3 burncd

If you have an ATAPI CD burner, you can use the `burncd` command to burn an ISO image onto a CD. `burncd` is part of the base system, installed as `/usr/sbin/burncd`. Usage is very simple, as it has few options:

```
# burncd -f cddevice data imagefile.iso fixate
```

Will burn a copy of *imagefile.iso* on *cddevice*. The default device is `/dev/acd0c`. See burncd(8) for options to set the write speed, eject the CD after burning, and write audio data.

12.5.4 cdrecord

If you do not have an ATAPI CD burner, you will have to use `cdrecord` to burn your CDs. `cdrecord` is not part of the base system; you must install it from either the port at `sysutils/cdrtools` or the appropriate package. Changes to the base system can cause binary versions of this program to fail, possibly resulting in a "coaster". You should therefore either upgrade the port when you upgrade your system, or if you are tracking -STABLE, upgrade the port when a new version becomes available.

While `cdrecord` has many options, basic usage is even simpler than `burncd`. Burning an ISO 9660 image is done with:

```
# cdrecord dev=device imagefile.iso
```

The tricky part of using `cdrecord` is finding the `dev` to use. To find the proper setting, use the `-scanbus` flag of `cdrecord`, which might produce results like this:

```
# cdrecord -scanbus
Cdrecord 1.9 (i386-unknown-freebsd4.2) Copyright (C) 1995-2000 Jörg Schilling
Using libscg version 'schily-0.1'
scsibus0:
        0,0,0     0) 'SEAGATE ' 'ST39236LW       ' '0004' Disk
        0,1,0     1) 'SEAGATE ' 'ST39173W        ' '5958' Disk
        0,2,0     2) *
        0,3,0     3) 'iomega  ' 'jaz 1GB         ' 'J.86' Removable Disk
        0,4,0     4) 'NEC     ' 'CD-ROM DRIVE:466' '1.26' Removable CD-ROM
        0,5,0     5) *
        0,6,0     6) *
        0,7,0     7) *
scsibus1:
        1,0,0   100) *
        1,1,0   101) *
        1,2,0   102) *
        1,3,0   103) *
        1,4,0   104) *
        1,5,0   105) 'YAMAHA  ' 'CRW4260         ' '1.0q' Removable CD-ROM
        1,6,0   106) 'ARTEC   ' 'AM12S           ' '1.06' Scanner
        1,7,0   107) *
```

This lists the appropriate `dev` value for the devices on the list. Locate your CD burner, and use the three numbers separated by commas as the value for `dev`. In this case, the CRW device is 1,5,0, so the appropriate input would be `dev=1,5,0`. There are easier ways to specify this value; see cdrecord(1) for details. That is also the place to look for information on writing audio tracks, controlling the speed, and other things.

12.5.5 Duplicating Audio CDs

You can duplicate an audio CD by extracting the audio data from the CD to a series of files, and then writing these files to a blank CD. The process is slightly different for ATAPI and SCSI drives.

SCSI Drives

1. Use `cdda2wav` to extract the audio.

   ```
   % cdda2wav -v255 -D2,0 -B -Owav
   ```

2. Use `cdrecord` to write the `.wav` files.

   ```
   % cdrecord -v dev=2,0 -dao -useinfo  *.wav
   ```

   Make sure that *2.0* is set appropriately, as described in Section 12.5.4.

ATAPI Drives

1. The ATAPI CD driver makes each track available as `/dev/acd`*`d`*`t`*`nn`*, where *d* is the drive number, and *nn* is the track number written with two decimal digits, prefixed with zero as needed. So the first track on the first disk is `/dev/acd0t01`, the second is `/dev/acd0t02`, the third is `/dev/acd0t03`, and so on.

   Make sure the appropriate files exist in `/dev`.

   ```
   # cd /dev
   ```

```
# sh MAKEDEV acd0t99
```

Note: In FreeBSD 5.0, devfs(5) will automatically create and manage entries in `/dev` for you, so it is not necessary to use `MAKEDEV`.

2. Extract each track using dd(1). You must also use a specific block size when extracting the files.

```
# dd if=/dev/acd0t01 of=track1.cdr bs=2352
# dd if=/dev/acd0t02 of=track2.cdr bs=2352
...
```

3. Burn the extracted files to disk using `burncd`. You must specify that these are audio files, and that `burncd` should fixate the disk when finished.

```
# burncd -f /dev/acd0c audio track1.cdr track2.cdr ... fixate
```

12.5.6 Duplicating Data CDs

You can copy a data CD to a image file that is functionally equivalent to the image file created with `sysutils/mkisofs`, and you can use it to duplicate any data CD. The example given here assumes that your CDROM device is `acd0`. Substitute your correct CDROM device. A `c` must be appended to the end of the device name to indicate the entire partition or, in the case of CDROMs, the entire disc.

```
# dd if=/dev/acd0c of=file.iso bs=2048
```

Now that you have an image, you can burn it to CD as described above.

12.5.7 Using Data CDs

Now that you have created a standard data CDROM, you probably want to mount it and read the data on it. By default, mount(8) assumes that a file system is of type `ufs`. If you try something like:

```
# mount /dev/cd0c /mnt
```

you will get a complaint about `Incorrect super block`, and no mount. The CDROM is not a `UFS` file system, so attempts to mount it as such will fail. You just need to tell mount(8) that the file system is of type `ISO9660`, and everything will work. You do this by specifying the `-t cd9660` option mount(8). For example, if you want to mount the CDROM device, `/dev/cd0c`, under `/mnt`, you would execute:

```
# mount -t cd9660 /dev/cd0c /mnt
```

Note that your device name (`/dev/cd0c` in this example) could be different, depending on the interface your CDROM uses. Also, the `-t cd9660` option just executes mount_cd9660(8). The above example could be shortened to:

```
# mount_cd9660 /dev/cd0c /mnt
```

You can generally use data CDROMs from any vendor in this way. Disks with certain ISO 9660 extensions might behave oddly, however. For example, Joliet disks store all filenames in two-byte Unicode characters. The FreeBSD kernel does not speak Unicode (yet!), so non-English characters show up as question marks. (If you are running FreeBSD 4.3 or later, the CD9660 driver includes hooks to load an appropriate Unicode conversion table on the fly. Modules for some of the common encodings are available via the `sysutils/cd9660_unicode` port.)

Occasionally, you might get `Device not configured` when trying to mount a CDROM. This usually means that the CDROM drive thinks that there is no disk in the tray, or that the drive is not visible on the bus. It can take a couple of seconds for a CDROM drive to realize that it has been fed, so be patient.

Sometimes, a SCSI CDROM may be missed because it didn't have enough time to answer the bus reset. If you have a SCSI CDROM please add the following option to your kernel configuration and rebuild your kernel.

```
options SCSI_DELAY=15000
```

This tells your SCSI bus to pause 15 seconds during boot, to give your CDROM drive every possible chance to answer the bus reset.

12.5.8 Burning Raw Data CDs

You can choose to burn a file directly to CD, without creating an ISO 9660 file system. Some people do this for backup purposes. This runs more quickly than burning a standard CD:

```
# burncd -f /dev/acd1c -s 12 data archive.tar.gz fixate
```

In order to retrieve the data burned to such a CD, you must read data from the raw device node:

```
# tar xzvf /dev/acd1c
```

You cannot mount this disk as you would a normal CDROM. Such a CDROM cannot be read under any operating system except FreeBSD. If you want to be able to mount the CD, or share data with another operating system, you must use `sysutils/mkisofs` as described above.

12.5.9 Using the ATAPI/CAM Driver

This driver allows ATAPI devices (CD-ROM, CD-RW, DVD drives etc...) to be accessed through the SCSI subsystem, and so allows the use of applications like `sysutils/cdrdao` or cdrecord(1).

To use this driver, you will need to add the following lines to your kernel configuration file:

```
device atapicam
device scbus
device cd
device pass
```

You also need the following lines in your kernel configuration file:

```
device ata
device atapicd
```

Both of which should already be present.

Then rebuild, install your new kernel, and reboot your machine. During the boot process, your burner should show up, like so:

```
acd0: CD-RW <MATSHITA CD-RW/DVD-ROM UJDA740> at ata1-master PIO4
cd0 at ata1 bus 0 target 0 lun 0
cd0: <MATSHITA CDRW/DVD UJDA740 1.00> Removable CD-ROM SCSI-0 device
cd0: 16.000MB/s transfers
cd0: Attempt to query device size failed: NOT READY, Medium not present - tray closed
```

The drive could now be accessed via the `/dev/cd0` device name, for example to mount a CD-ROM on `/mnt`, just type the following:

```
# mount -t cd9660 /dev/cd0c /mnt
```

As `root`, you can run the following command to get the SCSI address of the burner:

```
# camcontrol devlist
<MATSHITA CDRW/DVD UJDA740 1.00>   at scbus1 target 0 lun 0 (pass0,cd0)
```

So `1,0,0` will be the SCSI address to use with cdrecord(1) and other SCSI application.

For more information about ATAPI/CAM and SCSI system, refer to the atapicam(4) and cam(4) manual pages.

12.6 Creating and Using Floppy Disks

Original work by Julio Merino. Rewritten by Martin Karlsson.

Storing data on floppy disks is sometimes useful, for example when one does not have any other removable storage media or when one needs to transfer small amounts of data to another computer.

This section will explain how to use floppy disks in FreeBSD. It will primarily cover formatting and usage of 3.5inch DOS floppies, but the concepts are similar for other floppy disk formats.

12.6.1 Formatting Floppies

12.6.1.1 The Device

Floppy disks are accessed through entries in `/dev`, just like other devices. To access the raw floppy disk in 4.X and earlier releases, one uses `/dev/fdN`, where *N* stands for the drive number, usually 0, or `/dev/fdNX`, where *X* stands for a letter.

In 5.0 or newer releases, simply use `/dev/fdN`.

12.6.1.1.1 The Disk Size in 4.X and Earlier Releases

There are also `/dev/fdN.size` devices, where *size* is a floppy disk size in kilobytes. These entries are used at low-level format time to determine the disk size. 1440kB is the size that will be used in the following examples.

Sometimes the entries under `/dev` will have to be (re)created. To do that, issue:

```
# cd /dev && ./MAKEDEV "fd*"
```

12.6.1.1.2 The Disk Size in 5.0 and Newer Releases

In 5.0, devfs(5) will automatically manage device nodes in `/dev`, so use of `MAKEDEV` is not necessary.

The desired disk size is passed to fdformat(1) through the `-f` flag. Supported sizes are listed in fdcontrol(8), but be advised that 1440kB is what works best.

12.6.1.2 Formatting

A floppy disk needs to be low-level formated before it can be used. This is usually done by the vendor, but formatting is a good way to check media integrity. Although it is possible to force larger (or smaller) disk sizes, 1440kB is what most floppy disks are designed for.

To low-level format the floppy disk you need to use fdformat(1). This utility expects the device name as an argument.

Make note of any error messages, as these can help determine if the disk is good or bad.

12.6.1.2.1 Formatting in 4.X and Earlier Releases

Use the `/dev/fdN.size` devices to format the floppy. Insert a new 3.5inch floppy disk in your drive and issue:

```
# /usr/sbin/fdformat /dev/fd0.1440
```

12.6.1.2.2 Formatting in 5.0 and Newer Releases

Use the `/dev/fdN` devices to format the floppy. Insert a new 3.5inch floppy disk in your drive and issue:

```
# /usr/sbin/fdformat -f 1440 /dev/fd0
```

12.6.2 The Disk Label

After low-level formatting the disk, you will need to place a disk label on it. This disk label will be destroyed later, but it is needed by the system to determine the size of the disk and its geometry later.

The new disk label will take over the whole disk, and will contain all the proper information about the geometry of the floppy. The geometry values for the disk label are listed in `/etc/disktab`.

You can run now disklabel(8) like so:

```
# /sbin/disklabel -B -r -w /dev/fd0 fd1440
```

> **Note:** Since FreeBSD 5.1-RELEASE, the bsdlabel(8) utility replaces the old disklabel(8) program. With bsdlabel(8) a number of obsolete options and parameters have been retired; in the example above the option `-r` should be removed. For more information, please refer to the bsdlabel(8) manual page.

12.6.3 The File System

Now the floppy is ready to be high-level formated. This will place a new file system on it, which will let FreeBSD read and write to the disk. After creating the new file system, the disk label is destroyed, so if you want to reformat the disk, you will have to recreate the disk label.

The floppy's file system can be either UFS or FAT. FAT is generally a better choice for floppies.

To put a new file system on the floppy, issue:

```
# /sbin/newfs_msdos /dev/fd0
```

The disk is now ready for use.

12.6.4 Using the Floppy

To use the floppy, mount it with mount_msdos(8) (in 4.X and earlier releases) or mount_msdosfs(8) (in 5.0 or newer releases). One can also use `emulators/mtools` from the ports collection.

12.7 Creating and Using Data Tapes

The major tape media are the 4mm, 8mm, QIC, mini-cartridge and DLT.

12.7.1 4mm (DDS: Digital Data Storage)

4mm tapes are replacing QIC as the workstation backup media of choice. This trend accelerated greatly when Conner purchased Archive, a leading manufacturer of QIC drives, and then stopped production of QIC drives. 4mm drives are small and quiet but do not have the reputation for reliability that is enjoyed by 8mm drives. The cartridges are less expensive and smaller (3 x 2 x 0.5 inches, 76 x 51 x 12 mm) than 8mm cartridges. 4mm, like 8mm, has comparatively short head life for the same reason, both use helical scan.

Data throughput on these drives starts ~150 kB/s, peaking at ~500 kB/s. Data capacity starts at 1.3 GB and ends at 2.0 GB. Hardware compression, available with most of these drives, approximately doubles the capacity. Multi-drive tape library units can have 6 drives in a single cabinet with automatic tape changing. Library capacities reach 240 GB.

The DDS-3 standard now supports tape capacities up to 12 GB (or 24 GB compressed).

4mm drives, like 8mm drives, use helical-scan. All the benefits and drawbacks of helical-scan apply to both 4mm and 8mm drives.

Tapes should be retired from use after 2,000 passes or 100 full backups.

12.7.2 8mm (Exabyte)

8mm tapes are the most common SCSI tape drives; they are the best choice of exchanging tapes. Nearly every site has an Exabyte 2 GB 8mm tape drive. 8mm drives are reliable, convenient and quiet. Cartridges are inexpensive and small (4.8 x 3.3 x 0.6 inches; 122 x 84 x 15 mm). One downside of 8mm tape is relatively short head and tape life due to the high rate of relative motion of the tape across the heads.

Data throughput ranges from ~250 kB/s to ~500 kB/s. Data sizes start at 300 MB and go up to 7 GB. Hardware compression, available with most of these drives, approximately doubles the capacity. These drives are available as single units or multi-drive tape libraries with 6 drives and 120 tapes in a single cabinet. Tapes are changed automatically by the unit. Library capacities reach 840+ GB.

The Exabyte "Mammoth" model supports 12 GB on one tape (24 GB with compression) and costs approximately twice as much as conventional tape drives.

Data is recorded onto the tape using helical-scan, the heads are positioned at an angle to the media (approximately 6 degrees). The tape wraps around 270 degrees of the spool that holds the heads. The spool spins while the tape slides over the spool. The result is a high density of data and closely packed tracks that angle across the tape from one edge to the other.

12.7.3 QIC

QIC-150 tapes and drives are, perhaps, the most common tape drive and media around. QIC tape drives are the least expensive "serious" backup drives. The downside is the cost of media. QIC tapes are expensive compared to 8mm or 4mm tapes, up to 5 times the price per GB data storage. But, if your needs can be satisfied with a half-dozen tapes, QIC may be the correct choice. QIC is the *most* common tape drive. Every site has a QIC drive of some density or another. Therein lies the rub, QIC has a large number of densities on physically similar (sometimes identical) tapes. QIC drives are not quiet. These drives audibly seek before they begin to record data and are clearly audible whenever reading, writing or seeking. QIC tapes measure (6 x 4 x 0.7 inches; 15.2 x 10.2 x 1.7 mm). Mini-cartridges, which also use 1/4" wide tape are discussed separately. Tape libraries and changers are not available.

Data throughput ranges from ~150 kB/s to ~500 kB/s. Data capacity ranges from 40 MB to 15 GB. Hardware compression is available on many of the newer QIC drives. QIC drives are less frequently installed; they are being supplanted by DAT drives.

Data is recorded onto the tape in tracks. The tracks run along the long axis of the tape media from one end to the other. The number of tracks, and therefore the width of a track, varies with the tape's capacity. Most if not all newer drives provide backward-compatibility at least for reading (but often also for writing). QIC has a good reputation regarding the safety of the data (the mechanics are simpler and more robust than for helical scan drives).

Tapes should be retired from use after 5,000 backups.

12.7.4 XXX* Mini-Cartridge

12.7.5 DLT

DLT has the fastest data transfer rate of all the drive types listed here. The 1/2" (12.5mm) tape is contained in a single spool cartridge (4 x 4 x 1 inches; 100 x 100 x 25 mm). The cartridge has a swinging gate along one entire side of the cartridge. The drive mechanism opens this gate to extract the tape leader. The tape leader has an oval hole in it which the drive uses to "hook" the tape. The take-up spool is located inside the tape drive. All the other tape cartridges listed here (9 track tapes are the only exception) have both the supply and take-up spools located inside the tape cartridge itself.

Data throughput is approximately 1.5 MB/s, three times the throughput of 4mm, 8mm, or QIC tape drives. Data capacities range from 10 GB to 20 GB for a single drive. Drives are available in both multi-tape changers and multi-tape, multi-drive tape libraries containing from 5 to 900 tapes over 1 to 20 drives, providing from 50 GB to 9 TB of storage.

With compression, DLT Type IV format supports up to 70 GB capacity.

Data is recorded onto the tape in tracks parallel to the direction of travel (just like QIC tapes). Two tracks are written at once. Read/write head lifetimes are relatively long; once the tape stops moving, there is no relative motion between the heads and the tape.

12.7.6 AIT

AIT is a new format from Sony, and can hold up to 50 GB (with compression) per tape. The tapes contain memory chips which retain an index of the tape's contents. This index can be rapidly read by the tape drive to determine the position of files on the tape, instead of the several minutes that would be required for other tapes. Software such as **SAMS:Alexandria** can operate forty or more AIT tape libraries, communicating directly with the tape's memory chip to display the contents on screen, determine what files were backed up to which tape, locate the correct tape, load it, and restore the data from the tape.

Libraries like this cost in the region of $20,000, pricing them a little out of the hobbyist market.

12.7.7 Using a New Tape for the First Time

The first time that you try to read or write a new, completely blank tape, the operation will fail. The console messages should be similar to:

```
sa0(ncr1:4:0): NOT READY asc:4,1
sa0(ncr1:4:0):  Logical unit is in process of becoming ready
```

The tape does not contain an Identifier Block (block number 0). All QIC tape drives since the adoption of QIC-525 standard write an Identifier Block to the tape. There are two solutions:

- `mt fsf 1` causes the tape drive to write an Identifier Block to the tape.
- Use the front panel button to eject the tape.

  Re-insert the tape and `dump` data to the tape.

  `dump` will report `DUMP: End of tape detected` and the console will show: `HARDWARE FAILURE info:280 asc:80,96`.

  rewind the tape using: `mt rewind`.

  Subsequent tape operations are successful.

12.8 Backups to Floppies

12.8.1 Can I Use Floppies for Backing Up My Data?

Floppy disks are not really a suitable media for making backups as:

- The media is unreliable, especially over long periods of time.
- Backing up and restoring is very slow.
- They have a very limited capacity (the days of backing up an entire hard disk onto a dozen or so floppies has long since passed).

However, if you have no other method of backing up your data then floppy disks are better than no backup at all.

If you do have to use floppy disks then ensure that you use good quality ones. Floppies that have been lying around the office for a couple of years are a bad choice. Ideally use new ones from a reputable manufacturer.

12.8.2 So How Do I Backup My Data to Floppies?

The best way to backup to floppy disk is to use tar(1) with the `-M` (multi volume) option, which allows backups to span multiple floppies.

To backup all the files in the current directory and sub-directory use this (as `root`):

```
# tar Mcvf /dev/fd0 *
```

When the first floppy is full tar(1) will prompt you to insert the next volume (because tar(1) is media independent it refers to volumes; in this context it means floppy disk).

```
Prepare volume #2 for /dev/fd0 and hit return:
```

This is repeated (with the volume number incrementing) until all the specified files have been archived.

12.8.3 Can I Compress My Backups?

Unfortunately, tar(1) will not allow the `-z` option to be used for multi-volume archives. You could, of course, gzip(1) all the files, tar(1) them to the floppies, then gunzip(1) the files again!

12.8.4 How Do I Restore My Backups?

To restore the entire archive use:

```
# tar Mxvf /dev/fd0
```

There are two ways that you can use to restore only specific files. First, you can start with the first floppy and use:

```
# tar Mxvf /dev/fd0 filename
```

The utility tar(1) will prompt you to insert subsequent floppies until it finds the required file.

Alternatively, if you know which floppy the file is on then you can simply insert that floppy and use the same command as above. Note that if the first file on the floppy is a continuation from the previous one then tar(1) will warn you that it cannot restore it, even if you have not asked it to!

12.9 Backup Basics

The three major backup programs are dump(8), tar(1), and cpio(1).

12.9.1 Dump and Restore

The traditional UNIX backup programs are `dump` and `restore`. They operate on the drive as a collection of disk blocks, below the abstractions of files, links and directories that are created by the file systems. `dump` backs up an entire file system on a device. It is unable to backup only part of a file system or a directory tree that spans more than one file system. `dump` does not write files and directories to tape, but rather writes the raw data blocks that comprise files and directories.

> **Note:** If you use `dump` on your root directory, you would not back up `/home`, `/usr` or many other directories since these are typically mount points for other file systems or symbolic links into those file systems.

`dump` has quirks that remain from its early days in Version 6 of AT&T UNIX (circa 1975). The default parameters are suitable for 9-track tapes (6250 bpi), not the high-density media available today (up to 62,182 ftpi). These defaults must be overridden on the command line to utilize the capacity of current tape drives.

It is also possible to backup data across the network to a tape drive attached to another computer with `rdump` and `rrestore`. Both programs rely upon `rcmd` and `ruserok` to access the remote tape drive. Therefore, the user performing the backup must be listed in the `.rhosts` file on the remote computer. The arguments to `rdump` and `rrestore` must be suitable to use on the remote computer. When `rdump`ing from a FreeBSD computer to an Exabyte tape drive connected to a Sun called `komodo`, use:

```
# /sbin/rdump 0dsbfu 54000 13000 126 komodo:/dev/nsa8 /dev/da0a 2>&1
```

Beware: there are security implications to allowing `.rhosts` authentication. Evaluate your situation carefully.

It is also possible to use `dump` and `restore` in a more secure fashion over `ssh`.

Example 12-1. Using dump over ssh

```
# /sbin/dump -0uan -f - /usr | gzip -2 | ssh1 -c blowfish \
          targetuser@targetmachine.example.com dd of=/mybigfiles/dump-usr-l0.gz
```

12.9.2 `tar`

tar(1) also dates back to Version 6 of AT&T UNIX (circa 1975). `tar` operates in cooperation with the file system; `tar` writes files and directories to tape. `tar` does not support the full range of options that are available from cpio(1), but `tar` does not require the unusual command pipeline that `cpio` uses.

Most versions of `tar` do not support backups across the network. The GNU version of `tar`, which FreeBSD utilizes, supports remote devices using the same syntax as `rdump`. To `tar` to an Exabyte tape drive connected to a Sun called `komodo`, use:

```
# /usr/bin/tar cf komodo:/dev/nsa8 . 2>&1
```

For versions without remote device support, you can use a pipeline and `rsh` to send the data to a remote tape drive.

```
# tar cf - . | rsh hostname dd of=tape-device obs=20b
```

If you are worried about the security of backing up over a network you should use the `ssh` command instead of `rsh`.

12.9.3 cpio

cpio(1) is the original UNIX file interchange tape program for magnetic media. `cpio` has options (among many others) to perform byte-swapping, write a number of different archive formats, and pipe the data to other programs. This last feature makes `cpio` an excellent choice for installation media. `cpio` does not know how to walk the directory tree and a list of files must be provided through `stdin`.

`cpio` does not support backups across the network. You can use a pipeline and `rsh` to send the data to a remote tape drive.

```
# for f in directory_list; do
find $f >> backup.list
done
# cpio -v -o --format=newc < backup.list | ssh user@host "cat > backup_device"
```

Where *directory_list* is the list of directories you want to back up, *user@host* is the user/hostname combination that will be performing the backups, and *backup_device* is where the backups should be written to (e.g., `/dev/nsa0`).

12.9.4 pax

pax(1) is IEEE/POSIX's answer to `tar` and `cpio`. Over the years the various versions of `tar` and `cpio` have gotten slightly incompatible. So rather than fight it out to fully standardize them, POSIX created a new archive utility. `pax` attempts to read and write many of the various `cpio` and `tar` formats, plus new formats of its own. Its command set more resembles `cpio` than `tar`.

12.9.5 Amanda

Amanda (Advanced Maryland Network Disk Archiver) is a client/server backup system, rather than a single program. An **Amanda** server will backup to a single tape drive any number of computers that have **Amanda** clients and a network connection to the **Amanda** server. A common problem at sites with a number of large disks is that the length of time required to backup to data directly to tape exceeds the amount of time available for the task. **Amanda** solves this problem. **Amanda** can use a "holding disk" to backup several file systems at the same time. **Amanda** creates "archive sets": a group of tapes used over a period of time to create full backups of all the file systems listed in **Amanda**'s configuration file. The "archive set" also contains nightly incremental (or differential) backups of all the file systems. Restoring a damaged file system requires the most recent full backup and the incremental backups.

The configuration file provides fine control of backups and the network traffic that **Amanda** generates. **Amanda** will use any of the above backup programs to write the data to tape. **Amanda** is available as either a port or a package, it is not installed by default.

12.9.6 Do Nothing

"Do nothing" is not a computer program, but it is the most widely used backup strategy. There are no initial costs. There is no backup schedule to follow. Just say no. If something happens to your data, grin and bear it!

If your time and your data is worth little to nothing, then "Do nothing" is the most suitable backup program for your computer. But beware, UNIX is a useful tool, you may find that within six months you have a collection of files that are valuable to you.

"Do nothing" is the correct backup method for `/usr/obj` and other directory trees that can be exactly recreated by your computer. An example is the files that comprise the HTML or PostScript version of this Handbook. These document formats have been created from SGML input files. Creating backups of the HTML or PostScript files is not necessary. The SGML files are backed up regularly.

12.9.7 Which Backup Program Is Best?

dump(8) *Period.* Elizabeth D. Zwicky torture tested all the backup programs discussed here. The clear choice for preserving all your data and all the peculiarities of UNIX file systems is `dump`. Elizabeth created file systems containing a large variety of unusual conditions (and some not so unusual ones) and tested each program by doing a backup and restore of those file systems. The peculiarities included: files with holes, files with holes and a block of nulls, files with funny characters in their names, unreadable and unwritable files, devices, files that change size during the backup, files that are created/deleted during the backup and more. She presented the results at LISA V in Oct. 1991. See torture-testing Backup and Archive Programs (http://berdmann.dyndns.org/zwicky/testdump.doc.html).

12.9.8 Emergency Restore Procedure

12.9.8.1 Before the Disaster

There are only four steps that you need to perform in preparation for any disaster that may occur.

First, print the disklabel from each of your disks (e.g. `disklabel da0 | lpr`), your file system table (`/etc/fstab`) and all boot messages, two copies of each.

Second, determine that the boot and fix-it floppies (`boot.flp` and `fixit.flp`) have all your devices. The easiest way to check is to reboot your machine with the boot floppy in the floppy drive and check the boot messages. If all your devices are listed and functional, skip on to step three.

Otherwise, you have to create two custom bootable floppies which have a kernel that can mount all of your disks and access your tape drive. These floppies must contain: `fdisk`, `disklabel`, `newfs`, `mount`, and whichever backup program you use. These programs must be statically linked. If you use `dump`, the floppy must contain `restore`.

Third, create backup tapes regularly. Any changes that you make after your last backup may be irretrievably lost. Write-protect the backup tapes.

Fourth, test the floppies (either `boot.flp` and `fixit.flp` or the two custom bootable floppies you made in step two.) and backup tapes. Make notes of the procedure. Store these notes with the bootable floppy, the printouts and the backup tapes. You will be so distraught when restoring that the notes may prevent you from destroying your backup tapes (How? In place of `tar xvf /dev/sa0`, you might accidentally type `tar cvf /dev/sa0` and over-write your backup tape).

For an added measure of security, make bootable floppies and two backup tapes each time. Store one of each at a remote location. A remote location is NOT the basement of the same office building. A number of firms in the World Trade Center learned this lesson the hard way. A remote location should be physically separated from your computers and disk drives by a significant distance.

Example 12-2. A Script for Creating a Bootable Floppy

```
#!/bin/sh
#
# create a restore floppy
#
# format the floppy
#
PATH=/bin:/sbin:/usr/sbin:/usr/bin

fdformat -q fd0
if [ $? -ne 0 ]
then
 echo "Bad floppy, please use a new one"
 exit 1
fi

# place boot blocks on the floppy
#
disklabel -w -B /dev/fd0c fd1440

#
# newfs the one and only partition
#
newfs -t 2 -u 18 -l 1 -c 40 -i 5120 -m 5 -o space /dev/fd0a

#
# mount the new floppy
#
mount /dev/fd0a /mnt

#
# create required directories
#
mkdir /mnt/dev
mkdir /mnt/bin
mkdir /mnt/sbin
mkdir /mnt/etc
mkdir /mnt/root
mkdir /mnt/mnt # for the root partition
mkdir /mnt/tmp
mkdir /mnt/var

#
```

```
# populate the directories
#
if [ ! -x /sys/compile/MINI/kernel ]
then
 cat << EOM
The MINI kernel does not exist, please create one.
Here is an example config file:
#
# MINI -- A kernel to get FreeBSD onto a disk.
#
machine         "i386"
cpu             "I486_CPU"
ident           MINI
maxusers        5

options         INET                    # needed for _tcp _icmpstat _ipstat
                                        #            _udpstat _tcpstat _udb
options         FFS                     #Berkeley Fast File System
options         FAT_CURSOR              #block cursor in syscons or pccons
options         SCSI_DELAY=15           #Be pessimistic about Joe SCSI device
options         NCONS=2                 #1 virtual consoles
options         USERCONFIG              #Allow user configuration with -c XXX

config          kernel root on da0 swap on da0 and da1 dumps on da0

device          isa0
device          pci0

device          fdc0 at isa? port "IO_FD1" bio irq 6 drq 2 vector fdintr
device          fd0 at fdc0 drive 0

device          ncr0

device          scbus0

device          sc0 at isa? port "IO_KBD" tty irq 1 vector scintr
device          npx0 at isa? port "IO_NPX" irq 13 vector npxintr

device          da0
device          da1
device          da2

device          sa0

pseudo-device   loop            # required by INET
pseudo-device   gzip            # Exec gzipped a.out's
EOM
 exit 1
fi

cp -f /sys/compile/MINI/kernel /mnt

gzip -c -best /sbin/init > /mnt/sbin/init
```

```
gzip -c -best /sbin/fsck > /mnt/sbin/fsck
gzip -c -best /sbin/mount > /mnt/sbin/mount
gzip -c -best /sbin/halt > /mnt/sbin/halt
gzip -c -best /sbin/restore > /mnt/sbin/restore

gzip -c -best /bin/sh > /mnt/bin/sh
gzip -c -best /bin/sync > /mnt/bin/sync

cp /root/.profile /mnt/root

cp -f /dev/MAKEDEV /mnt/dev
chmod 755 /mnt/dev/MAKEDEV

chmod 500 /mnt/sbin/init
chmod 555 /mnt/sbin/fsck /mnt/sbin/mount /mnt/sbin/halt
chmod 555 /mnt/bin/sh /mnt/bin/sync
chmod 6555 /mnt/sbin/restore

#
# create the devices nodes
#
cd /mnt/dev
./MAKEDEV std
./MAKEDEV da0
./MAKEDEV da1
./MAKEDEV da2
./MAKEDEV sa0
./MAKEDEV pty0
cd /

#
# create minimum file system table
#
cat > /mnt/etc/fstab <<EOM
/dev/fd0a    /    ufs    rw  1  1
EOM

#
# create minimum passwd file
#
cat > /mnt/etc/passwd <<EOM
root:*:0:0:Charlie &:/root:/bin/sh
EOM

cat > /mnt/etc/master.passwd <<EOM
root::0:0::0:0:Charlie &:/root:/bin/sh
EOM

chmod 600 /mnt/etc/master.passwd
chmod 644 /mnt/etc/passwd
/usr/sbin/pwd_mkdb -d/mnt/etc /mnt/etc/master.passwd

#
```

```
# umount the floppy and inform the user
#
/sbin/umount /mnt
echo "The floppy has been unmounted and is now ready."
```

12.9.8.2 After the Disaster

The key question is: did your hardware survive? You have been doing regular backups so there is no need to worry about the software.

If the hardware has been damaged, the parts should be replaced before attempting to use the computer.

If your hardware is okay, check your floppies. If you are using a custom boot floppy, boot single-user (type `-s` at the `boot:` prompt). Skip the following paragraph.

If you are using the `boot.flp` and `fixit.flp` floppies, keep reading. Insert the `boot.flp` floppy in the first floppy drive and boot the computer. The original install menu will be displayed on the screen. Select the `Fixit--Repair mode with CDROM or floppy.` option. Insert the `fixit.flp` when prompted. `restore` and the other programs that you need are located in `/mnt2/stand`.

Recover each file system separately.

Try to `mount` (e.g. `mount /dev/da0a /mnt`) the root partition of your first disk. If the disklabel was damaged, use `disklabel` to re-partition and label the disk to match the label that you printed and saved. Use `newfs` to re-create the file systems. Re-mount the root partition of the floppy read-write (`mount -u -o rw /mnt`). Use your backup program and backup tapes to recover the data for this file system (e.g. `restore vrf /dev/sa0`). Unmount the file system (e.g. `umount /mnt`). Repeat for each file system that was damaged.

Once your system is running, backup your data onto new tapes. Whatever caused the crash or data loss may strike again. Another hour spent now may save you from further distress later.

12.10 Network, Memory, and File-Backed File Systems

Reorganized and enhanced by Marc Fonvieille.

Aside from the disks you physically insert into your computer: floppies, CDs, hard drives, and so forth; other forms of disks are understood by FreeBSD - the *virtual disks*.

These include network file systems such as the Network File System and Coda, memory-based file systems and file-backed file systems.

According to the FreeBSD version you run, you will have to use different tools for creation and use of file-backed and memory-based file systems.

> **Note:** The FreeBSD 4.X users will have to use MAKEDEV(8) to create the required devices. FreeBSD 5.0 and later use devfs(5) to allocate device nodes transparently for the user.

12.10.1 File-Backed File System under FreeBSD 4.X

The utility vnconfig(8) configures and enables vnode pseudo-disk devices. A *vnode* is a representation of a file, and is the focus of file activity. This means that vnconfig(8) uses files to create and operate a file system. One possible use is the mounting of floppy or CD images kept in files.

To use vnconfig(8), you need vn(4) support in your kernel configuration file:

```
pseudo-device vn
```

To mount an existing file system image:

Example 12-3. Using vnconfig to Mount an Existing File System Image under FreeBSD 4.X

```
# vnconfig vn0 diskimage
# mount /dev/vn0c /mnt
```

To create a new file system image with vnconfig(8):

Example 12-4. Creating a New File-Backed Disk with `vnconfig`

```
# dd if=/dev/zero of=newimage bs=1k count=5k
5120+0 records in
5120+0 records out
# vnconfig -s labels -c vn0 newimage
# disklabel -r -w vn0 auto
# newfs vn0c
Warning: 2048 sector(s) in last cylinder unallocated
/dev/vn0c:     10240 sectors in 3 cylinders of 1 tracks, 4096 sectors
        5.0MB in 1 cyl groups (16 c/g, 32.00MB/g, 1280 i/g)
super-block backups (for fsck -b #) at:
 32
# mount /dev/vn0c /mnt
# df /mnt
Filesystem  1K-blocks     Used    Avail Capacity  Mounted on
/dev/vn0c        4927        1     4532     0%    /mnt
```

12.10.2 File-Backed File System under FreeBSD 5.X

The utility mdconfig(8) is used to configure and enable memory disks, md(4), under FreeBSD 5.X. To use mdconfig(8), you have to load md(4) module or to add the support in your kernel configuration file:

```
device md
```

The mdconfig(8) command supports three kinds of memory backed virtual disks: memory disks allocated with malloc(9), memory disks using a file or swap space as backing. One possible use is the mounting of floppy or CD images kept in files.

To mount an existing file system image:

Example 12-5. Using `mdconfig` to Mount an Existing File System Image under FreeBSD 5.X

```
# mdconfig -a -t vnode -f diskimage -u 0
# mount /dev/md0c /mnt
```

To create a new file system image with mdconfig(8):

Example 12-6. Creating a New File-Backed Disk with `mdconfig`

```
# dd if=/dev/zero of=newimage bs=1k count=5k
5120+0 records in
5120+0 records out
# mdconfig -a -t vnode -f newimage -u 0
# disklabel -r -w md0 auto
# newfs md0c
/dev/md0c: 5.0MB (10240 sectors) block size 16384, fragment size 2048
using 4 cylinder groups of 1.27MB, 81 blks, 256 inodes.
super-block backups (for fsck -b #) at:
 32, 2624, 5216, 7808
# mount /dev/md0c /mnt
# df /mnt
Filesystem  1K-blocks     Used    Avail Capacity  Mounted on
/dev/md0c        4846        2     4458     0%    /mnt
```

If you do not specify the unit number with the `-u` option, mdconfig(8) will use the md(4) automatic allocation to select an unused device. The name of the allocated unit will be output on stdout like `md4`. For more details about mdconfig(8), please refer to the manual page.

> **Note:** Since FreeBSD 5.1-RELEASE, the bsdlabel(8) utility replaces the old disklabel(8) program. With bsdlabel(8) a number of obsolete options and parameters have been retired; in the example above the option `-r` should be removed. For more information, please refer to the bsdlabel(8) manual page.

The utility mdconfig(8) is very useful, however it asks many command lines to create a file-backed file system. FreeBSD 5.0 also comes with a tool called mdmfs(8), this program configures a md(4) disk using mdconfig(8), puts a UFS file system on it using newfs(8), and mounts it using mount(8). For example, if you want to create and mount the same file system image as above, simply type the following:

```
# dd if=/dev/zero of=newimage bs=1k count=5k
5120+0 records in
5120+0 records in
5120+0 records out
# mdmfs -F newimage -s 5m md0 /mnt
# df /mnt
Filesystem 1K-blocks Used Avail Capacity  Mounted on
/dev/md0        4846    2  4458     0%    /mnt
```

If you use the option `md` without unit number, mdmfs(8) will use md(4) auto-unit feature to automatically select an unused device. For more details about mdmfs(8), please refer to the manual page.

12.10.3 Memory-Based File System under FreeBSD 4.X

The md(4) driver is a simple, efficient means to create memory file systems under FreeBSD 4.X. malloc(9) is used to allocate the memory.

Simply take a file system you have prepared with, for example, vnconfig(8), and:

Example 12-7. md Memory Disk under FreeBSD 4.X

```
# dd if=newimage of=/dev/md0
5120+0 records in
5120+0 records out
# mount /dev/md0c /mnt
# df /mnt
Filesystem  1K-blocks     Used    Avail Capacity  Mounted on
/dev/md0c        4927        1     4532     0%    /mnt
```

For more details, please refer to md(4) manual page.

12.10.4 Memory-Based File System under FreeBSD 5.X

The same tools are used for memory-based and file-backed file systems: mdconfig(8) or mdmfs(8). The storage for memory-based file system is allocated with malloc(9).

Example 12-8. Creating a New Memory-Based Disk with `mdconfig`

```
# mdconfig -a -t malloc -s 5m -u 1
# newfs -U md1
/dev/md1: 5.0MB (10240 sectors) block size 16384, fragment size 2048
using 4 cylinder groups of 1.27MB, 81 blks, 256 inodes.
with soft updates
super-block backups (for fsck -b #) at:
 32, 2624, 5216, 7808
# mount /dev/md1 /mnt
# df /mnt
Filesystem 1K-blocks Used Avail Capacity  Mounted on
/dev/md1        4846    2  4458     0%    /mnt
```

Example 12-9. Creating a New Memory-Based Disk with `mdmfs`

```
# mdmfs -M -s 5m md2 /mnt
# df /mnt
Filesystem 1K-blocks Used Avail Capacity  Mounted on
/dev/md2        4846    2  4458     0%    /mnt
```

Instead of using a malloc(9) backed file system, it is possible to use swap, for that just replace `malloc` with `swap` in the command line of mdconfig(8). The mdmfs(8) utility by default (without `-M`) creates a swap-based disk. For more details, please refer to mdconfig(8) and mdmfs(8) manual pages.

12.10.5 Detaching a Memory Disk from the System

When a memory-based or file-based file system is not used, you should release all resources to the system. The first thing to do is to unmount the file system, then use mdconfig(8) to detach the disk from the system and release the resources.

For example to detach and free all resources used by `/dev/md4`:

```
# mdconfig -d -u 4
```

It is possible to list information about configured md(4) devices in using the command `mdconfig -l`.

For FreeBSD 4.X, vnconfig(8) is used to detach the device. For example to detach and free all resources used by `/dev/vn4`:

```
# vnconfig -u vn4
```

12.11 File System Snapshots

Contributed by Tom Rhodes.

FreeBSD 5.0 offers a new feature in conjunction with Soft Updates: File system snapshots.

Snapshots allow a user to create images of specified file systems, and treat them as a file. Snapshot files must be created in the file system that the action is performed on, and a user may create no more than 20 snapshots per file system. Active snapshots are recorded in the superblock so they are persistent across unmount and remount operations along with system reboots. When a snapshot is no longer required, it can be removed with the standard rm(1) command. Snapshots may be removed in any order, however all the used space may not be acquired because another snapshot will possibly claim some of the released blocks.

During initial creation, the `schg` flag (see the chflags(1) manual page) is set to ensure that even `root` cannot write to the snapshot. The unlink(1) command makes an exception for snapshot files since it allows them to be removed with the `schg` flag set, so it is not necessary to clear the `schg` flag before removing a snapshot file.

Snapshots are created with the mount(8) command. To place a snapshot of `/var` in the file `/var/snapshot/snap` use the following command:

```
# mount -u -o snapshot /var/snapshot/snap /var
```

Once a snapshot has been created, they have several uses:

- Some administrators will use a snapshot file for backup purposes, because the snapshot can be transfered to CDs or tape.
- File integrity, fsck(8) may be ran on the snapshot. Assuming that the file system was clean when it was mounted, you should always get a clean (and unchanging) result. This is essentially what the background fsck(8) process does.
- Run the dump(8) utility on the snapshot. A dump will be returned that is consistent with the file system and the timestamp of the snapshot. dump(8) can also take a snapshot, create a dump image and then remove the snapshot in one command using the `-L` flag.
- mount(8) the snapshot as a frozen image of the file system. To mount(8) the snapshot `/var/snapshot/snap` run:

```
# mdconfig -a -t vnode -f /var/snapshot/snap -u 4
# mount -r /dev/md4 /mnt
```

You can now walk the hierarchy of your frozen `/var` file system mounted at `/mnt`. Everything will be in the same state it was during the snapshot creation time. The only exception is that any earlier snapshots will appear as zero length files. When the use of a snapshot has delimited, it can be unmounted with:

```
# umount /mnt
# mdconfig -d -u 4
```

For more information about `softupdates` and file system snapshots, including technical papers, you can visit Marshall Kirk McKusick's website at http://www.mckusick.com. (http://www.mckusick.com/)

12.12 File System Quotas

Quotas are an optional feature of the operating system that allow you to limit the amount of disk space and/or the number of files a user or members of a group may allocate on a per-file system basis. This is used most often on timesharing systems where it is desirable to limit the amount of resources any one user or group of users may allocate. This will prevent one user or group of users from consuming all of the available disk space.

12.12.1 Configuring Your System to Enable Disk Quotas

Before attempting to use disk quotas, it is necessary to make sure that quotas are configured in your kernel. This is done by adding the following line to your kernel configuration file:

```
options QUOTA
```

The stock `GENERIC` kernel does not have this enabled by default, so you will have to configure, build and install a custom kernel in order to use disk quotas. Please refer to Chapter 9 for more information on kernel configuration.

Next you will need to enable disk quotas in `/etc/rc.conf`. This is done by adding the line:

```
enable_quotas="YES"
```

For finer control over your quota startup, there is an additional configuration variable available. Normally on bootup, the quota integrity of each file system is checked by the quotacheck(8) program. The quotacheck(8) facility insures that the data in the quota database properly reflects the data on the file system. This is a very time consuming process that will significantly affect the time your system takes to boot. If you would like to skip this step, a variable in `/etc/rc.conf` is made available for the purpose:

```
check_quotas="NO"
```

If you are running FreeBSD prior to 3.2-RELEASE, the configuration is simpler, and consists of only one variable. Set the following in your `/etc/rc.conf`:

```
check_quotas="YES"
```

Finally you will need to edit /etc/fstab to enable disk quotas on a per-file system basis. This is where you can either enable user or group quotas or both for all of your file systems.

To enable per-user quotas on a file system, add the userquota option to the options field in the /etc/fstab entry for the file system you want to enable quotas on. For example:

```
/dev/da1s2g   /home    ufs rw,userquota 1 2
```

Similarly, to enable group quotas, use the groupquota option instead of userquota. To enable both user and group quotas, change the entry as follows:

```
/dev/da1s2g    /home    ufs rw,userquota,groupquota 1 2
```

By default, the quota files are stored in the root directory of the file system with the names quota.user and quota.group for user and group quotas respectively. See fstab(5) for more information. Even though the fstab(5) manual page says that you can specify an alternate location for the quota files, this is not recommended because the various quota utilities do not seem to handle this properly.

At this point you should reboot your system with your new kernel. /etc/rc will automatically run the appropriate commands to create the initial quota files for all of the quotas you enabled in /etc/fstab, so there is no need to manually create any zero length quota files.

In the normal course of operations you should not be required to run the quotacheck(8), quotaon(8), or quotaoff(8) commands manually. However, you may want to read their manual pages just to be familiar with their operation.

12.12.2 Setting Quota Limits

Once you have configured your system to enable quotas, verify that they really are enabled. An easy way to do this is to run:

```
# quota -v
```

You should see a one line summary of disk usage and current quota limits for each file system that quotas are enabled on.

You are now ready to start assigning quota limits with the edquota(8) command.

You have several options on how to enforce limits on the amount of disk space a user or group may allocate, and how many files they may create. You may limit allocations based on disk space (block quotas) or number of files (inode quotas) or a combination of both. Each of these limits are further broken down into two categories: hard and soft limits.

A hard limit may not be exceeded. Once a user reaches his hard limit he may not make any further allocations on the file system in question. For example, if the user has a hard limit of 500 blocks on a file system and is currently using 490 blocks, the user can only allocate an additional 10 blocks. Attempting to allocate an additional 11 blocks will fail.

Soft limits, on the other hand, can be exceeded for a limited amount of time. This period of time is known as the grace period, which is one week by default. If a user stays over his or her soft limit longer than the grace period, the soft limit will turn into a hard limit and no further allocations will be allowed. When the user drops back below the soft limit, the grace period will be reset.

The following is an example of what you might see when you run the edquota(8) command. When the edquota(8) command is invoked, you are placed into the editor specified by the `EDITOR` environment variable, or in the **vi** editor if the `EDITOR` variable is not set, to allow you to edit the quota limits.

```
# edquota -u test
```

```
Quotas for user test:
/usr: blocks in use: 65, limits (soft = 50, hard = 75)
        inodes in use: 7, limits (soft = 50, hard = 60)
/usr/var: blocks in use: 0, limits (soft = 50, hard = 75)
        inodes in use: 0, limits (soft = 50, hard = 60)
```

You will normally see two lines for each file system that has quotas enabled. One line for the block limits, and one line for inode limits. Simply change the value you want updated to modify the quota limit. For example, to raise this user's block limit from a soft limit of 50 and a hard limit of 75 to a soft limit of 500 and a hard limit of 600, change:

```
/usr: blocks in use: 65, limits (soft = 50, hard = 75)
```

to:

```
 /usr: blocks in use: 65, limits (soft = 500, hard = 600)
```

The new quota limits will be in place when you exit the editor.

Sometimes it is desirable to set quota limits on a range of UIDs. This can be done by use of the `-p` option on the edquota(8) command. First, assign the desired quota limit to a user, and then run `edquota -p protouser startuid-enduid`. For example, if user `test` has the desired quota limits, the following command can be used to duplicate those quota limits for UIDs 10,000 through 19,999:

```
# edquota -p test 10000-19999
```

For more information see edquota(8) manual page.

12.12.3 Checking Quota Limits and Disk Usage

You can use either the quota(1) or the repquota(8) commands to check quota limits and disk usage. The quota(1) command can be used to check individual user or group quotas and disk usage. A user may only examine his own quota, and the quota of a group he is a member of. Only the super-user may view all user and group quotas. The repquota(8) command can be used to get a summary of all quotas and disk usage for file systems with quotas enabled.

The following is some sample output from the `quota -v` command for a user that has quota limits on two file systems.

```
Disk quotas for user test (uid 1002):
     Filesystem  blocks   quota   limit   grace   files   quota   limit   grace
           /usr      65*     50      75   5days       7      50      60
       /usr/var       0      50      75               0      50      60
```

On the `/usr` file system in the above example, this user is currently 15 blocks over the soft limit of 50 blocks and has 5 days of the grace period left. Note the asterisk `*` which indicates that the user is currently over his quota limit.

Normally file systems that the user is not using any disk space on will not show up in the output from the quota(1) command, even if he has a quota limit assigned for that file system. The `-v` option will display those file systems, such as the `/usr/var` file system in the above example.

12.12.4 Quotas over NFS

Quotas are enforced by the quota subsystem on the NFS server. The rpc.rquotad(8) daemon makes quota information available to the quota(1) command on NFS clients, allowing users on those machines to see their quota statistics.

Enable `rpc.rquotad` in `/etc/inetd.conf` like so:

```
rquotad/1      dgram rpc/udp wait root /usr/libexec/rpc.rquotad rpc.rquotad
```

Now restart `inetd`:

```
# kill -HUP ‘cat /var/run/inetd.pid‘
```

12.13 Encrypting Disk Partitions

Contributed by Lucky Green.

FreeBSD offers excellent online protections against unauthorized data access. File permissions and Mandatory Access Control (MAC) (see Section 10.12) help prevent unauthorized third-parties from accessing data while the operating system is active and the computer is powered up. However, the permissions enforced by the operating system are irrelevant if an attacker has physical access to a computer and can simply move the computer’s hard drive to another system to copy and analyze the sensitive data.

Regardless of how an attacker may have come into possession of a hard drive or powered-down computer, **GEOM Based Disk Encryption (gbde)** can protect the data on the computer’s file systems against even highly-motivated attackers with significant resources. Unlike cumbersome encryption methods that encrypt only individual files, **gbde** transparently encrypts entire file systems. No cleartext ever touches the hard drive’s platter.

12.13.1 Enabling gbde in the Kernel

1. Become `root`

   Configuring **gbde** requires super-user privileges.

   ```
   % su -
   Password:
   ```

2. Verify the Operating System Version

   gbde(4) requires FreeBSD 5.0 or higher.

   ```
   # uname -r
   5.0-RELEASE
   ```

3. Add gbde(4) Support to the Kernel Configuration File

   Using your favorite text editor, add the following line to your kernel configuration file:

```
options GEOM_BDE
```

Configure, recompile, and install the FreeBSD kernel. This process is described in Chapter 9.

Reboot into the new kernel.

12.13.2 Preparing the Encrypted Hard Drive

The following example assumes that you are adding a new hard drive to your system that will hold a single encrypted partition. This partition will be mounted as `/private`. **gbde** can also be used to encrypt `/home` and `/var/mail`, but this requires more complex instructions which exceed the scope of this introduction.

1. Add the New Hard Drive

   Install the new drive to the system as explained in Section 12.3. For the purposes of this example, a new hard drive partition has been added as `/dev/ad4s1c`. The `/dev/ad0s1*` devices represent existing standard FreeBSD partitions on the example system.

   ```
   # ls /dev/ad*
   /dev/ad0        /dev/ad0s1b     /dev/ad0s1e     /dev/ad4s1
   /dev/ad0s1      /dev/ad0s1c     /dev/ad0s1f     /dev/ad4s1c
   /dev/ad0s1a     /dev/ad0s1d     /dev/ad4
   ```

2. Create a Directory to Hold gbde Lock Files

   ```
   # mkdir /etc/gbde
   ```

   The **gbde** lock file contains information that **gbde** requires to access encrypted partitions. Without access to the lock file, **gbde** will not be able to decrypt the data contained in the encrypted partition without significant manual intervention which is not supported by the software. Each encrypted partition uses a separate lock file.

3. Initialize the gbde Partition

   A **gbde** partition must be initialized before it can be used. This initialization needs to be performed only once:

   ```
   # gbde init /dev/ad4s1c -i -L /etc/gbde/ad4s1c
   ```

   gbde(8) will open your editor, permitting you to set various configuration options in a template. For use with UFS1 or UFS2, set the sector_size to 2048:

   ```
   $FreeBSD: src/sbin/gbde/template.txt,v 1.1 2002/10/20 11:16:13 phk Exp $
   #
   # Sector size is the smallest unit of data which can be read or written.
   # Making it too small decreases performance and decreases available space.
   # Making it too large may prevent filesystems from working.  512 is the
   # minimum and always safe.  For UFS, use the fragment size
   #
   sector_size     =       2048
   [...]
   ```

   gbde(8) will ask you twice to type the passphrase that should be used to secure the data. The passphrase must be the same both times. **gbde**'s ability to protect your data depends entirely on the quality of the passphrase that you choose. [1]

   The `gbde init` command creates a lock file for your **gbde** partition that in this example is stored as `/etc/gbde/ad4s1c`.

Caution: gbde lock files *must* be backed up together with the contents of any encrypted partitions. While deleting a lock file alone cannot prevent a determined attacker from decrypting a **gbde** partition, without the lock file, the legitimate owner will be unable to access the data on the encrypted partition without a significant amount of work that is totally unsupported by gbde(8) and its designer.

4. Attach the Encrypted Partition to the Kernel

```
# gbde attach /dev/ad4s1c -l /etc/gbde/ad4s1c
```

You will be asked to provide the passphrase that you selected during the initialization of the encrypted partition. The new encrypted device will show up in `/dev` as `/dev/device_name.bde`:

```
# ls /dev/ad*
/dev/ad0        /dev/ad0s1b     /dev/ad0s1e     /dev/ad4s1
/dev/ad0s1      /dev/ad0s1c     /dev/ad0s1f     /dev/ad4s1c
/dev/ad0s1a     /dev/ad0s1d     /dev/ad4        /dev/ad4s1c.bde
```

5. Create a File System on the Encrypted Device

Once the encrypted device has been attached to the kernel, you can create a file system on the device. To create a file system on the encrypted device, use newfs(8). Since it is much faster to initialize a new UFS2 file system than it is to initialize the old UFS1 file system, using newfs(8) with the `-O2` option is recommended.

Note: The `-O2` option is the default with FreeBSD 5.1-RELEASE and later.

```
# newfs -U -O2 /dev/ad4s1c.bde
```

Note: The newfs(8) command must be performed on an attached **gbde** partition which is identified by a `*.bde` extension to the device name.

6. Mount the Encrypted Partition

Create a mount point for the encrypted file system.

```
# mkdir /private
```

Mount the encrypted file system.

```
# mount /dev/ad4s1c.bde /private
```

7. Verify That the Encrypted File System is Available

The encrypted file system should now be visible to df(1) and be available for use.

```
% df -H
Filesystem        Size   Used  Avail Capacity  Mounted on
/dev/ad0s1a      1037M    72M   883M     8%    /
/devfs            1.0K   1.0K     0B   100%    /dev
/dev/ad0s1f       8.1G    55K   7.5G     0%    /home
/dev/ad0s1e      1037M   1.1M   953M     0%    /tmp
/dev/ad0s1d       6.1G   1.9G   3.7G    35%    /usr
/dev/ad4s1c.bde   150G   4.1K   138G     0%    /private
```

12.13.3 Mounting Existing Encrypted File Systems

After each boot, any encrypted file systems must be re-attached to the kernel, checked for errors, and mounted, before the file systems can be used. The required commands must be executed as user `root`.

1. Attach the gbde Partition to the Kernel

   ```
   # gbde attach /dev/ad4s1c -l /etc/gbde/ad4s1c
   ```

   You will be asked to provide the passphrase that you selected during initialization of the encrypted gbde partition.

2. Check the File System for Errors

   Since encrypted file systems cannot yet be listed in `/etc/fstab` for automatic mounting, the file systems must be checked for errors by running fsck(8) manually before mounting.

   ```
   # fsck -p -t ffs /dev/ad4s1c.bde
   ```

3. Mount the Encrypted File System

   ```
   # mount /dev/ad4s1c.bde /private
   ```

   The encrypted file system is now available for use.

12.13.3.1 Automatically Mounting Encrypted Partitions

It is possible to create a script to automatically attach, check, and mount an encrypted partition, but for security reasons the script should not contain the gbde(8) password. Instead, it is recommended that such scripts be run manually while providing the password via the console or ssh(1).

12.13.4 Cryptographic Protections Employed by gbde

gbde(8) encrypts the sector payload using 128-bit AES in CBC mode. Each sector on the disk is encrypted with a different AES key. For more information on **gbde**'s cryptographic design, including how the sector keys are derived from the user-supplied passphrase, see gbde(4).

12.13.5 Compatibility Issues

sysinstall(8) is incompatible with **gbde**-encrypted devices. All `*.bde` devices must be detached from the kernel before starting sysinstall(8) or it will crash during its initial probing for devices. To detach the encrypted device used in our example, use the following command:

```
# gbde detach /dev/ad4s1c
```

Also note that, as vinum(4) does not use the geom(4) subsystem, you cannot use **gbde** with **vinum** volumes.

Notes

1. For tips on how to select a secure passphrase that is easy to remember, see the Diceware Passphrase (http://world.std.com/~reinhold/diceware.html) website.

Chapter 13 The Vinum Volume Manager

13.1 Synopsis

No matter what disks you have, there will always be limitations:

- They can be too small.
- They can be too slow.
- They can be too unreliable.

13.2 Disks Are Too Small

Originally written by Greg Lehey.

Vinum is a so-called *Volume Manager*, a virtual disk driver that addresses these three problems. Let us look at them in more detail. Various solutions to these problems have been proposed and implemented:

Disks are getting bigger, but so are data storage requirements. Often you will find you want a file system that is bigger than the disks you have available. Admittedly, this problem is not as acute as it was ten years ago, but it still exists. Some systems have solved this by creating an abstract device which stores its data on a number of disks.

13.3 Access Bottlenecks

Modern systems frequently need to access data in a highly concurrent manner. For example, large FTP or HTTP servers can maintain thousands of concurrent sessions and have multiple 100 Mbit/s connections to the outside world, well beyond the sustained transfer rate of most disks.

Current disk drives can transfer data sequentially at up to 70 MB/s, but this value is of little importance in an environment where many independent processes access a drive, where they may achieve only a fraction of these values. In such cases it is more interesting to view the problem from the viewpoint of the disk subsystem: the important parameter is the load that a transfer places on the subsystem, in other words the time for which a transfer occupies the drives involved in the transfer.

In any disk transfer, the drive must first position the heads, wait for the first sector to pass under the read head, and then perform the transfer. These actions can be considered to be atomic: it does not make any sense to interrupt them.

Consider a typical transfer of about 10 kB: the current generation of high-performance disks can position the heads in an average of 3.5 ms. The fastest drives spin at 15,000 rpm, so the average rotational latency (half a revolution) is 2 ms. At 70 MB/s, the transfer itself takes about 150 μs, almost nothing compared to the positioning time. In such a case, the effective transfer rate drops to a little over 1 MB/s and is clearly highly dependent on the transfer size.

The traditional and obvious solution to this bottleneck is "more spindles": rather than using one large disk, it uses several smaller disks with the same aggregate storage space. Each disk is capable of positioning and transferring independently, so the effective throughput increases by a factor close to the number of disks used.

The exact throughput improvement is, of course, smaller than the number of disks involved: although each drive is capable of transferring in parallel, there is no way to ensure that the requests are evenly distributed across the drives. Inevitably the load on one drive will be higher than on another.

The evenness of the load on the disks is strongly dependent on the way the data is shared across the drives. In the following discussion, it is convenient to think of the disk storage as a large number of data sectors which are addressable by number, rather like the pages in a book. The most obvious method is to divide the virtual disk into groups of consecutive sectors the size of the individual physical disks and store them in this manner, rather like taking a large book and tearing it into smaller sections. This method is called *concatenation* and has the advantage that the disks are not required to have any specific size relationships. It works well when the access to the virtual disk is spread evenly about its address space. When access is concentrated on a smaller area, the improvement is less marked. Figure 13-1 illustrates the sequence in which storage units are allocated in a concatenated organization.

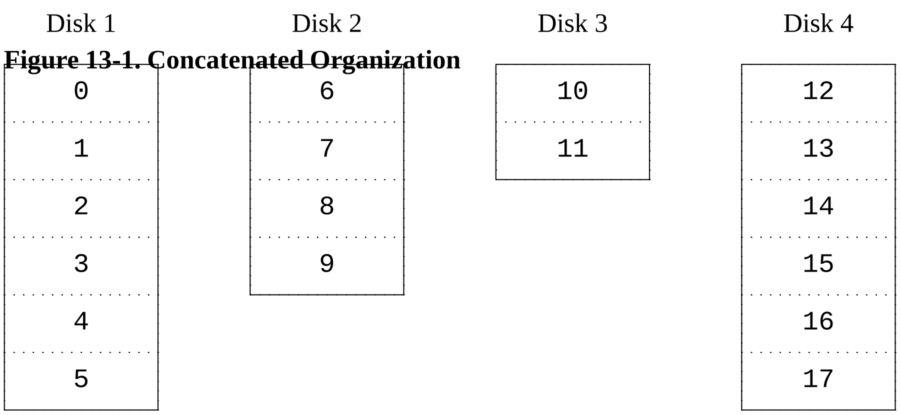


Figure 13-1. Concatenated Organization

An alternative mapping is to divide the address space into smaller, equal-sized components and store them sequentially on different devices. For example, the first 256 sectors may be stored on the first disk, the next 256 sectors on the next disk and so on. After filling the last disk, the process repeats until the disks are full. This mapping is called *striping* or RAID-0 [1]. Striping requires somewhat more effort to locate the data, and it can cause additional I/O load where a transfer is spread over multiple disks, but it can also provide a more constant load across the disks. Figure 13-2 illustrates the sequence in which storage units are allocated in a striped organization.

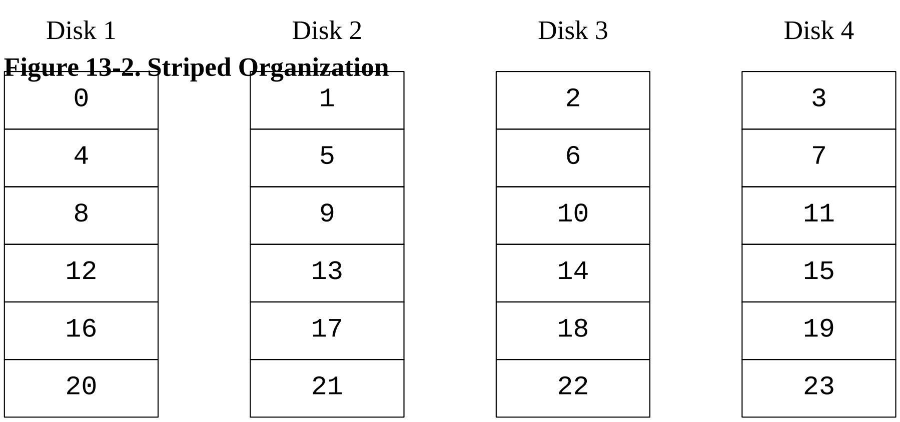


Figure 13-2. Striped Organization

13.4 Data Integrity

The final problem with current disks is that they are unreliable. Although disk drive reliability has increased tremendously over the last few years, they are still the most likely core component of a server to fail. When they do, the results can be catastrophic: replacing a failed disk drive and restoring data to it can take days.

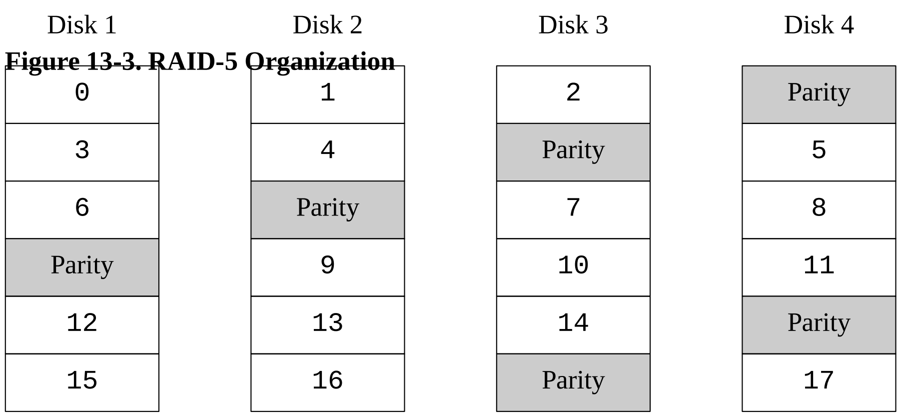
The traditional way to approach this problem has been *mirroring*, keeping two copies of the data on different physical hardware. Since the advent of the RAID levels, this technique has also been called RAID level 1 or RAID-1. Any write to the volume writes to both locations; a read can be satisfied from either, so if one drive fails, the data is still available on the other drive.

Mirroring has two problems:

- The price. It requires twice as much disk storage as a non-redundant solution.
- The performance impact. Writes must be performed to both drives, so they take up twice the bandwidth of a non-mirrored volume. Reads do not suffer from a performance penalty: it even looks as if they are faster.

An alternative solution is *parity*, implemented in the RAID levels 2, 3, 4 and 5. Of these, RAID-5 is the most interesting. As implemented in Vinum, it is a variant on a striped organization which dedicates one block of each stripe to parity of the other blocks. As implemented by Vinum, a RAID-5 plex is similar to a striped plex, except that it implements RAID-5 by including a parity block in each stripe. As required by RAID-5, the location of this parity block changes from one stripe to the next. The numbers in the data blocks indicate the relative block numbers.

Figure 13-3. RAID-5 Organization



Compared to mirroring, RAID-5 has the advantage of requiring significantly less storage space. Read access is similar to that of striped organizations, but write access is significantly slower, approximately 25% of the read performance. If one drive fails, the array can continue to operate in degraded mode: a read from one of the remaining accessible drives continues normally, but a read from the failed drive is recalculated from the corresponding block from all the remaining drives.

13.5 Vinum Objects

In order to address these problems, Vinum implements a four-level hierarchy of objects:

- The most visible object is the virtual disk, called a *volume*. Volumes have essentially the same properties as a UNIX disk drive, though there are some minor differences. They have no size limitations.
- Volumes are composed of *plexes*, each of which represent the total address space of a volume. This level in the hierarchy thus provides redundancy. Think of plexes as individual disks in a mirrored array, each containing the same data.
- Since Vinum exists within the UNIX disk storage framework, it would be possible to use UNIX partitions as the building block for multi-disk plexes, but in fact this turns out to be too inflexible: UNIX disks can have only a limited number of partitions. Instead, Vinum subdivides a single UNIX partition (the *drive*) into contiguous areas called *subdisks*, which it uses as building blocks for plexes.
- Subdisks reside on Vinum *drives*, currently UNIX partitions. Vinum drives can contain any number of subdisks. With the exception of a small area at the beginning of the drive, which is used for storing configuration and state information, the entire drive is available for data storage.

The following sections describe the way these objects provide the functionality required of Vinum.

13.5.1 Volume Size Considerations

Plexes can include multiple subdisks spread over all drives in the Vinum configuration. As a result, the size of an individual drive does not limit the size of a plex, and thus of a volume.

13.5.2 Redundant Data Storage

Vinum implements mirroring by attaching multiple plexes to a volume. Each plex is a representation of the data in a volume. A volume may contain between one and eight plexes.

Although a plex represents the complete data of a volume, it is possible for parts of the representation to be physically missing, either by design (by not defining a subdisk for parts of the plex) or by accident (as a result of the failure of a drive). As long as at least one plex can provide the data for the complete address range of the volume, the volume is fully functional.

13.5.3 Performance Issues

Vinum implements both concatenation and striping at the plex level:

- A *concatenated plex* uses the address space of each subdisk in turn.
- A *striped plex* stripes the data across each subdisk. The subdisks must all have the same size, and there must be at least two subdisks in order to distinguish it from a concatenated plex.

13.5.4 Which Plex Organization?

The version of Vinum supplied with FreeBSD 5.1 implements two kinds of plex:

- Concatenated plexes are the most flexible: they can contain any number of subdisks, and the subdisks may be of different length. The plex may be extended by adding additional subdisks. They require less CPU time than striped plexes, though the difference in CPU overhead is not measurable. On the other hand, they are most susceptible to hot spots, where one disk is very active and others are idle.
- The greatest advantage of striped (RAID-0) plexes is that they reduce hot spots: by choosing an optimum sized stripe (about 256 kB), you can even out the load on the component drives. The disadvantages of this approach are (fractionally) more complex code and restrictions on subdisks: they must be all the same size, and extending a plex by adding new subdisks is so complicated that Vinum currently does not implement it. Vinum imposes an additional, trivial restriction: a striped plex must have at least two subdisks, since otherwise it is indistinguishable from a concatenated plex.

Table 13-1 summarizes the advantages and disadvantages of each plex organization.

Table 13-1. Vinum Plex Organizations

Plex type	Minimum subdisks	Can add subdisks	Must be equal size	Application
concatenated	1	yes	no	Large data storage with maximum placement flexibility and moderate performance
striped	2	no	yes	High performance in combination with highly concurrent access

13.6 Some Examples

Vinum maintains a *configuration database* which describes the objects known to an individual system. Initially, the user creates the configuration database from one or more configuration files with the aid of the vinum(8) utility program. Vinum stores a copy of its configuration database on each disk slice (which Vinum calls a *device*) under its control. This database is updated on each state change, so that a restart accurately restores the state of each Vinum object.

13.6.1 The Configuration File

The configuration file describes individual Vinum objects. The definition of a simple volume might be:

```
drive a device /dev/da3h
volume myvol
  plex org concat
    sd length 512m drive a
```

This file describes four Vinum objects:

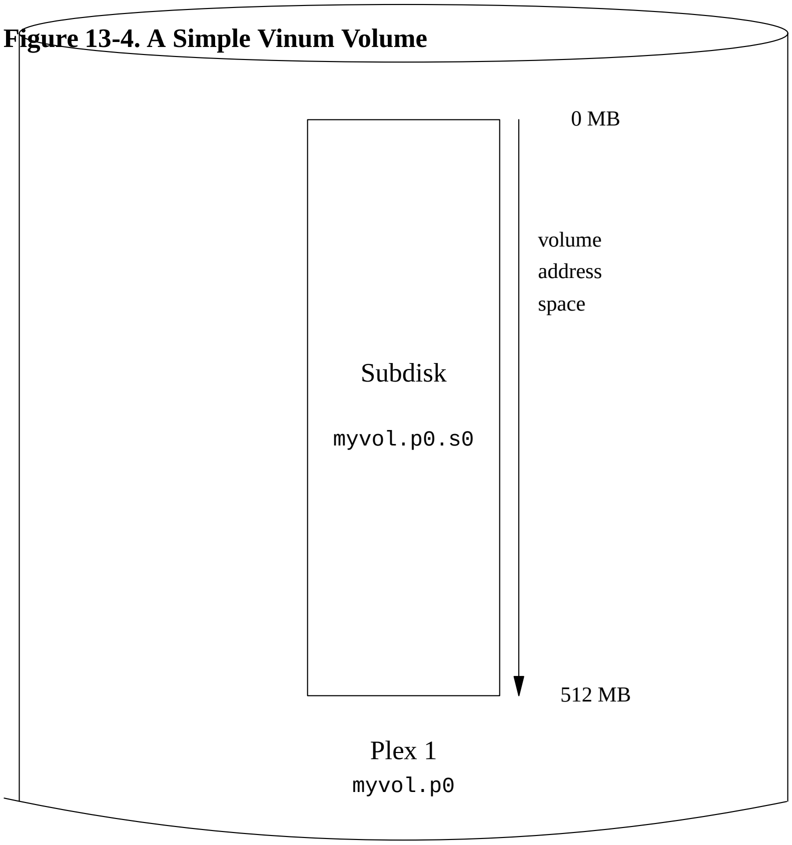
- The *drive* line describes a disk partition (*drive*) and its location relative to the underlying hardware. It is given the symbolic name *a*. This separation of the symbolic names from the device names allows disks to be moved from one location to another without confusion.
- The *volume* line describes a volume. The only required attribute is the name, in this case *myvol*.
- The *plex* line defines a plex. The only required parameter is the organization, in this case *concat*. No name is necessary: the system automatically generates a name from the volume name by adding the suffix *.px*, where *x* is the number of the plex in the volume. Thus this plex will be called *myvol.p0*.
- The *sd* line describes a subdisk. The minimum specifications are the name of a drive on which to store it, and the length of the subdisk. As with plexes, no name is necessary: the system automatically assigns names derived from the plex name by adding the suffix *.sx*, where *x* is the number of the subdisk in the plex. Thus Vinum gives this subdisk the name *myvol.p0.s0*.

After processing this file, vinum(8) produces the following output:

```
      # vinum -> create config1
      Configuration summary
      Drives:         1 (4 configured)
      Volumes:        1 (4 configured)
      Plexes:         1 (8 configured)
      Subdisks:       1 (16 configured)

D a                       State: up       Device /dev/da3h        Avail: 2061/2573 MB (80%)

V myvol                   State: up       Plexes:       1 Size:        512 MB

P myvol.p0              C State: up       Subdisks:     1 Size:        512 MB

S myvol.p0.s0             State: up       PO:        0  B Size:        512 MB
```

This output shows the brief listing format of vinum(8). It is represented graphically in Figure 13-4.

Figure 13-4. A Simple Vinum Volume



This figure, and the ones which follow, represent a volume, which contains the plexes, which in turn contain the subdisks. In this trivial example, the volume contains one plex, and the plex contains one subdisk.

This particular volume has no specific advantage over a conventional disk partition. It contains a single plex, so it is not redundant. The plex contains a single subdisk, so there is no difference in storage allocation from a conventional disk partition. The following sections illustrate various more interesting configuration methods.

13.6.2 Increased Resilience: Mirroring

The resilience of a volume can be increased by mirroring. When laying out a mirrored volume, it is important to ensure that the subdisks of each plex are on different drives, so that a drive failure will not take down both plexes. The following configuration mirrors a volume:

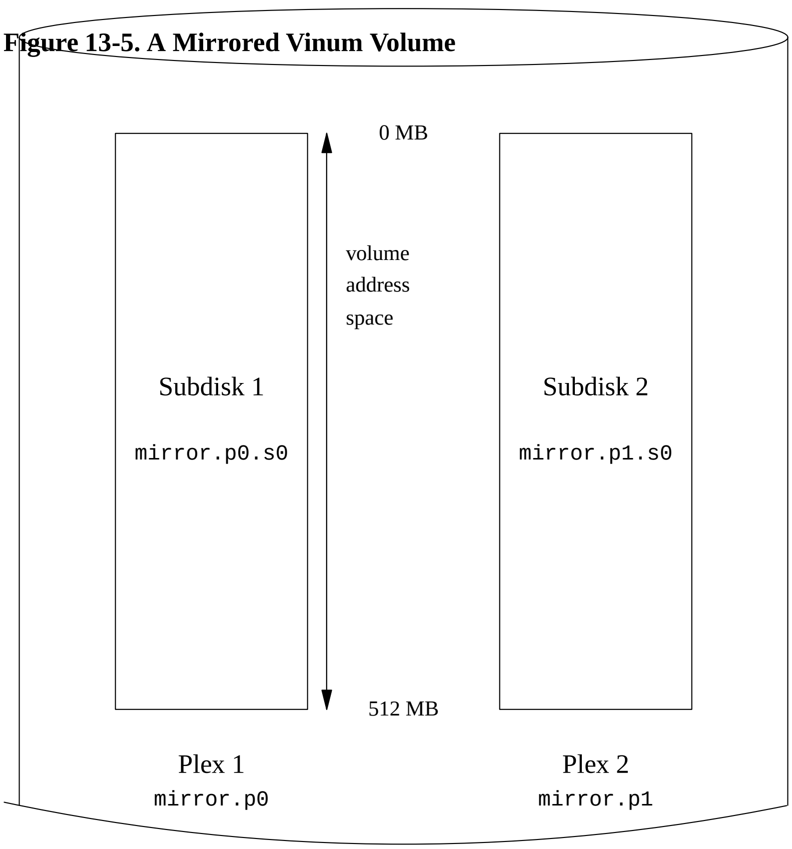
```
drive b device /dev/da4h
volume mirror
      plex org concat
        sd length 512m drive a
  plex org concat
    sd length 512m drive b
```

In this example, it was not necessary to specify a definition of drive *a* again, since Vinum keeps track of all objects in its configuration database. After processing this definition, the configuration looks like:

```
Drives:         2 (4 configured)
Volumes:        2 (4 configured)
Plexes:         3 (8 configured)
Subdisks:       3 (16 configured)

D a                     State: up       Device /dev/da3h        Avail: 1549/2573 MB (60%)
D b                     State: up       Device /dev/da4h        Avail: 2061/2573 MB (80%)

    V myvol                 State: up       Plexes:       1 Size:        512 MB
    V mirror                State: up       Plexes:       2 Size:        512 MB

    P myvol.p0            C State: up       Subdisks:     1 Size:        512 MB
    P mirror.p0           C State: up       Subdisks:     1 Size:        512 MB
    P mirror.p1           C State: initializing     Subdisks:     1 Size:        512 MB

    S myvol.p0.s0           State: up       PO:        0  B Size:        512 MB
S mirror.p0.s0          State: up       PO:        0  B Size:        512 MB
S mirror.p1.s0          State: empty    PO:        0  B Size:        512 MB
```

Figure 13-5 shows the structure graphically.

Figure 13-5. A Mirrored Vinum Volume



In this example, each plex contains the full 512 MB of address space. As in the previous example, each plex contains only a single subdisk.

13.6.3 Optimizing Performance

The mirrored volume in the previous example is more resistant to failure than an unmirrored volume, but its performance is less: each write to the volume requires a write to both drives, using up a greater proportion of the total disk bandwidth. Performance considerations demand a different approach: instead of mirroring, the data is striped across as many disk drives as possible. The following configuration shows a volume with a plex striped across four disk drives:

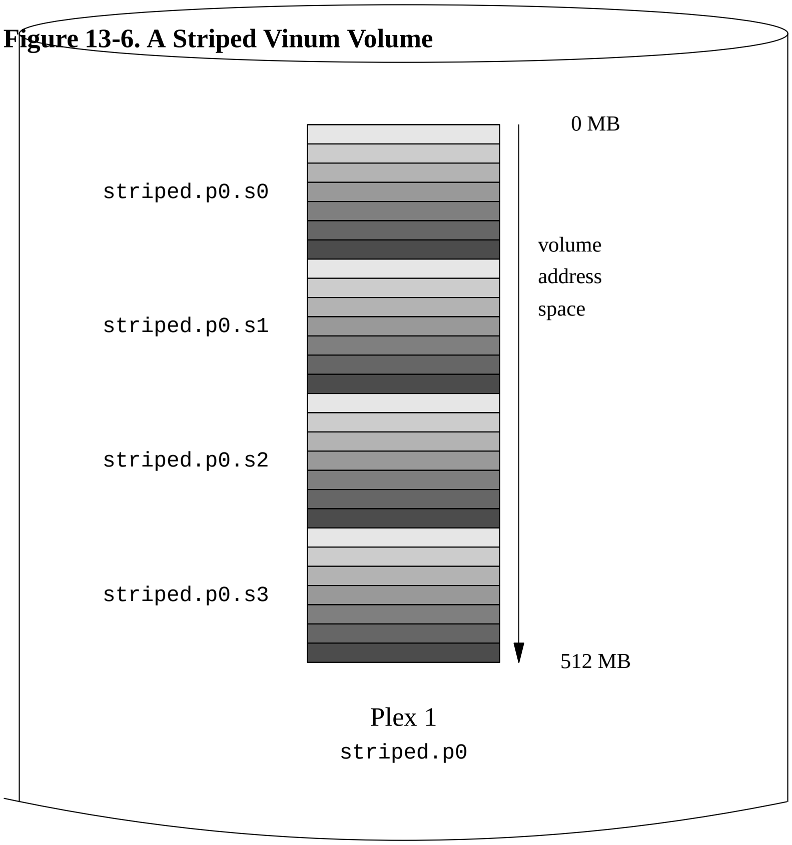
```
drive c device /dev/da5h
drive d device /dev/da6h
volume stripe
plex org striped 512k
  sd length 128m drive a
  sd length 128m drive b
  sd length 128m drive c
  sd length 128m drive d
```

As before, it is not necessary to define the drives which are already known to Vinum. After processing this definition, the configuration looks like:

```
Drives:         4 (4 configured)
Volumes:        3 (4 configured)
Plexes:         4 (8 configured)
Subdisks:       7 (16 configured)

    D a                     State: up       Device /dev/da3h        Avail: 1421/2573 MB (55%)
    D b                     State: up       Device /dev/da4h        Avail: 1933/2573 MB (75%)
    D c                     State: up       Device /dev/da5h        Avail: 2445/2573 MB (95%)
    D d                     State: up       Device /dev/da6h        Avail: 2445/2573 MB (95%)

    V myvol                 State: up       Plexes:       1 Size:        512 MB
    V mirror                State: up       Plexes:       2 Size:        512 MB
    V striped               State: up       Plexes:       1 Size:        512 MB

    P myvol.p0            C State: up       Subdisks:     1 Size:        512 MB
    P mirror.p0           C State: up       Subdisks:     1 Size:        512 MB
    P mirror.p1           C State: initializing     Subdisks:     1 Size:        512 MB
    P striped.p1            State: up       Subdisks:     1 Size:        512 MB

    S myvol.p0.s0           State: up       PO:        0  B Size:        512 MB
    S mirror.p0.s0          State: up       PO:        0  B Size:        512 MB
    S mirror.p1.s0          State: empty    PO:        0  B Size:        512 MB
    S striped.p0.s0         State: up       PO:        0  B Size:        128 MB
    S striped.p0.s1         State: up       PO:      512 kB Size:        128 MB
    S striped.p0.s2         State: up       PO:     1024 kB Size:        128 MB
```

```
    S striped.p0.s3         State: up       PO:     1536 kB Size:        128 MB
```

Figure 13-6. A Striped Vinum Volume



This volume is represented in Figure 13-6. The darkness of the stripes indicates the position within the plex address space: the lightest stripes come first, the darkest last.

13.6.4 Resilience and Performance

With sufficient hardware, it is possible to build volumes which show both increased resilience and increased performance compared to standard UNIX partitions. A typical configuration file might be:

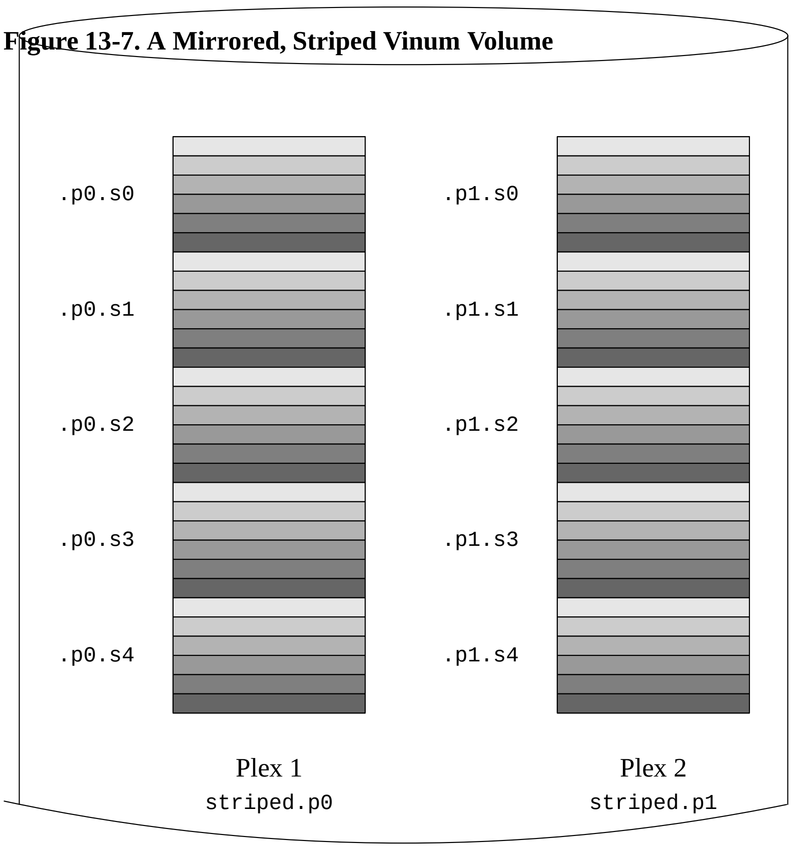
```
volume raid10
      plex org striped 512k
        sd length 102480k drive a
        sd length 102480k drive b
        sd length 102480k drive c
        sd length 102480k drive d
        sd length 102480k drive e
      plex org striped 512k
```

```
sd length 102480k drive c
sd length 102480k drive d
sd length 102480k drive e
sd length 102480k drive a
sd length 102480k drive b
```

The subdisks of the second plex are offset by two drives from those of the first plex: this helps ensure that writes do not go to the same subdisks even if a transfer goes over two drives.

Figure 13-7 represents the structure of this volume.

Figure 13-7. A Mirrored, Striped Vinum Volume



13.7 Object Naming

As described above, Vinum assigns default names to plexes and subdisks, although they may be overridden. Overriding the default names is not recommended: experience with the VERITAS volume manager, which allows arbitrary naming of objects, has shown that this flexibility does not bring a significant advantage, and it can cause confusion.

Names may contain any non-blank character, but it is recommended to restrict them to letters, digits and the underscore characters. The names of volumes, plexes and subdisks may be up to 64 characters long, and the names of drives may be up to 32 characters long.

Vinum objects are assigned device nodes in the hierarchy `/dev/vinum`. The configuration shown above would cause Vinum to create the following device nodes:

- The control devices `/dev/vinum/control` and `/dev/vinum/controld`, which are used by vinum(8) and the Vinum daemon respectively.
- Block and character device entries for each volume. These are the main devices used by Vinum. The block device names are the name of the volume, while the character device names follow the BSD tradition of prepending the letter *r* to the name. Thus the configuration above would include the block devices `/dev/vinum/myvol`, `/dev/vinum/mirror`, `/dev/vinum/striped`, `/dev/vinum/raid5` and `/dev/vinum/raid10`, and the character devices `/dev/vinum/rmyvol`, `/dev/vinum/rmirror`, `/dev/vinum/rstriped`, `/dev/vinum/rraid5` and `/dev/vinum/rraid10`. There is obviously a problem here: it is possible to have two volumes called *r* and *rr*, but there will be a conflict creating the device node `/dev/vinum/rr`: is it a character device for volume *r* or a block device for volume *rr*? Currently Vinum does not address this conflict: the first-defined volume will get the name.
- A directory `/dev/vinum/drive` with entries for each drive. These entries are in fact symbolic links to the corresponding disk nodes.
- A directory `/dev/vinum/volume` with entries for each volume. It contains subdirectories for each plex, which in turn contain subdirectories for their component subdisks.
- The directories `/dev/vinum/plex`, `/dev/vinum/sd`, and `/dev/vinum/rsd`, which contain block device nodes for each plex and block and character device nodes respectively for each subdisk.

For example, consider the following configuration file:

```
drive drive1 device /dev/sd1h
drive drive2 device /dev/sd2h
drive drive3 device /dev/sd3h
drive drive4 device /dev/sd4h
    volume s64 setupstate
      plex org striped 64k
        sd length 100m drive drive1
        sd length 100m drive drive2
        sd length 100m drive drive3
        sd length 100m drive drive4
```

After processing this file, vinum(8) creates the following structure in `/dev/vinum`:

```
brwx------  1 root  wheel   25, 0x40000001 Apr 13 16:46 Control
brwx------  1 root  wheel   25, 0x40000002 Apr 13 16:46 control
brwx------  1 root  wheel   25, 0x40000000 Apr 13 16:46 controld
drwxr-xr-x  2 root  wheel       512 Apr 13 16:46 drive
drwxr-xr-x  2 root  wheel       512 Apr 13 16:46 plex
crwxr-xr--  1 root  wheel   91,   2 Apr 13 16:46 rs64
drwxr-xr-x  2 root  wheel       512 Apr 13 16:46 rsd
drwxr-xr-x  2 root  wheel       512 Apr 13 16:46 rvol
brwxr-xr--  1 root  wheel   25,   2 Apr 13 16:46 s64
drwxr-xr-x  2 root  wheel       512 Apr 13 16:46 sd
```

```
drwxr-xr-x  3 root  wheel       512 Apr 13 16:46 vol

/dev/vinum/drive:
    total 0
    lrwxr-xr-x  1 root  wheel  9 Apr 13 16:46 drive1 -> /dev/sd1h
    lrwxr-xr-x  1 root  wheel  9 Apr 13 16:46 drive2 -> /dev/sd2h
    lrwxr-xr-x  1 root  wheel  9 Apr 13 16:46 drive3 -> /dev/sd3h
    lrwxr-xr-x  1 root  wheel  9 Apr 13 16:46 drive4 -> /dev/sd4h

    /dev/vinum/plex:
    total 0
    brwxr-xr--  1 root  wheel   25, 0x10000002 Apr 13 16:46 s64.p0

    /dev/vinum/rsd:
    total 0
    crwxr-xr--  1 root  wheel   91, 0x20000002 Apr 13 16:46 s64.p0.s0
    crwxr-xr--  1 root  wheel   91, 0x20100002 Apr 13 16:46 s64.p0.s1
    crwxr-xr--  1 root  wheel   91, 0x20200002 Apr 13 16:46 s64.p0.s2
    crwxr-xr--  1 root  wheel   91, 0x20300002 Apr 13 16:46 s64.p0.s3

    /dev/vinum/rvol:
    total 0
    crwxr-xr--  1 root  wheel   91,   2 Apr 13 16:46 s64

    /dev/vinum/sd:
    total 0
    brwxr-xr--  1 root  wheel   25, 0x20000002 Apr 13 16:46 s64.p0.s0
    brwxr-xr--  1 root  wheel   25, 0x20100002 Apr 13 16:46 s64.p0.s1
    brwxr-xr--  1 root  wheel   25, 0x20200002 Apr 13 16:46 s64.p0.s2
    brwxr-xr--  1 root  wheel   25, 0x20300002 Apr 13 16:46 s64.p0.s3

    /dev/vinum/vol:
    total 1
    brwxr-xr--  1 root  wheel   25,   2 Apr 13 16:46 s64
    drwxr-xr-x  3 root  wheel       512 Apr 13 16:46 s64.plex

    /dev/vinum/vol/s64.plex:
    total 1
    brwxr-xr--  1 root  wheel   25, 0x10000002 Apr 13 16:46 s64.p0
    drwxr-xr-x  2 root  wheel       512 Apr 13 16:46 s64.p0.sd

    /dev/vinum/vol/s64.plex/s64.p0.sd:
    total 0
    brwxr-xr--  1 root  wheel   25, 0x20000002 Apr 13 16:46 s64.p0.s0
    brwxr-xr--  1 root  wheel   25, 0x20100002 Apr 13 16:46 s64.p0.s1
    brwxr-xr--  1 root  wheel   25, 0x20200002 Apr 13 16:46 s64.p0.s2
    brwxr-xr--  1 root  wheel   25, 0x20300002 Apr 13 16:46 s64.p0.s3
```

Although it is recommended that plexes and subdisks should not be allocated specific names, Vinum drives must be named. This makes it possible to move a drive to a different location and still recognize it automatically. Drive names may be up to 32 characters long.

13.7.1 Creating File Systems

Volumes appear to the system to be identical to disks, with one exception. Unlike UNIX drives, Vinum does not partition volumes, which thus do not contain a partition table. This has required modification to some disk utilities, notably newfs(8), which previously tried to interpret the last letter of a Vinum volume name as a partition identifier. For example, a disk drive may have a name like `/dev/ad0a` or `/dev/da2h`. These names represent the first partition (`a`) on the first (0) IDE disk (`ad`) and the eighth partition (`h`) on the third (2) SCSI disk (`da`) respectively. By contrast, a Vinum volume might be called `/dev/vinum/concat`, a name which has no relationship with a partition name.

Normally, newfs(8) interprets the name of the disk and complains if it cannot understand it. For example:

```
# newfs /dev/vinum/concat
newfs: /dev/vinum/concat: can't figure out file system partition
```

Note: The following is only valid for FreeBSD versions prior to 5.0:

In order to create a file system on this volume, use the `-v` option to newfs(8):

```
# newfs -v /dev/vinum/concat
```

13.8 Configuring Vinum

The `GENERIC` kernel does not contain Vinum. It is possible to build a special kernel which includes Vinum, but this is not recommended. The standard way to start Vinum is as a kernel module (kld). You do not even need to use kldload(8) for Vinum: when you start vinum(8), it checks whether the module has been loaded, and if it is not, it loads it automatically.

13.8.1 Startup

Vinum stores configuration information on the disk slices in essentially the same form as in the configuration files. When reading from the configuration database, Vinum recognizes a number of keywords which are not allowed in the configuration files. For example, a disk configuration might contain the following text:

```
volume myvol state up
volume bigraid state down
plex name myvol.p0 state up org concat vol myvol
plex name myvol.p1 state up org concat vol myvol
plex name myvol.p2 state init org striped 512b vol myvol
plex name bigraid.p0 state initializing org raid5 512b vol bigraid
sd name myvol.p0.s0 drive a plex myvol.p0 state up len 1048576b driveoffset 265b plexoffset 0b
sd name myvol.p0.s1 drive b plex myvol.p0 state up len 1048576b driveoffset 265b plexoffset 1048576b
sd name myvol.p1.s0 drive c plex myvol.p1 state up len 1048576b driveoffset 265b plexoffset 0b
sd name myvol.p1.s1 drive d plex myvol.p1 state up len 1048576b driveoffset 265b plexoffset 1048576b
sd name myvol.p2.s0 drive a plex myvol.p2 state init len 524288b driveoffset 1048841b plexoffset 0b
sd name myvol.p2.s1 drive b plex myvol.p2 state init len 524288b driveoffset 1048841b plexoffset 5242
sd name myvol.p2.s2 drive c plex myvol.p2 state init len 524288b driveoffset 1048841b plexoffset 1048
sd name myvol.p2.s3 drive d plex myvol.p2 state init len 524288b driveoffset 1048841b plexoffset 1572
sd name bigraid.p0.s0 drive a plex bigraid.p0 state initializing len 4194304b driveoff set 1573129b p
```

```
sd name bigraid.p0.s1 drive b plex bigraid.p0 state initializing len 4194304b driveoff set 1573129b p
sd name bigraid.p0.s2 drive c plex bigraid.p0 state initializing len 4194304b driveoff set 1573129b p
sd name bigraid.p0.s3 drive d plex bigraid.p0 state initializing len 4194304b driveoff set 1573129b p
sd name bigraid.p0.s4 drive e plex bigraid.p0 state initializing len 4194304b driveoff set 1573129b p
```

The obvious differences here are the presence of explicit location information and naming (both of which are also allowed, but discouraged, for use by the user) and the information on the states (which are not available to the user). Vinum does not store information about drives in the configuration information: it finds the drives by scanning the configured disk drives for partitions with a Vinum label. This enables Vinum to identify drives correctly even if they have been assigned different UNIX drive IDs.

13.8.1.1 Automatic Startup

In order to start Vinum automatically when you boot the system, ensure that you have the following line in your `/etc/rc.conf`:

```
start_vinum="YES" # set to YES to start vinum
```

If you do not have a file `/etc/rc.conf`, create one with this content. This will cause the system to load the Vinum kld at startup, and to start any objects mentioned in the configuration. This is done before mounting file systems, so it is possible to automatically fsck(8) and mount file systems on Vinum volumes.

When you start Vinum with the `vinum start` command, Vinum reads the configuration database from one of the Vinum drives. Under normal circumstances, each drive contains an identical copy of the configuration database, so it does not matter which drive is read. After a crash, however, Vinum must determine which drive was updated most recently and read the configuration from this drive. It then updates the configuration if necessary from progressively older drives.

13.9 Using Vinum for the Root Filesystem

For a machine that has fully-mirrored filesystems using Vinum, it is desirable to also mirror the root filesystem. Setting up such a configuration is less trivial than mirroring an arbitrary filesystem because:

- The root filesystem must be available very early during the boot process, so the Vinum infrastructure must already be available at this time.
- The volume containing the root filesystem also contains the system bootstrap and the kernel, which must be read using the host system's native utilities (e. g. the BIOS on PC-class machines) which often cannot be taught about the details of Vinum.

In the following sections, the term "root volume" is generally used to describe the Vinum volume that contains the root filesystem. It is probably a good idea to use the name `"root"` for this volume, but this is not technically required in any way. All command examples in the following sections assume this name though.

13.9.1 Starting up Vinum Early Enough for the Root Filesystem

There are several measures to take for this to happen:

- Vinum must be available in the kernel at boot-time. Thus, the method to start Vinum automatically described in Section 13.8.1.1 is not applicable to accomplish this task, and the `start_vinum` parameter must actually *not* be set when the following setup is being arranged. The first option would be to compile Vinum statically into the kernel, so it is available all the time, but this is usually not desirable. There is another option as well, to have `/boot/loader` (Section 7.3.3) load the vinum kernel module early, before starting the kernel. This can be accomplished by putting the line

  ```
  vinum_load="YES"
  ```

  into the file `/boot/loader.conf`.

- Vinum must be initialized early since it needs to supply the volume for the root filesystem. By default, the Vinum kernel part is not looking for drives that might contain Vinum volume information until the administrator (or one of the startup scripts) issues a `vinum start` command.

  > **Note:** The following paragraphs are outlining the steps needed for FreeBSD 5.x and above. The setup required for FreeBSD 4.x differs, and is described below in Section 13.9.5.

  By placing the line:

  ```
  vinum.autostart="YES"
  ```

  into `/boot/loader.conf`, Vinum is instructed to automatically scan all drives for Vinum information as part of the kernel startup.

  Note that it is not necessary to instruct the kernel where to look for the root filesystem. `/boot/loader` looks up the name of the root device in `/etc/fstab`, and passes this information on to the kernel. When it comes to mount the root filesystem, the kernel figures out from the devicename provided which driver to ask to translate this into the internal device ID (major/minor number).

13.9.2 Making a Vinum-based Root Volume Accessible to the Bootstrap

Since the current FreeBSD bootstrap is only 7.5 KB of code, and already has the burden of reading files (like `/boot/loader`) from the UFS filesystem, it is sheer impossible to also teach it about internal Vinum structures so it could parse the Vinum configuration data, and figure out about the elements of a boot volume itself. Thus, some tricks are necessary to provide the bootstrap code with the illusion of a standard `"a"` partition that contains the root filesystem.

For this to be possible at all, the following requirements must be met for the root volume:

- The root volume must not be striped or RAID-5.
- The root volume must not contain more than one concatenated subdisk per plex.

Note that it is desirable and possible that there are multiple plexes, each containing one replica of the root filesystem. The bootstrap process will, however, only use one of these replica for finding the bootstrap and all the files, until the kernel will eventually mount the root filesystem itself. Each single subdisk within these plexes will then need its own `"a"` partition illusion, for the respective device to become bootable. It is not strictly needed that each of these faked `"a"` partitions is located at the same offset within its device, compared with other devices containing plexes of the root volume. However, it is probably a good idea to create the Vinum volumes that way so the resulting mirrored devices are symmetric, to avoid confusion.

In order to set up these `"a"` partitions, for each device containing part of the root volume, the following needs to be done:

1. The location (offset from the beginning of the device) and size of this device's subdisk that is part of the root volume need to be examined, using the command

   ```
   vinum l -rv root
   ```

   Note that Vinum offsets and sizes are measured in bytes. They must be divided by 512 in order to obtain the block numbers that are to be used in the `disklabel` command.

2. Run the command

   `disklabel -e` *`devname`*

   for each device that participates in the root volume. *`devname`* must be either the name of the disk (like `da0`) for disks without a slice (aka. fdisk) table, or the name of the slice (like `ad0s1`).

   If there is already an `"a"` partition on the device (presumably, containing a pre-Vinum root filesystem), it should be renamed to something else, so it remains accessible (just in case), but will no longer be used by default to bootstrap the system. Note that active partitions (like a root filesystem currently mounted) cannot be renamed, so this must be executed either when being booted from a "Fixit" medium, or in a two-step process, where (in a mirrored situation) the disk that has not been currently booted is being manipulated first.

   Then, the offset the Vinum partition on this device (if any) must be added to the offset of the respective root volume subdisk on this device. The resulting value will become the `"offset"` value for the new `"a"` partition. The `"size"` value for this partition can be taken verbatim from the calculation above. The `"fstype"` should be `4.2BSD`. The `"fsize"`, `"bsize"`, and `"cpg"` values should best be chosen to match the actual filesystem, though they are fairly unimportant within this context.

   That way, a new `"a"` partition will be established that overlaps the Vinum partition on this device. Note that the `disklabel` will only allow for this overlap if the Vinum partition has properly been marked using the `"vinum"` fstype.

3. That's all! A faked `"a"` partition does exist now on each device that has one replica of the root volume. It is highly recommendable to verify the result again, using a command like

   `fsck -n /dev/`*`devname`*`a`

It should be remembered that all files containing control information must be relative to the root filesystem in the Vinum volume which, when setting up a new Vinum root volume, might not match the root filesystem that is currently active. So in particular, the files `/etc/fstab` and `/boot/loader.conf` need to be taken care of.

At next reboot, the bootstrap should figure out the appropriate control information from the new Vinum-based root filesystem, and act accordingly. At the end of the kernel initialization process, after all devices have been announced, the prominent notice that shows the success of this setup is a message like:

```
Mounting root from ufs:/dev/vinum/root
```

13.9.3 Example of a Vinum-based Root Setup

After the Vinum root volume has been set up, the output of `vinum l -rv root` could look like:

```
...
Subdisk root.p0.s0:
Size:         125829120 bytes (120 MB)
State: up
Plex root.p0 at offset 0 (0  B)
Drive disk0 (/dev/da0h) at offset 135680 (132 kB)

Subdisk root.p1.s0:
Size:         125829120 bytes (120 MB)
State: up
Plex root.p1 at offset 0 (0  B)
Drive disk1 (/dev/da1h) at offset 135680 (132 kB)
```

The values to note are `135680` for the offset (relative to partition `/dev/da0h`). This translates to 265 512-byte disk blocks in `disklabel`'s terms. Likewise, the size of this root volume is 245760 512-byte blocks. `/dev/da1h`, containing the second replica of this root volume, has a symmetric setup.

The disklabel for these devices might look like:

```
...
8 partitions:
#        size   offset    fstype   [fsize bsize bps/cpg]
  a:   245760      281    4.2BSD     2048 16384     0   # (Cyl.    0*- 15*)
  c: 71771688        0    unused        0     0         # (Cyl.    0 - 4467*)
  h: 71771672       16     vinum                        # (Cyl.    0*- 4467*)
```

It can be observed that the `"size"` parameter for the faked `"a"` partition matches the value outlined above, while the `"offset"` parameter is the sum of the offset within the Vinum partition `"h"`, and the offset of this partition within the device (or slice). This is a typical setup that is necessary to avoid the problem described in Section 13.9.4.3. It can also be seen that the entire `"a"` partition is completely within the `"h"` partition containing all the Vinum data for this device.

Note that in the above example, the entire device is dedicated to Vinum, and there is no leftover pre-Vinum root partition, since this has been a newly set-up disk that was only meant to be part of a Vinum configuration, ever.

13.9.4 Troubleshooting

If something goes wrong, a way is needed to recover from the situation. The following list contains few known pitfalls and solutions.

13.9.4.1 System Bootstrap Loads, but System Does Not Boot

If for any reason the system does not continue to boot, the bootstrap can be interrupted with by pressing the **space** key at the 10-seconds warning. The loader variables (like `vinum.autostart`) can be examined using the `show`, and manipulated using `set` or `unset` commands.

If the only problem was that the Vinum kernel module was not yet in the list of modules to load automatically, a simple `load vinum` will help.

When ready, the boot process can be continued with a `boot -as`. The options `-as` will request the kernel to ask for the root filesystem to mount (`-a`), and make the boot process stop in single-user mode (`-s`), where the root filesystem is mounted read-only. That way, even if only one plex of a multi-plex volume has been mounted, no data inconsistency between plexes is being risked.

At the prompt asking for a root filesystem to mount, any device that contains a valid root filesystem can be entered. If `/etc/fstab` had been set up correctly, the default should be something like `ufs:/dev/vinum/root`. A typical alternate choice would be something like **`ufs:da0d`** which could be a hypothetical partition that contains the pre-Vinum root filesystem. Care should be taken if one of the alias `"a"` partitions are entered here that are actually reference to the subdisks of the Vinum root device, because in a mirrored setup, this would only mount one piece of a mirrored root device. If this filesystem is to be mounted read-write later on, it is necessary to remove the other plex(es) of the Vinum root volume since these plexes would otherwise carry inconsistent data.

13.9.4.2 Only Primary Bootstrap Loads

If `/boot/loader` fails to load, but the primary bootstrap still loads (visible by a single dash in the left column of the screen right after the boot process starts), an attempt can be made to interrupt the primary bootstrap at this point, using the **space** key. This will make the bootstrap stop in stage two, see Section 7.3.2. An attempt can be made here to boot off an alternate partition, like the partition containing the previous root filesystem that has been moved away from `"a"` above.

13.9.4.3 Nothing Boots, the Bootstrap Panics

This situation will happen if the bootstrap had been destroyed by the Vinum installation. Unfortunately, Vinum accidentally currently leaves only 4 KB at the beginning of its partition free before starting to write its Vinum header information. However, the stage one and two bootstraps plus the disklabel embedded between them currently require 8 KB. So if a Vinum partition was started at offset 0 within a slice or disk that was meant to be bootable, the Vinum setup will trash the bootstrap.

Similarly, if the above situation has been recovered, for example by booting from a "Fixit" medium, and the bootstrap has been re-installed using `disklabel -B` as described in Section 7.3.2, the bootstrap will trash the Vinum header, and Vinum will no longer find its disk(s). Though no actual Vinum configuration data or data in Vinum volumes will be trashed by this, and it would be possible to recover all the data by entering exact the same Vinum configuration data again, the situation is hard to fix at all. It would be necessary to move the entire Vinum partition by at least 4 KB off, in order to have the Vinum header and the system bootstrap no longer collide.

13.9.5 Differences for FreeBSD 4.x

Under FreeBSD 4.x, some internal functions required to make Vinum automatically scan all disks are missing, and the code that figures out the internal ID of the root device is not smart enough to handle a name like

`/dev/vinum/root` automatically. Therefore, things are a little different here.

Vinum must explicitly be told which disks to scan, using a line like the following one in `/boot/loader.conf`:

```
vinum.drives="/dev/da0 /dev/da1"
```

It is important that all drives are mentioned that could possibly contain Vinum data. It does not harm if *more* drives are listed, nor is it necessary to add each slice and/or partition explicitly, since Vinum will scan all slices and partitions of the named drives for valid Vinum headers.

Since the routines used to parse the name of the root filesystem, and derive the device ID (major/minor number) are only prepared to handle "classical" device names like `/dev/ad0s1a`, they cannot make any sense out of a root volume name like `/dev/vinum/root`. For that reason, Vinum itself needs to pre-setup the internal kernel parameter that holds the ID of the root device during its own initialization. This is requested by passing the name of the root volume in the loader variable `vinum.root`. The entry in `/boot/loader.conf` to accomplish this looks like:

```
vinum.root="root"
```

Now, when the kernel initialization tries to find out the root device to mount, it sees whether some kernel module has already pre-initialized the kernel parameter for it. If that is the case, *and* the device claiming the root device matches the major number of the driver as figured out from the name of the root device string being passed (that is, `"vinum"` in our case), it will use the pre-allocated device ID, instead of trying to figure out one itself. That way, during the usual automatic startup, it can continue to mount the Vinum root volume for the root filesystem.

However, when `boot -a` has been requesting to ask for entering the name of the root device manually, it must be noted that this routine still cannot actually parse a name entered there that refers to a Vinum volume. If any device name is entered that does not refer to a Vinum device, the mismatch between the major numbers of the pre-allocated root parameter and the driver as figured out from the given name will make this routine enter its normal parser, so entering a string like **`ufs:da0d`** will work as expected. Note that if this fails, it is however no longer possible to re-enter a string like **`ufs:vinum/root`** again, since it cannot be parsed. The only way out is to reboot again, and start over then. (At the "askroot" prompt, the initial `/dev/` can always be omitted.)

Notes

1. RAID stands for *Redundant Array of Inexpensive Disks* and offers various forms of fault tolerance, though the latter term is somewhat misleading: it provides no redundancy.

Chapter 14 Localization - I18N/L10N Usage and Setup

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14.1 Synopsis

FreeBSD is a very distributed project with users and contributors located all over the world. This chapter discusses the internationalization and localization features of FreeBSD that allow non-English speaking users to get real work done. There are many aspects of the i18n implementation in both the system and application levels, so where applicable we refer the reader to more specific sources of documentation.

After reading this chapter, you will know:

- How different languages and locales are encoded on modern operating systems.
- How to set the locale for your login shell.
- How to configure your console for non-English languages.
- How to use X Windows effectively with different languages.
- Where to find more information about writing i18n-compliant applications.

Before reading this chapter, you should:

- Know how to install additional third-party applications (Chapter 4).

14.2 The Basics

14.2.1 What Is I18N/L10N?

Developers shortened internationalization into the term I18N, counting the number of letters between the first and the last letters of internationalization. L10N uses the same naming scheme, coming from "localization". Combined together, I18N/L10N methods, protocols, and applications allow users to use languages of their choice.

I18N applications are programmed using I18N kits under libraries. It allows for developers to write a simple file and translate displayed menus and texts to each language. We strongly encourage programmers to follow this convention.

14.2.2 Why Should I Use I18N/L10N?

I18N/L10N is used whenever you wish to either view, input, or process data in non-English languages.

14.2.3 What Languages Are Supported in the I18N Effort?

I18N and L10N are not FreeBSD specific. Currently, one can choose from most of the major languages of the World, including but not limited to: Chinese, German, Japanese, Korean, French, Russian, Vietnamese and others.

14.3 Using Localization

In all its splendor, I18N is not FreeBSD-specific and is a convention. We encourage you to help FreeBSD in following this convention.

Localization settings are based on three main terms: Language Code, Country Code, and Encoding. Locale names are constructed from these parts as follows:

LanguageCode_CountryCode.Encoding

14.3.1 Language and Country Codes

In order to localize a FreeBSD system to a specific language (or any other I18N-supporting UNIX like systems), the user needs to find out the codes for the specify country and language (country codes tell applications what variation of given language to use). In addition, web browsers, SMTP/POP servers, web servers, etc. make decisions based on them. The following are examples of language/country codes:

Language/Country Code	Description
en_US	English - United States
ru_RU	Russian for Russia
zh_TW	Traditional Chinese for Taiwan

14.3.2 Encodings

Some languages use non-ASCII encodings that are 8-bit, wide or multibyte characters, see multibyte(3) for more details. Older applications do not recognize them and mistake them for control characters. Newer applications usually do recognize 8-bit characters. Depending on the implementation, users may be required to compile an application with wide or multibyte characters support, or configure it correctly. To be able to input and process wide or multibyte characters, the FreeBSD Ports collection (../../../../ports/index.html) has provided each language with different programs. Refer to the I18N documentation in the respective FreeBSD Port.

Specifically, the user needs to look at the application documentation to decide on how to configure it correctly or to pass correct values into the configure/Makefile/compiler.

Some things to keep in mind are:

- Language specific single C chars character sets (see multibyte(3)), i.e., ISO-8859-1, ISO-8859-15, KOI8-R, CP437.
- Wide or multibyte encodings, i.e. EUC, Big5.

You can check the active list of character sets at the IANA Registry (http://www.iana.org/assignments/character-sets).

> **Note:** FreeBSD versions 4.5 and up use X11-compatible locale encodings instead.

14.3.3 I18N Applications

In the FreeBSD Ports and Package system, I18N applications have been named with `I18N` in their names for easy identification. However, they do not always support the language needed.

14.3.4 Setting Locale

Usually it is sufficient to export the value of the locale name as `LANG` in the login shell. This could be done in the user's `~/.login_conf` file or in the startup file of the user's shell (`~/.profile`, `~/.bashrc`, `~/.cshrc`). There is no need to set the locale subsets such as `LC_CTYPE`, `LC_CTIME`. Please refer to language-specific FreeBSD documentation for more information.

You should set the following two environment variables in your configuration files:

- `LANG` for POSIX setlocale(3) family functions
- `MM_CHARSET` for applications' MIME character set

This includes the user shell configuration, the specific application configuration, and the X11 configuration.

14.3.4.1 Setting Locale Methods

There are two methods for setting locale, and both are described below. The first (recommended one) is by assigning the environment variables in login class, and the second is by adding the environment variable assignments to the system's shell startup file.

14.3.4.1.1 Login Classes Method

This method allows environment variables needed for locale name and MIME character sets to be assigned once for every possible shell instead of adding specific shell assignments to each shell's startup file. User Level Setup can be done by an user himself and Administrator Level Setup require superuser privileges.

14.3.4.1.1.1 User Level Setup

Here is a minimal example of a `.login_conf` file in user's home directory which has both variables set for Latin-1 encoding:

```
me:\
:charset=ISO-8859-1:\
:lang=de_DE.ISO8859-1:
```

Here is an example of a `.login_conf` that sets the variables for Traditional Chinese in BIG-5 encoding. Notice the many more variables set because some software does not respect locale variables correctly for Chinese, Japanese, and Korean.

```
#Users who do not wish to use monetary units or time formats
#of Taiwan can manually change each variable
me:\
lang=zh_TW.Big5:\
lc_all=zh_TW.Big:\
lc_collate=zh_TW.Big5:\
lc_ctype=zh_TW.Big5:\
```

```
lc_messages=zh_TW.Big5:\
lc_monetary=zh_TW.Big5:\
lc_numeric=zh_TW.Big5:\
lc_time=zh_TW.Big5:\
charset=big5:\
xmodifiers="@im=xcin": #Setting the XIM Input Server
```

See Administrator Level Setup and login.conf(5) for more details.

14.3.4.1.1.2 Administrator Level Setup

Verify that the user's login class in `/etc/login.conf` sets the correct language. Make sure these settings appear in `/etc/login.conf`:

```
language_name:accounts_title:\
:charset=MIME_charset:\
:lang=locale_name:\
:tc=default:
```

So sticking with our previous example using Latin-1, it would look like this:

```
german:German Users Accounts:\
:charset=ISO-8859-1:\
:lang=de_DE.ISO8859-1:\
:tc=default:
```

Changing Login Classes with vipw(8)

Use `vipw` to add new users, and make the entry look like this:

```
user:password:1111:11:language:0:0:User Name:/home/user:/bin/sh
```

Changing Login Classes with adduser(8)

Use `adduser` to add new users, and do the following:

- Set `defaultclass = language` in `/etc/adduser.conf`. Keep in mind you must enter a `default` class for all users of other languages in this case.
- An alternative variant is answering the specified language each time that

  ```
  Enter login class: default []:
  ```

  appears from adduser(8).
- Another alternative is to use the following for each user of a different language that you wish to add:

  ```
  # adduser -class language
  ```

Changing Login Classes with pw(8)

If you use pw(8) for adding new users, call it in this form:

```
# pw useradd user_name -L language
```

14.3.4.1.2 Shell Startup File Method

> **Note:** This method is not recommended because it requires a different setup for each possible shell program chosen. Use the Login Class Method instead.

To add the locale name and MIME character set, just set the two environment variables shown below in the `/etc/profile` and/or `/etc/csh.login` shell startup files. We will use the German language as an example below:

In `/etc/profile`:

```
LANG=de_DE.ISO8859-1; export LANG
MM_CHARSET=ISO-8859-1; export MM_CHARSET
```

Or in `/etc/csh.login`:

```
setenv LANG de_DE.ISO8859-1
setenv MM_CHARSET ISO-8859-1
```

Alternatively, you can add the above instructions to `/usr/share/skel/dot.profile` (similar to what was used in `/etc/profile` above), or `/usr/share/skel/dot.login` (similar to what was used in `/etc/csh.login` above).

For X11:

In `$HOME/.xinitrc`:

```
LANG=de_DE.ISO8859-1; export LANG
```

Or:

```
setenv LANG de_DE.ISO8859-1
```

Depending on your shell (see above).

14.3.5 Console Setup

For all single C chars character sets, set the correct console fonts in `/etc/rc.conf` for the language in question with:

```
font8x16=font_name
font8x14=font_name
font8x8=font_name
```

The *`font_name`* here is taken from the `/usr/share/syscons/fonts` directory, without the `.fnt` suffix.

Also be sure to set the correct keymap and screenmap for your single C chars character set through `/stand/sysinstall`. Once inside **sysinstall**, choose Confi gure, thenConsole. Alternatively, you can add the following to `/etc/rc.conf`:

```
scrnmap=screenmap_name
keymap=keymap_name
keychange="fkey_number sequence"
```

The *`screenmap_name`* here is taken from the `/usr/share/syscons/scrnmaps` directory, without the `.scm` suffix. A screenmap with a corresponding mapped font is usually needed as a workaround for expanding bit 8 to bit 9 on a VGA adapter's font character matrix in pseudographics area, i.e., to move letters out of that area if screen font uses a bit 8 column.

If you have the **moused** daemon enabled by setting the following in your `/etc/rc.conf`:

```
moused_enable="YES"
```

then examine the mouse cursor information in the next paragraph.

By default the mouse cursor of the syscons(4) driver occupies the 0xd0-0xd3 range in the character set. If your language uses this range, you need to move the cursor's range outside of it. To enable the workaround for FreeBSD versions before 5.0, insert the following line into your kernel configuration:

```
options SC_MOUSE_CHAR=0x03
```

For the FreeBSD versions 4.4 and up insert the following line into `/etc/rc.conf`:

```
mousechar_start=3
```

The *`keymap_name`* here is taken from the `/usr/share/syscons/keymaps` directory, without the `.kbd` suffix. If you're uncertain which keymap to use, you use can kbdmap(1) to test keymaps without rebooting.

The `keychange` is usually needed to program function keys to match the selected terminal type because function key sequences cannot be defined in the key map.

Also be sure to set the correct console terminal type in `/etc/ttys` for all `ttyv*` entries. Current pre-defined correspondences are:

Character Set	Terminal Type
ISO-8859-1 or ISO-8859-15	`cons25l1`
ISO-8859-2	`cons25l2`
ISO-8859-7	`cons25l7`
KOI8-R	`cons25r`
KOI8-U	`cons25u`
CP437 (VGA default)	`cons25`
US-ASCII	`cons25w`

For wide or multibyte characters languages, use the correct FreeBSD port in your `/usr/ports/`*`language`* directory. Some ports appear as console while the system sees it as serial vtty's, hence you must reserve enough vtty's for both X11 and the pseudo-serial console. Here is a partial list of applications for using other languages in console:

Language	Location
Traditional Chinese (BIG-5)	`chinese/big5con`
Japanese	`japanese/ja-kon2-*` or `japanese/Mule_Wnn`
Korean	`korean/ko-han`

14.3.6 X11 Setup

Although X11 is not part of the FreeBSD Project, we have included some information here for FreeBSD users. For more details, refer to the XFree86 web site (http://www.xfree86.org/) or whichever X11 Server you use.

In `~/.Xresources`, you can additionally tune application specific I18N settings (e.g., fonts, menus, etc.).

14.3.6.1 Displaying Fonts

Install the X11 TrueType Common server (`x11-servers/XttXF86srv-common`) and install the language TrueType fonts. Setting the correct locale should allow you to view your selected language in menus and such.

14.3.6.2 Inputting Non-English Characters

The X11 Input Method (XIM) Protocol is a new standard for all X11 clients. All X11 applications should be written as XIM clients that take input from XIM Input servers. There are several XIM servers available for different languages.

14.3.7 Printer Setup

Some single C chars character sets are usually hardware coded into printers. Wide or multibyte character sets require special setup and we recommend using **apsfilter**. You may also convert the document to PostScript or PDF formats using language specific converters.

14.3.8 Kernel and File Systems

The FreeBSD fast filesystem (FFS) is 8-bit clean, so it can be used with any single C chars character set (see multibyte(3)), but there is no character set name stored in the filesystem; i.e., it is raw 8-bit and does not know anything about encoding order. Officially, FFS does not support any form of wide or multibyte character sets yet. However, some wide or multibyte character sets have independent patches for FFS enabling such support. They are only temporary unportable solutions or hacks and we have decided to not include them in the source tree. Refer to respective languages' web sites for more informations and the patch files.

The FreeBSD MS-DOS filesystem has the configurable ability to convert between MS-DOS, Unicode character sets and chosen FreeBSD filesystem character sets. See mount_msdos(8) for details.

14.4 Compiling I18N Programs

Many FreeBSD Ports have been ported with I18N support. Some of them are marked with -I18N in the port name. These and many other programs have built in support for I18N and need no special consideration.

However, some applications such as **MySQL** need to be have the `Makefile` configured with the specific charset. This is usually done in the `Makefile` or done by passing a value to **configure** in the source.

14.5 Localizing FreeBSD to Specific Languages

14.5.1 Russian Language (KOI8-R Encoding)

Originally contributed by Andrey A. Chernov.

For more information about KOI8-R encoding, see the KOI8-R References (Russian Net Character Set) (http://koi8.pp.ru/).

14.5.1.1 Locale Setup

Put the following lines into your `~/.login_conf` file:

```
me:My Account:\
:charset=KOI8-R:\
:lang=ru_RU.KOI8-R:
```

See earlier in this chapter for examples of setting up the locale.

14.5.1.2 Console Setup

- For the FreeBSD versions before 5.0 add the following line to your kernel configuration file:

  ```
  options SC_MOUSE_CHAR=0x03
  ```

  For the FreeBSD versions 4.4 and up insert the following line into `/etc/rc.conf`:

  ```
  mousechar_start=3
  ```

- Use following settings in `/etc/rc.conf`:

  ```
  keymap="ru.koi8-r"
  scrnmap="koi8-r2cp866"
  font8x16="cp866b-8x16"
  font8x14="cp866-8x14"
  font8x8="cp866-8x8"
  ```

- For each `ttyv*` entry in `/etc/ttys`, use `cons25r` as the terminal type.

See earlier in this chapter for examples of setting up the console.

14.5.1.3 Printer Setup

Since most printers with Russian characters come with hardware code page CP866, a special output filter is needed to convert from KOI8-R to CP866. Such a filter is installed by default as `/usr/libexec/lpr/ru/koi2alt`. A Russian printer `/etc/printcap` entry should look like:

```
lp|Russian local line printer:\
:sh:of=/usr/libexec/lpr/ru/koi2alt:\
:lp=/dev/lpt0:sd=/var/spool/output/lpd:lf=/var/log/lpd-errs:
```

See printcap(5) for a detailed description.

14.5.1.4 MS-DOS FS and Russian Filenames

The following example fstab(5) entry enables support for Russian filenames in mounted MS-DOS filesystems:

```
/dev/ad0s2      /dos/c  msdos   rw,-Wkoi2dos,-Lru_RU.KOI8-R 0 0
```

The option `-L` selects the locale name used, and `-W` sets the character conversion table. To use the `-W` option, be sure to mount `/usr` before the MS-DOS partition because the conversion tables are located in `/usr/libdata/msdosfs`. For more informations, see the mount_msdos(8) manual page.

14.5.1.5 X11 Setup

1. Do non-X locale setup first as described.

   Note: The Russian KOI8-R locale may not work with old **XFree86** releases (lower than 3.3). **XFree86 4.X** is now the default version of the X Window System on FreeBSD. This should not be an issue unless you are using an old version of FreeBSD.

2. Go to the `russian/X.language` directory and issue the following command:

   ```
   # make install
   ```

   The above port installs the latest version of the KOI8-R fonts. **XFree86 3.3** already has some KOI8-R fonts, but these are scaled better.

   Check the `"Files"` section in your `/etc/XF86Config` file. The following lines must be added *before* any other `FontPath` entries:

   ```
   FontPath   "/usr/X11R6/lib/X11/fonts/cyrillic/misc"
   FontPath   "/usr/X11R6/lib/X11/fonts/cyrillic/75dpi"
   FontPath   "/usr/X11R6/lib/X11/fonts/cyrillic/100dpi"
   ```

   If you use a high resolution video mode, swap the 75 dpi and 100 dpi lines.

3. To activate a Russian keyboard, add the following to the `"Keyboard"` section of your `XF86Config` file.

   For **XFree86 3.X**:

   ```
   XkbLayout  "ru"
   XkbOptions "grp:caps_toggle"
   ```

   For **XFree86 4.X**:

   ```
   Option "XkbLayout"   "ru"
   Option "XkbOptions"  "grp:caps_toggle"
   ```

   Also make sure that `XkbDisable` is turned off (commented out) there.

The RUS/LAT switch will be **CapsLock**. The old **CapsLock** function is still available via **Shift**+**CapsLock** (in LAT mode only).

If you have "Windows" keys on your keyboard, and notice that some non-alphabetical keys are mapped incorrectly in RUS mode, add the following line in your `XF86Config` file.

For **XFree86 3.X**:

```
XkbVariant "winkeys"
```

For **XFree86 4.X**:

```
Option "XkbVariant" "winkeys"
```

> **Note:** The Russian XKB keyboard may not work with old **XFree86** versions, see the above note for more information. The Russian XKB keyboard may also not work with non-localized applications as well. Minimally localized applications should call a `XtSetLanguageProc (NULL, NULL, NULL);` function early in the program. See KOI8-R for X Window (http://koi8.pp.ru/xwin.html) for more instructions on localizing X11 applications.

14.5.2 Traditional Chinese Localization for Taiwan

The FreeBSD-Taiwan Project has an I18N/L10N tutorial for FreeBSD at http://freebsd.sinica.edu.tw/~ncvs/zh-l10n-tut/ using many Chinese ports. The editor for the `zh-L10N-tut` is Clive Lin <`Clive@CirX.org`>. You can also cvsup the following collections at `freebsd.sinica.edu.tw`:

Collection	Description
outta-port tag=.	Beta-quality ports collection for Chinese
zh-L10N-tut tag=.	Localizing FreeBSD Tutorial in BIG-5 Traditional Chinese
zh-doc tag=.	FreeBSD Documentation Translation to BIG-5 Traditional Chinese

Chuan-Hsing Shen <`s874070@mail.yzu.edu.tw`> has created the Chinese FreeBSD Collection (CFC) (http://cnpa.yzu.edu.tw/~cfc/) using FreeBSD-Taiwan's `zh-L10N-tut`. The packages and the script files are available at ftp://ftp.csie.ncu.edu.tw/OS/FreeBSD/taiwan/CFC/.

14.5.3 German Language Localization (for All ISO 8859-1 Languages)

Slaven Rezic <`eserte@cs.tu-berlin.de`> wrote a tutorial how to use umlauts on a FreeBSD machine. The tutorial is written in German and available at http://www.de.FreeBSD.org/de/umlaute/.

14.5.4 Japanese and Korean Language Localization

For Japanese, refer to http://www.jp.FreeBSD.org/, and for Korean, refer to http://www.kr.FreeBSD.org/.

14.5.5 Non-English FreeBSD Documentation

Some FreeBSD contributors have translated parts of FreeBSD to other languages. They are available through links on the main site (../../../../index.html) or in `/usr/share/doc`.

Chapter 15 Desktop Applications

Contributed by Christophe Juniet.

15.1 Synopsis

FreeBSD can run a wide variety of desktop applications, such as browsers and word processors. Most of these are available as packages or can be automatically built from the ports collection. Many new users expect to find these kinds of applications on their desktop. This chapter will show you how to install some popular desktop applications effortlessly, either from their packages or from the ports collection.

Note that when installing programs from the ports, they are compiled from source. This can take a very long time, depending on what you are compiling and the processing power of your machine(s). If building from source takes a prohibitively long amount of time for you, you can install most of the programs of the ports collection from pre-built packages.

As FreeBSD features Linux binary compatibility, many applications originally developed for Linux are available for your desktop. It is strongly recommended that you read Chapter 22 before installing any of the Linux applications. Many of the ports using the Linux binary compatibility start with "linux-". Remember this when you search for a particular port, for instance with whereis(1). In the following text, it is assumed that you have enabled Linux binary compatibility before installing any of the Linux applications.

Here are the categories covered by this chapter:

- Browsers (such as **Mozilla**, **Netscape**, **Opera**)
- Productivity (such as **KOffice**, **AbiWord**, **The GIMP**, **OpenOffice.org**)
- Document Viewers (such as **Acrobat Reader®**, **gv**, **Xpdf**, **GQview**)
- Finance (such as **GnuCash**, **Gnumeric**, **Abacus**)

Before reading this chapter, you should:

- Know how to install additional third-party software (Chapter 4).
- Know how to install additional Linux software (Chapter 22).

For information on how to get a multimedia environment, read Chapter 16. If you want to set up and use electronic mail, please refer to Chapter 20.

15.2 Browsers

FreeBSD does not come with a particular browser pre-installed. Instead, the www (http://www.FreeBSD.org/ports/www.html) directory of the ports collection contains a lot of browsers ready to be installed. If you do not have time to compile everything (this can take a very long time in some cases) many of them are available as packages.

KDE and **GNOME** already provide HTML browsers. Please refer to Section 5.7 for more information on how to set up these complete desktops.

If you are looking for light-weight browsers, you should investigate the ports collection for `www/dillo`, `www/links`, or `www/w3m`.

This section covers these applications:

Application Name	Resources Needed	Installation from Ports	Major Dependencies
Mozilla	heavy	heavy	**Gtk+**
Netscape	heavy	light	Linux Binary Compatibility
Opera	light	light	FreeBSD version: None. Linux version: Linux Binary Compatibility and **linux-openmotif**

15.2.1 Mozilla

Mozilla is perhaps the most suitable browser for your FreeBSD Desktop. It is modern, stable, and fully ported to FreeBSD. It features a very standards-compliant HTML display engine. It provides a mail and news reader. It even has a HTML composer if you plan to write some web pages yourself. Users of **Netscape** will recognize the similarities with **Communicator** suite, as both browsers shared the same basis.

On slow machines, with a CPU speed less than 233MHz or with less than 64MB of RAM, **Mozilla** can be too resource-consuming to be fully usable. You may want to look at the **Opera** browser instead, described a little later in this chapter.

If you cannot or do not want to compile **Mozilla** for any reason, the FreeBSD GNOME team has already done this for you. Just install the package from the network by:

```
# pkg_add -r mozilla
```

If the package is not available, and you have enough time and disk space, you can get the source for **Mozilla**, compile it and install it on your system. This is accomplished by:

```
# cd /usr/ports/www/mozilla
# make install clean
```

The **Mozilla** port ensures a correct initialization by running the chrome registry setup with `root` privileges. However, if you want to fetch some add-ons like mouse gestures, you must run **Mozilla** as `root` to get them properly installed.

Once you have completed the installation of **Mozilla**, you do not need to be `root` any longer. You can start **Mozilla** as a browser by typing:

```
% mozilla
```

You can start it directly as a mail and news reader as shown below:

```
% mozilla -mail
```

15.2.2 Mozilla, Java™, and Macromedia® Flash™

Contributed by Tom Rhodes.

Installing **Mozilla** is simple, but unfortunately installing **Mozilla** with support for add-ons like Java™ and Macromedia® Flash™ consumes both time and disk space.

The first thing is to download the files which will be used with **Mozilla**. Take your current web browser up to http://www.sun.com/software/java2/download.html and create an account on their website. Remember to save the username and password from here as it may be needed in the future. Download a copy of the file `j2sdk-1_3_1-src.tar.gz` and place this in `/usr/ports/distfiles/` as the port will not fetch it automatically. This is due to license restrictions. While we are here, download the "java environment" from http://java.sun.com/webapps/download/Display?BundleId=7905. The filename is `j2sdk-1_3_1_08-linux-i586.bin` and is large (about 25 megabytes!). Like before, this file must be placed into `/usr/ports/distfiles/`. Finally download a copy of the "java patchkit" from http://www.eyesbeyond.com/freebsddom/java/ and place it into `/usr/ports/distfiles/`.

Install the `java/jdk13` port with the standard `make install clean` and then install the `www/flashpluginwrapper` port. This port requires `emulators/linux_base` which is a large port. True that other **Flash** plugins exist, however they have not worked for me.

Install the `www/mozilla` port, if **Mozilla** is not already installed.

Now copy the **Flash** plug-in files with:

```
# cp /usr/local/lib/flash/libflashplayer.so \
/usr/X11R6/lib/browser_plugins/libflashplayer_linux.so
```

```
# cp /usr/local/lib/flash/ShockwaveFlash.class \
/usr/X11R6/lib/browser_plugins/
```

> **Note:** If you are using `www/mozilla-devel`, the destination directories will be different.

Now add the following lines to the top of (but right under `#!/bin/sh`) **Mozilla** startup script: `/usr/X11R6/bin/mozilla`.

```
LD_PRELOAD=/usr/local/lib/libflashplayer.so.1
export LD_PRELOAD
```

This will enable the **Flash** plug-in.

Now just start **Mozilla** with:

```
% mozilla &
```

And access the About Plug-ins option from the Help menu. A list should appear with all the currently available plugins. **Java** and **Shockwave® Flash** should both be listed.

15.2.3 Netscape®

The ports collection contains several versions of the Netscape browser. Since the native FreeBSD ones contain a serious security bug, installing them is strongly discouraged. Instead, use a more recent Linux or DIGITAL UNIX version.

The latest stable release of the Netscape browser is **Netscape 7**. It can be installed from the ports collection:

```
# cd /usr/ports/www/netscape7
# make install clean
```

There are localized versions in the French, German, and Japanese categories.

> **Caution: Netscape 4.x** versions are not recommended because they are not compliant with today's standards. However, **Netscape 7.x** and newer versions are only available for the i386 platform.

15.2.4 Opera

Opera is a very fast, full-featured, and standards-compliant browser. It comes in two favors: a "native" FreeBSD version and a version that runs under Linux emulation. For each operating system, there is a no-cost version of the browser that displays advertising and an ad-free version that can be purchased on the Opera web site (http://www.opera.com/).

To browse the Web with the FreeBSD version of **Opera**, install the package:

```
# pkg_add -r opera
```

Some FTP sites do not have all the packages, but the same result can be obtained with the ports collection by typing:

```
# cd /usr/ports/www/opera
# make install clean
```

To install the Linux version of **Opera**, substitute `linux-opera` in place of `opera` in the examples above. The Linux version is useful in situations requiring the use of plug-ins that are only available for Linux, such as **Adobe Acrobat Reader**. In all other respects, the FreeBSD and Linux versions appear to be functionally identical.

15.3 Productivity

When it comes to productivity, new users often look for a good office suite or a friendly word processor. While some desktop environments like **KDE** already provide an office suite, there is no default application. FreeBSD provides all that is needed, regardless of your desktop environment.

This section covers these applications:

Application Name	Resources Needed	Installation from Ports	Major Dependencies
KOffice	light	heavy	**KDE**
AbiWord	light	light	**Gtk+** or **GNOME**

Application Name	Resources Needed	Installation from Ports	Major Dependencies
The Gimp	light	heavy	**Gtk+**
OpenOffice.org	heavy	huge	**GCC 3.1**, **JDK™ 1.3**, **Mozilla**

15.3.1 KOffice

The KDE community has provided its desktop environment with an office suite which can be used outside **KDE**. It includes the four standard components that can be found in other office suites. **KWord** is the word processor, **KSpread** is the spreadsheet program, **KPresenter** manages slide presentations, and **Kontour** lets you draw graphical documents.

Before installing the latest **KOffice**, make sure you have an up-to-date version of **KDE**.

To install **KOffice** as a package, issue the following command:

```
# pkg_add -r koffice
```

If the package is not available, you can use the ports collection. For instance, to install **KOffice** for **KDE3**, do:

```
# cd /usr/ports/editors/koffice-kde3
# make install clean
```

15.3.2 AbiWord

AbiWord is a free word processing program similar in look and feel to **Microsoft Word**. It is suitable for typing papers, letters, reports, memos, and so forth. It is very fast, contains many features, and is very user-friendly.

AbiWord can import or export many file formats, including some proprietary ones like Microsoft `.doc`.

AbiWord is available as a package. You can install it by:

```
# pkg_add -r AbiWord-gnome
```

If the package is not available, it can be compiled from the ports collection. The ports collection should be more up to date. It can be done as follows:

```
# cd /usr/ports/editors/AbiWord
# make install clean
```

15.3.3 The GIMP

For image authoring or picture retouching, **The GIMP** is a very sophisticated image manipulation program. It can be used as a simple paint program or as a quality photo retouching suite. It supports a large number of plug-ins and features a scripting interface. **The GIMP** can read and write a wide range of file formats. It supports interfaces with scanners and tablets.

You can install the package by issuing this command:

```
# pkg_add -r gimp
```

If your FTP site does not have this package, you can use the ports collection. The graphics (http://www.FreeBSD.org/ports/graphics.html) directory of the ports collection also contains **The Gimp Manual**. Here is how to get them installed:

```
# cd /usr/ports/graphics/gimp1
# make install clean
# cd /usr/ports/graphics/gimp-manual-pdf
# make install clean
```

> **Note:** The graphics (http://www.FreeBSD.org/ports/graphics.html) directory of the ports collection holds the development version of **The GIMP** in `graphics/gimp-devel`. HTML and PostScript versions of **The Gimp Manual** are in `graphics/gimp-manual-html` and `graphics/gimp-manual-ps`.

15.3.4 OpenOffice.org

OpenOffice.org includes all of the mandatory applications in a complete office productivity suite: a word processor, a spreadsheet, a presentation manager, and a drawing program. Its user interface is very similar to other office suites, and it can import and export in various popular file formats. It is available in a number of different languages including interfaces, spell checkers, and dictionaries.

The word processor of **OpenOffice.org** uses a native XML file format for increased portability and flexibility. The spreadsheet program features a macro language and it can be interfaced with external databases. **OpenOffice.org** is already stable and runs natively on Windows, Solaris™, Linux, FreeBSD, and Mac OS X. More information about **OpenOffice.org** can be found on the OpenOffice web site (http://www.openoffice.org/). For FreeBSD specific information, and to directly download packages use the FreeBSD OpenOffice Porting Team (http://projects.imp.ch/openoffice/)'s web site.

To install **OpenOffice.org**, do:

```
# pkg_add -r openoffice
```

Once the package is installed, you must run the setup program and choose a `standard workstation installation`. Run this command as the user who will use **OpenOffice.org**:

```
% openoffice-setup
```

If the **OpenOffice.org** packages are not available, you still have the option to compile the port. However, you must bear in mind that it requires a lot of disk space and a fairly long time to compile.

```
# cd /usr/ports/editors/openoffice
# make install clean
```

Once this is done, run the setup as the user who will use **OpenOffice.org** and choose a `standard workstation installation` by:

```
% cd /usr/ports/editors/openoffice
% make install-user
```

If you want to use a localized version, here are the available ports:

Language	Port
Arabic	`editors/openoffice-ar`
Danish	`editors/openoffice-dk`
Spanish	`editors/openoffice-es`
Greek	`editors/openoffice-gr`
Italian	`editors/openoffice-it`
Dutch	`editors/openoffice-nl`
Swedish	`editors/openoffice-se`
Turkish	`editors/openoffice-tr`
French	`french/openoffice`
German	`german/openoffice`
Japanese	`japanese/openoffice`
Korean	`korean/openoffice`
Polish	`polish/openoffice`
Portuguese	`portuguese/openoffice`
Russian	`russian/openoffice`

15.4 Document Viewers

Some new document formats have recently gained popularity. The standard viewers they require may not be available in the base system. We will see how to install them in this section.

This section covers these applications:

Application Name	Resources Needed	Installation from Ports	Major Dependencies
Acrobat Reader	light	light	Linux Binary Compatibility
gv	light	light	**Xaw3d**
Xpdf	light	light	**FreeType**
GQview	light	light	**Gtk+** or **GNOME**

15.4.1 Acrobat Reader®

Many documents are now distributed as PDF files, which stands for "Portable Document Format". One of the recommended viewers for these types of files is **Acrobat Reader**, released by Adobe for Linux. As FreeBSD can run Linux binaries, it is also available for FreeBSD.

To install the **Acrobat Reader 5** package, do:

```
# pkg_add -r acroread5
```

As usual, if the package is not available or you want the latest version, you can use the ports collection as well:

```
# cd /usr/ports/print/acroread5
# make install clean
```

> **Note: Acrobat Reader** is available in several different versions. At this time of writing, there are: `print/acroread` (version 3.0.2), `print/acroread4` (version 4.0.5), and `print/acroread5` (version 5.0.6). They may not all have been packaged for your version of FreeBSD. The ports collection will always contain the latest versions.

15.4.2 gv

gv is a PostScript and PDF viewer. It is originally based on **ghostview** but it has a nicer look thanks to the **Xaw3d** library. It is fast and its interface is clean. **gv** has many features like orientation, paper size, scale, or antialias. Almost any operation can be done either from the keyboard or the mouse.

To install **gv** as a package, do:

```
# pkg_add -r gv
```

If you cannot get the package, you can use the ports collection:

```
# cd /usr/ports/print/gv
# make install clean
```

15.4.3 Xpdf

If you want a small FreeBSD PDF viewer, **Xpdf** is a light-weight and efficient viewer. It requires very few resources and is very stable. It uses the standard X fonts and does not require **Motif** or any other X toolkit.

To install the **Xpdf** package, issue this command:

```
# pkg_add -r xpdf
```

If the package is not available or you prefer to use the ports collection, do:

```
# cd /usr/ports/graphics/xpdf
# make install clean
```

Once the installation is complete, you can launch **Xpdf** and use the right mouse button to activate the menu.

15.4.4 GQview

GQview is an image manager. You can view a file with a single click, launch an external editor, get thumbnail previews, and much more. It also features a slideshow mode and some basic file operations. You can manage image collections and easily find duplicates. **GQview** can do full screen viewing and supports internationalization.

If you want to install the **GQview** package, do:

```
# pkg_add -r gqview
```

If the package is not available or you prefer to use the ports collection, do:

```
# cd /usr/ports/graphics/gqview
```

```
# make install clean
```

15.5 Finance

If, for any reason, you would like to manage your personal finances on your FreeBSD Desktop, there are some powerful and easy to use applications ready to be installed. Some of them are compatible with widespread file formats like those of **Quicken®** or **Excel** documents.

This section covers these applications:

Application Name	Resources Needed	Installation from Ports	Major Dependencies
GnuCash	light	heavy	**GNOME**
Gnumeric	light	heavy	**GNOME**
Abacus	light	light	**Tcl/Tk**

15.5.1 GnuCash

GnuCash is part of the **GNOME** effort to provide user-friendly yet powerful applications to end-users. With **GnuCash**, you can keep track of your income and expenses, your bank accounts, or your stocks. It features an intuitive interface while remaining very professional.

GnuCash provides a smart register, a hierarchical system of accounts, many keyboard accelerators and auto-completion methods. It can split a single transaction into several more detailed pieces. **GnuCash** can import and merge **Quicken** QIF files. It also handles most international date and currency formats.

To install **GnuCash** on your system, do:

```
# pkg_add -r gnucash
```

If the package is not available, you can use the ports collection:

```
# cd /usr/ports/finance/gnucash
# make install clean
```

15.5.2 Gnumeric

Gnumeric is a spreadsheet, part of the **GNOME** desktop environment. It features convenient automatic "guessing" of user input according to the cell format and an autofill system for many sequences. It can import files in a number of popular formats like those of **Excel**, **Lotus 1-2-3**, or **Quattro Pro**. **Gnumeric** supports graphs through the `math/guppi` graphing program. It has a large number of built-in functions and allows all of the usual cell formats such as number, currency, date, time, and much more.

To install **Gnumeric** as a package, type in:

```
# pkg_add -r gnumeric
```

If the package is not available, you can use the ports collection by doing:

```
# cd /usr/ports/math/gnumeric
# make install clean
```

15.5.3 Abacus

Abacus is a small and easy to use spreadsheet. It includes many built-in functions useful in several domains such as statistics, finances, and mathematics. It can import and export the **Excel** file format. **Abacus** can produce PostScript output.

To install **Abacus** from its package, do:

```
# pkg_add -r abacus
```

If the package is not available, you can use the ports collection by doing:

```
# cd /usr/ports/deskutils/abacus
# make install clean
```

15.6 Summary

While FreeBSD is popular among ISPs for its performance and stability, it is quite ready for day-to-day use as a desktop. With several thousand applications available as packages (http://www.FreeBSD.org/where.html) or ports (http://www.FreeBSD.org/ports/index.html), you can build a perfect desktop that suits all your needs.

Once you have achieved the installation of your desktop, you may want to go one step further with `misc/instant-workstation`. This "meta-port" allows you to build a typical set of ports for a workstation. You can customize it by editing `/usr/ports/misc/instant-workstation/Makefile`. Follow the syntax used for the default set to add or remove ports, and build it with the usual procedure. Eventually, you will be able to create a big package that corresponds to your very own desktop and install it to your other workstations!

Here is a quick review of all the desktop applications covered in this chapter:

Application Name	Package Name	Ports Name
Mozilla	`mozilla`	`www/mozilla`
Netscape	`linux-netscape7`	`www/netscape7`
Opera	`linux-opera`	`www/linux-opera`
KOffice	`koffice-kde3`	`editors/koffice-kde3`
AbiWord	`AbiWord-gnome`	`editors/AbiWord`
The GIMP	`gimp`	`graphics/gimp1`
OpenOffice.org	`openoffice`	`editors/openoffice`
Acrobat Reader	`acroread5`	`print/acroread5`
gv	`gv`	`print/gv`
Xpdf	`xpdf`	`graphics/xpdf`
GQview	`gqview`	`graphics/gqview`
GnuCash	`gnucash`	`finance/gnucash`

Application Name	Package Name	Ports Name
Gnumeric	`gnumeric`	`math/gnumeric`
Abacus	`abacus`	`deskutils/abacus`

Chapter 16 Multimedia

Edited by Ross Lippert.

16.1 Synopsis

FreeBSD supports a wide variety of sound cards, allowing you to enjoy high fidelity output from your computer. This includes the ability to record and playback audio in the MPEG Audio Layer 3 (MP3), WAV, and Ogg Vorbis formats as well as many other formats. The FreeBSD Ports Collection also contains applications allowing you to edit your recorded audio, add sound effects, and control attached MIDI devices.

With some willingness to experiment, FreeBSD can support playback of video files and DVD's. The number of applications to encode, convert, and playback various video media is more limited than the number of sound applications. For example as of this writing, there is no good re-encoding application in the FreeBSD Ports Collection, which could be use to convert between formats, as there is with `audio/sox`. However, the software landscape in this area is changing rapidly.

This chapter will describe the necessary steps to configure your sound card. The configuration and installation of **XFree86** (Chapter 5) has already taken care of the hardware issues for your video card, though there may be some tweaks to apply for better playback.

After reading this chapter, you will know:

- How to configure your system so that your sound card is recognized.
- Methods to test that your card is working using sample applications.
- How to troubleshoot your sound setup.
- How to playback and encode MP3s and other audio.
- How video is supported by **XFree86**.
- Some video player/encoder ports which give good results.
- How to playback DVD's, `.mpg` and `.avi` files.
- How to rip CD and DVD information into files.

Before reading this chapter, you should:

- Know how to configure and install a new kernel (Chapter 9).

For the video sections, it is assumed that **XFree86 4.X** (`x11/XFree86-4`) has been installed. **XFree86 3.X** may work, but it has not been tested with what is described in this chapter. If you find that something described here does work with **XFree86 3.X** please let us know.

> **Warning:** Trying to mount an audio CD or a video DVD with the mount(8) command will result in an error, at least, and a *kernel panic*, at worst. These media have specialized encodings which differ from the usual ISO-filesystem.

16.2 Setting Up the Sound Card

Contributed by Moses Moore.

16.2.1 Locating the Correct Device

Before you begin, you should know the model of the card you have, the chip it uses, and whether it is a PCI or ISA card. FreeBSD supports a wide variety of both PCI and ISA cards. If you do not see your card in the following list, check the pcm(4) manual page. This is not a complete list; however, it does list some of the most common cards.

- Crystal 4237, 4236, 4232, 4231
- Yamaha OPL-SAx
- OPTi931
- Ensoniq AudioPCI 1370/1371
- ESS Solo-1/1E
- NeoMagic 256AV/ZX
- SoundBlaster® Pro, 16, 32, AWE64, AWE128, Live
- Creative ViBRA16
- Advanced Asound 100, 110, and Logic ALS120
- ES 1868, 1869, 1879, 1888
- Gravis UltraSound
- Aureal Vortex 1 or 2

To use your sound device, you will need to load the proper device driver. This may be accomplished in one of two ways. The easiest way is to simply load a kernel module for your sound card with kldload(8) which can either be done from the command line:

```
# kldload snd_emu10k1.ko
```

or by adding the appropriate line to the file `/boot/loader.conf` like this:

```
snd_emu10k1_load="YES"
```

These examples are for a Creative SoundBlaster Live! sound card. Other available loadable sound modules are listed in `/boot/defaults/loader.conf`.

Alternatively, you may statically compile in support for your sound card in your kernel. The sections below provide the information you need to add support for your hardware in this manner. For more information about recompiling your kernel, please see Chapter 9.

16.2.1.1 Creative, Advance, and ESS Sound Cards

If you have one of the above cards, you will need to add:

```
device pcm
```

to your kernel configuration file. If you have a PnP ISA card, you will also need to add:

```
device sbc
```

For a non-PnP ISA card, add:

```
device pcm
device sbc0 at isa? port 0x220 irq 5 drq 1 flags 0x15
```

to your kernel configuration file. The settings shown above are the defaults. You may need to change the IRQ or the other settings to match your card. See the sbc(4) manual page for more information.

> **Note:** The Sound Blaster Live is not supported under FreeBSD 4.0 without a patch, which this section will not cover. It is recommended that you update to the latest -STABLE before trying to use this card.

16.2.1.2 Gravis UltraSound Cards

For a PnP ISA card, you will need to add:

```
device pcm
device gusc
```

to your kernel configuration file. If you have a non-PnP ISA card, you will need to add:

```
device pcm
device gus0 at isa? port 0x220 irq 5 drq 1 flags 0x13
```

to your kernel configuration file. You may need to change the IRQ or the other settings to match your card. See the gusc(4) manual page for more information.

16.2.1.3 Crystal Sound Cards

For Crystal cards, you will need to add:

```
device pcm
device csa
```

to your kernel configuration file.

16.2.1.4 Generic Support

For PnP ISA or PCI cards, you will need to add:

```
device pcm
```

to your kernel configuration file. If you have a non-PnP ISA sound card that does not have a bridge driver, you will need to add:

```
device pcm0 at isa? irq 10 drq 1 flags 0x0
```

to your kernel configuration file. You may need to change the IRQ or the other settings to match your card.

16.2.1.5 Onboard Sound

Some systems with built-in motherboard sound devices may require the following option in your kernel configuration:

```
options PNPBIOS
```

16.2.2 Creating and Testing the Device Nodes

After you reboot, log in and check for the device in the `/var/run/dmesg.boot` file, as shown below:

```
# grep pcm /var/run/dmesg.boot
pcm0: <SB16 DSP 4.11> on sbc0
```

The output from your system may look different. If no `pcm` devices show up, something went wrong earlier. If that happens, go through your kernel configuration file again and make sure you chose the correct device. Common problems are listed in Section 16.2.2.1.

> **Note:** If you are running FreeBSD 5.0 or later, you can safely skip the rest of this section. These versions use devfs(5) to automatically create devices nodes.

If the previous command returned `pcm0`, you will have to run the following as `root`:

```
# cd /dev
# sh MAKEDEV snd0
```

If the command returned `pcm1`, follow the same steps as shown above, replacing `snd0` with `snd1`.

> **Note:** The above commands will *not* create a `/dev/snd` device!

`MAKEDEV` will create a group of device nodes, including:

Device	Description
`/dev/audio`	Sparc® compatible audio device
`/dev/dsp`	Digitized voice device
`/dev/dspW`	Like `/dev/dsp`, but 16 bits per sample
`/dev/midi`	Raw midi access device
`/dev/mixer`	Control port mixer device
`/dev/music`	Level 2 sequencer interface
`/dev/sequencer`	Sequencer device
`/dev/pss`	Programmable device interface

If all goes well, you should now have a functioning sound card. If your CD-ROM or DVD-ROM drive is properly coupled to your sound card, you can put a CD in the drive and play it with cdcontrol(1):

```
% cdcontrol -f /dev/acd0c play 1
```

Various applications, such as `audio/workman` offer a better interface. You may want to install an application such as `audio/mpg123` to listen to MP3 audio files.

16.2.2.1 Common Problems

Error	Solution
`unsupported subdevice XX`	One or more of the device nodes was not created correctly. Repeat the steps above.
`sb_dspwr(XX) timed out`	The I/O port is not set correctly.
`bad irq XX`	The IRQ is set incorrectly. Make sure that the set IRQ and the sound IRQ are the same.
`xxx: gus pcm not attached, out of memory`	There is not enough available memory to use the device.
`xxx: can't open /dev/dsp!`	Check with `fstat | grep dsp` if another application is holding the device open. Noteworthy troublemakers are **esound** and **KDE**'s sound support.

16.2.3 Utilizing Multiple Sound Sources

Contributed by Munish Chopra.

It is often desirable to have multiple sources of sound that are able to play simultaneously, such as when **esound** or **artsd** do not support sharing of the sound device with a certain application.

FreeBSD lets you do this through *Virtual Sound Channels*, which can be set with the sysctl(8) facility. Virtual channels allow you to multiplex your sound card's playback channels by mixing sound in the kernel.

To set the number of virtual channels, there are two sysctl knobs which, if you are the `root` user, can be set like this:

```
# sysctl hw.snd.pcm0.vchans=4
# sysctl hw.snd.maxautovchans=4
```

The above example allocates four virtual channels, which is a practical number for everyday use. `hw.snd.pcm0.vchans` is the number of virtual channels `pcm0` has, and is configurable once a device has been attached. `hw.snd.maxautovchans` is the number of virtual channels a new audio device is given when it is attached using kldload(8). Since the `pcm` module can be loaded independently of the hardware drivers, `hw.snd.maxautovchans` can store how many virtual channels any devices which are attached later will be given.

If you are not using devfs(5), you will have to point your applications at `/dev/dsp0.x`, where *x* is 0 to 3 if `hw.snd.pcm.0.vchans` is set to 4 as in the above example. On a system using devfs(5), the above will automatically be allocated transparently to the user.

16.3 MP3 Audio

Contributed by Chern Lee.

MP3 (MPEG Layer 3 Audio) accomplishes near CD-quality sound, leaving no reason to let your FreeBSD workstation fall short of its offerings.

16.3.1 MP3 Players

By far, the most popular **XFree86** MP3 player is **XMMS** (X Multimedia System). **Winamp** skins can be used with **XMMS** since the GUI is almost identical to that of Nullsoft's **Winamp**. **XMMS** also has native plug-in support.

XMMS can be installed from the `multimedia/xmms` port or package.

XMMS' interface is intuitive, with a playlist, graphic equalizer, and more. Those familiar with **Winamp** will find **XMMS** simple to use.

The `audio/mpg123` port is an alternative, command-line MP3 player.

mpg123 can be run by specifying the sound device and the MP3 file on the command line, as shown below:

```
# mpg123 -a /dev/dsp1.0 Foobar-GreatestHits.mp3
High Performance MPEG 1.0/2.0/2.5 Audio Player for Layer 1, 2 and 3.
Version 0.59r (1999/Jun/15). Written and copyrights by Michael Hipp.
Uses code from various people. See 'README' for more!
THIS SOFTWARE COMES WITH ABSOLUTELY NO WARRANTY! USE AT YOUR OWN RISK!





Playing MPEG stream from Foobar-GreatestHits.mp3 ...
MPEG 1.0 layer III, 128 kbit/s, 44100 Hz joint-stereo
```

`/dev/dsp1.0` should be replaced with the `dsp` device entry on your system.

16.3.2 Ripping CD Audio Tracks

Before encoding a CD or CD track to MP3, the audio data on the CD must be ripped onto the hard drive. This is done by copying the raw CDDA (CD Digital Audio) data to WAV files.

The `cdda2wav` tool, which is a part of the `sysutils/cdrtools` suite, is used for ripping audio information from CDs and the information associated with them.

With the audio CD in the drive, the following command can be issued (as `root`) to rip an entire CD into individual (per track) WAV files:

```
# cdda2wav -D 0,1,0 -B
```

cdda2wav will support ATAPI (IDE) CDROM drives. To rip from an IDE drive, specify the device name in place of the SCSI unit numbers. For example, to rip track 7 from an IDE drive:

```
# cdda2wav -D /dev/acd0a -t 7
```

The `-D 0,1,0` indicates the SCSI device `0,1,0`, which corresponds to the output of `cdrecord -scanbus`.

To rip individual tracks, make use of the `-t` option as shown:

```
# cdda2wav -D 0,1,0 -t 7
```

This example rips track seven of the audio CDROM. To rip a range of tracks, for example, track one to seven, specify a range:

```
# cdda2wav -D 0,1,0 -t 1+7
```

The utility dd(1) can also be used to extract audio tracks on ATAPI drives, read Section 12.5.5 for more information on that possibility.

16.3.3 Encoding MP3s

Nowadays, the mp3 encoder of choice is **lame**. **Lame** can be found at `audio/lame` in the ports tree.

Using the ripped WAV files, the following command will convert `audio01.wav` to `audio01.mp3`:

```
# lame -h -b 128 \
--tt "Foo Song Title" \
--ta "FooBar Artist" \
--tl "FooBar Album" \
--ty "2001" \
--tc "Ripped and encoded by Foo" \
--tg "Genre" \
audio01.wav audio01.mp3
```

128 kbits seems to be the standard MP3 bitrate in use. Many enjoy the higher quality 160, or 192. The higher the bitrate, the more disk space the resulting MP3 will consume--but the quality will be higher. The `-h` option turns on the "higher quality but a little slower" mode. The options beginning with `--t` indicate ID3 tags, which usually contain song information, to be embedded within the MP3 file. Additional encoding options can be found by consulting the lame man page.

16.3.4 Decoding MP3s

In order to burn an audio CD from MP3s, they must be converted to a non-compressed WAV format. Both **XMMS** and **mpg123** support the output of MP3 to an uncompressed file format.

Writing to Disk in **XMMS**:

1. Launch **XMMS**.
2. Right-click on the window to bring up the **XMMS** menu.
3. Select `Preference` under `Options`.
4. Change the Output Plugin to "Disk Writer Plugin".
5. Press `Configure`.
6. Enter (or choose browse) a directory to write the uncompressed files to.

7. Load the MP3 file into **XMMS** as usual, with volume at 100% and EQ settings turned off.
8. Press `Play` — **XMMS** will appear as if it is playing the MP3, but no music will be heard. It is actually playing the MP3 to a file.
9. Be sure to set the default Output Plugin back to what it was before in order to listen to MP3s again.

Writing to stdout in **mpg123**:

1. Run mpg123 -s *audio01.mp3* > audio01.pcm

XMMS writes a file in the WAV format, while **mpg123** converts the MP3 into raw PCM audio data. Both of these formats can be used with **cdrecord** to create audio CDs. You have to use raw PCM with burncd(8). If you use WAV files, you will notice a small tick sound at the beginning of each track, this sound is the header of the WAV file. You can simply remove the header of a WAV file with the utility **SoX** (it can be installed from the `audio/sox` port or package):

```
% sox -t wav -r 44100 -s -w -c 2 track.wav track.raw
```

Read Section 12.5 for more information on using a CD burner in FreeBSD.

16.4 Video Playback

Contributed by Ross Lippert.

Video playback is a very new and rapidly developing application area. Be patient. Not everything is going to work as smoothly as it did with sound.

Before you begin, you should know the model of the video card you have and the chip it uses. While **XFree86** supports a wide variety of video cards, fewer give good playback performance. To obtain a list of extensions supported by the X server using your card use the command xdpyinfo(1) while X11 is running.

It is a good idea to have a short MPEG file which can be treated as a test file for evaluating various players and options. Since some DVD players will look for DVD media in `/dev/dvd` by default, or have this device name hardcoded in them, you might find it useful to make symbolic links to the proper devices:

```
# ln -sf /dev/acd0c /dev/dvd
# ln -sf /dev/racd0c /dev/rdvd
```

On FreeBSD 5.X, which uses devfs(5) there is a slightly different set of recommended links:

```
# ln -sf /dev/acd0c /dev/dvd
# ln -sf /dev/acd0c /dev/rdvd
```

Additionally, DVD decryption, which requires invoking special DVD-ROM functions, requires write permission on the DVD devices.

Some of the ports discussed rely on the following kernel options to build correctly. Before attempting to build, add these options to the kernel configuration file, build a new kernel, and reboot:

```
option CPU_ENABLE_SSE
option USER_LDT
```

To enhance the shared memory X11 interface, it is recommended that the values of some sysctl(8) variables should be increased:

```
kern.ipc.shmmax=67108864
kern.ipc.shmall=32768
```

16.4.1 Determining Video Capabilities

There are several possible ways to display video under X11. What will really work is largely hardware dependent. Each method described below will have varying quality across different hardware. Secondly, the rendering of video in X11 is a topic receiving a lot of attention lately, and with each version of **XFree86** there may be significant improvement.

A list of common video interfaces:

1. X11: normal X11 output using shared memory.
2. XVideo: an extension to the X11 interface which supports video in any X11 drawable.
3. SDL: the Simple Directmedia Layer.
4. DGA: the Direct Graphics Access.
5. SVGAlib: low level console graphics layer.

16.4.1.1 XVideo

XFree86 4.X has an extension called *XVideo* (aka Xvideo, aka Xv, aka xv) which allows video to be directly displayed in drawable objects through a special acceleration. This extension provides very good quality playback even on low-end machines (for example my PIII 400 Mhz laptop). Unfortunately, the list of cards in which this feature is supported “out of the box” is currently:

1. 3DFX Voodoo 3
2. Intel i810 and i815
3. some S3 chips (such as Savage/IX and Savage/MX)

If your card is not one of these, do not be disappointed yet. **XFree86 4.X** adds new xv capabilities with each release [1]. To check whether the extension is running, use `xvinfo`:

```
% xvinfo
```

XVideo is supported for your card if the result looks like:

```
X-Video Extension version 2.2
screen #0
  Adaptor #0: "Savage Streams Engine"
    number of ports: 1
    port base: 43
    operations supported: PutImage
    supported visuals:
      depth 16, visualID 0x22
      depth 16, visualID 0x23
    number of attributes: 5
```

```
  "XV_COLORKEY" (range 0 to 16777215)
          client settable attribute
          client gettable attribute (current value is 2110)
  "XV_BRIGHTNESS" (range -128 to 127)
          client settable attribute
          client gettable attribute (current value is 0)
  "XV_CONTRAST" (range 0 to 255)
          client settable attribute
          client gettable attribute (current value is 128)
  "XV_SATURATION" (range 0 to 255)
          client settable attribute
          client gettable attribute (current value is 128)
  "XV_HUE" (range -180 to 180)
          client settable attribute
          client gettable attribute (current value is 0)
maximum XvImage size: 1024 x 1024
Number of image formats: 7
  id: 0x32595559 (YUY2)
    guid: 59555932-0000-0010-8000-00aa00389b71
    bits per pixel: 16
    number of planes: 1
    type: YUV (packed)
  id: 0x32315659 (YV12)
    guid: 59563132-0000-0010-8000-00aa00389b71
    bits per pixel: 12
    number of planes: 3
    type: YUV (planar)
  id: 0x30323449 (I420)
    guid: 49343230-0000-0010-8000-00aa00389b71
    bits per pixel: 12
    number of planes: 3
    type: YUV (planar)
  id: 0x36315652 (RV16)
    guid: 52563135-0000-0000-0000-000000000000
    bits per pixel: 16
    number of planes: 1
    type: RGB (packed)
    depth: 0
    red, green, blue masks: 0x1f, 0x3e0, 0x7c00
  id: 0x35315652 (RV15)
    guid: 52563136-0000-0000-0000-000000000000
    bits per pixel: 16
    number of planes: 1
    type: RGB (packed)
    depth: 0
    red, green, blue masks: 0x1f, 0x7e0, 0xf800
  id: 0x31313259 (Y211)
    guid: 59323131-0000-0010-8000-00aa00389b71
    bits per pixel: 6
    number of planes: 3
    type: YUV (packed)
  id: 0x0
    guid: 00000000-0000-0000-0000-000000000000
```

```
        bits per pixel: 0
        number of planes: 0
        type: RGB (packed)
        depth: 1
        red, green, blue masks: 0x0, 0x0, 0x0
```

Also note that the formats listed (YUV2, YUV12, etc) are not present with every implementation of XVideo and their absence may hinder some players.

If the result looks like:

```
X-Video Extension version 2.2
screen #0
no adaptors present
```

Then XVideo is probably not supported for your card.

If XVideo is not supported for your card, this only means that it will be more difficult for your display to meet the computational demands of rendering video. Depending on your video card and processor, though, you might still be able to have a satisfying experience. You should probably read about ways of improving performance in the advanced reading Section 16.4.3.

16.4.1.2 Simple Directmedia Layer

The Simple Directmedia Layer, SDL, was intended to be a porting layer between Microsoft Windows, BeOS, and UNIX, allowing cross-platform applications to be developed which made efficient use of sound and graphics. The SDL layer provides a low-level abstraction to the hardware which can sometimes be more efficient than the X11 interface.

The SDL can be found at `devel/sdl12`

16.4.1.3 Direct Graphics Access

Direct Graphics Access is an **XFree86** extension which allows a program to bypass the X server and directly alter the framebuffer. Because it relies on a low level memory mapping to effect this sharing, programs using it must must be run as `root`.

The DGA extension can be tested and benchmarked by dga(1). When `dga` is running, it changes the colors of the display whenever a key is pressed. To quit, use **q**.

16.4.2 Ports and Packages Dealing with Video

This section discusses the software available from the FreeBSD Ports Collection which can be used for video playback. Video playback is a very active area of software development, and the capabilities of various applications are bound to diverge somewhat from the descriptions given here.

Firstly, it is important to know that many of the video applications which run on FreeBSD were developed as Linux applications. Many of these applications are still beta-quality. Some of the problems that you may encounter with video packages on FreeBSD include :

1. An application cannot playback a file which another application produced.
2. An application cannot playback a file which the application itself produced.
3. The same application on two different machines, rebuilt on each machine for that machine, plays back the same file differently.
4. A seemingly trivial filter like rescaling of the image size results in very bad artifacts from a buggy rescaling routine.
5. An application frequently dumps core.
6. Documentation is not installed with the port and can be found either on the web or under the port's `work` directory.

Many of these applications may also exhibit "Linux-isms". That is, there may be issues resulting from the way some standard libraries are implemented in the Linux distributions, or some features of the Linux kernel which have been assumed by the authors of the applications. These issues are not always noticed and worked around by the port maintainers, which can lead to problems like these:

1. The use of `/proc/cpuinfo` to detect processor characteristics.
2. A misuse of threads which causes a program to hang upon completion instead of truly terminating.
3. Software not yet in the FreeBSD Ports Collection which is commonly used in conjunction with the application.

So far, these application developers have been cooperative with port maintainers to minimize the work-arounds needed for port-ing.

16.4.2.1 MPlayer

MPlayer is a recently developed and rapidly developing video player. The goals of the **MPlayer** team are speed and flexibility on Linux and other Unices. The project was started when the team founder got fed up with bad playback performance on then available players. Some would say that the graphical interface has been sacrificed for a streamlined design. However, once you get used to the command line options and the key-stroke controls, it works very well.

16.4.2.1.1 Building MPlayer

MPlayer resides in `multimedia/mplayer`. **MPlayer** performs a variety of hardware checks during the build process, resulting in a binary which will not be portable from one system to another. Therefore, it is important to build it from ports and not to use a binary package. Additionally, a number of options can be specified in the `make` command line, as described at the start of the build.

```
# cd /usr/ports/multimedia/mplayer
# make
You can enable additional compilation optimizations
by defining WITH_OPTIMIZED_CFLAGS
You can enable GTK GUI by defining WITH_GUI.
You can enable DVD support by defining WITH_DVD.
You can enable SVGALIB support by defining WITH_SVGALIB.
You can enable VORBIS sound support by defining WITH_VORBIS.
You can enable XAnim DLL support by defining WITH_XANIM.
```

If you have x11-toolkits/gtk12 installed, then you might as well enable the GUI. Otherwise, it is not worth the effort. If you intend to play (possibly CSS encoded) DVD's with **MPlayer** you must enable the DVD support option here [2]. Some reasonable options are:

```
# make WITH_DVD=yes WITH_SVGALIB=yes
```

As of this writing, the **MPlayer** port will build its HTML documentation and one executable, mplayer. It can also be made to build an encoder, mencoder, which is a tool for re-encoding video. A modification to the Makefile can enable it. It may be enabled by default in subsequent versions of the port.

The HTML documentation for **MPlayer** is very informative. If the reader finds the information on video hardware and interfaces in this chapter lacking, the **MPlayer** documentation is a very thorough supplement. You should definitely take the time to read the **MPlayer** documentation if you are looking for information about video support in UNIX.

16.4.2.1.2 Using MPlayer

Any user of **MPlayer** must set up a .mplayer subdirectory of her home directory. To create this necessary subdirectory, you can type the following:

```
% cd /usr/ports/multimedia/mplayer
% make install-user
```

The command options for mplayer are listed in the manual page. For even more detail there is HTML documentation. In this section, we will describe only a few common uses.

To play a file, such as *testfile.avi*, through one of the various video interfaces set the -vo option:

```
% mplayer -vo xv testfile.avi

% mplayer -vo sdl testfile.avi

% mplayer -vo x11 testfile.avi

# mplayer -vo dga testfile.avi

# mplayer -vo 'sdl:dga' testfile.avi
```

It is worth trying all of these options, as their relative performance depends on many factors and will vary significantly with hardware.

To play from a DVD, replace the testfile.avi with -dvd <N> *DEVICE* where <N> is the title number to play and *DEVICE* is the device node for the DVD-ROM. For example, to play title 3 from /dev/dvd:

```
# mplayer -vo dga -dvd 2 /dev/dvd
```

To stop, pause, advance and so on, consult the keybindings, which are output by running mplayer -h or read the manual page.

Additional important options for playback are: -fs -zoom which engages the fullscreen mode and -framedrop which helps performance.

In order for the mplayer command line to not become too large, the user can create a file .mplayer/config and set default options there:

```
vo=xv
fs=yes
zoom=yes
```

Finally, `mplayer` can be used to rip a DVD title into a `.vob` file. To dump out the second title from a DVD, type this:

```
# mplayer -dumpstream -dumpfile out.vob -dvd 2 /dev/dvd
```

The output file, `out.vob`, will be MPEG and can be manipulated by the other packages described in this section.

16.4.2.1.3 mencoder

If you opt to install `mencoder` when you build **MPlayer**, be forewarned that it is still an experimental component. Before using `mencoder` it is a good idea to familiarize yourself with the options from the HTML documentation. There is a manual page, but it is not very useful without the HTML documentation. There are innumerable ways to improve quality, lower bitrate, and change formats, and some of these tricks may make the difference between good or bad performance. Here are a couple of examples to get you going. First a simple copy:

```
% mencoder input.avi -oac copy -ovc copy -o output.avi
```

Improper combinations of command line options can yield output files that are unplayable even by `mplayer`. Thus, if you just want to rip to a file, stick to the `-dumpfile` in `mplayer`.

To convert `input.avi` to the MPEG4 codec with MPEG3 audio encoding (`audio/lame` is required):

```
% mencoder input.avi -oac mp3lame -lameopts br=192 \
 -ovc lavc -lavcopts vcodec=mpeg4:vhq -o output.avi
```

This has produced output playable by `mplayer` and `xine`.

`input.avi` can be replaced with `-dvd 1 /dev/dvd` and run as `root` to re-encode a DVD title directly. Since you are likely to be dissatisfied with your results the first time around, it is recommended you dump the title to a file and work on the file.

16.4.2.2 The xine Video Player

The **xine** video player is a project of wide scope aiming not only at being an all in one video solution, but also in producing a reusable base library and a modular executable which can be extended with plugins. It comes both as a package and as a port, `multimedia/xine`.

The **xine** player is still very rough around the edges, but it is clearly off to a good start. In practice, **xine** requires either a fast CPU with a fast video card, or support for the XVideo extension. The GUI is usable, but a bit clumsy.

As of this writing, there is no input module shipped with **xine** which will play CSS encoded DVD’s. There are third party builds which do have modules for this built in them, but none of these are in the FreeBSD Ports Collection.

Compared to **MPlayer**, **xine** does more for the user, but at the same time, takes some of the more fine-grained control away from the user. The **xine** video player performs best on XVideo interfaces.

By default, **xine** player will start up in a graphical user interface. The menus can then be used to open a specific file:

```
% xine
```

Alternatively, it may be invoked to play a file immediately without the GUI interface with the command:

```
% xine -g -p mymovie.avi
```

16.4.2.3 The transcode Utilities

The software **transcode** is not a player, but a suite of tools for re-encoding `.avi` and `.mpg` files. With **transcode**, one has the ability to merge video files, repair broken files, using command line tools with `stdin/stdout` stream interfaces.

Like **MPlayer**, **transcode** is very experimental software which must be build from the port `multimedia/transcode`. Using a great many options to the `make` command. I recommend:

```
# make WITH_LIBMPEG2=yes
```

If you plan to install `multimedia/avifile`, then add the `WITH_AVIFILE` option to your `make` command line, as shown here:

```
# make WITH_AVIFILE=yes WITH_LIBMPEG2=yes
```

Here are two examples of using `transcode` for video conversion which produce rescaled output. The first encodes the output to an openDIVX AVI file, while the second encodes to the much more portable MPEG format.

```
% transcode -i input.vob -x vob -V -Z 320x240 \
-y opendivx -N 0x55 -o output.avi
```

```
% transcode -i input.vob -x vob -V -Z 320x240 \
-y mpeg -N 0x55 -o output.tmp
% tcmplex -o output.mpg -i output.tmp.m1v -p output.tmp.mpa -m 1
```

There is a manual page for `transcode`, but there is little documentation for the various `tc*` utilities (such as `tcmplex`) which are also installed. However, the `-h` command line option can always be given to get curt usage instructions for a command.

In comparison, `transcode` runs significantly slower than `mencoder`, but it has a better chance of producing a more widely playable file. MPEGs created by `transcode` have been known to play on older copies of **Windows Media® Player** and Apple's **Quicktime®**, for example.

16.4.3 Further Reading

The various video software packages for FreeBSD are developing rapidly. It is quite possible that in the near future many of the problems discussed here will have been resolved. In the mean time, those who want to get the very most out of FreeBSD's A/V capabilities will have to cobble together knowledge from several FAQs and tutorials and use a few different applications. This section exists to give the reader pointers to such additional information.

The MPlayer documentation (http://www.mplayerhq.hu/DOCS/) is very technically informative. These documents should probably be consulted by anyone wishing to obtain a high level of expertise with UNIX video. The **MPlayer** mailing list is hostile to anyone who has not bothered to read the documentation, so if you plan on making bug reports to them, RTFM.

The xine HOWTO (http://dvd.sourceforge.net/xine-howto/en_GB/html/howto.html) contains a chapter on performance improvement which is general to all players.

Finally, there are some other promising applications which the reader may try:

- Avifile (http://avifile.sourceforge.net/) which is also a port `multimedia/avifile`.
- Ogle (http://www.dtek.chalmers.se/groups/dvd/) which is also a port `multimedia/ogle`.
- Xtheater (http://xtheater.sourceforge.net/)
- `multimedia/dvdauthor`, an open source package for authoring DVD content.

Notes

1. A popular familiar graphics card with generally very good **XFree86** performance, nVidia, has yet to release the specifications on their XVideo support to the **XFree86** team. It may be some time before **XFree86** fully support XVideo for these cards.
2. Unauthorized DVD playback is a serious criminal act in some countries. Check local laws before enabling this option.

Chapter 17 Serial Communications

17.1 Synopsis

UNIX has always had support for serial communications. In fact, the very first UNIX machines relied on serial lines for user input and output. Things have changed a lot from the days when the average "terminal" consisted of a 10-character-per-second serial printer and a keyboard. This chapter will cover some of the ways in which FreeBSD uses serial communications.

After reading this chapter, you will know:

- How to connect terminals to your FreeBSD system.
- How to use a modem to dial out to remote hosts.
- How to allow remote users to login to your system with a modem.
- How to boot your system from a serial console.

Before reading this chapter, you should:

- Know how to configure and install a new kernel (Chapter 9).
- Understand UNIX permissions and processes (Chapter 3).
- Have access to the technical manual for the serial hardware (modem or multi-port card) that you would like to use with FreeBSD.

17.2 Introduction

17.2.1 Terminology

bps

Bits per Second — the rate at which data is transmitted

DTE

Data Terminal Equipment — for example, your computer

DCE

Data Communications Equipment — your modem

RS-232

EIA standard for hardware serial communications

When talking about communications data rates, this section does not use the term "baud". Baud refers to the number of electrical state transitions that may be made in a period of time, while "bps" (bits per second) is the *correct* term to use (at least it does not seem to bother the curmudgeons quite as much).

17.2.2 Cables and Ports

To connect a modem or terminal to your FreeBSD system, you will need a serial port on your computer and the proper cable to connect to your serial device. If you are already familiar with your hardware and the cable it requires, you can safely skip this section.

17.2.2.1 Cables

There are several different kinds of serial cables. The two most common types for our purposes are null-modem cables and standard ("straight") RS-232 cables. The documentation for your hardware should describe the type of cable required.

17.2.2.1.1 Null-modem Cables

A null-modem cable passes some signals, such as "signal ground", straight through, but switches other signals. For example, the "send data" pin on one end goes to the "receive data" pin on the other end.

If you like making your own cables, you can construct a null-modem cable for use with terminals. This table shows the RS-232C signal names and the pin numbers on a DB-25 connector.

Signal	Pin #		Pin #	Signal
SG	7	connects to	7	SG
TxD	2	connects to	3	RxD
RxD	3	connects to	2	TxD
RTS	4	connects to	5	CTS
CTS	5	connects to	4	RTS
DTR	20	connects to	6	DSR
DCD	8		6	DSR
DSR	6	connects to	20	DTR

> **Note:** Connect "Data Set Ready" (DSR) and "Data Carrier Detect" (DCD) internally in the connector hood, and then to "Data Terminal Ready" (DTR) in the remote hood.

17.2.2.1.2 Standard RS-232C Cables

A standard serial cable passes all the RS-232C signals straight-through. That is, the "send data" pin on one end of the cable goes to the "send data" pin on the other end. This is the type of cable to use to connect a modem to your FreeBSD system, and is also appropriate for some terminals.

17.2.2.2 Ports

Serial ports are the devices through which data is transferred between the FreeBSD host computer and the terminal. This section describes the kinds of ports that exist and how they are addressed in FreeBSD.

17.2.2.2.1 Kinds of Ports

Several kinds of serial ports exist. Before you purchase or construct a cable, you need to make sure it will fit the ports on your terminal and on the FreeBSD system.

Most terminals will have DB25 ports. Personal computers, including PCs running FreeBSD, will have DB25 or DB9 ports. If you have a multiport serial card for your PC, you may have RJ-12 or RJ-45 ports.

See the documentation that accompanied the hardware for specifications on the kind of port in use. A visual inspection of the port often works too.

17.2.2.2.2 Port Names

In FreeBSD, you access each serial port through an entry in the `/dev` directory. There are two different kinds of entries:

- Call-in ports are named `/dev/ttydN` where `N` is the port number, starting from zero. Generally, you use the call-in port for terminals. Call-in ports require that the serial line assert the data carrier detect (DCD) signal to work correctly.
- Call-out ports are named `/dev/cuaaN`. You usually do not use the call-out port for terminals, just for modems. You may use the call-out port if the serial cable or the terminal does not support the carrier detect signal.

If you have connected a terminal to the first serial port (`COM1` in MS-DOS), then you will use `/dev/ttyd0` to refer to the terminal. If the terminal is on the second serial port (also known as `COM2`), use `/dev/ttyd1`, and so forth.

17.2.3 Kernel Configuration

FreeBSD supports four serial ports by default. In the MS-DOS world, these are known as `COM1`, `COM2`, `COM3`, and `COM4`. FreeBSD currently supports "dumb" multiport serial interface cards, such as the BocaBoard 1008 and 2016, as well as more intelligent multi-port cards such as those made by Digiboard and Stallion Technologies. However, the default kernel only looks for the standard COM ports.

To see if your kernel recognizes any of your serial ports, watch for messages while the kernel is booting, or use the `/sbin/dmesg` command to replay the kernel's boot messages. In particular, look for messages that start with the characters `sio`.

> **Tip:** To view just the messages that have the word `sio`, use the command:
>
> ```
> # /sbin/dmesg | grep 'sio'
> ```

For example, on a system with four serial ports, these are the serial-port specific kernel boot messages:

```
sio0 at 0x3f8-0x3ff irq 4 on isa
sio0: type 16550A
sio1 at 0x2f8-0x2ff irq 3 on isa
sio1: type 16550A
sio2 at 0x3e8-0x3ef irq 5 on isa
```

```
sio2: type 16550A
sio3 at 0x2e8-0x2ef irq 9 on isa
sio3: type 16550A
```

If your kernel does not recognize all of your serial ports, you will probably need to configure a custom FreeBSD kernel for your system. For detailed information on configuring your kernel, please see Chapter 9.

The relevant device lines for your kernel configuration file would look like this, for FreeBSD 4.X:

```
device sio0 at isa? port IO_COM1 irq 4
device sio1 at isa? port IO_COM2 irq 3
device sio2 at isa? port IO_COM3 irq 5
device sio3 at isa? port IO_COM4 irq 9
```

and like this, for FreeBSD 5.X:

```
device sio
```

You can comment-out or completely remove lines for devices you do not have in the case of FreeBSD 4.X; for FreeBSD 5.X you have to edit your `/boot/device.hints` file to configure your serial ports. Please refer to the sio(4) manual page for more information on serial ports and multiport boards configuration. Be careful if you are using a configuration file that was previously used for a different version of FreeBSD because the device flags and the syntax have changed between versions.

> **Note:** `port IO_COM1` is a substitution for `port 0x3f8`, `IO_COM2` is `0x2f8`, `IO_COM3` is `0x3e8`, and `IO_COM4` is `0x2e8`, which are fairly common port addresses for their respective serial ports; interrupts 4, 3, 5, and 9 are fairly common interrupt request lines. Also note that regular serial ports *cannot* share interrupts on ISA-bus PCs (multiport boards have on-board electronics that allow all the 16550A's on the board to share one or two interrupt request lines).

17.2.4 Device Special Files

Most devices in the kernel are accessed through "device special files", which are located in the `/dev` directory. The `sio` devices are accessed through the `/dev/ttydN` (dial-in) and `/dev/cuaaN` (call-out) devices. FreeBSD also provides initialization devices (`/dev/ttyidN` and `/dev/cuaiaN`) and locking devices (`/dev/ttyldN` and `/dev/cualaN`). The initialization devices are used to initialize communications port parameters each time a port is opened, such as `crtscts` for modems which use `RTS/CTS` signaling for flow control. The locking devices are used to lock flags on ports to prevent users or programs changing certain parameters; see the manual pages termios(4), sio(4), and stty(1) for information on the terminal settings, locking and initializing devices, and setting terminal options, respectively.

17.2.4.1 Making Device Special Files

> **Note:** FreeBSD 5.0 includes the devfs(5) filesystem which automatically creates device nodes as needed. If you are running a version of FreeBSD with `devfs` enabled then you can safely skip this section.

A shell script called `MAKEDEV` in the `/dev` directory manages the device special files. To use `MAKEDEV` to make dial-up device special files for `COM1` (port 0), `cd` to `/dev` and issue the command `MAKEDEV ttyd0`. Likewise, to make dial-up device special files for `COM2` (port 1), use `MAKEDEV ttyd1`.

`MAKEDEV` not only creates the `/dev/ttydN` device special files, but also the `/dev/cuaaN`, `/dev/cuaiaN`, `/dev/cualaN`, `/dev/ttyldN`, and `/dev/ttyidN` nodes.

After making new device special files, be sure to check the permissions on the files (especially the `/dev/cua*` files) to make sure that only users who should have access to those device special files can read and write on them — you probably do not want to allow your average user to use your modems to dial-out. The default permissions on the `/dev/cua*` files should be sufficient:

```
crw-rw----    1 uucp     dialer    28, 129 Feb 15 14:38 /dev/cuaa1
crw-rw----    1 uucp     dialer    28, 161 Feb 15 14:38 /dev/cuaia1
crw-rw----    1 uucp     dialer    28, 193 Feb 15 14:38 /dev/cuala1
```

These permissions allow the user `uucp` and users in the group `dialer` to use the call-out devices.

17.2.5 Serial Port Configuration

The `ttydN` (or `cuaaN`) device is the regular device you will want to open for your applications. When a process opens the device, it will have a default set of terminal I/O settings. You can see these settings with the command

```
# stty -a -f /dev/ttyd1
```

When you change the settings to this device, the settings are in effect until the device is closed. When it is reopened, it goes back to the default set. To make changes to the default set, you can open and adjust the settings of the "initial state" device. For example, to turn on `CLOCAL` mode, 8 bit communication, and `XON/XOFF` flow control by default for `ttyd5`, type:

```
# stty -f /dev/ttyid5 clocal cs8 ixon ixoff
```

System-wide initialization of the serial devices is controlled in `/etc/rc.serial`. This file affects the default settings of serial devices.

To prevent certain settings from being changed by an application, make adjustments to the "lock state" device. For example, to lock the speed of `ttyd5` to 57600 bps, type:

```
# stty -f /dev/ttyld5 57600
```

Now, an application that opens `ttyd5` and tries to change the speed of the port will be stuck with 57600 bps.

Naturally, you should make the initial state and lock state devices writable only by the `root` account.

17.3 Terminals

Contributed by Sean Kelly.

Terminals provide a convenient and low-cost way to access your FreeBSD system when you are not at the computer's console or on a connected network. This section describes how to use terminals with FreeBSD.

17.3.1 Uses and Types of Terminals

The original UNIX systems did not have consoles. Instead, people logged in and ran programs through terminals that were connected to the computer's serial ports. It is quite similar to using a modem and terminal software to dial into a remote system to do text-only work.

Today's PCs have consoles capable of high quality graphics, but the ability to establish a login session on a serial port still exists in nearly every UNIX style operating system today; FreeBSD is no exception. By using a terminal attached to an unused serial port, you can log in and run any text program that you would normally run on the console or in an `xterm` window in the X Window System.

For the business user, you can attach many terminals to a FreeBSD system and place them on your employees' desktops. For a home user, a spare computer such as an older IBM PC or a Macintosh can be a terminal wired into a more powerful computer running FreeBSD. You can turn what might otherwise be a single-user computer into a powerful multiple user system.

For FreeBSD, there are three kinds of terminals:

- Dumb terminals
- PCs acting as terminals
- X terminals

The remaining subsections describe each kind.

17.3.1.1 Dumb Terminals

Dumb terminals are specialized pieces of hardware that let you connect to computers over serial lines. They are called "dumb" because they have only enough computational power to display, send, and receive text. You cannot run any programs on them. It is the computer to which you connect them that has all the power to run text editors, compilers, email, games, and so forth.

There are hundreds of kinds of dumb terminals made by many manufacturers, including Digital Equipment Corporation's VT-100 and Wyse's WY-75. Just about any kind will work with FreeBSD. Some high-end terminals can even display graphics, but only certain software packages can take advantage of these advanced features.

Dumb terminals are popular in work environments where workers do not need access to graphical applications such as those provided by the X Window System.

17.3.1.2 PCs Acting as Terminals

If a dumb terminal has just enough ability to display, send, and receive text, then certainly any spare personal computer can be a dumb terminal. All you need is the proper cable and some *terminal emulation* software to run on the computer.

Such a configuration is popular in homes. For example, if your spouse is busy working on your FreeBSD system's console, you can do some text-only work at the same time from a less powerful personal computer hooked up as a terminal to the FreeBSD system.

17.3.1.3 X Terminals

X terminals are the most sophisticated kind of terminal available. Instead of connecting to a serial port, they usually connect to a network like Ethernet. Instead of being relegated to text-only applications, they can display any X application.

We introduce X terminals just for the sake of completeness. However, this chapter does *not* cover setup, configuration, or use of X terminals.

17.3.2 Configuration

This section describes what you need to configure on your FreeBSD system to enable a login session on a terminal. It assumes you have already configured your kernel to support the serial port to which the terminal is connected—and that you have connected it.

Recall from Chapter 7 that the `init` process is responsible for all process control and initialization at system startup. One of the tasks performed by `init` is to read the `/etc/ttys` file and start a `getty` process on the available terminals. The `getty` process is responsible for reading a login name and starting the `login` program.

Thus, to configure terminals for your FreeBSD system the following steps should be taken as `root`:

1. Add a line to `/etc/ttys` for the entry in the `/dev` directory for the serial port if it is not already there.
2. Specify that `/usr/libexec/getty` be run on the port, and specify the appropriate *`getty`* type from the `/etc/gettytab` file.
3. Specify the default terminal type.
4. Set the port to "on."
5. Specify whether the port should be "secure."
6. Force `init` to reread the `/etc/ttys` file.

As an optional step, you may wish to create a custom *`getty`* type for use in step 2 by making an entry in `/etc/gettytab`. This chapter does not explain how to do so; you are encouraged to see the gettytab(5) and the getty(8) manual pages for more information.

17.3.2.1 Adding an Entry to `/etc/ttys`

The `/etc/ttys` file lists all of the ports on your FreeBSD system where you want to allow logins. For example, the first virtual console `ttyv0` has an entry in this file. You can log in on the console using this entry. This file also contains entries for the other virtual consoles, serial ports, and pseudo-ttys. For a hardwired terminal, just list the serial port's `/dev` entry without the `/dev` part (for example, `/dev/ttyv0` would be listed as `ttyv0`).

A default FreeBSD install includes an `/etc/ttys` file with support for the first four serial ports: `ttyd0` through `ttyd3`. If you are attaching a terminal to one of those ports, you do not need to add another entry.

Example 17-1. Adding Terminal Entries to `/etc/ttys`

Suppose we would like to connect two terminals to the system: a Wyse-50 and an old 286 IBM PC running **Procomm** terminal software emulating a VT-100 terminal. We connect the Wyse to the second serial port and the

286 to the sixth serial port (a port on a multiport serial card). The corresponding entries in the /etc/ttys file would look like this:

```
ttyd1❶  "/usr/libexec/getty std.38400"❷  wy50❸  on❹  insecure❺
ttyd5   "/usr/libexec/getty std.19200"  vt100  on  insecure
```

❶ The first field normally specifies the name of the terminal special file as it is found in /dev.

❷ The second field is the command to execute for this line, which is usually getty(8). getty initializes and opens the line, sets the speed, prompts for a user name and then executes the login(1) program.

The getty program accepts one (optional) parameter on its command line, the *getty* type. A *getty* type configures characteristics on the terminal line, like bps rate and parity. The getty program reads these characteristics from the file /etc/gettytab.

The file /etc/gettytab contains lots of entries for terminal lines both old and new. In almost all cases, the entries that start with the text std will work for hardwired terminals. These entries ignore parity. There is a std entry for each bps rate from 110 to 115200. Of course, you can add your own entries to this file. The gettytab(5) manual page provides more information.

When setting the *getty* type in the /etc/ttys file, make sure that the communications settings on the terminal match.

For our example, the Wyse-50 uses no parity and connects at 38400 bps. The 286 PC uses no parity and connects at 19200 bps.

❸ The third field is the type of terminal usually connected to that tty line. For dial-up ports, unknown or dialup is typically used in this field since users may dial up with practically any type of terminal or software. For hardwired terminals, the terminal type does not change, so you can put a real terminal type from the termcap(5) database file in this field.

For our example, the Wyse-50 uses the real terminal type while the 286 PC running **Procomm** will be set to emulate at VT-100.

❹ The fourth field specifies if the port should be enabled. Putting on here will have the init process start the program in the second field, getty. If you put off in this field, there will be no getty, and hence no logins on the port.

❺ The final field is used to specify whether the port is secure. Marking a port as secure means that you trust it enough to allow the root account (or any account with a user ID of 0) to login from that port. Insecure ports do not allow root logins. On an insecure port, users must login from unprivileged accounts and then use su(1) or a similar mechanism to gain superuser privileges.

It is highly recommended that you use "insecure" even for terminals that are behind locked doors. It is quite easy to login and use su if you need superuser privileges.

17.3.2.2 Force init to Reread /etc/ttys

After making the necessary changes to the /etc/ttys file you should send a SIGHUP (hangup) signal to the init process to force it to re-read its configuration file. For example:

```
# kill -HUP 1
```

Note: `init` is always the first process run on a system, therefore it will always have PID 1.

If everything is set up correctly, all cables are in place, and the terminals are powered up, then a `getty` process should be running on each terminal and you should see login prompts on your terminals at this point.

17.3.3 Troubleshooting Your Connection

Even with the most meticulous attention to detail, something could still go wrong while setting up a terminal. Here is a list of symptoms and some suggested fixes.

17.3.3.1 No Login Prompt Appears

Make sure the terminal is plugged in and powered up. If it is a personal computer acting as a terminal, make sure it is running terminal emulation software on the correct serial port.

Make sure the cable is connected firmly to both the terminal and the FreeBSD computer. Make sure it is the right kind of cable.

Make sure the terminal and FreeBSD agree on the bps rate and parity settings. If you have a video display terminal, make sure the contrast and brightness controls are turned up. If it is a printing terminal, make sure paper and ink are in good supply.

Make sure that a `getty` process is running and serving the terminal. For example, to get a list of running `getty` processes with `ps`, type:

```
# ps -axww|grep getty
```

You should see an entry for the terminal. For example, the following display shows that a `getty` is running on the second serial port `ttyd1` and is using the `std.38400` entry in `/etc/gettytab`:

```
22189  d1  Is+    0:00.03 /usr/libexec/getty std.38400 ttyd1
```

If no `getty` process is running, make sure you have enabled the port in `/etc/ttys`. Also remember to run `kill -HUP 1` after modifying the `ttys` file.

If the `getty` process is running but the terminal still does not display a login prompt, or if it displays a prompt but will not allow you to type, your terminal or cable may not support hardware handshaking. Try changing the entry in `/etc/ttys` from `std.38400` to `3wire.38400` remember to run `kill -HUP 1` after modifying `/etc/ttys`). The `3wire` entry is similar to `std`, but ignores hardware handshaking. You may need to reduce the baud rate or enable software flow control when using `3wire` to prevent buffer overflows.

17.3.3.2 If Garbage Appears Instead of a Login Prompt

Make sure the terminal and FreeBSD agree on the bps rate and parity settings. Check the `getty` processes to make sure the correct *`getty`* type is in use. If not, edit `/etc/ttys` and run `kill -HUP 1`.

17.3.3.3 Characters Appear Doubled; the Password Appears When Typed

Switch the terminal (or the terminal emulation software) from "half duplex" or "local echo" to "full duplex."

17.4 Dial-in Service

Contributed by Guy Helmer. Additions by Sean Kelly.

Configuring your FreeBSD system for dial-in service is very similar to connecting terminals except that you are dealing with modems instead of terminals.

17.4.1 External vs. Internal Modems

External modems seem to be more convenient for dial-up, because external modems often can be semi-permanently configured via parameters stored in non-volatile RAM and they usually provide lighted indicators that display the state of important RS-232 signals. Blinking lights impress visitors, but lights are also very useful to see whether a modem is operating properly.

Internal modems usually lack non-volatile RAM, so their configuration may be limited only to setting DIP switches. If your internal modem has any signal indicator lights, it is probably difficult to view the lights when the system's cover is in place.

17.4.1.1 Modems and Cables

If you are using an external modem, then you will of course need the proper cable. A standard RS-232C serial cable should suffice as long as all of the normal signals are wired:

- Transmitted Data (SD)
- Received Data (RD)
- Request to Send (RTS)
- Clear to Send (CTS)
- Data Set Ready (DSR)
- Data Terminal Ready (DTR)
- Carrier Detect (CD)
- Signal Ground (SG)

FreeBSD needs the RTS and CTS signals for flow-control at speeds above 2400 bps, the CD signal to detect when a call has been answered or the line has been hung up, and the DTR signal to reset the modem after a session is complete. Some cables are wired without all of the needed signals, so if you have problems, such as a login session not going away when the line hangs up, you may have a problem with your cable.

Like other UNIX like operating systems, FreeBSD uses the hardware signals to find out when a call has been answered or a line has been hung up and to hangup and reset the modem after a call. FreeBSD avoids sending commands to the modem or watching for status reports from the modem. If you are familiar with connecting modems to PC-based bulletin board systems, this may seem awkward.

17.4.2 Serial Interface Considerations

FreeBSD supports NS8250-, NS16450-, NS16550-, and NS16550A-based EIA RS-232C (CCITT V.24) communications interfaces. The 8250 and 16450 devices have single-character buffers. The 16550 device provides a 16-character buffer, which allows for better system performance. (Bugs in plain 16550's prevent the use of the 16-character buffer, so use 16550A's if possible). Because single-character-buffer devices require more work by the operating system than the 16-character-buffer devices, 16550A-based serial interface cards are much preferred. If the system has many active serial ports or will have a heavy load, 16550A-based cards are better for low-error-rate communications.

17.4.3 Quick Overview

As with terminals, `init` spawns a `getty` process for each configured serial port for dial-in connections. For example, if a modem is attached to `/dev/ttyd0`, the command `ps ax` might show this:

```
 4850 ??  I      0:00.09 /usr/libexec/getty V19200 ttyd0
```

When a user dials the modem's line and the modems connect, the CD (Carrier Detect) line is reported by the modem. The kernel notices that carrier has been detected and completes `getty`'s open of the port. `getty` sends a `login:` prompt at the specified initial line speed. `getty` watches to see if legitimate characters are received, and, in a typical configuration, if it finds junk (probably due to the modem's connection speed being different than `getty`'s speed), `getty` tries adjusting the line speeds until it receives reasonable characters.

After the user enters his/her login name, `getty` executes `/usr/bin/login`, which completes the login by asking for the user's password and then starting the user's shell.

17.4.4 Configuration Files

There are three system configuration files in the `/etc` directory that you will probably need to edit to allow dial-up access to your FreeBSD system. The first, `/etc/gettytab`, contains configuration information for the `/usr/libexec/getty` daemon. Second, `/etc/ttys` holds information that tells `/sbin/init` what `tty` devices should have `getty` processes running on them. Lastly, you can place port initialization commands in the `/etc/rc.serial` script.

There are two schools of thought regarding dial-up modems on UNIX. One group likes to configure their modems and systems so that no matter at what speed a remote user dials in, the local computer-to-modem RS-232 interface runs at a locked speed. The benefit of this configuration is that the remote user always sees a system login prompt immediately. The downside is that the system does not know what a user's true data rate is, so full-screen programs like Emacs will not adjust their screen-painting methods to make their response better for slower connections.

The other school configures their modems' RS-232 interface to vary its speed based on the remote user's connection speed. For example, V.32bis (14.4 Kbps) connections to the modem might make the modem run its RS-232 interface at 19.2 Kbps, while 2400 bps connections make the modem's RS-232 interface run at 2400 bps. Because `getty` does not understand any particular modem's connection speed reporting, `getty` gives a `login:` message at an initial speed and watches the characters that come back in response. If the user sees junk, it is assumed that they know they should press the Enter key until they see a recognizable prompt. If the data rates do not match, `getty` sees anything the user types as "junk", tries going to the next speed and gives the `login:` prompt again. This procedure can continue ad nauseam, but normally only takes a keystroke or two before the user sees a good prompt. Obviously, this login sequence does not look as clean as the former "locked-speed" method, but a user on a low-speed connection should receive better interactive response from full-screen programs.

This section will try to give balanced configuration information, but is biased towards having the modem's data rate follow the connection rate.

17.4.4.1 `/etc/gettytab`

`/etc/gettytab` is a termcap(5)-style file of configuration information for getty(8). Please see the gettytab(5) manual page for complete information on the format of the file and the list of capabilities.

17.4.4.1.1 Locked-speed Config

If you are locking your modem's data communications rate at a particular speed, you probably will not need to make any changes to `/etc/gettytab`.

17.4.4.1.2 Matching-speed Config

You will need to set up an entry in `/etc/gettytab` to give `getty` information about the speeds you wish to use for your modem. If you have a 2400 bps modem, you can probably use the existing `D2400` entry.

```
#
# Fast dialup terminals, 2400/1200/300 rotary (can start either way)
#
D2400|d2400|Fast-Dial-2400:\
        :nx=D1200:tc=2400-baud:
3|D1200|Fast-Dial-1200:\
        :nx=D300:tc=1200-baud:
5|D300|Fast-Dial-300:\
        :nx=D2400:tc=300-baud:
```

If you have a higher speed modem, you will probably need to add an entry in `/etc/gettytab`; here is an entry you could use for a 14.4 Kbps modem with a top interface speed of 19.2 Kbps:

```
#
# Additions for a V.32bis Modem
#
um|V300|High Speed Modem at 300,8-bit:\
        :nx=V19200:tc=std.300:
un|V1200|High Speed Modem at 1200,8-bit:\
        :nx=V300:tc=std.1200:
uo|V2400|High Speed Modem at 2400,8-bit:\
        :nx=V1200:tc=std.2400:
up|V9600|High Speed Modem at 9600,8-bit:\
        :nx=V2400:tc=std.9600:
uq|V19200|High Speed Modem at 19200,8-bit:\
        :nx=V9600:tc=std.19200:
```

This will result in 8-bit, no parity connections.

The example above starts the communications rate at 19.2 Kbps (for a V.32bis connection), then cycles through 9600 bps (for V.32), 2400 bps, 1200 bps, 300 bps, and back to 19.2 Kbps. Communications rate cycling is implemented with the `nx=` ("next table") capability. Each of the lines uses a `tc=` ("table continuation") entry to pick up the rest of the "standard" settings for a particular data rate.

If you have a 28.8 Kbps modem and/or you want to take advantage of compression on a 14.4 Kbps modem, you need to use a higher communications rate than 19.2 Kbps. Here is an example of a `gettytab` entry starting a 57.6 Kbps:

```
#
# Additions for a V.32bis or V.34 Modem
# Starting at 57.6 Kbps
#
vm|VH300|Very High Speed Modem at 300,8-bit:\
        :nx=VH57600:tc=std.300:
vn|VH1200|Very High Speed Modem at 1200,8-bit:\
        :nx=VH300:tc=std.1200:
vo|VH2400|Very High Speed Modem at 2400,8-bit:\
        :nx=VH1200:tc=std.2400:
vp|VH9600|Very High Speed Modem at 9600,8-bit:\
        :nx=VH2400:tc=std.9600:
vq|VH57600|Very High Speed Modem at 57600,8-bit:\
        :nx=VH9600:tc=std.57600:
```

If you have a slow CPU or a heavily loaded system and do not have 16550A-based serial ports, you may receive `sio` “silo” errors at 57.6 Kbps.

17.4.4.2 `/etc/ttys`

Configuration of the `/etc/ttys` file was covered in Example 17-1. Configuration for modems is similar but we must pass a different argument to `getty` and specify a different terminal type. The general format for both locked-speed and matching-speed configurations is:

```
ttyd0   "/usr/libexec/getty xxx"   dialup on
```

The first item in the above line is the device special file for this entry — `ttyd0` means `/dev/ttyd0` is the file that this `getty` will be watching. The second item, `"/usr/libexec/getty xxx"` (*xxx* will be replaced by the initial `gettytab` capability) is the process `init` will run on the device. The third item, `dialup`, is the default terminal type. The fourth parameter, `on`, indicates to `init` that the line is operational. There can be a fifth parameter, `secure`, but it should only be used for terminals which are physically secure (such as the system console).

The default terminal type (`dialup` in the example above) may depend on local preferences. `dialup` is the traditional default terminal type on dial-up lines so that users may customize their login scripts to notice when the terminal is `dialup` and automatically adjust their terminal type. However, the author finds it easier at his site to specify `vt102` as the default terminal type, since the users just use VT102 emulation on their remote systems.

After you have made changes to `/etc/ttys`, you may send the `init` process a HUP signal to re-read the file. You can use the command

```
# kill -HUP 1
```

to send the signal. If this is your first time setting up the system, you may want to wait until your modem(s) are properly configured and connected before signaling `init`.

17.4.4.2.1 Locked-speed Config

For a locked-speed configuration, your `ttys` entry needs to have a fixed-speed entry provided to `getty`. For a modem whose port speed is locked at 19.2 Kbps, the `ttys` entry might look like this:

```
ttyd0   "/usr/libexec/getty std.19200"   dialup on
```

If your modem is locked at a different data rate, substitute the appropriate value for `std.speed` instead of `std.19200`. Make sure that you use a valid type listed in `/etc/gettytab`.

17.4.4.2.2 Matching-speed Config

In a matching-speed configuration, your `ttys` entry needs to reference the appropriate beginning "auto-baud" (sic) entry in `/etc/gettytab`. For example, if you added the above suggested entry for a matching-speed modem that starts at 19.2 Kbps (the `gettytab` entry containing the `V19200` starting point), your `ttys` entry might look like this:

```
ttyd0   "/usr/libexec/getty V19200"   dialup on
```

17.4.4.3 /etc/rc.serial

High-speed modems, like V.32, V.32bis, and V.34 modems, need to use hardware (`RTS/CTS`) flow control. You can add `stty` commands to `/etc/rc.serial` to set the hardware flow control flag in the FreeBSD kernel for the modem ports.

For example to set the `termios` flag `crtscts` on serial port #1's (`COM2`) dial-in and dial-out initialization devices, the following lines could be added to `/etc/rc.serial`:

```
# Serial port initial configuration
stty -f /dev/ttyid1 crtscts
stty -f /dev/cuaia1 crtscts
```

17.4.5 Modem Settings

If you have a modem whose parameters may be permanently set in non-volatile RAM, you will need to use a terminal program (such as Telix under MS-DOS or `tip` under FreeBSD) to set the parameters. Connect to the modem using the same communications speed as the initial speed `getty` will use and configure the modem's non-volatile RAM to match these requirements:

- CD asserted when connected
- DTR asserted for operation; dropping DTR hangs up line and resets modem
- CTS transmitted data flow control
- Disable XON/XOFF flow control
- RTS received data flow control
- Quiet mode (no result codes)

- No command echo

Please read the documentation for your modem to find out what commands and/or DIP switch settings you need to give it.

For example, to set the above parameters on a U.S. Robotics® Sportster® 14,400 external modem, one could give these commands to the modem:

```
ATZ
AT&C1&D2&H1&I0&R2&W
```

You might also want to take this opportunity to adjust other settings in the modem, such as whether it will use V.42bis and/or MNP5 compression.

The U.S. Robotics Sportster 14,400 external modem also has some DIP switches that need to be set; for other modems, perhaps you can use these settings as an example:

- Switch 1: UP — DTR Normal
- Switch 2: N/A (Verbal Result Codes/Numeric Result Codes)
- Switch 3: UP — Suppress Result Codes
- Switch 4: DOWN — No echo, offline commands
- Switch 5: UP — Auto Answer
- Switch 6: UP — Carrier Detect Normal
- Switch 7: UP — Load NVRAM Defaults
- Switch 8: N/A (Smart Mode/Dumb Mode)

Result codes should be disabled/suppressed for dial-up modems to avoid problems that can occur if `getty` mistakenly gives a `login:` prompt to a modem that is in command mode and the modem echoes the command or returns a result code. This sequence can result in a extended, silly conversation between `getty` and the modem.

17.4.5.1 Locked-speed Config

For a locked-speed configuration, you will need to configure the modem to maintain a constant modem-to-computer data rate independent of the communications rate. On a U.S. Robotics Sportster 14,400 external modem, these commands will lock the modem-to-computer data rate at the speed used to issue the commands:

```
ATZ
AT&B1&W
```

17.4.5.2 Matching-speed Config

For a variable-speed configuration, you will need to configure your modem to adjust its serial port data rate to match the incoming call rate. On a U.S. Robotics Sportster 14,400 external modem, these commands will lock the modem's error-corrected data rate to the speed used to issue the commands, but allow the serial port rate to vary for non-error-corrected connections:

```
ATZ
AT&B2&W
```

17.4.5.3 Checking the Modem's Configuration

Most high-speed modems provide commands to view the modem's current operating parameters in a somewhat human-readable fashion. On the U.S. Robotics Sportster 14,400 external modems, the command `ATI5` displays the settings that are stored in the non-volatile RAM. To see the true operating parameters of the modem (as influenced by the modem's DIP switch settings), use the commands `ATZ` and then `ATI4`.

If you have a different brand of modem, check your modem's manual to see how to double-check your modem's configuration parameters.

17.4.6 Troubleshooting

Here are a few steps you can follow to check out the dial-up modem on your system.

17.4.6.1 Checking Out the FreeBSD System

Hook up your modem to your FreeBSD system, boot the system, and, if your modem has status indication lights, watch to see whether the modem's DTR indicator lights when the `login:` prompt appears on the system's console — if it lights up, that should mean that FreeBSD has started a `getty` process on the appropriate communications port and is waiting for the modem to accept a call.

If the DTR indicator does not light, login to the FreeBSD system through the console and issue a `ps ax` to see if FreeBSD is trying to run a `getty` process on the correct port. You should see lines like these among the processes displayed:

```
114 ??  I      0:00.10 /usr/libexec/getty V19200 ttyd0
115 ??  I      0:00.10 /usr/libexec/getty V19200 ttyd1
```

If you see something different, like this:

```
114 d0  I      0:00.10 /usr/libexec/getty V19200 ttyd0
```

and the modem has not accepted a call yet, this means that `getty` has completed its open on the communications port. This could indicate a problem with the cabling or a mis-configured modem, because `getty` should not be able to open the communications port until CD (carrier detect) has been asserted by the modem.

If you do not see any `getty` processes waiting to open the desired `ttydN` port, double-check your entries in `/etc/ttys` to see if there are any mistakes there. Also, check the log file `/var/log/messages` to see if there are any log messages from `init` or `getty` regarding any problems. If there are any messages, triple-check the configuration files `/etc/ttys` and `/etc/gettytab`, as well as the appropriate device special files `/dev/ttydN`, for any mistakes, missing entries, or missing device special files.

17.4.6.2 Try Dialing In

Try dialing into the system; be sure to use 8 bits, no parity, and 1 stop bit on the remote system. If you do not get a prompt right away, or get garbage, try pressing Enter about once per second. If you still do not see a `login:` prompt after a while, try sending a `BREAK`. If you are using a high-speed modem to do the dialing, try dialing again after locking the dialing modem's interface speed (via `AT&B1` on a U.S. Robotics Sportster modem, for example).

If you still cannot get a `login:` prompt, check `/etc/gettytab` again and double-check that

- The initial capability name specified in `/etc/ttys` for the line matches a name of a capability in `/etc/gettytab`
- Each `nx=` entry matches another `gettytab` capability name
- Each `tc=` entry matches another `gettytab` capability name

If you dial but the modem on the FreeBSD system will not answer, make sure that the modem is configured to answer the phone when DTR is asserted. If the modem seems to be configured correctly, verify that the DTR line is asserted by checking the modem's indicator lights (if it has any).

If you have gone over everything several times and it still does not work, take a break and come back to it later. If it still does not work, perhaps you can send an electronic mail message to the FreeBSD general questions mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-questions) describing your modem and your problem, and the good folks on the list will try to help.

17.5 Dial-out Service

The following are tips for getting your host to be able to connect over the modem to another computer. This is appropriate for establishing a terminal session with a remote host.

This is useful to log onto a BBS.

This kind of connection can be extremely helpful to get a file on the Internet if you have problems with PPP. If you need to FTP something and PPP is broken, use the terminal session to FTP it. Then use zmodem to transfer it to your machine.

17.5.1 My Stock Hayes Modem Is Not Supported, What Can I Do?

Actually, the manual page for `tip` is out of date. There is a generic Hayes dialer already built in. Just use `at=hayes` in your `/etc/remote` file.

The Hayes driver is not smart enough to recognize some of the advanced features of newer modems—messages like `BUSY`, `NO DIALTONE`, or `CONNECT 115200` will just confuse it. You should turn those messages off when you use `tip` (using `ATX0&W`).

Also, the dial timeout for `tip` is 60 seconds. Your modem should use something less, or else tip will think there is a communication problem. Try `ATS7=45&W`.

> **Note:** As shipped, `tip` does not yet support Hayes modems fully. The solution is to edit the file `tipconf.h` in the directory `/usr/src/usr.bin/tip/tip`. Obviously you need the source distribution to do this.
>
> Edit the line `#define HAYES 0` to `#define HAYES 1`. Then `make` and `make install`. Everything works nicely after that.

17.5.2 How Am I Expected to Enter These AT Commands?

Make what is called a "direct" entry in your `/etc/remote` file. For example, if your modem is hooked up to the first serial port, `/dev/cuaa0`, then put in the following line:

```
cuaa0:dv=/dev/cuaa0:br#19200:pa=none
```

Use the highest bps rate your modem supports in the br capability. Then, type `tip cuaa0` and you will be connected to your modem.

If there is no `/dev/cuaa0` on your system, do this:

```
# cd /dev
# sh MAKEDEV cuaa0
```

Or use `cu` as `root` with the following command:

```
# cu -lline -sspeed
```

line is the serial port (e.g.`/dev/cuaa0`) and *speed* is the speed (e.g.`57600`). When you are done entering the AT commands hit **~.** to exit.

17.5.3 The @ Sign for the pn Capability Does Not Work!

The `@` sign in the phone number capability tells tip to look in `/etc/phones` for a phone number. But the `@` sign is also a special character in capability files like `/etc/remote`. Escape it with a backslash:

```
pn=\@
```

17.5.4 How Can I Dial a Phone Number on the Command Line?

Put what is called a "generic" entry in your `/etc/remote` file. For example:

```
tip115200|Dial any phone number at 115200 bps:\
        :dv=/dev/cuaa0:br#115200:at=hayes:pa=none:du:
tip57600|Dial any phone number at 57600 bps:\
        :dv=/dev/cuaa0:br#57600:at=hayes:pa=none:du:
```

Then you can do things like:

```
# tip -115200 5551234
```

If you prefer `cu` over `tip`, use a generic `cu` entry:

```
cu115200|Use cu to dial any number at 115200bps:\
        :dv=/dev/cuaa1:br#57600:at=hayes:pa=none:du:
```

and type:

```
# cu 5551234 -s 115200
```

17.5.5 Do I Have to Type in the bps Rate Every Time I Do That?

Put in an entry for `tip1200` or `cu1200`, but go ahead and use whatever bps rate is appropriate with the br capability. `tip` thinks a good default is 1200 bps which is why it looks for a `tip1200` entry. You do not have to use 1200 bps, though.

17.5.6 I Access a Number of Hosts Through a Terminal Server

Rather than waiting until you are connected and typing `CONNECT <host>` each time, use tip's `cm` capability. For example, these entries in `/etc/remote`:

```
pain|pain.deep13.com|Forrester's machine:\
        :cm=CONNECT pain\n:tc=deep13:
muffin|muffin.deep13.com|Frank's machine:\
        :cm=CONNECT muffin\n:tc=deep13:
deep13:Gizmonics Institute terminal server:\
        :dv=/dev/cuaa2:br#38400:at=hayes:du:pa=none:pn=5551234:
```

will let you type `tip pain` or `tip muffin` to connect to the hosts pain or muffin, and `tip deep13` to get to the terminal server.

17.5.7 Can Tip Try More Than One Line for Each Site?

This is often a problem where a university has several modem lines and several thousand students trying to use them.

Make an entry for your university in `/etc/remote` and use `@` for the `pn` capability:

```
big-university:\
        :pn=\@:tc=dialout
dialout:\
        :dv=/dev/cuaa3:br#9600:at=courier:du:pa=none:
```

Then, list the phone numbers for the university in `/etc/phones`:

```
big-university 5551111
big-university 5551112
big-university 5551113
big-university 5551114
```

`tip` will try each one in the listed order, then give up. If you want to keep retrying, run `tip` in a while loop.

17.5.8 Why Do I Have to Hit Ctrl+P Twice to Send Ctrl+P Once?

Ctrl+**P** is the default "force" character, used to tell `tip` that the next character is literal data. You can set the force character to any other character with the `~s` escape, which means "set a variable."

Type `~sforce=`*`single-char`* followed by a newline. *`single-char`* is any single character. If you leave out *`single-char`*, then the force character is the nul character, which you can get by typing **Ctrl**+**2** or **Ctrl**+**Space**. A pretty good value for *`single-char`* is **Shift**+**Ctrl**+**6**, which is only used on some terminal servers.

You can have the force character be whatever you want by specifying the following in your `$HOME/.tiprc` file:

```
force=<single-char>
```

17.5.9 Suddenly Everything I Type Is in Upper Case??

You must have pressed **Ctrl**+**A**, `tip`'s "raise character," specially designed for people with broken caps-lock keys. Use `~s` as above and set the variable `raisechar` to something reasonable. In fact, you can set it to the same as the force character, if you never expect to use either of these features.

Here is a sample .tiprc file perfect for **Emacs** users who need to type **Ctrl**+**2** and **Ctrl**+**A** a lot:

```
force=^^
raisechar=^^
```

The ^^ is **Shift**+**Ctrl**+**6**.

17.5.10 How Can I Do File Transfers with `tip`?

If you are talking to another UNIX system, you can send and receive files with `~p` (put) and `~t` (take). These commands run `cat` and `echo` on the remote system to accept and send files. The syntax is:

`~p` local-file [remote-file]

`~t` remote-file [local-file]

There is no error checking, so you probably should use another protocol, like zmodem.

17.5.11 How Can I Run zmodem with `tip`?

To receive files, start the sending program on the remote end. Then, type `~C rz` to begin receiving them locally.

To send files, start the receiving program on the remote end. Then, type `~C sz` *`files`* to send them to the remote system.

17.6 Setting Up the Serial Console

Contributed by Kazutaka YOKOTA. Based on a document by Bill Paul.

17.6.1 Introduction

FreeBSD has the ability to boot on a system with only a dumb terminal on a serial port as a console. Such a configuration should be useful for two classes of people: system administrators who wish to install FreeBSD on machines that have no keyboard or monitor attached, and developers who want to debug the kernel or device drivers.

As described in Chapter 7, FreeBSD employs a three stage bootstrap. The first two stages are in the boot block code which is stored at the beginning of the FreeBSD slice on the boot disk. The boot block will then load and run the boot loader (`/boot/loader`) as the third stage code.

In order to set up the serial console you must configure the boot block code, the boot loader code and the kernel.

17.6.2 Serial Console Configuration

1. Prepare a serial cable.

   You will need either a null-modem cable or a standard serial cable and a null-modem adapter. See Section 17.2.2 for a discussion on serial cables.

2. Unplug your keyboard.

   Most PC systems probe for the keyboard during the Power-On Self-Test (POST) and will generate an error if the keyboard is not detected. Some machines complain loudly about the lack of a keyboard and will not continue to boot until it is plugged in.

   If your computer complains about the error, but boots anyway, then you do not have to do anything special. (Some machines with Phoenix BIOS installed merely say `Keyboard failed` and continue to boot normally.)

   If your computer refuses to boot without a keyboard attached then you will have to configure the BIOS so that it ignores this error (if it can). Consult your motherboard's manual for details on how to do this.

   > **Tip:** Setting the keyboard to "Not installed" in the BIOS setup does *not* mean that you will not be able to use your keyboard. All this does is tell the BIOS not to probe for a keyboard at power-on, so it will not complain if the keyboard is not plugged in. You can leave the keyboard plugged in even with this flag set to "Not installed" and the keyboard will still work.

   > **Note:** If your system has a PS/2® mouse, chances are very good that you may have to unplug your mouse as well as your keyboard. This is because PS/2 mice share some hardware with the keyboard and leaving the mouse plugged in can fool the keyboard probe into thinking the keyboard is still there. It is said that a Gateway 2000 Pentium 90 MHz system with an AMI BIOS that behaves this way. In general, this is not a problem since the mouse is not much good without the keyboard anyway.

3. Plug a dumb terminal into `COM1` (`sio0`).

   If you do not have a dumb terminal, you can use an old PC/XT with a modem program, or the serial port on another UNIX box. If you do not have a `COM1` (`sio0`), get one. At this time, there is no way to select a port other than `COM1` for the boot blocks without recompiling the boot blocks. If you are already using `COM1` for another device, you will have to temporarily remove that device and install a new boot block and kernel once you get FreeBSD up and running. (It is assumed that `COM1` will be available on a file/compute/terminal server anyway; if you really need `COM1` for something else (and you cannot switch that something else to `COM2` (`sio1`)), then you probably should not even be bothering with all this in the first place.)

4. Make sure the configuration file of your kernel has appropriate flags set for `COM1` (`sio0`).

   Relevant flags are:

   `0x10`

   Enables console support for this unit. The other console flags are ignored unless this is set. Currently, at most one unit can have console support; the first one (in config file order) with this flag set is preferred.

This option alone will not make the serial port the console. Set the following flag or use the `-h` option described below, together with this flag.

`0x20`

Forces this unit to be the console (unless there is another higher priority console), regardless of the `-h` option discussed below. This flag replaces the `COMCONSOLE` option in FreeBSD versions 2.*X*. The flag `0x20` must be used together with the `0x10` flag.

`0x40`

Reserves this unit (in conjunction with `0x10`) and makes the unit unavailable for normal access. You should not set this flag to the serial port unit which you want to use as the serial console. The only use of this flag is to designate the unit for kernel remote debugging. See The Developer's Handbook (../developers-handbook/index.html) for more information on remote debugging.

> **Note:** In FreeBSD 4.0 or later the semantics of the flag `0x40` are slightly different and there is another flag to specify a serial port for remote debugging.

Example:

```
device sio0 at isa? port IO_COM1 flags 0x10 irq 4
```

See the sio(4) manual page for more details.

If the flags were not set, you need to run UserConfig (on a different console) or recompile the kernel.

5. Create `boot.config` in the root directory of the `a` partition on the boot drive.

This file will instruct the boot block code how you would like to boot the system. In order to activate the serial console, you need one or more of the following options—if you want multiple options, include them all on the same line:

`-h`

Toggles internal and serial consoles. You can use this to switch console devices. For instance, if you boot from the internal (video) console, you can use `-h` to direct the boot loader and the kernel to use the serial port as its console device. Alternatively, if you boot from the serial port, you can use the `-h` to tell the boot loader and the kernel to use the video display as the console instead.

`-D`

Toggles single and dual console configurations. In the single configuration the console will be either the internal console (video display) or the serial port, depending on the state of the `-h` option above. In the dual console configuration, both the video display and the serial port will become the console at the same time, regardless of the state of the `-h` option. However, note that the dual console configuration takes effect only during the boot block is running. Once the boot loader gets control, the console specified by the `-h` option becomes the only console.

`-P`

Makes the boot block probe the keyboard. If no keyboard is found, the `-D` and `-h` options are automatically set.

> **Note:** Due to space constraints in the current version of the boot blocks, the `-P` option is capable of detecting extended keyboards only. Keyboards with less than 101 keys (and without F11 and F12 keys) may not be detected. Keyboards on some laptop computers may not be properly found because of this limitation. If this is the case with your system, you have to abandon using the `-P` option. Unfortunately there is no workaround for this problem.

Use either the `-P` option to select the console automatically, or the `-h` option to activate the serial console.

You may include other options described in boot(8) as well.

The options, except for `-P`, will be passed to the boot loader (`/boot/loader`). The boot loader will determine which of the internal video or the serial port should become the console by examining the state of the `-h` option alone. This means that if you specify the `-D` option but not the `-h` option in `/boot.config`, you can use the serial port as the console only during the boot block; the boot loader will use the internal video display as the console.

6. Boot the machine.

   When you start your FreeBSD box, the boot blocks will echo the contents of `/boot.config` to the console. For example:

```
/boot.config: -P
Keyboard: no
```

The second line appears only if you put `-P` in `/boot.config` and indicates presence/absence of the keyboard. These messages go to either serial or internal console, or both, depending on the option in `/boot.config`.

Options	Message goes to
none	internal console
`-h`	serial console
`-D`	serial and internal consoles
`-Dh`	serial and internal consoles
`-P`, keyboard present	internal console
`-P`, keyboard absent	serial console

After the above messages, there will be a small pause before the boot blocks continue loading the boot loader and before any further messages printed to the console. Under normal circumstances, you do not need to interrupt the boot blocks, but you may want to do so in order to make sure things are set up correctly.

Hit any key, other than Enter, at the console to interrupt the boot process. The boot blocks will then prompt you for further action. You should now see something like:

```
>> FreeBSD/i386 BOOT
Default: 0:wd(0,a)/boot/loader
boot:
```

Verify the above message appears on either the serial or internal console or both, according to the options you put in `/boot.config`. If the message appears in the correct console, hit Enter to continue the boot process.

If you want the serial console but you do not see the prompt on the serial terminal, something is wrong with your settings. In the meantime, you enter `-h` and hit Enter/Return (if possible) to tell the boot block (and then the boot loader and the kernel) to choose the serial port for the console. Once the system is up, go back and check what went wrong.

After the boot loader is loaded and you are in the third stage of the boot process you can still switch between the internal console and the serial console by setting appropriate environment variables in the boot loader. See Section 17.6.5.

17.6.3 Summary

Here is the summary of various settings discussed in this section and the console eventually selected.

17.6.3.1 Case 1: You Set the Flags to 0x10 for `sio0`

```
device sio0 at isa? port IO_COM1 flags 0x10 irq 4
```

Options in /boot.config	Console during boot blocks	Console during boot loader	Console in kernel
nothing	internal	internal	internal
`-h`	serial	serial	serial
`-D`	serial and internal	internal	internal
`-Dh`	serial and internal	serial	serial
`-P`, keyboard present	internal	internal	internal
`-P`, keyboard absent	serial and internal	serial	serial

17.6.3.2 Case 2: You Set the Flags to 0x30 for sio0

```
device sio0 at isa? port IO_COM1 flags 0x30 irq 4
```

Options in /boot.config	Console during boot blocks	Console during boot loader	Console in kernel
nothing	internal	internal	serial
`-h`	serial	serial	serial
`-D`	serial and internal	internal	serial
`-Dh`	serial and internal	serial	serial
`-P`, keyboard present	internal	internal	serial
`-P`, keyboard absent	serial and internal	serial	serial

17.6.4 Tips for the Serial Console

17.6.4.1 Setting a Faster Serial Port Speed

By default, the serial port settings are: 9600 baud, 8 bits, no parity, and 1 stop bit. If you wish to change the speed, you need to recompile at least the boot blocks. Add the following line to `/etc/make.conf` and compile new boot blocks:

```
BOOT_COMCONSOLE_SPEED=19200
```

If the serial console is configured in some other way than by booting with `-h`, or if the serial console used by the kernel is different from the one used by the boot blocks, then you must also add the following option to the kernel configuration file and compile a new kernel:

```
options CONSPEED=19200
```

17.6.4.2 Using Serial Port Other Than `sio0` for the Console

Using a port other than `sio0` as the console requires some recompiling. If you want to use another serial port for whatever reasons, recompile the boot blocks, the boot loader and the kernel as follows.

1. Get the kernel source. (See Chapter 21)
2. Edit `/etc/make.conf` and set `BOOT_COMCONSOLE_PORT` to the address of the port you want to use (0x3F8, 0x2F8, 0x3E8 or 0x2E8). Only `sio0` through `sio3` (`COM1` through `COM4`) can be used; multiport serial cards will not work. No interrupt setting is needed.
3. Create a custom kernel configuration file and add appropriate flags for the serial port you want to use. For example, if you want to make `sio1` (`COM2`) the console:

   ```
   device sio1 at isa? port IO_COM2 flags 0x10 irq 3
   ```

   or

   ```
   device sio1 at isa? port IO_COM2 flags 0x30 irq 3
   ```

   The console flags for the other serial ports should not be set.
4. Recompile and install the boot blocks and the boot loader:

   ```
   # cd /sys/boot
   # make
   # make install
   ```
5. Rebuild and install the kernel.
6. Write the boot blocks to the boot disk with disklabel(8) and boot from the new kernel.

17.6.4.3 Entering the DDB Debugger from the Serial Line

If you wish to drop into the kernel debugger from the serial console (useful for remote diagnostics, but also dangerous if you generate a spurious BREAK on the serial port!) then you should compile your kernel with the following options:

```
options BREAK_TO_DEBUGGER
options DDB
```

17.6.4.4 Getting a Login Prompt on the Serial Console

While this is not required, you may wish to get a *login* prompt over the serial line, now that you can see boot messages and can enter the kernel debugging session through the serial console. Here is how to do it.

Open the file `/etc/ttys` with an editor and locate the lines:

```
ttyd0 "/usr/libexec/getty std.9600" unknown off secure
ttyd1 "/usr/libexec/getty std.9600" unknown off secure
ttyd2 "/usr/libexec/getty std.9600" unknown off secure
ttyd3 "/usr/libexec/getty std.9600" unknown off secure
```

`ttyd0` through `ttyd3` corresponds to `COM1` through `COM4`. Change `off` to `on` for the desired port. If you have changed the speed of the serial port, you need to change `std.9600` to match the current setting, e.g. `std.19200`.

You may also want to change the terminal type from `unknown` to the actual type of your serial terminal.

After editing the file, you must `kill -HUP 1` to make this change take effect.

17.6.5 Changing Console from the Boot Loader

Previous sections described how to set up the serial console by tweaking the boot block. This section shows that you can specify the console by entering some commands and environment variables in the boot loader. As the boot loader is invoked at the third stage of the boot process, after the boot block, the settings in the boot loader will override the settings in the boot block.

17.6.5.1 Setting Up the Serial Console

You can easily specify the boot loader and the kernel to use the serial console by writing just one line in `/boot/loader.rc`:

```
set console=comconsole
```

This will take effect regardless of the settings in the boot block discussed in the previous section.

You had better put the above line as the first line of `/boot/loader.rc` so as to see boot messages on the serial console as early as possible.

Likewise, you can specify the internal console as:

```
set console=vidconsole
```

If you do not set the boot loader environment variable `console`, the boot loader, and subsequently the kernel, will use whichever console indicated by the `-h` option in the boot block.

In versions 3.2 or later, you may specify the console in `/boot/loader.conf.local` or `/boot/loader.conf`, rather than in `/boot/loader.rc`. In this method your `/boot/loader.rc` should look like:

```
include /boot/loader.4th
```

```
start
```

Then, create `/boot/loader.conf.local` and put the following line there.

```
console=comconsole
```

or

```
console=vidconsole
```

See loader.conf(5) for more information.

> **Note:** At the moment, the boot loader has no option equivalent to the `-P` option in the boot block, and there is no provision to automatically select the internal console and the serial console based on the presence of the keyboard.

17.6.5.2 Using a Serial Port Other Than `sio0` for the Console

You need to recompile the boot loader to use a serial port other than `sio0` for the serial console. Follow the procedure described in Section 17.6.4.2.

17.6.6 Caveats

The idea here is to allow people to set up dedicated servers that require no graphics hardware or attached keyboards. Unfortunately, while most systems will let you boot without a keyboard, there are quite a few that will not let you boot without a graphics adapter. Machines with AMI BIOSes can be configured to boot with no graphics adapter installed simply by changing the "graphics adapter" setting in the CMOS configuration to "Not installed."

However, many machines do not support this option and will refuse to boot if you have no display hardware in the system. With these machines, you will have to leave some kind of graphics card plugged in, (even if it is just a junky mono board) although you will not have to attach a monitor. You might also try installing an AMI BIOS.

Chapter 18 PPP and SLIP

Restructured, reorganized, and updated by Jim Mock.

18.1 Synopsis

FreeBSD has a number of ways to link one computer to another. To establish a network or Internet connection through a dial-up modem, or to allow others to do so through you, requires the use of PPP or SLIP. This chapter describes setting up these modem-based communication services in detail.

After reading this chapter, you will know:

- How to set up user PPP.
- How to set up kernel PPP.
- How to set up PPPoE (PPP over Ethernet).
- How to set up PPPoA (PPP over ATM).
- How to configure and set up a SLIP client and server.

Before reading this chapter, you should:

- Be familiar with basic network terminology.
- Understand the basics and purpose of a dialup connection and PPP and/or SLIP.

You may be wondering what the main difference is between user PPP and kernel PPP. The answer is simple: user PPP processes the inbound and outbound data in userland rather than in the kernel. This is expensive in terms of copying the data between the kernel and userland, but allows a far more feature-rich PPP implementation. User PPP uses the `tun` device to communicate with the outside world whereas kernel PPP uses the `ppp` device.

> **Note:** Throughout in this chapter, user PPP will simply be referred to as **ppp** unless a distinction needs to be made between it and any other PPP software such as **pppd**. Unless otherwise stated, all of the commands explained in this chapter should be executed as `root`.

18.2 Using User PPP

Updated and enhanced by Tom Rhodes. Originally contributed by Brian Somers. With input from Nik Clayton, Dirk Frömberg, and Peter Childs.

18.2.1 User PPP

18.2.1.1 Assumptions

This document assumes you have the following:

- An account with an Internet Service Provider (ISP) which you connect to using PPP.
- You have a modem or other device connected to your system and configured correctly which allows you to connect to your ISP.
- The dial-up number(s) of your ISP.
- Your login name and password. (Either a regular UNIX style login and password pair, or a PAP or CHAP login and password pair.)
- The IP address of one or more name servers. Normally, you will be given two IP addresses by your ISP to use for this. If they have not given you at least one, then you can use the `enable dns` command in `ppp.conf` and **ppp** will set the name servers for you. This feature depends on your ISPs PPP implementation supporting DNS negotiation.

The following information may be supplied by your ISP, but is not completely necessary:

- The IP address of your ISP's gateway. The gateway is the machine to which you will connect and will be set up as your *default route*. If you do not have this information, we can make one up and your ISP's PPP server will tell us the correct value when we connect.

  This IP number is referred to as `HISADDR` by **ppp**.

- The netmask you should use. If your ISP has not provided you with one, you can safely use `255.255.255.255`.
- If your ISP provides you with a static IP address and hostname, you can enter it. Otherwise, we simply let the peer assign whatever IP address it sees fit.

If you do not have any of the required information, contact your ISP.

> **Note:** Throughout this section, many of the examples showing the contents of configuration files are numbered by line. These numbers serve to aid in the presentation and discussion only and are not meant to be placed in the actual file. Proper indentation with tab and space characters is also important.

18.2.1.2 Creating PPP Device Nodes

Under normal circumstances, most users will only need one `tun` device (`/dev/tun0`). References to `tun0` below may be changed to `tunN` where *N* is any unit number corresponding to your system.

For FreeBSD installations that do not have devfs(5) enabled (FreeBSD 4.X and earlier), the existence of the `tun0` device should be verified (this is not necessary if devfs(5) is enabled as device nodes will be created on demand).

The easiest way to make sure that the `tun0` device is configured correctly is to remake the device. To remake the device, do the following:

```
# cd /dev
  # sh MAKEDEV tun0
```

If you need 16 tunnel devices in your kernel, you will need to create them. This can be done by executing the following commands:

```
# cd /dev
```

```
# sh MAKEDEV tun15
```

18.2.1.3 Automatic PPP Configuration

Both `ppp` and `pppd` (the kernel level implementation of PPP) use the configuration files located in the `/etc/ppp` directory. Examples for user ppp can be found in `/usr/share/examples/ppp/`.

Configuring `ppp` requires that you edit a number of files, depending on your requirements. What you put in them depends to some extent on whether your ISP allocates IP addresses statically (i.e., you get given one IP address, and always use that one) or dynamically (i.e., your IP address changes each time you connect to your ISP).

18.2.1.3.1 PPP and Static IP Addresses

You will need to edit the `/etc/ppp/ppp.conf` configuration file. It should look similar to the example below.

> **Note:** Lines that end in a `:` start in the first column (beginning of the line)— all other lines should be indented as shown using spaces or tabs.

```
1     default:
2       set log Phase Chat LCP IPCP CCP tun command
3       ident user-ppp VERSION (built COMPILATIONDATE)
4       set device /dev/cuaa0
5       set speed 115200
6       set dial "ABORT BUSY ABORT NO\\sCARRIER TIMEOUT 5 \
7                 \"\" AT OK-AT-OK ATE1Q0 OK \\dATDT\\T TIMEOUT 40 CONNECT"
8       set timeout 180
9       enable dns
10
11    provider:
12      set phone "(123) 456 7890"
13      set authname foo
14      set authkey bar
15      set login "TIMEOUT 10 \"\" \"\" gin:--gin: \\U word: \\P col: ppp"
16      set timeout 300
17      set ifaddr x.x.x.x y.y.y.y 255.255.255.255 0.0.0.0
18      add default HISADDR
```

Line 1:

Identifies the default entry. Commands in this entry are executed automatically when ppp is run.

Line 2:

Enables logging parameters. When the configuration is working satisfactorily, this line should be reduced to saying

`set log phase tun`

in order to avoid excessive log file sizes.

Line 3:

Tells PPP how to identify itself to the peer. PPP identifies itself to the peer if it has any trouble negotiating and setting up the link, providing information that the peers administrator may find useful when investigating such problems.

Line 4:

Identifies the device to which the modem is connected. `COM1` is `/dev/cuaa0` and `COM2` is `/dev/cuaa1`.

Line 5:

Sets the speed you want to connect at. If 115200 does not work (it should with any reasonably new modem), try 38400 instead.

Line 6 & 7:

The dial string. User PPP uses an expect-send syntax similar to the chat(8) program. Refer to the manual page for information on the features of this language.

Note that this command continues onto the next line for readability. Any command in `ppp.conf` may do this if the last character on the line is a "\" character.

Line 8:

Sets the idle timeout for the link. 180 seconds is the default, so this line is purely cosmetic.

Line 9:

Tells PPP to ask the peer to confirm the local resolver settings. If you run a local name server, this line should be commented out or removed.

Line 10:

A blank line for readability. Blank lines are ignored by PPP.

Line 11:

Identifies an entry for a provider called "provider". This could be changed to the name of your ISP so that later you can use the `load ISP` to start the connection.

Line 12:

Sets the phone number for this provider. Multiple phone numbers may be specified using the colon (`:`) or pipe character (`|`)as a separator. The difference between the two separators is described in ppp(8). To summarize, if you want to rotate through the numbers, use a colon. If you want to always attempt to dial the first number first and only use the other numbers if the first number fails, use the pipe character. Always quote the entire set of phone numbers as shown.

You must enclose the phone number in quotation marks (`"`) if there is any intention on using spaces in the phone number. This can cause a simple, yet subtle error.

Line 13 & 14:

Identifies the user name and password. When connecting using a UNIX style login prompt, these values are referred to by the `set login` command using the \U and \P variables. When connecting using PAP or CHAP, these values are used at authentication time.

Line 15:

If you are using PAP or CHAP, there will be no login at this point, and this line should be commented out or removed. See PAP and CHAP authentication for further details.

The login string is of the same chat-like syntax as the dial string. In this example, the string works for a service whose login session looks like this:

```
J. Random Provider
login: foo
password: bar
protocol: ppp
```

You will need to alter this script to suit your own needs. When you write this script for the first time, you should ensure that you have enabled "chat" logging so you can determine if the conversation is going as expected.

Line 16:

Sets the default idle timeout (in seconds) for the connection. Here, the connection will be closed automatically after 300 seconds of inactivity. If you never want to timeout, set this value to zero or use the `-ddial` command line switch.

Line 17:

Sets the interface addresses. The string *`x.x.x.x`* should be replaced by the IP address that your provider has allocated to you. The string *`y.y.y.y`* should be replaced by the IP address that your ISP indicated for their gateway (the machine to which you connect). If your ISP has not given you a gateway address, use `10.0.0.2/0`. If you need to use a "guessed" address, make sure that you create an entry in `/etc/ppp/ppp.linkup` as per the instructions for PPP and Dynamic IP addresses. If this line is omitted, `ppp` cannot run in `-auto` mode.

Line 18:

Adds a default route to your ISP's gateway. The special word `HISADDR` is replaced with the gateway address specified on line 9. It is important that this line appears after line 9, otherwise `HISADDR` will not yet be initialized.

If you do not wish to run ppp in `-auto`, this line should be moved to the `ppp.linkup` file.

It is not necessary to add an entry to `ppp.linkup` when you have a static IP address and are running ppp in `-auto` mode as your routing table entries are already correct before you connect. You may however wish to create an entry to invoke programs after connection. This is explained later with the sendmail example.

Example configuration files can be found in the `/usr/share/examples/ppp/` directory.

18.2.1.3.2 PPP and Dynamic IP Addresses

If your service provider does not assign static IP addresses, `ppp` can be configured to negotiate the local and remote addresses. This is done by "guessing" an IP address and allowing `ppp` to set it up correctly using the IP Configuration Protocol (IPCP) after connecting. The `ppp.conf` configuration is the same as PPP and Static IP Addresses, with the following change:

```
17      set ifaddr 10.0.0.1/0 10.0.0.2/0 255.255.255.255
```

Again, do not include the line number, it is just for reference. Indentation of at least one space is required.

Line 17:

> The number after the `/` character is the number of bits of the address that ppp will insist on. You may wish to use IP numbers more appropriate to your circumstances, but the above example will always work.
>
> The last argument (`0.0.0.0`) tells PPP to start negotiations using address `0.0.0.0` rather than `10.0.0.1` and is necessary for some ISPs. Do not use `0.0.0.0` as the first argument to `set ifaddr` as it prevents PPP from setting up an initial route in `-auto` mode.

If you are not running in `-auto` mode, you will need to create an entry in `/etc/ppp/ppp.linkup`. `ppp.linkup` is used after a connection has been established. At this point, `ppp` will have assigned the interface addresses and it will now be possible to add the routing table entries:

```
1     provider:
2      add default HISADDR
```

Line 1:

> On establishing a connection, `ppp` will look for an entry in `ppp.linkup` according to the following rules: First, try to match the same label as we used in `ppp.conf`. If that fails, look for an entry for the IP address of our gateway. This entry is a four-octet IP style label. If we still have not found an entry, look for the `MYADDR` entry.

Line 2:

> This line tells `ppp` to add a default route that points to `HISADDR`. `HISADDR` will be replaced with the IP number of the gateway as negotiated by the IPCP.

See the `pmdemand` entry in the files `/usr/share/examples/ppp/ppp.conf.sample` and `/usr/share/examples/ppp/ppp.linkup.sample` for a detailed example.

18.2.1.3.3 Receiving Incoming Calls

When you configure **ppp** to receive incoming calls on a machine connected to a LAN, you must decide if you wish to forward packets to the LAN. If you do, you should allocate the peer an IP number from your LAN's subnet, and use the command `enable proxy` in your `/etc/ppp/ppp.conf` file. You should also confirm that the `/etc/rc.conf` file contains the following:

```
gateway_enable="YES"
```

18.2.1.3.4 Which getty?

Configuring FreeBSD for Dial-up Services provides a good description on enabling dial-up services using getty(8).

An alternative to `getty` is mgetty (http://www.leo.org/~doering/mgetty/index.html), a smarter version of `getty` designed with dial-up lines in mind.

The advantages of using `mgetty` is that it actively *talks* to modems, meaning if port is turned off in `/etc/ttys` then your modem will not answer the phone.

Later versions of `mgetty` (from 0.99beta onwards) also support the automatic detection of PPP streams, allowing your clients script-less access to your server.

Refer to Mgetty and AutoPPP for more information on `mgetty`.

18.2.1.3.5 **PPP** Permissions

The `ppp` command must normally be run as the `root` user. If however, you wish to allow `ppp` to run in server mode as a normal user by executing `ppp` as described below, that user must be given permission to run `ppp` by adding them to the `network` group in `/etc/group`.

You will also need to give them access to one or more sections of the configuration file using the `allow` command:

```
allow users fred mary
```

If this command is used in the `default` section, it gives the specified users access to everything.

18.2.1.3.6 PPP Shells for Dynamic-IP Users

Create a file called `/etc/ppp/ppp-shell` containing the following:

```
#!/bin/sh
IDENT=‘echo $0 | sed -e ’s/^.*-\(.*\)$/\1/’‘
CALLEDAS="$IDENT"
TTY=‘tty‘

if [ x$IDENT = xdialup ]; then
        IDENT=‘basename $TTY‘
fi

echo "PPP for $CALLEDAS on $TTY"
echo "Starting PPP for $IDENT"

exec /usr/sbin/ppp -direct $IDENT
```

This script should be executable. Now make a symbolic link called `ppp-dialup` to this script using the following commands:

```
# ln -s ppp-shell /etc/ppp/ppp-dialup
```

You should use this script as the *shell* for all of your dialup users. This is an example from `/etc/password` for a dialup PPP user with username `pchilds` (remember do not directly edit the password file, use `vipw`).

```
pchilds:*:1011:300:Peter Childs PPP:/home/ppp:/etc/ppp/ppp-dialup
```

Create a `/home/ppp` directory that is world readable containing the following 0 byte files:

```
-r--r--r--   1 root     wheel           0 May 27 02:23 .hushlogin
-r--r--r--   1 root     wheel           0 May 27 02:22 .rhosts
```

which prevents `/etc/motd` from being displayed.

18.2.1.3.7 PPP Shells for Static-IP Users

Create the `ppp-shell` file as above, and for each account with statically assigned IPs create a symbolic link to `ppp-shell`.

For example, if you have three dialup customers, `fred`, `sam`, and `mary`, that you route class C networks for, you would type the following:

```
# ln -s /etc/ppp/ppp-shell /etc/ppp/ppp-fred
# ln -s /etc/ppp/ppp-shell /etc/ppp/ppp-sam
# ln -s /etc/ppp/ppp-shell /etc/ppp/ppp-mary
```

Each of these users dialup accounts should have their shell set to the symbolic link created above (for example, `mary`'s shell should be `/etc/ppp/ppp-mary`).

18.2.1.3.8 Setting Up `ppp.conf` for Dynamic-IP Users

The `/etc/ppp/ppp.conf` file should contain something along the lines of:

```
default:
  set debug phase lcp chat
  set timeout 0

ttyd0:
  set ifaddr 203.14.100.1 203.14.100.20 255.255.255.255
  enable proxy

ttyd1:
  set ifaddr 203.14.100.1 203.14.100.21 255.255.255.255
  enable proxy
```

> **Note:** The indenting is important.

The `default:` section is loaded for each session. For each dialup line enabled in `/etc/ttys` create an entry similar to the one for `ttyd0:` above. Each line should get a unique IP address from your pool of IP addresses for dynamic users.

18.2.1.3.9 Setting Up `ppp.conf` for Static-IP Users

Along with the contents of the sample `/usr/share/examples/ppp/ppp.conf` above you should add a section for each of the statically assigned dialup users. We will continue with our `fred`, `sam`, and `mary` example.

```
fred:
  set ifaddr 203.14.100.1 203.14.101.1 255.255.255.255

sam:
  set ifaddr 203.14.100.1 203.14.102.1 255.255.255.255

mary:
  set ifaddr 203.14.100.1 203.14.103.1 255.255.255.255
```

The file `/etc/ppp/ppp.linkup` should also contain routing information for each static IP user if required. The line below would add a route for the `203.14.101.0` class C via the client's ppp link.

```
fred:
  add 203.14.101.0 netmask 255.255.255.0 HISADDR

sam:
  add 203.14.102.0 netmask 255.255.255.0 HISADDR

mary:
  add 203.14.103.0 netmask 255.255.255.0 HISADDR
```

18.2.1.3.10 `mgetty` and AutoPPP

Configuring and compiling `mgetty` with the `AUTO_PPP` option enabled allows `mgetty` to detect the LCP phase of PPP connections and automatically spawn off a ppp shell. However, since the default login/password sequence does not occur it is necessary to authenticate users using either PAP or CHAP.

This section assumes the user has successfully configured, compiled, and installed a version of `mgetty` with the `AUTO_PPP` option (v0.99beta or later).

Make sure your `/usr/local/etc/mgetty+sendfax/login.config` file has the following in it:

```
/AutoPPP/ -     -       /etc/ppp/ppp-pap-dialup
```

This will tell `mgetty` to run the `ppp-pap-dialup` script for detected PPP connections.

Create a file called `/etc/ppp/ppp-pap-dialup` containing the following (the file should be executable):

```
#!/bin/sh
exec /usr/sbin/ppp -direct pap$IDENT
```

For each dialup line enabled in `/etc/ttys`, create a corresponding entry in `/etc/ppp/ppp.conf`. This will happily co-exist with the definitions we created above.

```
pap:
  enable pap
  set ifaddr 203.14.100.1 203.14.100.20-203.14.100.40
  enable proxy
```

Each user logging in with this method will need to have a username/password in `/etc/ppp/ppp.secret` file, or alternatively add the following option to authenticate users via PAP from `/etc/password` file.

```
enable passwdauth
```

If you wish to assign some users a static IP number, you can specify the number as the third argument in `/etc/ppp/ppp.secret`. See `/usr/share/examples/ppp/ppp.secret.sample` for examples.

18.2.1.3.11 MS Extensions

It is possible to configure PPP to supply DNS and NetBIOS nameserver addresses on demand.

To enable these extensions with PPP version 1.x, the following lines might be added to the relevant section of `/etc/ppp/ppp.conf`.

```
enable msext
set ns 203.14.100.1 203.14.100.2
set nbns 203.14.100.5
```

And for PPP version 2 and above:

```
accept dns
set dns 203.14.100.1 203.14.100.2
set nbns 203.14.100.5
```

This will tell the clients the primary and secondary name server addresses, and a NetBIOS nameserver host.

In version 2 and above, if the `set dns` line is omitted, PPP will use the values found in `/etc/resolv.conf`.

18.2.1.3.12 PAP and CHAP Authentication

Some ISPs set their system up so that the authentication part of your connection is done using either of the PAP or CHAP authentication mechanisms. If this is the case, your ISP will not give a `login:` prompt when you connect, but will start talking PPP immediately.

PAP is less secure than CHAP, but security is not normally an issue here as passwords, although being sent as plain text with PAP, are being transmitted down a serial line only. There is not much room for crackers to "eavesdrop".

Referring back to the PPP and Static IP addresses or PPP and Dynamic IP addresses sections, the following alterations must be made:

```
7       set login
...
12      set authname MyUserName
13      set authkey MyPassword
```

Line 7:

> Your ISP will not normally require that you log into the server if you are using PAP or CHAP. You must therefore disable your "set login" string.

Line 12:

> This line specifies your PAP/CHAP user name. You will need to insert the correct value for *`MyUserName`*.

Line 13:

This line specifies your PAP/CHAP password. You will need to insert the correct value for *MyPassword*. You may want to add an additional line, such as:

```
15      accept PAP
```

or

```
15      accept CHAP
```

to make it obvious that this is the intention, but PAP and CHAP are both accepted by default.

18.2.1.3.13 Changing Your ppp Configuration on the Fly

It is possible to talk to the ppp program while it is running in the background, but only if a suitable diagnostic port has been set up. To do this, add the following line to your configuration:

```
set server /var/run/ppp-tun%d DiagnosticPassword 0177
```

This will tell PPP to listen to the specified UNIX domain socket, asking clients for the specified password before allowing access. The `%d` in the name is replaced with the `tun` device number that is in use.

Once a socket has been set up, the pppctl(8) program may be used in scripts that wish to manipulate the running program.

18.2.1.4 Using PPP Network Address Translation Capability

PPP has ability to use internal NAT without kernel diverting capabilities. This functionality may be enabled by the following line in `/etc/ppp/ppp.conf`:

```
nat enable yes
```

Alternatively, PPP NAT may be enabled by command-line option `-nat`. There is also `/etc/rc.conf` knob named `ppp_nat`, which is enabled by default.

If you use this feature, you may also find useful the following `/etc/ppp/ppp.conf` options to enable incoming connections forwarding:

```
nat port tcp 10.0.0.2:ftp ftp
nat port tcp 10.0.0.2:http http
```

or do not trust the outside at all

```
nat deny_incoming yes
```

18.2.1.5 Final System Configuration

You now have ppp configured, but there are a few more things to do before it is ready to work. They all involve editing the `/etc/rc.conf` file.

Working from the top down in this file, make sure the `hostname=` line is set, e.g.:

```
hostname="foo.example.com"
```

If your ISP has supplied you with a static IP address and name, it is probably best that you use this name as your host name.

Look for the `network_interfaces` variable. If you want to configure your system to dial your ISP on demand, make sure the `tun0` device is added to the list, otherwise remove it.

```
network_interfaces="lo0 tun0"
ifconfig_tun0=
```

> **Note:** The `ifconfig_tun0` variable should be empty, and a file called `/etc/start_if.tun0` should be created. This file should contain the line:
>
> ```
> ppp -auto mysystem
> ```
>
> This script is executed at network configuration time, starting your ppp daemon in automatic mode. If you have a LAN for which this machine is a gateway, you may also wish to use the `-alias` switch. Refer to the manual page for further details.

Set the router program to `NO` with following line in your `/etc/rc.conf`:

```
router_enable="NO"
```

It is important that the `routed` daemon is not started (it is started by default), as `routed` tends to delete the default routing table entries created by `ppp`.

It is probably worth your while ensuring that the `sendmail_flags` line does not include the `-q` option, otherwise `sendmail` will attempt to do a network lookup every now and then, possibly causing your machine to dial out. You may try:

```
sendmail_flags="-bd"
```

The downside of this is that you must force `sendmail` to re-examine the mail queue whenever the ppp link is up by typing:

```
# /usr/sbin/sendmail -q
```

You may wish to use the `!bg` command in `ppp.linkup` to do this automatically:

```
provider:
  delete ALL
  add 0 0 HISADDR
  !bg sendmail -bd -q30m
```

If you do not like this, it is possible to set up a “dfilter” to block SMTP traffic. Refer to the sample files for further details.

Now the only thing left to do is reboot the machine.

All that is left is to reboot the machine. After rebooting, you can now either type:

```
# ppp
```

and then `dial provider` to start the PPP session, or, if you want `ppp` to establish sessions automatically when there is outbound traffic (and you have not created the `start_if.tun0` script), type:

```
# ppp -auto provider
```

18.2.1.6 Summary

To recap, the following steps are necessary when setting up ppp for the first time:

Client side:

1. Ensure that the `tun` device is built into your kernel.
2. Ensure that the `tunN` device file is available in the `/dev` directory.
3. Create an entry in `/etc/ppp/ppp.conf`. The `pmdemand` example should suffice for most ISPs.
4. If you have a dynamic IP address, create an entry in `/etc/ppp/ppp.linkup`.
5. Update your `/etc/rc.conf` file.
6. Create a `start_if.tun0` script if you require demand dialing.

Server side:

1. Ensure that the `tun` device is built into your kernel.
2. Ensure that the `tunN` device file is available in the `/dev` directory.
3. Create an entry in `/etc/passwd` (using the vipw(8) program).
4. Create a profile in this users home directory that runs `ppp -direct direct-server` or similar.
5. Create an entry in `/etc/ppp/ppp.conf`. The `direct-server` example should suffice.
6. Create an entry in `/etc/ppp/ppp.linkup`.
7. Update your `/etc/rc.conf` file.

18.3 Using Kernel PPP

Parts originally contributed by Gennady B. Sorokopud and Robert Huff.

18.3.1 Setting Up Kernel PPP

Before you start setting up PPP on your machine, make sure that `pppd` is located in `/usr/sbin` and the directory `/etc/ppp` exists.

`pppd` can work in two modes:

1. As a "client" — you want to connect your machine to the outside world via a PPP serial connection or modem line.

2. As a “server”— your machine is located on the network, and is used to connect other computers using PPP.

In both cases you will need to set up an options file (`/etc/ppp/options` or `~/.ppprc` if you have more than one user on your machine that uses PPP).

You will also need some modem/serial software (preferably `comms/kermit`), so you can dial and establish a connection with the remote host.

18.3.2 Using pppd as a Client

Based on information provided by Trev Roydhouse.

The following `/etc/ppp/options` might be used to connect to a Cisco terminal server PPP line.

```
crtscts         # enable hardware flow control
modem           # modem control line
noipdefault     # remote PPP server must supply your IP address
                # if the remote host does not send your IP during IPCP
                # negotiation, remove this option
passive         # wait for LCP packets
domain ppp.foo.com      # put your domain name here

:<remote_ip>     # put the IP of remote PPP host here
                # it will be used to route packets via PPP link
                # if you didn't specified the noipdefault option
                # change this line to <local_ip>:<remote_ip>

defaultroute    # put this if you want that PPP server will be your
                # default router
```

To connect:

1. Dial to the remote host using **kermit** (or some other modem program), and enter your user name and password (or whatever is needed to enable PPP on the remote host).
2. Exit **kermit** (without hanging up the line).
3. Enter the following:

   ```
   # /usr/src/usr.sbin/pppd.new/pppd /dev/tty01 19200
   ```

   Be sure to use the appropriate speed and device name.

Now your computer is connected with PPP. If the connection fails, you can add the `debug` option to the `/etc/ppp/options` file, and check console messages to track the problem.

Following `/etc/ppp/pppup` script will make all 3 stages automatic:

```
#!/bin/sh
ps ax |grep pppd |grep -v grep
pid=`ps ax |grep pppd |grep -v grep|awk '{print $1;}'`
if [ "X${pid}" != "X" ] ; then
        echo 'killing pppd, PID=' ${pid}
        kill ${pid}
fi
```

```
ps ax |grep kermit |grep -v grep
pid=‘ps ax |grep kermit |grep -v grep|awk ’{print $1;}’‘
if [ "X${pid}" != "X" ] ; then
        echo ’killing kermit, PID=’ ${pid}
        kill -9 ${pid}
fi

ifconfig ppp0 down
ifconfig ppp0 delete

kermit -y /etc/ppp/kermit.dial
pppd /dev/tty01 19200
```

`/etc/ppp/kermit.dial` is a **kermit** script that dials and makes all necessary authorization on the remote host (an example of such a script is attached to the end of this document).

Use the following `/etc/ppp/pppdown` script to disconnect the PPP line:

```
#!/bin/sh
pid=‘ps ax |grep pppd |grep -v grep|awk ’{print $1;}’‘
if [ X${pid} != "X" ] ; then
        echo ’killing pppd, PID=’ ${pid}
        kill -TERM ${pid}
fi

ps ax |grep kermit |grep -v grep
pid=‘ps ax |grep kermit |grep -v grep|awk ’{print $1;}’‘
if [ "X${pid}" != "X" ] ; then
        echo ’killing kermit, PID=’ ${pid}
        kill -9 ${pid}
fi

/sbin/ifconfig ppp0 down
/sbin/ifconfig ppp0 delete
kermit -y /etc/ppp/kermit.hup
/etc/ppp/ppptest
```

Check to see if `pppd` is still running by executing `/usr/etc/ppp/ppptest`, which should look like this:

```
#!/bin/sh
pid=‘ps ax| grep pppd |grep -v grep|awk ’{print $1;}’‘
if [ X${pid} != "X" ] ; then
        echo ’pppd running: PID=’ ${pid-NONE}
else
        echo ’No pppd running.’
fi
set -x
netstat -n -I ppp0
ifconfig ppp0
```

To hang up the modem, execute `/etc/ppp/kermit.hup`, which should contain:

```
set line /dev/tty01 ; put your modem device here
set speed 19200
```

```
set file type binary
set file names literal
set win 8
set rec pack 1024
set send pack 1024
set block 3
set term bytesize 8
set command bytesize 8
set flow none

pau 1
out +++
inp 5 OK
out ATH0\13
echo \13
exit
```

Here is an alternate method using `chat` instead of `kermit`:

The following two files are sufficient to accomplish a `pppd` connection.

`/etc/ppp/options`:

```
/dev/cuaa1 115200

crtscts # enable hardware flow control
modem # modem control line
connect "/usr/bin/chat -f /etc/ppp/login.chat.script"
noipdefault # remote PPP serve must supply your IP address
        # if the remote host doesn't send your IP during
                # IPCP negotiation, remove this option
passive         # wait for LCP packets
domain <your.domain> # put your domain name here

: # put the IP of remote PPP host here
        # it will be used to route packets via PPP link
                # if you didn't specified the noipdefault option
                # change this line to <local_ip>:<remote_ip>

defaultroute # put this if you want that PPP server will be
        # your default router
```

`/etc/ppp/login.chat.script`:

> **Note:** The following should go on a single line.

```
ABORT BUSY ABORT 'NO CARRIER' "" AT OK ATDT<phone.number>
  CONNECT "" TIMEOUT 10 ogin:-\\r-ogin: <login-id>
  TIMEOUT 5 sword: <password>
```

Once these are installed and modified correctly, all you need to do is run `pppd`, like so:

```
# pppd
```

18.3.3 Using pppd as a Server

`/etc/ppp/options` should contain something similar to the following:

```
crtscts                          # Hardware flow control
netmask 255.255.255.0            # netmask (not required)
192.114.208.20:192.114.208.165  # IP’s of local and remote hosts
                                 # local ip must be different from one
                                 # you assigned to the ethernet (or other)
                                 # interface on your machine.
                                 # remote IP is IP address that will be
                                 # assigned to the remote machine
domain ppp.foo.com               # your domain
passive                          # wait for LCP
modem                            # modem line
```

The following `/etc/ppp/pppserv` script will tell **pppd** to behave as a server:

```
#!/bin/sh
ps ax |grep pppd |grep -v grep
pid=‘ps ax |grep pppd |grep -v grep|awk ’{print $1;}’‘
if [ "X${pid}" != "X" ] ; then
        echo ’killing pppd, PID=’ ${pid}
        kill ${pid}
fi
ps ax |grep kermit |grep -v grep
pid=‘ps ax |grep kermit |grep -v grep|awk ’{print $1;}’‘
if [ "X${pid}" != "X" ] ; then
        echo ’killing kermit, PID=’ ${pid}
        kill -9 ${pid}
fi

# reset ppp interface
ifconfig ppp0 down
ifconfig ppp0 delete

# enable autoanswer mode
kermit -y /etc/ppp/kermit.ans

# run ppp
pppd /dev/tty01 19200
```

Use this `/etc/ppp/pppservdown` script to stop the server:

```
#!/bin/sh
ps ax |grep pppd |grep -v grep
pid=‘ps ax |grep pppd |grep -v grep|awk ’{print $1;}’‘
if [ "X${pid}" != "X" ] ; then
        echo ’killing pppd, PID=’ ${pid}
        kill ${pid}
fi
ps ax |grep kermit |grep -v grep
pid=‘ps ax |grep kermit |grep -v grep|awk ’{print $1;}’‘
if [ "X${pid}" != "X" ] ; then
```

```
        echo 'killing kermit, PID=' ${pid}
        kill -9 ${pid}
fi
ifconfig ppp0 down
ifconfig ppp0 delete

kermit -y /etc/ppp/kermit.noans
```

The following **kermit** script (`/etc/ppp/kermit.ans`) will enable/disable autoanswer mode on your modem. It should look like this:

```
set line /dev/tty01
set speed 19200
set file type binary
set file names literal
set win 8
set rec pack 1024
set send pack 1024
set block 3
set term bytesize 8
set command bytesize 8
set flow none

pau 1
out +++
inp 5 OK
out ATH0\13
inp 5 OK
echo \13
out ATS0=1\13   ; change this to out ATS0=0\13 if you want to disable
                ; autoanswer mode
inp 5 OK
echo \13
exit
```

A script named `/etc/ppp/kermit.dial` is used for dialing and authenticating on the remote host. You will need to customize it for your needs. Put your login and password in this script; you will also need to change the input statement depending on responses from your modem and remote host.

```
;
; put the com line attached to the modem here:
;
set line /dev/tty01
;
; put the modem speed here:
;
set speed 19200
set file type binary            ; full 8 bit file xfer
set file names literal
set win 8
set rec pack 1024
set send pack 1024
set block 3
```

```
set term bytesize 8
set command bytesize 8
set flow none
set modem hayes
set dial hangup off
set carrier auto                ; Then SET CARRIER if necessary,
set dial display on             ; Then SET DIAL if necessary,
set input echo on
set input timeout proceed
set input case ignore
def \%x 0                       ; login prompt counter
goto slhup

:slcmd                          ; put the modem in command mode
echo Put the modem in command mode.
clear                           ; Clear unread characters from input buffer
pause 1
output +++                      ; hayes escape sequence
input 1 OK\13\10                ; wait for OK
if success goto slhup
output \13
pause 1
output at\13
input 1 OK\13\10
if fail goto slcmd              ; if modem doesn't answer OK, try again

:slhup                          ; hang up the phone
clear                           ; Clear unread characters from input buffer
pause 1
echo Hanging up the phone.
output ath0\13                  ; hayes command for on hook
input 2 OK\13\10
if fail goto slcmd              ; if no OK answer, put modem in command mode

:sldial                         ; dial the number
pause 1
echo Dialing.
output atdt9,550311\13\10               ; put phone number here
assign \%x 0                    ; zero the time counter

:look
clear                           ; Clear unread characters from input buffer
increment \%x                   ; Count the seconds
input 1 {CONNECT }
if success goto sllogin
reinput 1 {NO CARRIER\13\10}
if success goto sldial
reinput 1 {NO DIALTONE\13\10}
if success goto slnodial
reinput 1 {\255}
if success goto slhup
reinput 1 {\127}
if success goto slhup
```

```
if < \%x 60 goto look
else goto slhup

:sllogin                        ; login
assign \%x 0                    ; zero the time counter
pause 1
echo Looking for login prompt.

:slloop
increment \%x                   ; Count the seconds
clear                           ; Clear unread characters from input buffer
output \13
;
; put your expected login prompt here:
;
input 1 {Username: }
if success goto sluid
reinput 1 {\255}
if success goto slhup
reinput 1 {\127}
if success goto slhup
if < \%x 10 goto slloop         ; try 10 times to get a login prompt
else goto slhup                 ; hang up and start again if 10 failures

:sluid
;
; put your userid here:
;
output ppp-login\13
input 1 {Password: }
;
; put your password here:
;
output ppp-password\13
input 1 {Entering SLIP mode.}
echo
quit

:slnodial
echo \7No dialtone.  Check the telephone line!\7
exit 1

; local variables:
; mode: csh
; comment-start: "; "
; comment-start-skip: "; "
; end:
```

18.4 Troubleshooting PPP Connections

Contributed by Tom Rhodes.

This section covers a few issues which may arise when using PPP over a modem connection. For instance, perhaps you need to know exactly what prompts the system you are dialing into will present. Some ISPs present the `ssword` prompt, and others will present `password`; if the `ppp` script is not written accordingly, the login attempt will fail. The most common way to debug `ppp` connections is by connecting manually. The following information will walk you through a manual connection step by step.

18.4.1 Check the Device Nodes

If you reconfigured your kernel then you recall the `sio` device. If you did not configure your kernel, there is no reason to worry. Just check the `dmesg` output for the modem device with:

```
#dmesg | grep sio
```

You should get some pertinent output about the `sio` devices. These are the COM ports we need. If your modem acts like a standard serial port then you should see it listed on `sio1`, or COM2. If so, you are not required to rebuild the kernel, you just need to make the serial device. You can do this by changing your directory to `/dev` and running the `MAKEDEV` script like above. Now make the serial devices with:

```
# sh MAKEDEV cuaa0 cuaa1 cuaa2 cuaa3
```

which will create the serial devices for your system. When matching up sio modem is on `sio1` or COM2 if you are in DOS, then your modem device would be `/dev/cuaa1`.

18.4.2 Connecting Manually

Connecting to the Internet by manually controlling `ppp` is quick, easy, and a great way to debug a connection or just get information on how your ISP treats `ppp` client connections. Lets start **PPP** from the command line. Note that in all of our examples we will use *example* as the hostname of the machine running **PPP**. You start `ppp` by just typing `ppp`:

```
# ppp
```

We have now started `ppp`.

```
ppp ON example> set device /dev/cuaa1
```

We set our modem device, in this case it is `cuaa1`.

```
ppp ON example> set speed 115200
```

Set the connection speed, in this case we are using 115,200 kbps.

```
ppp ON example> enable dns
```

Tell `ppp` to configure our resolver and add the nameserver lines to `/etc/resolv.conf`. If `ppp` cannot determine our hostname, we can set one manually later.

```
ppp ON example> term
```

Switch to "terminal" mode so that we can manually control the modem.

```
deflink: Entering terminal mode on /dev/cuaa1
type '~h' for help
```

```
at
OK
atdt123456789
```

Use `at` to initialize the modem, then use `atdt` and the number for your ISP to begin the dial in process.

```
CONNECT
```

Confirmation of the connection, if we are going to have any connection problems, unrelated to hardware, here is where we will attempt to resolve them.

```
ISP Login:myusername
```

Here you are prompted for a username, return the prompt with the username that was provided by the ISP.

```
ISP Pass:mypassword
```

This time we are prompted for a password, just reply with the password that was provided by the ISP. Just like logging into FreeBSD, the password will not echo.

```
Shell or PPP:ppp
```

Depending on your ISP this prompt may never appear. Here we are being asked if we wish to use a shell on the provider, or to start `ppp`. In this example, we have chosen to use `ppp` as we want an Internet connection.

```
Ppp ON example>
```

Notice that in this example the first `p` has been capitalized. This shows that we have successfully connected to the ISP.

```
PPp ON example>
```

We have successfully authenticated with our ISP and are waiting for the assigned IP address.

```
PPP ON example>
```

We have made an agreement on an IP address and successfully completed our connection.

```
PPP ON example>add default HISADDR
```

Here we add our default route, we need to do this before we can talk to the outside world as currently the only established connection is with the peer. If this fails due to existing routes you can put a bang character `!` in front of the `add`. Alternatively, you can set this before making the actual connection and it will negotiate a new route accordingly.

If everything went good we should now have an active connection to the Internet, which could be thrown into the background using **CTRL+z** If you notice the `PPP` return to `ppp` then we have lost our connection. This is good to know because it shows our connection status. Capital P's show that we have a connection to the ISP and lowercase p's show that the connection has been lost for whatever reason. `ppp` only has these 2 states.

18.4.2.1 Debugging

If you have a direct line and cannot seem to make a connection, then turn hardware flow CTS/RTS to off with the `set ctsrts off`. This is mainly the case if you are connected to some **PPP** capable terminal servers, where **PPP** hangs when it tries to write data to your communication link, so it would be waiting for a CTS, or Clear To Send signal which may never come. If you use this option however, you should also use the `set accmap` option, which may be required to defeat hardware dependent on passing certain characters from end to end, most of the time XON/XOFF. See the ppp(8) manual page for more information on this option, and how it is used.

If you have an older modem, you may need to use the `set parity even`. Parity is set at none be default, but is used for error checking (with a large increase in traffic) on older modems and some ISPs. You may need this option for the Compuserve ISP.

PPP may not return to the command mode, which is usually a negotiation error where the ISP is waiting for your side to start negotiating. At this point, using the `~p` command will force ppp to start sending the configuration information.

If you never obtain a login prompt, then most likely you need to use PAP or CHAP authentication instead of the UNIX style in the example above. To use PAP or CHAP just add the following options to **PPP** before going into terminal mode:

```
ppp ON example> set authname myusername
```

Where *myusername* should be replaced with the username that was assigned by the ISP.

```
ppp ON example> set authkey mypassword
```

Where *mypassword* should be replaced with the password that was assigned by the ISP.

If you connect fine, but cannot seem to find any domain name, try to use ping(8) with an IP address and see if you can get any return information. If you experience 100 percent (100%) packet loss, then it is most likely that you were not assigned a default route. Double check that the option `add default HISADDR` was set during the connection. If you can connect to a remote IP address then it is possible that a resolver address has not been added to the `/etc/resolv.conf`. This file should look like:

```
domain example.com
nameserver x.x.x.x
nameserver y.y.y.y
```

Where *x.x.x.x* and *y.y.y.y* should be replaced with the IP address of your ISP's DNS servers. This information may or may not have been provided when you signed up, but a quick call to your ISP should remedy that.

You could also have syslog(3) provide a logging function for your **PPP** connection. Just add:

```
!ppp
*.*     /var/log/ppp.log
```

to `/etc/syslog.conf`. In most cases, this functionality already exists.

18.5 Using PPP over Ethernet (PPPoE)

Contributed (from http://node.to/freebsd/how-tos/how-to-freebsd-pppoe.html) by Jim Mock.

This section describes how to set up PPP over Ethernet (PPPoE).

18.5.1 Configuring the Kernel

No kernel configuration is necessary for PPPoE any longer. If the necessary netgraph support is not built into the kernel, it will be dynamically loaded by **ppp**.

18.5.2 Setting Up `ppp.conf`

Here is an example of a working `ppp.conf`:

```
default:
  set log Phase tun command # you can add more detailed logging if you wish
  set ifaddr 10.0.0.1/0 10.0.0.2/0

name_of_service_provider:
  set device PPPoE:xl1 # replace xl1 with your ethernet device
  set authname YOURLOGINNAME
  set authkey YOURPASSWORD
  set dial
  set login
  add default HISADDR
```

18.5.3 Running ppp

As `root`, you can run:

```
# ppp -ddial name_of_service_provider
```

18.5.4 Starting ppp at Boot

Add the following to your `/etc/rc.conf` file:

```
ppp_enable="YES"
ppp_mode="ddial"
ppp_nat="YES" # if you want to enable nat for your local network, otherwise NO
ppp_profile="name_of_service_provider"
```

18.5.5 Using a PPPoE Service Tag

Sometimes it will be necessary to use a service tag to establish your connection. Service tags are used to distinguish between different PPPoE servers attached to a given network.

You should have been given any required service tag information in the documentation provided by your ISP. If you cannot locate it there, ask your ISP's tech support personnel.

As a last resort, you could try the method suggested by the Roaring Penguin PPPoE (http://www.roaringpenguin.com/pppoe/) program which can be found in the ports collection. Bear in mind however, this may de-program your modem and render it useless, so think twice before doing it. Simply install the program shipped with the modem by your provider. Then, access the System menu from the program. The name of your profile should be listed there. It is usually *ISP*.

The profile name (service tag) will be used in the PPPoE configuration entry in `ppp.conf` as the provider part of the `set device` command (see the ppp(8) manual page for full details). It should look like this:

```
set device PPPoE:xl1:ISP
```

Do not forget to change *`xl1`* to the proper device for your Ethernet card.

Do not forget to change *`ISP`* to the profile you have just found above.

For additional information, see:

- Cheaper Broadband with FreeBSD on DSL (http://renaud.waldura.com/doc/freebsd/pppoe/) by Renaud Waldura.
- Nutzung von T-DSL und T-Online mit FreeBSD (http://www.ruhr.de/home/nathan/FreeBSD/tdsl-freebsd.html) by Udo Erdelhoff (in German).

18.5.6 PPPoE with a 3Com® HomeConnect® ADSL Modem Dual Link

This modem does not follow RFC 2516 (http://www.faqs.org/rfcs/rfc2516.html) (*A Method for transmitting PPP over Ethernet (PPPoE)*, written by L. Mamakos, K. Lidl, J. Evarts, D. Carrel, D. Simone, and R. Wheeler). Instead, different packet type codes have been used for the Ethernet frames. Please complain to 3Com (http://www.3com.com/) if you think it should comply with the PPPoE specification.

In order to make FreeBSD capable of communicating with this device, a sysctl must be set. This can be done automatically at boot time by updating `/etc/sysctl.conf`:

```
net.graph.nonstandard_pppoe=1
```

or can be done for immediate effect with the command `sysctl net.graph.nonstandard_pppoe=1`.

Unfortunately, because this is a system-wide setting, it is not possible to talk to a normal PPPoE client or server and a 3Com HomeConnect® ADSL Modem at the same time.

18.6 Using PPP over ATM (PPPoA)

The following describes how to set up PPP over ATM (PPPoA). PPPoA is a popular choice among European DSL providers.

18.6.1 Using PPPoA with the Alcatel SpeedTouch™ USB

PPPoA support for this device is supplied as a port in FreeBSD because the firmware is distributed under Alcatel's license agreement (http://www.speedtouchdsl.com/disclaimer_lx.htm) and can not be redistributed freely with the base system of FreeBSD.

To install the software, simply use the ports collection. Install the `net/pppoa` port and follow the instructions provided with it.

Like many USB devices, the Alcatel SpeedTouch™ USB needs to download firmware from the host computer to operate properly. It is possible to automate this process in FreeBSD so that this transfer takes place whenever the device is plugged into a USB port. The following information can be added to the `/etc/usbd.conf` file to enable this automatic firmware transfer. This file must be edited as the `root` user.

```
device "Alcatel SpeedTouch USB"
    devname "ugen[0-9]+"
    vendor 0x06b9
    product 0x4061
    attach "/usr/local/sbin/modem_run -f /usr/local/libdata/mgmt.o"
```

To enable the USB daemon, **usbd**, put the following the line into `/etc/rc.conf`:

```
usbd_enable="YES"
```

It is also possible to set up **ppp** to dial up at startup. To do this add the following lines to `/etc/rc.conf`. Again, for this procedure you will need to be logged in as the `root` user.

```
ppp_enable="YES"
ppp_mode="ddial"
ppp_profile="adsl"
```

For this to work correctly you will need to have used the sample `ppp.conf` which is supplied with the `net/pppoa` port.

18.6.2 Using mpd

You can use **mpd** to connect to a variety of services, in particular PPTP services. You can find **mpd** in the ports collection, `net/mpd`. Many ADSL modems require that a PPTP tunnel is created between the modem and computer, one such modem is the Alcatel SpeedTouch Home.

First you must install the port, and then you can configure **mpd** to suit your requirements and provider settings. The port places a set of sample configuration files which are well documented in *`PREFIX`*`/etc/mpd/`. Note here that *`PREFIX`* means the directory into which your ports are installed, this defaults to `/usr/local/`. A complete guide to configure **mpd** is available in HTML format once the port has been installed. It is placed in *`PREFIX`*`/share/mpd/`. Here is a sample configuration for connecting to an ADSL service with **mpd**. The configuration is spread over two files, first the `mpd.conf`:

```
default:
    load adsl

adsl:
    new -i ng0 adsl adsl
    set bundle authname username ❶
```

```
    set bundle password password ❷
    set bundle disable multilink

    set link no pap acfcomp protocomp
    set link disable chap
    set link accept chap
    set link keep-alive 30 10

    set ipcp no vjcomp
    set ipcp ranges 0.0.0.0/0 0.0.0.0/0

    set iface route default
    set iface disable on-demand
    set iface enable proxy-arp
    set iface idle 0

    open
```

❶ The username used to authenticate with your ISP.

❷ The password used to authenticate with your ISP.

The `mpd.links` file contains information about the link, or links, you wish to establish. An example `mpd.links` to accompany the above example is given beneath:

```
adsl:
    set link type pptp
    set pptp mode active
    set pptp enable originate incoming outcall
    set pptp self 10.0.0.1 ❶
    set pptp peer 10.0.0.138 ❷
```

❶ The IP address of your FreeBSD computer which you will be using **mpd** from.

❷ The IP address of your ADSL modem. For the Alcatel SpeedTouch Home this address defaults to `10.0.0.138`.

It is possible to initialize the connection easily by issuing the following command as `root`:

```
# mpd -b adsl
```

You can see the status of the connection with the following command:

```
% ifconfig ng0
ng0: flags=88d1<UP,POINTOPOINT,RUNNING,NOARP,SIMPLEX,MULTICAST> mtu 1500
     inet 216.136.204.117 --> 204.152.186.171 netmask 0xffffffff
```

Using **mpd** is the recommended way to connect to an ADSL service with FreeBSD.

18.6.3 Using pptpclient

It is also possible to use FreeBSD to connect to other PPPoA services using `net/pptpclient`.

To use `net/pptpclient` to connect to a DSL service, install the port or package and edit your `/etc/ppp/ppp.conf`. You will need to be `root` to perform both of these operations. An example section of `ppp.conf` is given below. For further information on `ppp.conf` options consult the **ppp** manual page, ppp(8).

```
adsl:
 set log phase chat lcp ipcp ccp tun command
 set timeout 0
 enable dns
 set authname username ❶
 set authkey password ❷
 set ifaddr 0 0
 add default HISADDR
```

❶ The username of your account with the DSL provider.

❷ The password for your account.

> **Warning:** Because you must put your account's password in the `ppp.conf` file in plain text form you should make sure than nobody can read the contents of this file. The following series of commands will make sure the file is only readable by the `root` account. Refer to the manuals pages for chmod(1) and chown(8) for further information.
>
> ```
> # chown root:wheel /etc/ppp/ppp.conf
> # chmod 600 /etc/ppp/ppp.conf
> ```

This will open a tunnel for a PPP session to your DSL router. Ethernet DSL modems have a preconfigured LAN IP address which you connect to. In the case of the Alcatel SpeedTouch Home this address is `10.0.0.138`. Your router documentation should tell you which address your device uses. To open the tunnel and start a PPP session execute the following command:

```
# pptp address adsl
```

> **Tip:** You may wish to add an ampersand ("&") to the end of the previous command because **pptp** will not return your prompt to you otherwise.

A `tun` virtual tunnel device will be created for interaction between the **pptp** and **ppp** processes. Once you have been returned to your prompt, or the **pptp** process has confirmed a connection you can examine the tunnel like so:

```
% ifconfig tun0
tun0: flags=8051<UP,POINTOPOINT,RUNNING,MULTICAST> mtu 1500
        inet 216.136.204.21 --> 204.152.186.171 netmask 0xffffff00
        Opened by PID 918
```

If you are unable to connect, check the configuration of your router, which is usually accessible via **telnet** or with a web browser. If you still cannot connect you should examine the output of the `pptp` command and the contents of the **ppp** log file, `/var/log/ppp.log` for clues.

18.7 Using SLIP

Originally contributed by Satoshi Asami. With input from Guy Helmer and Piero Serini.

18.7.1 Setting Up a SLIP Client

The following is one way to set up a FreeBSD machine for SLIP on a static host network. For dynamic hostname assignments (your address changes each time you dial up), you probably need to have a more complex setup.

First, determine which serial port your modem is connected to. Many people set up a symbolic link, such as `/dev/modem`, to point to the real device name, `/dev/cuaaN`. This allows you to abstract the actual device name should you ever need to move the modem to a different port. It can become quite cumbersome when you need to fix a bunch of files in `/etc` and `.kermrc` files all over the system!

> **Note:** `/dev/cuaa0` is `COM1`, `cuaa1` is `COM2`, etc.

Make sure you have the following in your kernel configuration file:

```
pseudo-device   sl      1
```

It is included in the `GENERIC` kernel, so this should not be a problem unless you have deleted it.

18.7.1.1 Things You Have to Do Only Once

1. Add your home machine, the gateway and nameservers to your `/etc/hosts` file. Mine looks like this:

   ```
   127.0.0.1               localhost loghost
   136.152.64.181          water.CS.Example.EDU water.CS water
   136.152.64.1            inr-3.CS.Example.EDU inr-3 slip-gateway
   128.32.136.9            ns1.Example.EDU ns1
   128.32.136.12           ns2.Example.EDU ns2
   ```

2. Make sure you have `hosts` before `bind` in your `/etc/host.conf` on FreeBSD versions prior to 5.0. Since FreeBSD 5.0, the system uses the file `/etc/nsswitch.conf` instead, make sure you have `files` before `dns` in the `hosts` line of this file. Without these parameters funny things may happen.
3. Edit the `/etc/rc.conf` file.
   1. Set your hostname by editing the line that says:

      ```
      hostname="myname.my.domain"
      ```

      Your machine's full Internet hostname should be placed here.

   2. Add `sl0` to the list of network interfaces by changing the line that says:

```
network_interfaces="lo0"
```

to:

```
network_interfaces="lo0 sl0"
```

3. Set the startup flags of `sl0` by adding a line:

```
ifconfig_sl0="inet ${hostname} slip-gateway netmask 0xffffff00 up"
```

4. Designate the default router by changing the line:

```
defaultrouter="NO"
```

to:

```
defaultrouter="slip-gateway"
```

4. Make a file `/etc/resolv.conf` which contains:

```
domain CS.Example.EDU
nameserver 128.32.136.9
nameserver 128.32.136.12
```

As you can see, these set up the nameserver hosts. Of course, the actual domain names and addresses depend on your environment.

5. Set the password for `root` and `toor` (and any other accounts that do not have a password).
6. Reboot your machine and make sure it comes up with the correct hostname.

18.7.1.2 Making a SLIP Connection

1. Dial up, type `slip` at the prompt, enter your machine name and password. What is required to be entered depends on your environment. If you use kermit, you can try a script like this:

```
# kermit setup
set modem hayes
set line /dev/modem
set speed 115200
set parity none
set flow rts/cts
set terminal bytesize 8
set file type binary
# The next macro will dial up and login
define slip dial 643-9600, input 10 =>, if failure stop, -
output slip\x0d, input 10 Username:, if failure stop, -
output silvia\x0d, input 10 Password:, if failure stop, -
output ***\x0d, echo \x0aCONNECTED\x0a
```

Of course, you have to change the hostname and password to fit yours. After doing so, you can just type `slip` from the kermit prompt to connect.

Note: Leaving your password in plain text anywhere in the filesystem is generally a *bad* idea. Do it at your own risk.

2. Leave the kermit there (you can suspend it by **Ctrl-z**) and as `root`, type:

   ```
   # slattach -h -c -s 115200 /dev/modem
   ```

   If you are able to `ping` hosts on the other side of the router, you are connected! If it does not work, you might want to try `-a` instead of `-c` as an argument to `slattach`.

18.7.1.3 How to Shutdown the Connection

Do the following:

```
# kill -INT ‘cat /var/run/slattach.modem.pid‘
```

to kill `slattach`. Keep in mind you must be `root` to do the above. Then go back to kermit (by running `fg` if you suspended it) and exit from it (`q`).

The `slattach` manual page says you have to use `ifconfig sl0 down` to mark the interface down, but this does not seem to make any difference for me. (`ifconfig sl0` reports the same thing.)

Some times, your modem might refuse to drop the carrier (mine often does). In that case, simply start kermit and quit it again. It usually goes out on the second try.

18.7.1.4 Troubleshooting

If it does not work, feel free to ask me. The things that people tripped over so far:

- Not using `-c` or `-a` in `slattach` (This should not be fatal, but some users have reported that this solves their problems.)
- Using `s10` instead of `sl0` (might be hard to see the difference on some fonts).
- Try `ifconfig sl0` to see your interface status. For example, you might get:

  ```
  # ifconfig sl0
  sl0: flags=10<POINTOPOINT>
          inet 136.152.64.181 --> 136.152.64.1 netmask ffffff00
  ```

- If you get `no route to host` messages from ping, there may be a problem with your routing table. You can use the `netstat -r` command to display the current routes :

  ```
  # netstat -r
  Routing tables
  Destination      Gateway            Flags     Refs     Use  IfaceMTU    Rtt    Netmasks:

  (root node)
  (root node)

  Route Tree for Protocol Family inet:
  ```

```
(root node) =>
default          inr-3.Example.EDU  UG          8   224515  sl0 -      -
localhost.Exampl localhost.Example. UH          5    42127  lo0 -       0.438
inr-3.Example.ED water.CS.Example.E UH          1        0  sl0 -      -
water.CS.Example localhost.Example. UGH        34 47641234  lo0 -       0.438
(root node)
```

The preceding examples are from a relatively busy system. The numbers on your system will vary depending on network activity.

18.7.2 Setting Up a SLIP Server

This document provides suggestions for setting up SLIP Server services on a FreeBSD system, which typically means configuring your system to automatically startup connections upon login for remote SLIP clients.

18.7.2.1 Prerequisites

This section is very technical in nature, so background knowledge is required. It is assumed that you are familiar with the TCP/IP network protocol, and in particular, network and node addressing, network address masks, subnetting, routing, and routing protocols, such as RIP. Configuring SLIP services on a dial-up server requires a knowledge of these concepts, and if you are not familiar with them, please read a copy of either Craig Hunt's *TCP/IP Network Administration* published by O'Reilly & Associates, Inc. (ISBN Number 0-937175-82-X), or Douglas Comer's books on the TCP/IP protocol.

It is further assumed that you have already set up your modem(s) and configured the appropriate system files to allow logins through your modems. If you have not prepared your system for this yet, please see the tutorial for configuring dialup services; if you have a World-Wide Web browser available, browse the list of tutorials at http://www.FreeBSD.org/ (../../../../index.html). You may also want to check the manual pages for sio(4) for information on the serial port device driver and ttys(5), gettytab(5), getty(8), & init(8) for information relevant to configuring the system to accept logins on modems, and perhaps stty(1) for information on setting serial port parameters (such as `clocal` for directly-connected serial interfaces).

18.7.2.2 Quick Overview

In its typical configuration, using FreeBSD as a SLIP server works as follows: a SLIP user dials up your FreeBSD SLIP Server system and logs in with a special SLIP login ID that uses `/usr/sbin/sliplogin` as the special user's shell. The `sliplogin` program browses the file `/etc/sliphome/slip.hosts` to find a matching line for the special user, and if it finds a match, connects the serial line to an available SLIP interface and then runs the shell script `/etc/sliphome/slip.login` to configure the SLIP interface.

18.7.2.2.1 An Example of a SLIP Server Login

For example, if a SLIP user ID were `Shelmerg`, `Shelmerg`'s entry in `/etc/master.passwd` would look something like this:

```
Shelmerg:password:1964:89::0:0:Guy Helmer - SLIP:/usr/users/Shelmerg:/usr/sbin/sliplogin
```

When Shelmerg logs in, sliplogin will search /etc/sliphome/slip.hosts for a line that had a matching user ID; for example, there may be a line in /etc/sliphome/slip.hosts that reads:

```
Shelmerg        dc-slip sl-helmer       0xfffffc00   autocomp
```

sliplogin will find that matching line, hook the serial line into the next available SLIP interface, and then execute /etc/sliphome/slip.login like this:

```
/etc/sliphome/slip.login 0 19200 Shelmerg dc-slip sl-helmer 0xfffffc00 autocomp
```

If all goes well, /etc/sliphome/slip.login will issue an ifconfig for the SLIP interface to which sliplogin attached itself (slip interface 0, in the above example, which was the first parameter in the list given to slip.login) to set the local IP address (dc-slip), remote IP address (sl-helmer), network mask for the SLIP interface (0xfffffc00), and any additional flags (autocomp). If something goes wrong, sliplogin usually logs good informational messages via the daemon syslog facility, which usually logs to /var/log/messages (see the manual pages for syslogd(8) and syslog.conf(5) and perhaps check /etc/syslog.conf to see to what syslogd is logging and where it is logging to).

OK, enough of the examples — let us dive into setting up the system.

18.7.2.3 Kernel Configuration

FreeBSD's default kernels usually come with two SLIP interfaces defined (sl0 and sl1); you can use netstat -i to see whether these interfaces are defined in your kernel.

Sample output from netstat -i:

```
Name  Mtu   Network     Address            Ipkts Ierrs    Opkts Oerrs  Coll
ed0   1500  <Link>0.0.c0.2c.5f.4a         291311     0   174209     0   133
ed0   1500  138.247.224 ivory            291311     0   174209     0   133
lo0   65535 <Link>                           79     0       79     0     0
lo0   65535 loop        localhost           79     0       79     0     0
sl0*  296   <Link>                            0     0        0     0     0
sl1*  296   <Link>                            0     0        0     0     0
```

The sl0 and sl1 interfaces shown from netstat -i indicate that there are two SLIP interfaces built into the kernel. (The asterisks after the sl0 and sl1 indicate that the interfaces are "down".)

However, FreeBSD's default kernel does not come configured to forward packets (by default, your FreeBSD machine will not act as a router) due to Internet RFC requirements for Internet hosts (see RFCs 1009 [Requirements for Internet Gateways], 1122 [Requirements for Internet Hosts — Communication Layers], and perhaps 1127 [A Perspective on the Host Requirements RFCs]). If you want your FreeBSD SLIP Server to act as a router, you will have to edit the /etc/rc.conf file and change the setting of the gateway_enable variable to YES.

You will then need to reboot for the new settings to take effect.

You will notice that near the end of the default kernel configuration file (/sys/i386/conf/GENERIC) is a line that reads:

```
pseudo-device sl 2
```

This is the line that defines the number of SLIP devices available in the kernel; the number at the end of the line is the maximum number of SLIP connections that may be operating simultaneously.

Please refer to Chapter 9 on Configuring the FreeBSD Kernel for help in reconfiguring your kernel.

18.7.2.4 Sliplogin Configuration

As mentioned earlier, there are three files in the `/etc/sliphome` directory that are part of the configuration for `/usr/sbin/sliplogin` (see sliplogin(8) for the actual manual page for `sliplogin`): `slip.hosts`, which defines the SLIP users and their associated IP addresses; `slip.login`, which usually just configures the SLIP interface; and (optionally) `slip.logout`, which undoes `slip.login`'s effects when the serial connection is terminated.

18.7.2.4.1 `slip.hosts` Configuration

`/etc/sliphome/slip.hosts` contains lines which have at least four items separated by whitespace:

- SLIP user's login ID
- Local address (local to the SLIP server) of the SLIP link
- Remote address of the SLIP link
- Network mask

The local and remote addresses may be host names (resolved to IP addresses by `/etc/hosts` or by the domain name service, depending on your specifications in the file `/etc/nsswitch.conf` on FreeBSD 5.X, in `/etc/host.conf` if you use FreeBSD 4.X), and the network mask may be a name that can be resolved by a lookup into `/etc/networks`. On a sample system, `/etc/sliphome/slip.hosts` looks like this:

```
#
# login local-addr      remote-addr     mask            opt1    opt2
#                                               (normal,compress,noicmp)
#
Shelmerg  dc-slip       sl-helmerg      0xfffffc00      autocomp
```

At the end of the line is one or more of the options.

- `normal` — no header compression
- `compress` — compress headers
- `autocomp` — compress headers if the remote end allows it
- `noicmp` — disable ICMP packets (so any "ping" packets will be dropped instead of using up your bandwidth)

Your choice of local and remote addresses for your SLIP links depends on whether you are going to dedicate a TCP/IP subnet or if you are going to use "proxy ARP" on your SLIP server (it is not "true" proxy ARP, but that is the terminology used in this section to describe it). If you are not sure which method to select or how to assign IP addresses, please refer to the TCP/IP books referenced in the SLIP Prerequisites (Section 18.7.2.1) and/or consult your IP network manager.

If you are going to use a separate subnet for your SLIP clients, you will need to allocate the subnet number out of your assigned IP network number and assign each of your SLIP client's IP numbers out of that subnet. Then, you will probably need to configure a static route to the SLIP subnet via your SLIP server on your nearest IP router.

Otherwise, if you will use the "proxy ARP" method, you will need to assign your SLIP client's IP addresses out of your SLIP server's Ethernet subnet, and you will also need to adjust your `/etc/sliphome/slip.login` and

/etc/sliphome/slip.logout scripts to use arp(8) to manage the proxy-ARP entries in the SLIP server's ARP table.

18.7.2.4.2 slip.login Configuration

The typical /etc/sliphome/slip.login file looks like this:

```
#!/bin/sh -
#
#       @(#)slip.login  5.1 (Berkeley) 7/1/90

#
# generic login file for a slip line.  sliplogin invokes this with
# the parameters:
#      1        2         3        4          5         6     7-n
#   slipunit ttyspeed loginname local-addr remote-addr mask opt-args
#
/sbin/ifconfig sl$1 inet $4 $5 netmask $6
```

This slip.login file merely runs ifconfig for the appropriate SLIP interface with the local and remote addresses and network mask of the SLIP interface.

If you have decided to use the "proxy ARP" method (instead of using a separate subnet for your SLIP clients), your /etc/sliphome/slip.login file will need to look something like this:

```
#!/bin/sh -
#
#       @(#)slip.login  5.1 (Berkeley) 7/1/90

#
# generic login file for a slip line.  sliplogin invokes this with
# the parameters:
#      1        2         3        4          5         6     7-n
#   slipunit ttyspeed loginname local-addr remote-addr mask opt-args
#
/sbin/ifconfig sl$1 inet $4 $5 netmask $6
# Answer ARP requests for the SLIP client with our Ethernet addr
/usr/sbin/arp -s $5 00:11:22:33:44:55 pub
```

The additional line in this slip.login, arp -s $5 00:11:22:33:44:55 pub, creates an ARP entry in the SLIP server's ARP table. This ARP entry causes the SLIP server to respond with the SLIP server's Ethernet MAC address whenever another IP node on the Ethernet asks to speak to the SLIP client's IP address.

When using the example above, be sure to replace the Ethernet MAC address (00:11:22:33:44:55) with the MAC address of your system's Ethernet card, or your "proxy ARP" will definitely not work! You can discover your SLIP server's Ethernet MAC address by looking at the results of running netstat -i; the second line of the output should look something like:

```
ed0   1500  <Link>0.2.c1.28.5f.4a         191923 0   129457     0   116
```

This indicates that this particular system's Ethernet MAC address is 00:02:c1:28:5f:4a — the periods in the Ethernet MAC address given by netstat -i must be changed to colons and leading zeros should be added to each single-digit hexadecimal number to convert the address into the form that arp(8) desires; see the manual page on arp(8) for complete information on usage.

> **Note:** When you create `/etc/sliphome/slip.login` and `/etc/sliphome/slip.logout`, the "execute" bit (`chmod 755 /etc/sliphome/slip.login /etc/sliphome/slip.logout`) must be set, or `sliplogin` will be unable to execute it.

18.7.2.4.3 `slip.logout` Configuration

`/etc/sliphome/slip.logout` is not strictly needed (unless you are implementing "proxy ARP"), but if you decide to create it, this is an example of a basic `slip.logout` script:

```
#!/bin/sh -
#
#       slip.logout

#
# logout file for a slip line.  sliplogin invokes this with
# the parameters:
#      1        2         3        4          5         6     7-n
#   slipunit ttyspeed loginname local-addr remote-addr mask opt-args
#
/sbin/ifconfig sl$1 down
```

If you are using "proxy ARP", you will want to have `/etc/sliphome/slip.logout` remove the ARP entry for the SLIP client:

```
#!/bin/sh -
#
#       @(#)slip.logout

#
# logout file for a slip line.  sliplogin invokes this with
# the parameters:
#      1        2         3        4          5         6     7-n
#   slipunit ttyspeed loginname local-addr remote-addr mask opt-args
#
/sbin/ifconfig sl$1 down
# Quit answering ARP requests for the SLIP client
/usr/sbin/arp -d $5
```

The `arp -d $5` removes the ARP entry that the "proxy ARP" `slip.login` added when the SLIP client logged in.

It bears repeating: make sure `/etc/sliphome/slip.logout` has the execute bit set after you create it (ie, `chmod 755 /etc/sliphome/slip.logout`).

18.7.2.5 Routing Considerations

If you are not using the "proxy ARP" method for routing packets between your SLIP clients and the rest of your network (and perhaps the Internet), you will probably have to add static routes to your closest default router(s) to route your SLIP client subnet via your SLIP server.

18.7.2.5.1 Static Routes

Adding static routes to your nearest default routers can be troublesome (or impossible if you do not have authority to do so...). If you have a multiple-router network in your organization, some routers, such as those made by Cisco and Proteon, may not only need to be configured with the static route to the SLIP subnet, but also need to be told which static routes to tell other routers about, so some expertise and troubleshooting/tweaking may be necessary to get static-route-based routing to work.

18.7.2.5.2 Running `gated`

> **Note:** `gated` is proprietary software now and will not be available as source code to the public anymore (more info on the gated (http://www.gated.org/) website). This section only exists to ensure backwards compatibility for those that are still using an older version.

An alternative to the headaches of static routes is to install `gated` on your FreeBSD SLIP server and configure it to use the appropriate routing protocols (RIP/OSPF/BGP/EGP) to tell other routers about your SLIP subnet. You'll need to write a `/etc/gated.conf` file to configure your gated; here is a sample, similar to what the author used on a FreeBSD SLIP server:

```
#
# gated configuration file for dc.dsu.edu; for gated version 3.5alpha5
# Only broadcast RIP information for xxx.xxx.yy out the ed Ethernet interface
#
#
# tracing options
#
traceoptions "/var/tmp/gated.output" replace size 100k files 2 general ;

rip yes {
  interface sl noripout noripin ;
  interface ed ripin ripout version 1 ;
  traceoptions route ;
} ;

#
# Turn on a bunch of tracing info for the interface to the kernel:
kernel {
  traceoptions remnants request routes info interface ;
} ;

#
# Propagate the route to xxx.xxx.yy out the Ethernet interface via RIP
#
```

```
export proto rip interface ed {
  proto direct {
      xxx.xxx.yy mask 255.255.252.0 metric 1; # SLIP connections
  } ;
} ;

#
# Accept routes from RIP via ed Ethernet interfaces

import proto rip interface ed {
  all ;
} ;
```

The above sample `gated.conf` file broadcasts routing information regarding the SLIP subnet *`xxx.xxx.yy`* via RIP onto the Ethernet; if you are using a different Ethernet driver than the `ed` driver, you will need to change the references to the `ed` interface appropriately. This sample file also sets up tracing to `/var/tmp/gated.output` for debugging `gated`'s activity; you can certainly turn off the tracing options if `gated` works OK for you. You will need to change the *`xxx.xxx.yy`*'s into the network address of your own SLIP subnet (be sure to change the net mask in the `proto direct` clause as well).

Once you have installed and configured `gated` on your system, you will need to tell the FreeBSD startup scripts to run `gated` in place of `routed`. The easiest way to accomplish this is to set the `router` and `router_flags` variables in `/etc/rc.conf`. Please see the manual page for `gated` for information on command-line parameters.

Chapter 19 Advanced Networking

19.1 Synopsis

This chapter will cover some of the more frequently used network services on UNIX systems. We will cover how to define, set up, test and maintain all of the network services that FreeBSD utilizes. In addition, there have been example configuration files included throughout this chapter for you to benefit from.

After reading this chapter, you will know:

- The basics of gateways and routes.
- How to make FreeBSD act as a bridge.
- How to set up a network filesystem.
- How to set up network booting on a diskless machine.
- How to set up a network information server for sharing user accounts.
- How to set up automatic network settings using DHCP.
- How to set up a domain name server.
- How to synchronize the time and date, and set up a time server, with the NTP protocol.
- How to set up network address translation.
- How to manage the **inetd** daemon.
- How to connect two computers via PLIP.
- How to set up IPv6 on a FreeBSD machine.

Before reading this chapter, you should:

- Understand the basics of the `/etc/rc` scripts.
- Be familiar with basic network terminology.

19.2 Gateways and Routes

Contributed by Coranth Gryphon.

For one machine to be able to find another over a network, there must be a mechanism in place to describe how to get from one to the other. This is called *routing*. A "route" is a defined pair of addresses: a "destination" and a "gateway". The pair indicates that if you are trying to get to this *destination*, communicate through this *gateway*. There are three types of destinations: individual hosts, subnets, and "default". The "default route" is used if none of the other routes apply. We will talk a little bit more about default routes later on. There are also three types of gateways: individual hosts, interfaces (also called "links"), and Ethernet hardware addresses (MAC addresses).

19.2.1 An Example

To illustrate different aspects of routing, we will use the following example from `netstat`:

```
% netstat -r
Routing tables

Destination      Gateway            Flags     Refs     Use     Netif Expire

default          outside-gw         UGSc       37      418      ppp0
localhost        localhost          UH          0      181       lo0
test0            0:e0:b5:36:cf:4f   UHLW        5    63288       ed0     77
10.20.30.255     link#1             UHLW        1     2421
example.com      link#1             UC          0        0
host1            0:e0:a8:37:8:1e    UHLW        3     4601       lo0
host2            0:e0:a8:37:8:1e    UHLW        0        5       lo0 =>
host2.example.com link#1             UC          0        0
224              link#1             UC          0        0
```

The first two lines specify the default route (which we will cover in the next section) and the `localhost` route.

The interface (`Netif` column) that this routing table specifies to use for `localhost` is `lo0`, also known as the loopback device. This says to keep all traffic for this destination internal, rather than sending it out over the LAN, since it will only end up back where it started.

The next thing that stands out are the addresses beginning with `0:e0:`. These are Ethernet hardware addresses, which are also known as MAC addresses. FreeBSD will automatically identify any hosts (`test0` in the example) on the local Ethernet and add a route for that host, directly to it over the Ethernet interface, `ed0`. There is also a timeout (`Expire` column) associated with this type of route, which is used if we fail to hear from the host in a specific amount of time. When this happens, the route to this host will be automatically deleted. These hosts are identified using a mechanism known as RIP (Routing Information Protocol), which figures out routes to local hosts based upon a shortest path determination.

FreeBSD will also add subnet routes for the local subnet (`10.20.30.255` is the broadcast address for the subnet `10.20.30`, and `example.com` is the domain name associated with that subnet). The designation `link#1` refers to the first Ethernet card in the machine. You will notice no additional interface is specified for those.

Both of these groups (local network hosts and local subnets) have their routes automatically configured by a daemon called **routed**. If this is not run, then only routes which are statically defined (i.e. entered explicitly) will exist.

The `host1` line refers to our host, which it knows by Ethernet address. Since we are the sending host, FreeBSD knows to use the loopback interface (`lo0`) rather than sending it out over the Ethernet interface.

The two `host2` lines are an example of what happens when we use an ifconfig(8) alias (see the section on Ethernet for reasons why we would do this). The `=>` symbol after the `lo0` interface says that not only are we using the loopback (since this address also refers to the local host), but specifically it is an alias. Such routes only show up on the host that supports the alias; all other hosts on the local network will simply have a `link#1` line for such routes.

The final line (destination subnet `224`) deals with multicasting, which will be covered in another section.

Finally, various attributes of each route can be seen in the `Flags` column. Below is a short table of some of these flags and their meanings:

U	Up: The route is active.
H	Host: The route destination is a single host.

G	Gateway: Send anything for this destination on to this remote system, which will figure out from there where to send it.
S	Static: This route was configured manually, not automatically generated by the system.
C	Clone: Generates a new route based upon this route for machines we connect to. This type of route is normally used for local networks.
W	WasCloned: Indicated a route that was auto-configured based upon a local area network (Clone) route.
L	Link: Route involves references to Ethernet hardware.

19.2.2 Default Routes

When the local system needs to make a connection to a remote host, it checks the routing table to determine if a known path exists. If the remote host falls into a subnet that we know how to reach (Cloned routes), then the system checks to see if it can connect along that interface.

If all known paths fail, the system has one last option: the "default" route. This route is a special type of gateway route (usually the only one present in the system), and is always marked with a `c` in the flags field. For hosts on a local area network, this gateway is set to whatever machine has a direct connection to the outside world (whether via PPP link, DSL, cable modem, T1, or another network interface).

If you are configuring the default route for a machine which itself is functioning as the gateway to the outside world, then the default route will be the gateway machine at your Internet Service Provider's (ISP) site.

Let us look at an example of default routes. This is a common configuration:

[Local2] <--ether--> [Local1] <--PPP--> [ISP-Serv] <--ether--> [T1-GW]

The hosts `Local1` and `Local2` are at your site. `Local1` is connected to an ISP via a dial up PPP connection. This PPP server computer is connected through a local area network to another gateway computer through an external interface to the ISPs Internet feed.

The default routes for each of your machines will be:

Host	Default Gateway	Interface
Local2	Local1	Ethernet
Local1	T1-GW	PPP

A common question is "Why (or how) would we set the `T1-GW` to be the default gateway for `Local1`, rather than the ISP server it is connected to?".

Remember, since the PPP interface is using an address on the ISP's local network for your side of the connection, routes for any other machines on the ISP's local network will be automatically generated. Hence, you will already know how to reach the `T1-GW` machine, so there is no need for the intermediate step of sending traffic to the ISP server.

As a final note, it is common to use the address X.X.X.1 as the gateway address for your local network. So (using the same example), if your local class-C address space was 10.20.30 and your ISP was using 10.9.9 then the default routes would be:

Host	Default Route
Local2 (10.20.30.2)	Local1 (10.20.30.1)
Local1 (10.20.30.1, 10.9.9.30)	T1-GW (10.9.9.1)

19.2.3 Dual Homed Hosts

There is one other type of configuration that we should cover, and that is a host that sits on two different networks. Technically, any machine functioning as a gateway (in the example above, using a PPP connection) counts as a dual-homed host. But the term is really only used to refer to a machine that sits on two local-area networks.

In one case, the machine has two Ethernet cards, each having an address on the separate subnets. Alternately, the machine may only have one Ethernet card, and be using ifconfig(8) aliasing. The former is used if two physically separate Ethernet networks are in use, the latter if there is one physical network segment, but two logically separate subnets.

Either way, routing tables are set up so that each subnet knows that this machine is the defined gateway (inbound route) to the other subnet. This configuration, with the machine acting as a router between the two subnets, is often used when we need to implement packet filtering or firewall security in either or both directions.

If you want this machine to actually forward packets between the two interfaces, you need to tell FreeBSD to enable this ability.

19.2.4 Building a Router

A network router is simply a system that forwards packets from one interface to another. Internet standards and good engineering practice prevent the FreeBSD Project from enabling this by default in FreeBSD. You can enable this feature by changing the following variable to YES in rc.conf(5):

```
gateway_enable=YES          # Set to YES if this host will be a gateway
```

This option will set the sysctl(8) variable net.inet.ip.forwarding to 1. If you should need to stop routing temporarily, you can reset this to 0 temporarily.

Your new router will need routes to know where to send the traffic. If your network is simple enough you can use static routes. FreeBSD also comes with the standard BSD routing daemon routed(8), which speaks RIP (both version 1 and version 2) and IRDP. Support for BGP v4, OSPF v2, and other sophisticated routing protocols is available with the net/zebra package. Commercial products such as gated are also available for more complex network routing solutions.

Even when FreeBSD is configured in this way, it does not completely comply with the Internet standard requirements for routers. It comes close enough for ordinary use, however.

19.2.5 Routing Propagation

We have already talked about how we define our routes to the outside world, but not about how the outside world finds us.

We already know that routing tables can be set up so that all traffic for a particular address space (in our examples, a class-C subnet) can be sent to a particular host on that network, which will forward the packets inbound.

When you get an address space assigned to your site, your service provider will set up their routing tables so that all traffic for your subnet will be sent down your PPP link to your site. But how do sites across the country know to send to your ISP?

There is a system (much like the distributed DNS information) that keeps track of all assigned address-spaces, and defines their point of connection to the Internet Backbone. The "Backbone" are the main trunk lines that carry Internet traffic across the country, and around the world. Each backbone machine has a copy of a master set of tables, which direct traffic for a particular network to a specific backbone carrier, and from there down the chain of service providers until it reaches your network.

It is the task of your service provider to advertise to the backbone sites that they are the point of connection (and thus the path inward) for your site. This is known as route propagation.

19.2.6 Troubleshooting

Sometimes, there is a problem with routing propagation, and some sites are unable to connect to you. Perhaps the most useful command for trying to figure out where routing is breaking down is the traceroute(8) command. It is equally useful if you cannot seem to make a connection to a remote machine (i.e. ping(8) fails).

The traceroute(8) command is run with the name of the remote host you are trying to connect to. It will show the gateway hosts along the path of the attempt, eventually either reaching the target host, or terminating because of a lack of connection.

For more information, see the manual page for traceroute(8).

19.2.7 Multicast Routing

FreeBSD supports both multicast applications and multicast routing natively. Multicast applications do not require any special configuration of FreeBSD; applications will generally run out of the box. Multicast routing requires that support be compiled into the kernel:

```
options MROUTING
```

In addition, the multicast routing daemon, mrouted(8) must be configured to set up tunnels and DVMRP via `/etc/mrouted.conf`. More details on multicast configuration may be found in the man pages for mrouted.

19.3 Wireless Networking

Written by Eric Anderson.

19.3.1 Introduction

It can be very useful to be able to use a computer without the annoyance of having a network cable attached at all times. FreeBSD can be used as a wireless client, and even as a wireless "access point".

19.3.2 Wireless Modes of Operation

There are two different ways to configure 802.11 wireless devices: BSS and IBSS.

19.3.2.1 BSS Mode

BSS mode is the mode that typically is used. BSS mode is also called infrastructure mode. In this mode, a number of wireless access points are connected to a wired network. Each wireless network has its own name. This name is called the SSID of the network.

Wireless clients connect to these wireless access points. The IEEE 802.11 standard defines the protocol that wireless networks use to connect. A wireless client can be tied to a specific network, when a SSID is set. A wireless client can also attach to any network by not explicitly setting a SSID.

19.3.2.2 IBSS Mode

IBSS mode, also called ad-hoc mode, is designed for point to point connections. There are actually two types of ad-hoc mode. One is IBSS mode, also called ad-hoc or IEEE ad-hoc mode. This mode is defined by the IEEE 802.11 standards. The second is called demo ad-hoc mode or Lucent ad-hoc mode (and sometimes, confusingly, ad-hoc mode). This is the old, pre-802.11 ad-hoc mode and should only be used for legacy installations. We will not cover either of the ad-hoc modes further.

19.3.3 Infrastructure Mode

19.3.3.1 Access Points

Access points are wireless networking devices that allow one or more wireless clients to use the device as a central hub. When using an access point, all clients communicate through the access point. Multiple access points are often used to cover a complete area such as a house, business, or park with a wireless network.

Access points typically have multiple network connections: the wireless card, and one or more wired Ethernet adapters for connection to the rest of the network.

Access points can either be purchased prebuilt, or you can build your own with FreeBSD and a supported wireless card. Several vendors make wireless access points and wireless cards with various features.

19.3.3.2 Building a FreeBSD Access Point

19.3.3.2.1 Requirements

In order to set up a wireless access point with FreeBSD, you need to have a compatible wireless card. Currently, only cards with the Prism chipset are supported. You will also need a wired network card that is supported by FreeBSD (this should not be difficult to find, FreeBSD supports a lot of different devices). For this guide, we will assume you want to bridge(4) all traffic between the wireless device and the network attached to the wired network card.

The hostap functionality that FreeBSD uses to implement the access point works best with certain versions of firmware. Prism 2 cards should use firmware version 1.3.4 or newer. Prism 2.5 and Prism 3 cards should use firmware 1.4.9. Older versions of the firmware way or may not function correctly. At this time, the only way to update cards is with Windows firmware update utilities available from your card’s manufacturer.

19.3.3.2.2 Setting It Up

First, make sure your system can see the wireless card:

```
# ifconfig -a
wi0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet6 fe80::202:2dff:fe2d:c938%wi0 prefixlen 64 scopeid 0x7
        inet 0.0.0.0 netmask 0xff000000 broadcast 255.255.255.255
        ether 00:09:2d:2d:c9:50
        media: IEEE 802.11 Wireless Ethernet autoselect (DS/2Mbps)
        status: no carrier
        ssid ""
        stationname "FreeBSD Wireless node"
        channel 10 authmode OPEN powersavemode OFF powersavesleep 100
        wepmode OFF weptxkey 1
```

Do not worry about the details now, just make sure it shows you something to indicate you have a wireless card installed. If you have trouble seeing the wireless interface, and you are using a PC Card, you may want to check out pccardc(8) and pccardd(8) manual pages for more information.

Next, you will need to load a module in order to get the bridging part of FreeBSD ready for the access point. In order to load the bridge(4) module, simply run the following command:

```
# kldload bridge
```

It should not have produced any errors when loading the module. If it did, you may need to compile the bridge(4) code into your kernel. The Bridging section of the handbook should be able to help you accomplish that task.

Now that you have the bridging stuff done, we need to tell the FreeBSD kernel which interfaces to bridge together. We do that by using sysctl(8):

```
# sysctl net.link.ether.bridge=1
# sysctl net.link.ether.bridge_cfg="wi0 xl0"
# sysctl net.inet.ip.forwarding=1
```

Now it is time for the wireless card setup.

The following command will set the card into an access point:

```
# ifconfig wi0 ssid my_net channel 11 media DS/11Mbps mediaopt hostap up stationname "FreeBSD AP"
```

The ifconfig(8) line brings the `wi0` interface up, sets its SSID to `my_net`, and sets the station name to `FreeBSD AP`. The `media DS/11Mbps` sets the card into 11Mbps mode and is needed for any `mediaopt` to take effect. The `mediaopt hostap` option places the interface into access point mode. The `channel 11` option sets the 802.11b channel to use. The wicontrol(8) man page has valid channel options for your regulatory domain.

Now you should have a complete functioning access point up and running. You are encouraged to read wicontrol(8), ifconfig(8), and wi(4) for further information.

It is also suggested that you read the section on encryption that follows.

19.3.3.2.3 Status Information

Once the access point is configured and operational, operators will want to see the clients that are associated with the access point. At any time, the operator may type:

```
# wicontrol -l
1 station:
00:09:b7:7b:9d:16  asid=04c0, flags=3<ASSOC,AUTH>, caps=1<ESS>, rates=f<1M,2M,5.5M,11M>, sig=38/15
```

This shows that there's one station associated, along with its parameters. The signal indicated should be used as a relative indication of strength only. Its translation to dBm or other units varies between different firmware revisions.

19.3.3.3 Clients

A wireless client is a system that accesses an access point or another client directly.

Typically, wireless clients only have one network device, the wireless networking card.

There are a few different ways to configure a wireless client. These are based on the different wireless modes, generally BSS (infrastructure mode, which requires an access point), and IBSS (ad-hoc, or peer-to-peer mode). In our example, we will use the most popular of the two, BSS mode, to talk to an access point.

19.3.3.3.1 Requirements

There is only one real requirement for setting up FreeBSD as a wireless client. You will need a wireless card that is supported by FreeBSD.

19.3.3.3.2 Setting Up a Wireless FreeBSD Client

You will need to know a few things about the wireless network you are joining before you start. In this example, we are joining a network that has a name of `my_net`, and encryption turned off.

Note: In this example, we are not using encryption, which is a dangerous situation. In the next section, you will learn how to turn on encryption, and why it is important to do so, and why some encryption technologies still do not completely protect you.

Make sure your card is recognized by FreeBSD:

```
# ifconfig -a
wi0: flags=8843<UP,BROADCAST,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet6 fe80::202:2dff:fe2d:c938%wi0 prefixlen 64 scopeid 0x7
        inet 0.0.0.0 netmask 0xff000000 broadcast 255.255.255.255
        ether 00:09:2d:2d:c9:50
        media: IEEE 802.11 Wireless Ethernet autoselect (DS/2Mbps)
        status: no carrier
        ssid ""
        stationname "FreeBSD Wireless node"
        channel 10 authmode OPEN powersavemode OFF powersavesleep 100
        wepmode OFF weptxkey 1
```

Now, we will set the card to the correct settings for our network:

```
# ifconfig wi0 inet 192.168.0.20 netmask 255.255.255.0 ssid my_net
```

Replace `192.168.0.20` and `255.255.255.0` with a valid IP address and netmask on your wired network. Remember, our access point is bridging the data between the wireless network, and the wired network, so it will appear to the other devices on your network that you are on the wired network just as they are.

Once you have done that, you should be able to ping hosts on the wired network just as if you were connected using a standard wired connection.

If you are experiencing problems with your wireless connection, check to make sure that your are associated (connected) to the access point:

```
# ifconfig wi0
```

should return some information, and you should see:

```
status: associated
```

If it does not show associated, then you may be out of range of the access point, do not have encryption on, or possibly have a configuration problem.

19.3.3.4 Encryption

Encryption on a wireless network is important because you no longer have the ability to keep the network contained in a well protected area. Your wireless data will be broadcast across your entire neighborhood, so anyone who cares to read it can. This is where encryption comes in. By encrypting the data that is sent over the airwaves, you make it much more difficult for any interested party to grab your data right out of the air.

The two most common ways to encrypt the data between your client and the access point, are WEP, and ipsec(4).

19.3.3.4.1 WEP

WEP is an abbreviation for Wired Equivalency Protocol. WEP is an attempt to make wireless networks as safe and secure as a wired network. Unfortunately, it has been cracked, and is fairly trivial to break. This also means it is not something to rely on when it comes to encrypting sensitive data.

It is better than nothing, so use the following to turn on WEP on your new FreeBSD access point:

```
# ifconfig wi0 inet up ssid my_net wepmode on wepkey 0x1234567890 media DS/11Mbps mediaopt hostap
```

And you can turn on WEP on a client with this command:

```
# ifconfig wi0 inet 192.168.0.20 netmask 255.255.255.0 ssid my_net wepmode on wepkey 0x1234567890
```

Note that you should replace the `0x1234567890` with a more unique key.

19.3.3.4.2 IPsec

ipsec(4) is a much more robust and powerful tool for encrypting data across a network. This is definitely the preferred way to encrypt wireless data over a network. You can read more about ipsec(4) security and how to implement it in the IPsec section of the handbook.

19.3.3.5 Tools

There are a small number of tools available for use in debugging and setting up your wireless network, and here we will attempt to describe some of them and what they do.

*19.3.3.5.1 The **bsd-airtools** Package*

The **bsd-airtools** package is a complete toolset that includes wireless auditing tools for WEP key cracking, access point detection, etc.

The **bsd-airtools** utilities can be installed from the `net/bsd-airtools` port. Information on installing ports can be found in Chapter 4 of the handbook.

The program `dstumbler` is the packaged tool that allows for access point discovery and signal to noise ratio graphing. If you are having a hard time getting your access point up and running, `dstumbler` may help you get started.

To test your wireless network security, you may choose to use "dweputils" (`dwepcrack`, `dwepdump` and `dwepkeygen`) to help you determine if WEP is the right solution to your wireless security needs.

*19.3.3.5.2 The **wicontrol**, **ancontrol** and **raycontrol** Utilities*

These are the tools you use to control how your wireless card behaves on the wireless network. In the examples above, we have chosen to use wicontrol(8), since our wireless card is a `wi0` interface. If you had a Cisco wireless device, it would come up as `an0`, and therefore you would use ancontrol(8).

*19.3.3.5.3 The **ifconfig** Command*

ifconfig(8) can be used to do many of the same options as wicontrol(8), however it does lack a few options. Check ifconfig(8) for command line parameters and options.

19.3.3.6 Supported Cards

19.3.3.6.1 Access Points

The only cards that are currently supported for BSS (as an access point) mode are devices based on the Prism 2, 2.5, or 3 chipsets. For a complete list, look at wi(4).

19.3.3.6.2 Clients

Almost all 802.11b wireless cards are currently supported under FreeBSD. Most cards based on Prism, Spectrum24, Hermes, Aironet, and Raylink will work as a wireless network card in IBSS (ad-hoc, peer-to-peer, and BSS) mode.

19.4 Bluetooth

Written by Pav Lucistnik.

19.4.1 Introduction

Bluetooth is a wireless technology for creating personal networks operating in the 2.4 GHz unlicensed band, with a range of 10 meters. Networks are usually formed ad-hoc from portable devices such as cellular phones, handhelds and laptops. Unlike the other popular wireless technology, Wi-Fi, Bluetooth offers higher level service profiles, e.g. FTP-like file servers, file pushing, voice transport, serial line emulation, and more.

The Bluetooth stack in FreeBSD is implemented using the Netgraph framework (see netgraph(4)). A broad variety of Bluetooth USB dongles is supported by the ng_ubt(4) driver. The Broadcom BCM2033 chip based Bluetooth devices are supported via the ubtbcmfw(4) and ng_ubt(4) drivers. The 3Com Bluetooth PC Card 3CRWB60-A is supported by the ng_bt3c(4) driver. Serial and UART based Bluetooth devices are supported via sio(4), ng_h4(4) and hcseriald(8). This chapter describes the use of the USB Bluetooth dongle. Bluetooth support is available in FreeBSD 5.0 and newer systems.

19.4.2 Plugging in the Device

By default Bluetooth device drivers are available as kernel modules. Before attaching a device, you will need to load the driver into the kernel.

```
# kldload ng_ubt
```

If the Bluetooth device is present in the system during system startup, load the module from `/boot/loader.conf`.

```
ng_ubt_load="YES"
```

Plug in your USB dongle. The output similar to the following will appear on the console (or in syslog).

```
ubt0: vendor 0x0a12 product 0x0001, rev 1.10/5.25, addr 2
ubt0: Interface 0 endpoints: interrupt=0x81, bulk-in=0x82, bulk-out=0x2
ubt0: Interface 1 (alt.config 5) endpoints: isoc-in=0x83, isoc-out=0x3,
```

```
    wMaxPacketSize=49, nframes=6, buffer size=294
```

Copy `/usr/share/examples/netgraph/bluetooth/rc.bluetooth` into some convenient place, like `/etc/rc.bluetooth`. This script is used to start and stop the Bluetooth stack. It is a good idea to stop the stack before unplugging the device, but it is not (usually) fatal. When starting the stack, you will receive output similar to the following:

```
# /etc/rc.bluetooth start ubt0
BD_ADDR: 00:02:72:00:d4:1a
Features: 0xff 0xff 0xf 00 00 00 00 00
<3-Slot> <5-Slot> <Encryption> <Slot offset>
<Timing accuracy> <Switch> <Hold mode> <Sniff mode>
<Park mode> <RSSI> <Channel quality> <SCO link>
<HV2 packets> <HV3 packets> <u-law log> <A-law log> <CVSD>
<Paging scheme> <Power control> <Transparent SCO data>
Max. ACL packet size: 192 bytes
Number of ACL packets: 8
Max. SCO packet size: 64 bytes
Number of SCO packets: 8
```

19.4.3 Host Controller Interface (HCI)

Host Controller Interface (HCI) provides a command interface to the baseband controller and link manager, and access to hardware status and control registers. This interface provides a uniform method of accessing the Bluetooth baseband capabilities. HCI layer on the Host exchanges data and commands with the HCI firmware on the Bluetooth hardware. The Host Controller Transport Layer (i.e. physical bus) driver provides both HCI layers with the ability to exchange information with each other.

A single Netgraph node of type *hci* is created for a single Bluetooth device. The HCI node is normally connected to the Bluetooth device driver node (downstream) and the L2CAP node (upstream). All HCI operations must be performed on the HCI node and not on the device driver node. Default name for the HCI node is "devicehci". For more details refer to the ng_hci(4) man page.

One of the most common tasks is discovery of Bluetooth devices in RF proximity. This operation is called *inquiry*. Inquiry and other HCI realated operations are done with the hccontrol(8) utility. The example below shows how to find out which Bluetooth devices are in range. You should receive the list of devices in a few seconds. Note that a remote device will only answer the inquiry if it put into *discoverable* mode.

```
% hccontrol -n ubt0hci inquiry
Inquiry result, num_responses=1
Inquiry result #0
       BD_ADDR: 00:80:37:29:19:a4
       Page Scan Rep. Mode: 0x1
       Page Scan Period Mode: 00
       Page Scan Mode: 00
       Class: 52:02:04
       Clock offset: 0x78ef
Inquiry complete. Status: No error [00]
```

`BD_ADDR` is unique address of a Bluetooth device, similar to MAC addresses of a network card. This address is needed for further communication with a device. It is possible to assign human readable name to a BD_ADDR. The

`/etc/bluetooth/hosts` file contains information regarding the known Bluetooth hosts. The following example shows how to obtain human readable name that was assigned to the remote device.

```
% hccontrol -n ubt0hci remote_name_request 00:80:37:29:19:a4
BD_ADDR: 00:80:37:29:19:a4
Name: Pav's T39
```

If you perform an inquiry on a remote Bluetooth device, it will find your computer as "your.host.name (ubt0)". The name assigned to the local device can be changed at any time.

The Bluetooth system provides a point-to-point connection (only two Bluetooth units involved), or a point-to-multipoint connection. In the point-to-multipoint connection the connection is shared among several Bluetooth devices. The following example shows how to obtain the list of active baseband connections for the local device.

```
% hccontrol -n ubt0hci read_connection_list
Remote BD_ADDR    Handle Type Mode Role Encrypt Pending Queue State
00:80:37:29:19:a4     41  ACL    0 MAST    NONE       0     0 OPEN
```

A *connection handle* is useful when termination of the baseband connection is required. Note, that it is normally not required to do it by hand. The stack will automatically terminate inactive baseband connections.

```
# hccontrol -n ubt0hci disconnect 41
Connection handle: 41
Reason: Connection terminated by local host [0x16]
```

Refer to `hccontrol help` for a complete listing of available HCI commands. Most of the HCI commands do not require superuser privileges.

19.4.4 Logical Link Control and Adaptation Protocol (L2CAP)

Logical Link Control and Adaptation Protocol (L2CAP) provides connection-oriented and connectionless data services to upper layer protocols with protocol multiplexing capability and segmentation and reassembly operation. L2CAP permits higher level protocols and applications to transmit and receive L2CAP data packets up to 64 kilobytes in length.

L2CAP is based around the concept of *channels*. Channel is a logical connection on top of baseband connection. Each channel is bound to a single protocol in a many-to-one fashion. Multiple channels can be bound to the same protocol, but a channel cannot be bound to multiple protocols. Each L2CAP packet received on a channel is directed to the appropriate higher level protocol. Multiple channels can share the same baseband connection.

A single Netgraph node of type *l2cap* is created for a single Bluetooth device. The L2CAP node is normally connected to the Bluetooth HCI node (downstream) and Bluetooth sockets nodes (upstream). Default name for the L2CAP node is "devicel2cap". For more details refer to the ng_l2cap(4) man page.

A useful command is l2ping(8), which can be used to ping other devices. Some Bluetooth implementations might not return all of the data sent to them, so *0 bytes* in the following example is normal.

```
# l2ping -a 00:80:37:29:19:a4
0 bytes from 0:80:37:29:19:a4 seq_no=0 time=48.633 ms result=0
0 bytes from 0:80:37:29:19:a4 seq_no=1 time=37.551 ms result=0
0 bytes from 0:80:37:29:19:a4 seq_no=2 time=28.324 ms result=0
0 bytes from 0:80:37:29:19:a4 seq_no=3 time=46.150 ms result=0
```

The l2control(8) utility is used to perform various operations on L2CAP nodes. This example shows how to obtain the list of logical connections (channels) and the list of baseband connections for the local device.

```
% l2control -a 00:02:72:00:d4:1a read_channel_list
L2CAP channels:
Remote BD_ADDR     SCID/ DCID   PSM  IMTU/ OMTU State
00:07:e0:00:0b:ca    66/   64     3   132/  672 OPEN
% l2control -a 00:02:72:00:d4:1a read_connection_list
L2CAP connections:
Remote BD_ADDR    Handle Flags Pending State
00:07:e0:00:0b:ca     41 O           0 OPEN
```

Another diagnostic tool is btsockstat(1). It does a job similar to as netstat(1) does, but for Bluetooth network-related data structures. The example below shows the same logical connection as l2control(8) above.

```
% btsockstat
Active L2CAP sockets
PCB      Recv-Q Send-Q Local address/PSM       Foreign address   CID   State
c2afe900      0      0 00:02:72:00:d4:1a/3     00:07:e0:00:0b:ca 66    OPEN
Active RFCOMM sessions
L2PCB    PCB      Flag MTU   Out-Q DLCs State
c2afe900 c2b53380 1    127   0     Yes  OPEN
Active RFCOMM sockets
PCB      Recv-Q Send-Q Local address     Foreign address   Chan DLCI State
c2e8bc80      0    250 00:02:72:00:d4:1a 00:07:e0:00:0b:ca 3    6    OPEN
```

19.4.5 RFCOMM Protocol

The RFCOMM protocol provides emulation of serial ports over the L2CAP protocol. The protocol is based on the ETSI standard TS 07.10. RFCOMM is a simple transport protocol, with additional provisions for emulating the 9 circuits of RS-232 (EIATIA-232-E) serial ports. The RFCOMM protocol supports up to 60 simultaneous connections (RFCOMM channels) between two Bluetooth devices.

For the purposes of RFCOMM, a complete communication path involves two applications running on different devices (the communication endpoints) with a communication segment between them. RFCOMM is intended to cover applications that make use of the serial ports of the devices in which they reside. The communication segment is a Bluetooth link from one device to another (direct connect).

RFCOMM is only concerned with the connection between the devices in the direct connect case, or between the device and a modem in the network case. RFCOMM can support other configurations, such as modules that communicate via Bluetooth wireless technology on one side and provide a wired interface on the other side.

In FreeBSD the RFCOMM protocol is implemented at the Bluetooth sockets layer.

19.4.6 Pairing of Devices

By default, Bluetooth communication is not authenticated, and any device can talk to any other device. A Bluetooth device (for example, cellular phone) may choose to require authentication to provide a particular service (for example, Dial-Up service). Bluetooth authentication is normally done with *PIN codes*. A PIN code is an ASCII string up to 16 characters in length. User is required to enter the same PIN code on both devices. Once user has entered the PIN code, both devices will generate a *link key*. After that the link key can be stored either in the devices themselves or in a persistent storage. Next time both devices will use previously generated link key. The described above procedure is called *pairing*. Note that if the link key is lost by any device then pairing must be repeated.

The hcsecd(8) daemon is responsible for handling of all Bluetooth authentication requests. The default configuration file is `/etc/bluetooth/hcsecd.conf`. An example section for a cellular phone with the PIN code arbitrarily set to "1234" is shown below.

```
device {
        bdaddr  00:80:37:29:19:a4;
        name    "Pav’s T39";
        key     nokey;
        pin     "1234";
      }
```

There is no limitation on PIN codes (except length). Some devices (for example Bluetooth headsets) may have a fixed PIN code built in. The `-d` switch forces the hcsecd(8) daemon to stay in the foreground, so it is easy to see what is happening. Set the remote device to receive pairing and initiate the Bluetooth connection to the remote device. The remote device should say that pairing was accepted, and request the PIN code. Enter the same PIN code as you have in `hcsecd.conf`. Now your PC and the remote device are paired. Alternatively, you can initiate pairing on the remote device. Below in the sample `hcsecd` output.

```
hcsecd[16484]: Got Link_Key_Request event from ’ubt0hci’, remote bdaddr 0:80:37:29:19:a4
hcsecd[16484]: Found matching entry, remote bdaddr 0:80:37:29:19:a4, name ’Pav’s T39’, link key doesn
hcsecd[16484]: Sending Link_Key_Negative_Reply to ’ubt0hci’ for remote bdaddr 0:80:37:29:19:a4
hcsecd[16484]: Got PIN_Code_Request event from ’ubt0hci’, remote bdaddr 0:80:37:29:19:a4
hcsecd[16484]: Found matching entry, remote bdaddr 0:80:37:29:19:a4, name ’Pav’s T39’, PIN code exist
hcsecd[16484]: Sending PIN_Code_Reply to ’ubt0hci’ for remote bdaddr 0:80:37:29:19:a4
```

19.4.7 Service Discovery Protocol (SDP)

The Service Discovery Protocol (SDP) provides the means for client applications to discover the existence of services provided by server applications as well as the attributes of those services. The attributes of a service include the type or class of service offered and the mechanism or protocol information needed to utilize the service.

SDP involves communication between a SDP server and a SDP client. The server maintains a list of service records that describe the characteristics of services associated with the server. Each service record contains information about a single service. A client may retrieve information from a service record maintained by the SDP server by issuing a SDP request. If the client, or an application associated with the client, decides to use a service, it must open a separate connection to the service provider in order to utilize the service. SDP provides a mechanism for discovering services and their attributes, but it does not provide a mechanism for utilizing those services.

Normally, a SDP client searches for services based on some desired characteristics of the services. However, there are times when it is desirable to discover which types of services are described by an SDP server’s service records without any a priori information about the services. This process of looking for any offered services is called *browsing*.

Currently Bluetooth SDP server and client are implemented in a third-party package **sdp-1.5** that can be downloaded from here (http://www.geocities.com/m_evmenkin/). The **sdptool** is a command line SDP client. The following example shows how to perform a SDP browse query.

```
# sdptool browse 00:80:37:29:19:a4
Browsing 00:80:37:29:19:A4 ...
```

```
Service Name: Dial-up Networking
Protocol Descriptor List:
 "L2CAP" (0x0100)
 "RFCOMM" (0x0003)
   Channel: 1

Service Name: Fax
Protocol Descriptor List:
 "L2CAP" (0x0100)
 "RFCOMM" (0x0003)
   Channel: 2

Service Name: Voice gateway
Service Class ID List:
 "Headset Audio Gateway" (0x1112)
 "Generic Audio" (0x1203)
Protocol Descriptor List:
 "L2CAP" (0x0100)
 "RFCOMM" (0x0003)
   Channel: 3
```

... and so on. Note that each service has a list of attributes (RFCOMM channel for example). Depending on the service you might need to make a note of some of the attributes. Some Bluetooth implementations do not support service browsing and may return an empty list. In this case it is possible to search for the specific service. The example below shows how to search for the OBEX Object Push (OPUSH) service.

```
# sdptool search --bdaddr 00:07:e0:00:0b:ca OPUSH
```

Offering services on FreeBSD to Bluetooth clients is done with the **sdpd** server.

```
# sdpd
```

The **sdptool** is also used to register a service with the local SDP server. The example below shows how to register the Network Access with PPP (LAN) service. Note that some services require attributes (RFCOMM channel for example).

```
# sdptool add --channel=7 LAN
```

The list of services registered with local SDP server can be obtained by issuing SDP browse query to a "special" BD_ADDR.

```
# sdptool browse ff:ff:ff:00:00:00
```

19.4.8 Dial-Up Networking (DUN) and Network Access with PPP (LAN) Profiles

The Dial-Up Networking (DUN) profile is mostly used with modems and cellular phones. The scenarios covered by this profile are the following:

- use of a cellular phone or modem by a computer as a wireless modem for connecting to a dial-up internet access server, or using other dial-up services;

- use of a cellular phone or modem by a computer to receive data calls.

Network Access with PPP (LAN) profile can be used in the following situations:

- LAN access for a single Bluetooth device;
- LAN access for multiple Bluetooth devices;
- PC to PC (using PPP networking over serial cable emulation).

In FreeBSD both profiles are implemented with ppp(8) and rfcomm_pppd(8) - a wrapper that converts RFCOMM Bluetooth connection into something PPP can operate with. Before any profile can be used, a new PPP label in `/etc/ppp/ppp.conf` must be created. Consult rfcomm_pppd(8) manual page for examples.

In the following example rfcomm_pppd(8) will be used to open RFCOMM connection to remote device with BD_ADDR 00:80:37:29:19:a4 on DUN RFCOMM channel. The actual RFCOMM channel number will be obtained from the remote device via SDP. It is possible to specify RFCOMM channel by hand, and in this case rfcomm_pppd(8) will not perform SDP query. Use **sdptool** to find out RFCOMM channel on the remote device.

```
# rfcomm_pppd -a 00:80:37:29:19:a4 -c -C dun -l rfcomm-dialup
```

In order to provide Network Access with PPP (LAN) service **sdpd** server must be running. It is also required to register LAN service with the local SDP server. Note that LAN service requires RFCOMM channel attribute. A new entry for LAN clients must be created in `/etc/ppp/ppp.conf` file. Consult rfcomm_pppd(8) manual page for examples. Finally, RFCOMM PPP server must be running and listening on the same RFCOMM channel as registered with the local SDP server. The example below shows how to start RFCOMM PPP server.

```
# rfcomm_pppd -s -C 7 -l rfcomm-server
```

19.4.9 OBEX Push (OPUSH) Profile

OBEX is a widely used protocol for simple file transfers between mobile devices. Its main use is in infrared communication, where it is used for generic file transfers between notebooks or Palm handhelds, and for sending business cards or calendar entries between cellular phones and other devices with PIM applications.

The OBEX server and client are implemented as a third-party package **obexapp-1.0** that can be downloaded from here (http://www.geocities.com/m_evmenkin/). The package requires the **openobex** library (included) and the `devel/glib12` port. Note that **obexapp** does not require root privileges to operate.

OBEX client is used to push and/or pull objects from the OBEX server. An object can, for example, be a business card or an appointment. The OBEX client can obtain RFCOMM channel number from the remote device via SDP. This can be done by specifying service name instead of RFCOMM channel number. Supported service names are: IrMC, FTRN and OPUSH. It is possible to specify RFCOMM channel as a number. Below is an example of an OBEX session, where device information object is pulled from the cellular phone, and a new object (business card) is pushed into the phone's directory.

```
% obexapp -a 00:80:37:29:19:a4 -C IrMC
obex> get
get: remote file> telecom/devinfo.txt
get: local file> devinfo-t39.txt
Success, response: OK, Success (0x20)
obex> put
put: local file> new.vcf
```

```
put: remote file> new.vcf
Success, response: OK, Success (0x20)
obex> di
Success, response: OK, Success (0x20)
```

In order to provide OBEX Push service, **sdpd** server must be running. It is also required to register OPUSH service with the local SDP server. Note that OPUSH service requires RFCOMM channel attribute. A root folder, where all incoming objects will be stored, must be created. The default path to the root folder is `/var/spool/obex`. Finally, OBEX server must be running and listening on the same RFCOMM channel as registered with the local SDP server. The example below shows how to start OBEX server.

```
# obexapp -s -C 10
```

19.4.10 Serial Port (SP) Profile

The Serial Port (SP) profile allows Bluetooth device to perform RS232 (or similar) serial cable emulation. The scenario covered by this profile deals with legacy applications using Bluetooth as a cable replacement, through a virtual serial port abstraction.

The rfcomm_sppd(1) utility implements the Serial Port profile. Pseudo tty is used as a virtual serial port abstraction. The example below shows how to connect to a remote device Serial Port service. Note that you do not have to specify RFCOMM channel - rfcomm_sppd(1) can obtain it from the remote device via SDP. If you would like to override this, specify RFCOMM channel in the command line.

```
# rfcomm_sppd -a 00:07:E0:00:0B:CA -t /dev/ttyp6
rfcomm_sppd[94692]: Starting on /dev/ttyp6...
```

Once connected pseudo tty can be used as serial port.

```
# cu -l ttyp6
```

19.4.11 Troubleshooting

19.4.11.1 A remote device cannot connect

Some older Bluetooth devices do not support role switching. By default, when FreeBSD is accepting a new connection, it tries to perform role switch and become a master. Devices, which do not support this will not be able to connect. Note the role switching is performed when a new connection is being established, so it is not possible to ask the remote device if it does support role switching. There is a HCI option to disable role switching on the local side.

```
# hccontrol -n ubt0hci write_node_role_switch 0
```

19.4.11.2 Something is going wrong, can I see what exactly is happening?

Yes, you can. Use the **hcidump-1.5** third-party package that can be downloaded from from here (http://www.geocities.com/m_evmenkin/). The **hcidump** utility is similar to tcpdump(1). It can used to display the content of the Bluetooth packets on the terminal and to dump the Bluetooth packets to a file.

19.5 Bridging

Written by Steve Peterson.

19.5.1 Introduction

It is sometimes useful to divide one physical network (such as an Ethernet segment) into two separate network segments without having to create IP subnets and use a router to connect the segments together. A device that connects two networks together in this fashion is called a "bridge". A FreeBSD system with two network interface cards can act as a bridge.

The bridge works by learning the MAC layer addresses (Ethernet addresses) of the devices on each of its network interfaces. It forwards traffic between two networks only when its source and destination are on different networks.

In many respects, a bridge is like an Ethernet switch with very few ports.

19.5.2 Situations Where Bridging Is Appropriate

There are two common situations in which a bridge is used today.

19.5.2.1 High Traffic on a Segment

Situation one is where your physical network segment is overloaded with traffic, but you do not want for whatever reason to subnet the network and interconnect the subnets with a router.

Let us consider an example of a newspaper where the Editorial and Production departments are on the same subnetwork. The Editorial users all use server A for file service, and the Production users are on server B. An Ethernet is used to connect all users together, and high loads on the network are slowing things down.

If the Editorial users could be segregated on one network segment and the Production users on another, the two network segments could be connected with a bridge. Only the network traffic destined for interfaces on the "other" side of the bridge would be sent to the other network, reducing congestion on each network segment.

19.5.2.2 Filtering/Traffic Shaping Firewall

The second common situation is where firewall functionality is needed without IP Masquerading (NAT).

An example is a small company that is connected via DSL or ISDN to their ISP. They have a 13 globally-accessible IP addresses from their ISP and have 10 PCs on their network. In this situation, using a router-based firewall is difficult because of subnetting issues.

A bridge-based firewall can be configured and dropped into the path just downstream of their DSL/ISDN router without any IP numbering issues.

19.5.3 Configuring a Bridge

19.5.3.1 Network Interface Card Selection

A bridge requires at least two network cards to function. Unfortunately, not all network interface cards as of FreeBSD 4.0 support bridging. Read bridge(4) for details on the cards that are supported.

Install and test the two network cards before continuing.

19.5.3.2 Kernel Configuration Changes

To enable kernel support for bridging, add the:

```
options BRIDGE
```

statement to your kernel configuration file, and rebuild your kernel.

19.5.3.3 Firewall Support

If you are planning to use the bridge as a firewall, you will need to add the `IPFIREWALL` option as well. Read Section 10.8 for general information on configuring the bridge as a firewall.

If you need to allow non-IP packets (such as ARP) to flow through the bridge, there is an undocumented firewall option that must be set. This option is `IPFIREWALL_DEFAULT_TO_ACCEPT`. Note that this changes the default rule for the firewall to accept any packet. Make sure you know how this changes the meaning of your ruleset before you set it.

19.5.3.4 Traffic Shaping Support

If you want to use the bridge as a traffic shaper, you will need to add the `DUMMYNET` option to your kernel configuration. Read dummynet(4) for further information.

19.5.4 Enabling the Bridge

Add the line:

```
net.link.ether.bridge=1
```

to `/etc/sysctl.conf` to enable the bridge at runtime, and the line:

```
net.link.ether.bridge_cfg=if1,if2
```

to enable bridging on the specified interfaces (replace *`if1`* and *`if2`* with the names of your two network interfaces). If you want the bridged packets to be filtered by ipfw(8), you should add:

```
net.link.ether.bridge_ipfw=1
```

as well.

19.5.5 Other Information

If you want to be able to telnet into the bridge from the network, it is OK to assign one of the network cards an IP address. The consensus is that assigning both cards an address is a bad idea.

If you have multiple bridges on your network, there cannot be more than one path between any two workstations. Technically, this means that there is no support for spanning tree link management.

A bridge can add latency to your ping times, especially for traffic from one segment to another.

19.6 NFS

Reorganized and enhanced by Tom Rhodes. Written by Bill Swingle.

Among the many different filesystems that FreeBSD supports is the Network File System, also known as NFS. NFS allows a system to share directories and files with others over a network. By using NFS, users and programs can access files on remote systems almost as if they were local files.

Some of the most notable benefits that NFS can provide are:

- Local workstations use less disk space because commonly used data can be stored on a single machine and still remain accessible to others over the network.
- There is no need for users to have separate home directories on every network machine. Home directories could be set up on the NFS server and made available throughout the network.
- Storage devices such as floppy disks, CDROM drives, and ZIP drives can be used by other machines on the network. This may reduce the number of removable media drives throughout the network.

19.6.1 How NFS Works

NFS consists of at least two main parts: a server and one or more clients. The client remotely accesses the data that is stored on the server machine. In order for this to function properly a few processes have to be configured and running:

> **Note:** In FreeBSD 5.X, the **portmap** utility has been replaced with the `rpcbind` utility. Thus, in FreeBSD 5.X the user is required to replace every instance of **portmap** with `rpcbind` in the forthcoming examples.

The server has to be running the following daemons:

Daemon	Description
nfsd	The NFS daemon which services requests from the NFS clients.
mountd	The NFS mount daemon which carries out the requests that nfsd(8) passes on to it.
portmap	The portmapper daemon allows NFS clients to discover which port the NFS server is using.

The client can also run a daemon, known as **nfsiod**. The **nfsiod** daemon services the requests from the NFS server.

This is optional, and improves performance, but is not required for normal and correct operation. See the nfsiod(8) manual page for more information.

19.6.2 Configuring NFS

NFS configuration is a relatively straightforward process. The processes that need to be running can all start at boot time with a few modifications to your `/etc/rc.conf` file.

On the NFS server, make sure that the following options are configured in the `/etc/rc.conf` file:

```
portmap_enable="YES"
nfs_server_enable="YES"
mountd_flags="-r"
```

`mountd` runs automatically whenever the NFS server is enabled.

On the client, make sure this option is present in `/etc/rc.conf`:

```
nfs_client_enable="YES"
```

The `/etc/exports` file specifies which filesystems NFS should export (sometimes referred to as "share"). Each line in `/etc/exports` specifies a filesystem to be exported and which machines have access to that filesystem. Along with what machines have access to that filesystem, access options may also be specified. There are many such options that can be used in this file but only a few will be mentioned here. You can easily discover other options by reading over the exports(5) manual page.

Here are a few example `/etc/exports` entries:

The following examples give an idea of how to export filesystems, although the settings may be different depending on your environment and network configuration. For instance, to export the `/cdrom` directory to three example machines that have the same domain name as the server (hence the lack of a domain name for each) or have entries in your `/etc/hosts` file. The `-ro` flag makes the exported filesystem read-only. With this flag, the remote system will not be able to write any changes to the exported filesystem.

```
/cdrom -ro host1 host2 host3
```

The following line exports `/home` to three hosts by IP address. This is a useful setup if you have a private network without a DNS server configured. Optionally the `/etc/hosts` file could be configured for internal hostnames; please review hosts(5) for more information. The `-alldirs` flag allows the subdirectories to be mount points. In other words, it will not mount the subdirectories but permit the client to mount only the directories that are required or needed.

```
/home  -alldirs  10.0.0.2 10.0.0.3 10.0.0.4
```

The following line exports `/a` so that two clients from different domains may access the filesystem. The `-maproot=root` flag allows the `root` user on the remote system to write data on the exported filesystem as `root`. If the `-maproot=root` flag is not specified, then even if a user has `root` access on the remote system, they will not be able to modify files on the exported filesystem.

```
/a  -maproot=root  host.example.com box.example.org
```

In order for a client to access an exported filesystem, the client must have permission to do so. Make sure the client is listed in your `/etc/exports` file.

In /etc/exports, each line represents the export information for one filesystem to one host. A remote host can only be specified once per filesystem, and may only have one default entry. For example, assume that /usr is a single filesystem. The following /etc/exports would be invalid:

```
/usr/src   client
/usr/ports client
```

One filesystem, /usr, has two lines specifying exports to the same host, client. The correct format for this situation is:

```
/usr/src /usr/ports  client
```

The properties of one filesystem exported to a given host must all occur on one line. Lines without a client specified are treated as a single host. This limits how you can export filesystems, but for most people this is not an issue.

The following is an example of a valid export list, where /usr and /exports are local filesystems:

```
# Export src and ports to client01 and client02, but only
# client01 has root privileges on it
/usr/src /usr/ports -maproot=root    client01
/usr/src /usr/ports               client02
# The client machines have root and can mount anywhere
# on /exports. Anyone in the world can mount /exports/obj read-only
/exports -alldirs -maproot=root      client01 client02
/exports/obj -ro
```

You must restart mountd whenever you modify /etc/exports so the changes can take effect. This can be accomplished by sending the HUP signal to the mountd process:

```
# kill -HUP ‘cat /var/run/mountd.pid‘
```

Alternatively, a reboot will make FreeBSD set everything up properly. A reboot is not necessary though. Executing the following commands as root should start everything up.

On the NFS server:

```
# portmap
# nfsd -u -t -n 4
# mountd -r
```

On the NFS client:

```
# nfsiod -n 4
```

Now everything should be ready to actually mount a remote file system. In these examples the server's name will be server and the client's name will be client. If you only want to temporarily mount a remote filesystem or would rather test the configuration, just execute a command like this as root on the client:

```
# mount server:/home /mnt
```

This will mount the /home directory on the server at /mnt on the client. If everything is set up correctly you should be able to enter /mnt on the client and see all the files that are on the server.

If you want to automatically mount a remote filesystem each time the computer boots, add the filesystem to the /etc/fstab file. Here is an example:

```
server:/home /mnt nfs rw 0 0
```

The fstab(5) manual page lists all the available options.

19.6.3 Practical Uses

NFS has many practical uses. Some of the more common ones are listed below:

- Set several machines to share a CDROM or other media among them. This is cheaper and often a more convenient method to install software on multiple machines.
- On large networks, it might be more convenient to configure a central NFS server in which to store all the user home directories. These home directories can then be exported to the network so that users would always have the same home directory, regardless of which workstation they log in to.
- Several machines could have a common `/usr/ports/distfiles` directory. That way, when you need to install a port on several machines, you can quickly access the source without downloading it on each machine.

19.6.4 Automatic Mounts with amd

Contributed by Wylie Stilwell. Rewritten by Chern Lee.

amd(8) (the automatic mounter daemon) automatically mounts a remote filesystem whenever a file or directory within that filesystem is accessed. Filesystems that are inactive for a period of time will also be automatically unmounted by **amd**. Using **amd** provides a simple alternative to permanent mounts, as permanent mounts are usually listed in `/etc/fstab`.

amd operates by attaching itself as an NFS server to the `/host` and `/net` directories. When a file is accessed within one of these directories, **amd** looks up the corresponding remote mount and automatically mounts it. `/net` is used to mount an exported filesystem from an IP address, while `/host` is used to mount an export from a remote hostname.

An access to a file within `/host/foobar/usr` would tell **amd** to attempt to mount the `/usr` export on the host `foobar`.

Example 19-1. Mounting an Export with amd

You can view the available mounts of a remote host with the `showmount` command. For example, to view the mounts of a host named `foobar`, you can use:

```
% showmount -e foobar
Exports list on foobar:
/usr                               10.10.10.0
/a                                 10.10.10.0
% cd /host/foobar/usr
```

As seen in the example, the `showmount` shows `/usr` as an export. When changing directories to `/host/foobar/usr`, **amd** attempts to resolve the hostname `foobar` and automatically mount the desired export.

amd can be started by the startup scripts by placing the following lines in `/etc/rc.conf`:

```
amd_enable="YES"
```

Additionally, custom flags can be passed to **amd** from the `amd_flags` option. By default, `amd_flags` is set to:

```
amd_flags="-a /.amd_mnt -l syslog /host /etc/amd.map /net /etc/amd.map"
```

The `/etc/amd.map` file defines the default options that exports are mounted with. The `/etc/amd.conf` file defines some of the more advanced features of **amd**.

Consult the amd(8) and amd.conf(5) manual pages for more information.

19.6.5 Problems Integrating with Other Systems

Contributed by John Lind.

Certain Ethernet adapters for ISA PC systems have limitations which can lead to serious network problems, particularly with NFS. This difficulty is not specific to FreeBSD, but FreeBSD systems are affected by it.

The problem nearly always occurs when (FreeBSD) PC systems are networked with high-performance workstations, such as those made by Silicon Graphics, Inc., and Sun Microsystems, Inc. The NFS mount will work fine, and some operations may succeed, but suddenly the server will seem to become unresponsive to the client, even though requests to and from other systems continue to be processed. This happens to the client system, whether the client is the FreeBSD system or the workstation. On many systems, there is no way to shut down the client gracefully once this problem has manifested itself. The only solution is often to reset the client, because the NFS situation cannot be resolved.

Though the "correct" solution is to get a higher performance and capacity Ethernet adapter for the FreeBSD system, there is a simple workaround that will allow satisfactory operation. If the FreeBSD system is the *server*, include the option `-w=1024` on the mount from the client. If the FreeBSD system is the *client*, then mount the NFS filesystem with the option `-r=1024`. These options may be specified using the fourth field of the `fstab` entry on the client for automatic mounts, or by using the `-o` parameter of the mount command for manual mounts.

It should be noted that there is a different problem, sometimes mistaken for this one, when the NFS servers and clients are on different networks. If that is the case, make *certain* that your routers are routing the necessary UDP information, or you will not get anywhere, no matter what else you are doing.

In the following examples, `fastws` is the host (interface) name of a high-performance workstation, and `freebox` is the host (interface) name of a FreeBSD system with a lower-performance Ethernet adapter. Also, `/sharedfs` will be the exported NFS filesystem (see exports(5)), and `/project` will be the mount point on the client for the exported filesystem. In all cases, note that additional options, such as `hard` or `soft` and `bg` may be desirable in your application.

Examples for the FreeBSD system (`freebox`) as the client in `/etc/fstab` on freebox:

```
fastws:/sharedfs /project nfs rw,-r=1024 0 0
```

As a manual mount command on `freebox`:

```
# mount -t nfs -o -r=1024 fastws:/sharedfs /project
```

Examples for the FreeBSD system as the server in `/etc/fstab` on `fastws`:

```
freebox:/sharedfs /project nfs rw,-w=1024 0 0
```

As a manual mount command on `fastws`:

```
# mount -t nfs -o -w=1024 freebox:/sharedfs /project
```

Nearly any 16-bit Ethernet adapter will allow operation without the above restrictions on the read or write size.

For anyone who cares, here is what happens when the failure occurs, which also explains why it is unrecoverable. NFS typically works with a "block" size of 8 k (though it may do fragments of smaller sizes). Since the maximum Ethernet packet is around 1500 bytes, the NFS "block" gets split into multiple Ethernet packets, even though it is still a single unit to the upper-level code, and must be received, assembled, and *acknowledged* as a unit. The high-performance workstations can pump out the packets which comprise the NFS unit one right after the other, just as close together as the standard allows. On the smaller, lower capacity cards, the later packets overrun the earlier packets of the same unit before they can be transferred to the host and the unit as a whole cannot be reconstructed or acknowledged. As a result, the workstation will time out and try again, but it will try again with the entire 8 K unit, and the process will be repeated, ad infinitum.

By keeping the unit size below the Ethernet packet size limitation, we ensure that any complete Ethernet packet received can be acknowledged individually, avoiding the deadlock situation.

Overruns may still occur when a high-performance workstations is slamming data out to a PC system, but with the better cards, such overruns are not guaranteed on NFS "units". When an overrun occurs, the units affected will be retransmitted, and there will be a fair chance that they will be received, assembled, and acknowledged.

19.7 Diskless Operation

Updated by Jean-François Dockès.

A FreeBSD machine can boot over the network and operate without a local disk, using filesystems mounted from an NFS server. No system modification is necessary, beyond standard configuration files. Such a system is easy to set up because all the necessary elements are readily available:

- There are at least two possible methods to load the kernel over the network:
  - *PXE*: The Intel Preboot Execution Environment system is a form of smart boot ROM built into some networking cards or motherboards. See pxeboot(8) for more details.
  - *The **etherboot** port* (`net/etherboot`) produces ROM-able code to boot kernels over the network. The code can be either burnt into a boot PROM on a network card, or loaded from a local floppy (or hard) disk drive, or from a running MS-DOS system. Many network cards are supported.
- A sample script (`/usr/share/examples/diskless/clone_root`) eases the creation and maintenance of the workstation's root filesystem on the server. The script will probably require a little customization but it will get you started very quickly.
- Standard system startup files exist in `/etc` to detect and support a diskless system startup.
- Swapping, if needed, can be done either to an NFS file or to a local disk.

There are many ways to set up diskless workstations. Many elements are involved, and most can be customized to suit local taste. The following will describe the setup of a complete system, emphasizing simplicity and compatibility with the standard FreeBSD startup scripts. The system described has the following characteristics:

- The diskless workstations use a shared read-only `root` filesystem, and a shared read-only `/usr`.

The `root` filesystem is a copy of a standard FreeBSD root (typically the server's), with some configuration files overridden by ones specific to diskless operation or, possibly, to the workstation they belong to.

The parts of the `root` which have to be writable are overlaid with mfs(8) filesystems. Any changes will be lost when the system reboots.

- The kernel is loaded by **etherboot** , using DHCP (or BOOTP) and TFTP.

> **Caution:** As described, this system is insecure. It should live in a protected area of a network, and be untrusted by other hosts.

19.7.1 Setup Instructions

19.7.1.1 Configuring DHCP/BOOTP

There are two protocols that are commonly used to boot a workstation that retrieves its configuration over the network: BOOTP and DHCP. They are used at several points in the workstation bootstrap:

- **etherboot** uses DHCP (by default) or BOOTP (needs a configuration option) to find the kernel. (PXE uses DHCP).
- The kernel uses BOOTP to locate the NFS root.

It is possible to configure a system to use only BOOTP. The bootpd(8) server program is included in the base FreeBSD system.

However, DHCP has a number of advantages over BOOTP (nicer configuration files, possibility of using PXE, plus many others not directly related to diskless operation), and we shall describe both a pure BOOTP, and a BOOTP+DHCP configuration, with an emphasis on the latter, which will use the ISC DHCP software package.

19.7.1.1.1 Configuration Using ISC DHCP

The **isc-dhcp** server can answer both BOOTP and DHCP requests.

As of release 4.4, **isc-dhcp 3.0** is not part of the base system. You will first need to install the `net/isc-dhcp3` port or the corresponding package. Please refer to Chapter 4 for general information about ports and packages.

Once **isc-dhcp** is installed, it needs a configuration file to run, (normally named `/usr/local/etc/dhcpd.conf`). Here follows a commented example:

```
default-lease-time 600;
max-lease-time 7200;
authoritative;

option domain-name "example.com";
option domain-name-servers 192.168.4.1;
option routers 192.168.4.1;

subnet 192.168.4.0 netmask 255.255.255.0 {
  use-host-decl-names on; ❶
  option subnet-mask 255.255.255.0;
```

```
    option broadcast-address 192.168.4.255;

    host margaux {
      hardware ethernet 01:23:45:67:89:ab;
      fixed-address margaux.example.com;
      next-server 192.168.4.4;❷
      filename "/tftpboot/kernel.diskless";❸
      option root-path "192.168.4.4:/data/misc/diskless";❹
    }
  }
```

❶ This option tells `dhcpd` to send the value in the `host` declarations as the hostname for the diskless host. An alternate way would be to add an `option host-name` *`margaux`* inside the host declarations.

❷ The `next-server` directive designates the TFTP server (the default is to use the same host as the DHCP server).

❸ The `filename` directive defines the file that **etherboot** will load as a kernel.

> **Note:** PXE appears to prefer a relative file name, and it loads `pxeboot`, not the kernel (`option filename "pxeboot"`).

❹ The `root-path` option defines the path to the root filesystem, in usual NFS notation.

19.7.1.1.2 Configuration Using BOOTP

Here follows an equivalent `bootpd` configuration. This would be found in `/etc/bootptab`.

Please note that **etherboot** must be compiled with the non-default option `NO_DHCP_SUPPORT` in order to use BOOTP, and that PXE *needs* DHCP. The only obvious advantage of **bootpd** is that it exists in the base system.

```
.def100:\
  :hn:ht=1:sa=192.168.4.4:vm=rfc1048:\
  :sm=255.255.255.0:\
  :ds=192.168.4.1:\
  :gw=192.168.4.1:\
  :hd="/tftpboot":\
  :bf="/kernel.diskless":\
  :rp="192.168.4.4:/data/misc/diskless":

margaux:ha=0123456789ab:tc=.def100
```

19.7.1.2 Preparing a Boot Program with Etherboot

Etherboot's Web site (http://etherboot.sourceforge.net) contains extensive documentation (http://etherboot.sourceforge.net/doc/html/userman.html) mainly intended for Linux systems, but nonetheless containing useful information. The following will just outline how you would use **etherboot** on a FreeBSD system.

You must first install the `net/etherboot` package or port. The **etherboot** port can normally be found in `/usr/ports/net/etherboot`. If the ports tree is installed on your system, just typing `make` in this directory should take care of everything. Else refer to Chapter 4 for information about ports and packages.

For our setup, we shall use a boot floppy. For other methods (PROM, or dos program), please refer to the **etherboot** documentation.

To make a boot floppy, insert a floppy in the drive on the machine where you installed **etherboot**, then change your current directory to the `src` directory in the **etherboot** tree and type:

```
# gmake bin32/devicetype.fd0
```

devicetype depends on the type of the Ethernet card in the diskless workstation. Refer to the `NIC` file in the same directory to determine the right *devicetype*.

19.7.1.3 Configuring the TFTP and NFS Servers

You need to enable `tftpd` on the TFTP server:

1. Create a directory from which `tftpd` will serve the files, e.g. `/tftpboot`.
2. Add this line to your `/etc/inetd.conf`:

   ```
   tftp    dgram   udp     wait    root   /usr/libexec/tftpd    tftpd -s /tftpboot
   ```

   > **Note:** It appears that at least some PXE versions want the TCP version of TFTP. In this case, add a second line, replacing `dgram udp` with `stream tcp`.

3. Tell `inetd` to reread its configuration file:

   ```
   # kill -HUP ‘cat /var/run/inetd.pid‘
   ```

You can place the `tftpboot` directory anywhere on the server. Make sure that the location is set in both `inetd.conf` and `dhcpd.conf`.

You also need to enable NFS and export the appropriate filesystem on the NFS server.

1. Add this to `/etc/rc.conf`:

   ```
   nfs_server_enable="YES"
   ```

2. Export the filesystem where the diskless root directory is located by adding the following to `/etc/exports` (adjust the volume mount point and replace *margaux* with the name of the diskless workstation):

   ```
   /data/misc -alldirs -ro margaux
   ```

3. Tell `mountd` to reread its configuration file. If you actually needed to enable NFS in `/etc/rc.conf` at the first step, you probably want to reboot instead.

```
# kill -HUP `cat /var/run/mountd.pid`
```

19.7.1.4 Building a Diskless Kernel

Create a kernel configuration file for the diskless client with the following options (in addition to the usual ones):

```
options     BOOTP          # Use BOOTP to obtain IP address/hostname
options     BOOTP_NFSROOT  # NFS mount root filesystem using BOOTP info
options     BOOTP_COMPAT   # Workaround for broken bootp daemons.
```

You may also want to use `BOOTP_NFSV3` and `BOOTP_WIRED_TO` (refer to `LINT`).

Build the kernel (See Chapter 9), and copy it to the tftp directory, under the name listed in `dhcpd.conf`.

19.7.1.5 Preparing the Root Filesystem

You need to create a root filesystem for the diskless workstations, in the location listed as `root-path` in `dhcpd.conf`.

The easiest way to do this is to use the `/usr/share/examples/diskless/clone_root` shell script. This script needs customization, at least to adjust the place where the filesystem will be created (the `DEST` variable).

Refer to the comments at the top of the script for instructions. They explain how the base filesystem is built, and how files may be selectively overridden by versions specific to diskless operation, to a subnetwork, or to an individual workstation. They also give examples for the diskless `/etc/fstab` and `/etc/rc.conf` files.

The `README` files in `/usr/share/examples/diskless` contain a lot of interesting background information, but, together with the other examples in the `diskless` directory, they actually document a configuration method which is distinct from the one used by `clone_root` and `/etc/rc.diskless[12]`, which is a little confusing. Use them for reference only, except if you prefer the method that they describe, in which case you will need customized `rc` scripts.

19.7.1.6 Configuring Swap

If needed, a swap file located on the server can be accessed via NFS. The exact `bootptab` or `dhcpd.conf` options are not clearly documented at this time. The following configuration suggestions have been reported to work in some installations using isc-dhcp 3.0rc11.

1. Add the following lines to `dhcpd.conf`:

```
# Global section
option swap-path code 128 = string;
option swap-size code 129 = integer 32;

host margaux {
  ... # Standard lines, see above
  option swap-path "192.168.4.4:/netswapvolume/netswap";
  option swap-size 64000;
}
```

The idea is that, at least for a FreeBSD client, DHCP/BOOTP option code 128 is the path to the NFS swap file, and option code 129 is the swap size in kilobytes. Older versions of `dhcpd` allowed a syntax of `option option-128 "...`, which does not seem to work any more.

`/etc/bootptab` would use the following syntax instead:

```
T128="192.168.4.4:/netswapvolume/netswap":T129=64000
```

2. On the NFS swap file server, create the swap file(s)

```
# mkdir /netswapvolume/netswap
# cd /netswapvolume/netswap
# dd if=/dev/zero bs=1024 count=64000 of=swap.192.168.4.6
# chmod 0600 swap.192.168.4.6
```

`192.168.4.6` is the IP address for the diskless client.

3. On the NFS swap file server, add the following line to `/etc/exports`:

```
/netswapvolume  -maproot=0:10 -alldirs margaux
```

Then tell **mountd** to reread the exports file, as above.

19.7.1.7 Miscellaneous Issues

19.7.1.7.1 Running with a Read-only `/usr`

If the diskless workstation is configured to run X, you will have to adjust the xdm configuration file, which puts the error log on `/usr` by default.

19.7.1.7.2 Using a Non-FreeBSD Server

When the server for the root filesystem is not running FreeBSD, you will have to create the root filesystem on a FreeBSD machine, then copy it to its destination, using `tar` or `cpio`.

In this situation, there are sometimes problems with the special files in `/dev`, due to differing major/minor integer sizes. A solution to this problem is to export a directory from the non-FreeBSD server, mount this directory onto a FreeBSD machine, and run `MAKEDEV` on the FreeBSD machine to create the correct device entries (FreeBSD 5.0 and later use devfs(5) to allocate device nodes transparently for the user, running `MAKEDEV` on these versions is useless).

19.8 ISDN

A good resource for information on ISDN technology and hardware is Dan Kegel's ISDN Page (http://alumni.caltech.edu/~dank/isdn/).

A quick simple road map to ISDN follows:

- If you live in Europe you might want to investigate the ISDN card section.
- If you are planning to use ISDN primarily to connect to the Internet with an Internet Provider on a dial-up non-dedicated basis, you might look into Terminal Adapters. This will give you the most flexibility, with the fewest problems, if you change providers.
- If you are connecting two LANs together, or connecting to the Internet with a dedicated ISDN connection, you might consider the stand alone router/bridge option.

Cost is a significant factor in determining what solution you will choose. The following options are listed from least expensive to most expensive.

19.8.1 ISDN Cards

Contributed by Hellmuth Michaelis.

FreeBSD's ISDN implementation supports only the DSS1/Q.931 (or Euro-ISDN) standard using passive cards. Starting with FreeBSD 4.4, some active cards are supported where the firmware also supports other signaling protocols; this also includes the first supported Primary Rate (PRI) ISDN card.

Isdn4bsd allows you to connect to other ISDN routers using either IP over raw HDLC or by using synchronous PPP: either by using kernel PPP with isppp, a modified sppp driver, or by using userland ppp(8). By using userland ppp(8), channel bonding of two or more ISDN B-channels is possible. A telephone answering machine application is also available as well as many utilities such as a software 300 Baud modem.

Some growing number of PC ISDN cards are supported under FreeBSD and the reports show that it is successfully used all over Europe and in many other parts of the world.

The passive ISDN cards supported are mostly the ones with the Infineon (formerly Siemens) ISAC/HSCX/IPAC ISDN chipsets, but also ISDN cards with chips from Cologne Chip (ISA bus only), PCI cards with Winbond W6692 chips, some cards with the Tiger300/320/ISAC chipset combinations and some vendor specific chipset based cards such as the AVM Fritz!Card PCI V.1.0 and the AVM Fritz!Card PnP.

Currently the active supported ISDN cards are the AVM B1 (ISA and PCI) BRI cards and the AVM T1 PCI PRI cards.

For documentation on **isdn4bsd**, have a look at `/usr/share/examples/isdn/` directory on your FreeBSD system or at the homepage of isdn4bsd (http://www.freebsd-support.de/i4b/) which also has pointers to hints, erratas and much more documentation such as the isdn4bsd handbook (http://people.FreeBSD.org/~hm/).

In case you are interested in adding support for a different ISDN protocol, a currently unsupported ISDN PC card or otherwise enhancing **isdn4bsd**, please get in touch with Hellmuth Michaelis <`hm@FreeBSD.org`>.

For questions regarding the installation, configuration and troubleshooting **isdn4bsd**, a freebsd-isdn (http://lists.FreeBSD.org/mailman/listinfo/freebsd-isdn) mailing list is available.

19.8.2 ISDN Terminal Adapters

Terminal adapters(TA), are to ISDN what modems are to regular phone lines.

Most TA's use the standard hayes modem AT command set, and can be used as a drop in replacement for a modem.

A TA will operate basically the same as a modem except connection and throughput speeds will be much faster than your old modem. You will need to configure PPP exactly the same as for a modem setup. Make sure you set your serial speed as high as possible.

The main advantage of using a TA to connect to an Internet Provider is that you can do Dynamic PPP. As IP address space becomes more and more scarce, most providers are not willing to provide you with a static IP anymore. Most stand-alone routers are not able to accommodate dynamic IP allocation.

TA's completely rely on the PPP daemon that you are running for their features and stability of connection. This allows you to upgrade easily from using a modem to ISDN on a FreeBSD machine, if you already have PPP set up. However, at the same time any problems you experienced with the PPP program and are going to persist.

If you want maximum stability, use the kernel PPP option, not the user-land iijPPP.

The following TA's are known to work with FreeBSD.

- Motorola BitSurfer and Bitsurfer Pro
- Adtran

Most other TA's will probably work as well, TA vendors try to make sure their product can accept most of the standard modem AT command set.

The real problem with external TA's is that, like modems, you need a good serial card in your computer.

You should read the FreeBSD Serial Hardware (../../articles/serial-uart/index.html) tutorial for a detailed understanding of serial devices, and the differences between asynchronous and synchronous serial ports.

A TA running off a standard PC serial port (asynchronous) limits you to 115.2 Kbs, even though you have a 128 Kbs connection. To fully utilize the 128 Kbs that ISDN is capable of, you must move the TA to a synchronous serial card.

Do not be fooled into buying an internal TA and thinking you have avoided the synchronous/asynchronous issue. Internal TA's simply have a standard PC serial port chip built into them. All this will do is save you having to buy another serial cable and find another empty electrical socket.

A synchronous card with a TA is at least as fast as a stand-alone router, and with a simple 386 FreeBSD box driving it, probably more flexible.

The choice of sync/TA v.s. stand-alone router is largely a religious issue. There has been some discussion of this in the mailing lists. I suggest you search the archives (../../../../search/index.html) for the complete discussion.

19.8.3 Stand-alone ISDN Bridges/Routers

ISDN bridges or routers are not at all specific to FreeBSD or any other operating system. For a more complete description of routing and bridging technology, please refer to a Networking reference book.

In the context of this page, the terms router and bridge will be used interchangeably.

As the cost of low end ISDN routers/bridges comes down, it will likely become a more and more popular choice. An ISDN router is a small box that plugs directly into your local Ethernet network, and manages its own connection to the other bridge/router. It has built in software to communicate via PPP and other popular protocols.

A router will allow you much faster throughput than a standard TA, since it will be using a full synchronous ISDN connection.

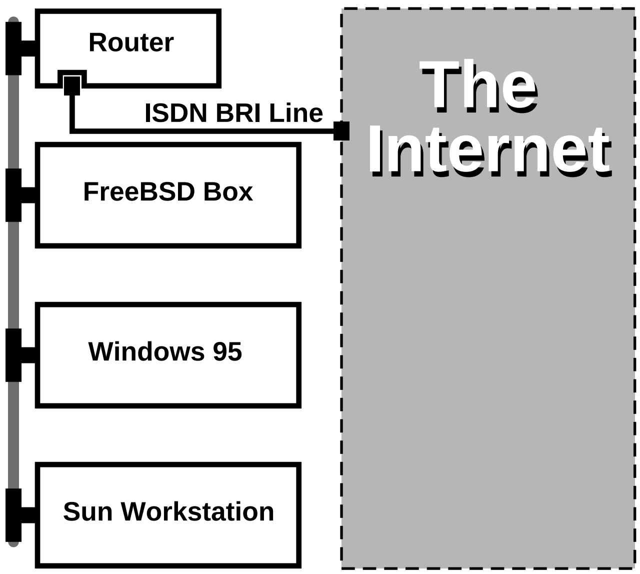
The main problem with ISDN routers and bridges is that interoperability between manufacturers can still be a problem. If you are planning to connect to an Internet provider, you should discuss your needs with them.

If you are planning to connect two LAN segments together, such as your home LAN to the office LAN, this is the simplest lowest maintenance solution. Since you are buying the equipment for both sides of the connection you can be assured that the link will work.

For example to connect a home computer or branch office network to a head office network the following setup could be used.

Example 19-2. Branch Office or Home Network

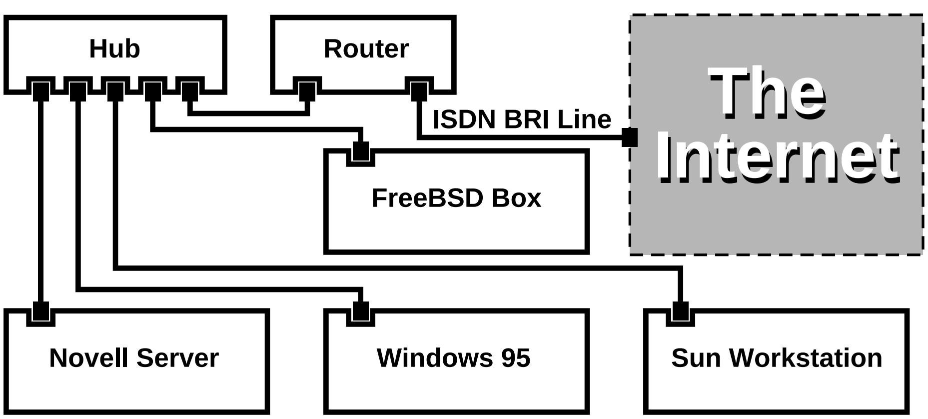
Network uses a bus based topology with 10 base 2 Ethernet ("thinnet"). Connect router to network cable with AUI/10BT transceiver, if necessary.



If your home/branch office is only one computer you can use a twisted pair crossover cable to connect to the stand-alone router directly.

Example 19-3. Head Office or Other LAN

Network uses a star topology with 10 base T Ethernet ("Twisted Pair").



One large advantage of most routers/bridges is that they allow you to have 2 *separate independent* PPP connections to 2 separate sites at the *same* time. This is not supported on most TA's, except for specific (usually expensive) models that have two serial ports. Do not confuse this with channel bonding, MPP, etc.

This can be a very useful feature if, for example, you have an dedicated ISDN connection at your office and would like to tap into it, but do not want to get another ISDN line at work. A router at the office location can manage a dedicated B channel connection (64 Kbps) to the Internet and use the other B channel for a separate data connection. The second B channel can be used for dial-in, dial-out or dynamically bonding (MPP, etc.) with the first B channel for more bandwidth.

An Ethernet bridge will also allow you to transmit more than just IP traffic. You can also send IPX/SPX or whatever other protocols you use.

19.9 NIS/YP

Written by Bill Swingle. Enhanced by Eric Ogren and Udo Erdelhoff.

19.9.1 What Is It?

NIS, which stands for Network Information Services, was developed by Sun Microsystems to centralize administration of UNIX (originally SunOS) systems. It has now essentially become an industry standard; all major UNIX like systems (Solaris, HP-UX, AIX®, Linux, NetBSD, OpenBSD, FreeBSD, etc) support NIS.

NIS was formerly known as Yellow Pages, but because of trademark issues, Sun changed the name. The old term (and yp) is still often seen and used.

It is a RPC-based client/server system that allows a group of machines within an NIS domain to share a common set of configuration files. This permits a system administrator to set up NIS client systems with only minimal configuration data and add, remove or modify configuration data from a single location.

It is similar to the Windows NT® domain system; although the internal implementation of the two are not at all similar, the basic functionality can be compared.

19.9.2 Terms/Processes You Should Know

There are several terms and several important user processes that you will come across when attempting to implement NIS on FreeBSD, whether you are trying to create an NIS server or act as an NIS client:

Term	Description
NIS domainname	An NIS master server and all of its clients (including its slave servers) have a NIS domainname. Similar to an Windows NT domain name, the NIS domainname does not have anything to do with DNS.
portmap	Must be running in order to enable RPC (Remote Procedure Call, a network protocol used by NIS). If `portmap` is not running, it will be impossible to run an NIS server, or to act as an NIS client.

Term	Description
ypbind	"Binds" an NIS client to its NIS server. It will take the NIS domainname from the system, and using RPC, connect to the server. `ypbind` is the core of client-server communication in an NIS environment; if `ypbind` dies on a client machine, it will not be able to access the NIS server.
ypserv	Should only be running on NIS servers; this is the NIS server process itself. If ypserv(8) dies, then the server will no longer be able to respond to NIS requests (hopefully, there is a slave server to take over for it). There are some implementations of NIS (but not the FreeBSD one), that do not try to reconnect to another server if the server it used before dies. Often, the only thing that helps in this case is to restart the server process (or even the whole server) or the `ypbind` process on the client.
rpc.yppasswdd	Another process that should only be running on NIS master servers; this is a daemon that will allow NIS clients to change their NIS passwords. If this daemon is not running, users will have to login to the NIS master server and change their passwords there.

19.9.3 How Does It Work?

There are three types of hosts in an NIS environment: master servers, slave servers, and clients. Servers act as a central repository for host configuration information. Master servers hold the authoritative copy of this information, while slave servers mirror this information for redundancy. Clients rely on the servers to provide this information to them.

Information in many files can be shared in this manner. The `master.passwd`, `group`, and `hosts` files are commonly shared via NIS. Whenever a process on a client needs information that would normally be found in these files locally, it makes a query to the NIS server that it is bound to instead.

19.9.3.1 Machine Types

- A *NIS master server*. This server, analogous to a Windows NT primary domain controller, maintains the files used by all of the NIS clients. The `passwd`, `group`, and other various files used by the NIS clients live on the master server.

  Note: It is possible for one machine to be an NIS master server for more than one NIS domain. However, this will not be covered in this introduction, which assumes a relatively small-scale NIS environment.

- *NIS slave servers*. Similar to the Windows NT backup domain controllers, NIS slave servers maintain copies of the NIS master's data files. NIS slave servers provide the redundancy, which is needed in important environments.

They also help to balance the load of the master server: NIS Clients always attach to the NIS server whose response they get first, and this includes slave-server-replies.

- *NIS clients*. NIS clients, like most Windows NT workstations, authenticate against the NIS server (or the Windows NT domain controller in the Windows NT Workstation case) to log on.

19.9.4 Using NIS/YP

This section will deal with setting up a sample NIS environment.

> **Note:** This section assumes that you are running FreeBSD 3.3 or later. The instructions given here will *probably* work for any version of FreeBSD greater than 3.0, but there are no guarantees that this is true.

19.9.4.1 Planning

Let us assume that you are the administrator of a small university lab. This lab, which consists of 15 FreeBSD machines, currently has no centralized point of administration; each machine has its own `/etc/passwd` and `/etc/master.passwd`. These files are kept in sync with each other only through manual intervention; currently, when you add a user to the lab, you must run `adduser` on all 15 machines. Clearly, this has to change, so you have decided to convert the lab to use NIS, using two of the machines as servers.

Therefore, the configuration of the lab now looks something like:

Machine name	IP address	Machine role
`ellington`	`10.0.0.2`	NIS master
`coltrane`	`10.0.0.3`	NIS slave
`basie`	`10.0.0.4`	Faculty workstation
`bird`	`10.0.0.5`	Client machine
`cli[1-11]`	`10.0.0.[6-17]`	Other client machines

If you are setting up a NIS scheme for the first time, it is a good idea to think through how you want to go about it. No matter what the size of your network, there are a few decisions that need to be made.

19.9.4.1.1 Choosing a NIS Domain Name

This might not be the "domainname" that you are used to. It is more accurately called the "NIS domainname". When a client broadcasts its requests for info, it includes the name of the NIS domain that it is part of. This is how multiple servers on one network can tell which server should answer which request. Think of the NIS domainname as the name for a group of hosts that are related in some way.

Some organizations choose to use their Internet domainname for their NIS domainname. This is not recommended as it can cause confusion when trying to debug network problems. The NIS domainname should be unique within your network and it is helpful if it describes the group of machines it represents. For example, the Art department at Acme Inc. might be in the "acme-art" NIS domain. For this example, assume you have chosen the name *test-domain*.

However, some operating systems (notably SunOS) use their NIS domain name as their Internet domain name. If one or more machines on your network have this restriction, you *must* use the Internet domain name as your NIS domain name.

19.9.4.1.2 Physical Server Requirements

There are several things to keep in mind when choosing a machine to use as a NIS server. One of the unfortunate things about NIS is the level of dependency the clients have on the server. If a client cannot contact the server for its NIS domain, very often the machine becomes unusable. The lack of user and group information causes most systems to temporarily freeze up. With this in mind you should make sure to choose a machine that will not be prone to being rebooted regularly, or one that might be used for development. The NIS server should ideally be a stand alone machine whose sole purpose in life is to be an NIS server. If you have a network that is not very heavily used, it is acceptable to put the NIS server on a machine running other services, just keep in mind that if the NIS server becomes unavailable, it will affect *all* of your NIS clients adversely.

19.9.4.2 NIS Servers

The canonical copies of all NIS information are stored on a single machine called the NIS master server. The databases used to store the information are called NIS maps. In FreeBSD, these maps are stored in `/var/yp/[domainname]` where `[domainname]` is the name of the NIS domain being served. A single NIS server can support several domains at once, therefore it is possible to have several such directories, one for each supported domain. Each domain will have its own independent set of maps.

NIS master and slave servers handle all NIS requests with the `ypserv` daemon. `ypserv` is responsible for receiving incoming requests from NIS clients, translating the requested domain and map name to a path to the corresponding database file and transmitting data from the database back to the client.

19.9.4.2.1 Setting Up a NIS Master Server

Setting up a master NIS server can be relatively straight forward, depending on your needs. FreeBSD comes with support for NIS out-of-the-box. All you need is to add the following lines to `/etc/rc.conf`, and FreeBSD will do the rest for you.

1.
   ```
   nisdomainname="test-domain"
   ```
   This line will set the NIS domainname to *test-domain* upon network setup (e.g. after reboot).
2.
   ```
   nis_server_enable="YES"
   ```
   This will tell FreeBSD to start up the NIS server processes when the networking is next brought up.
3.
   ```
   nis_yppasswdd_enable="YES"
   ```
   This will enable the `rpc.yppasswdd` daemon which, as mentioned above, will allow users to change their NIS password from a client machine.

> **Note:** Depending on your NIS setup, you may need to add further entries. See the section about NIS servers that are also NIS clients, below, for details.

Now, all you have to do is to run the command `/etc/netstart` as superuser. It will set up everything for you, using the values you defined in `/etc/rc.conf`.

19.9.4.2.2 Initializing the NIS Maps

The *NIS maps* are database files, that are kept in the `/var/yp` directory. They are generated from configuration files in the `/etc` directory of the NIS master, with one exception: the `/etc/master.passwd` file. This is for a good reason; you do not want to propagate passwords to your `root` and other administrative accounts to all the servers in the NIS domain. Therefore, before we initialize the NIS maps, you should:

```
# cp /etc/master.passwd /var/yp/master.passwd
# cd /var/yp
# vi master.passwd
```

You should remove all entries regarding system accounts (`bin`, `tty`, `kmem`, `games`, etc), as well as any accounts that you do not want to be propagated to the NIS clients (for example `root` and any other UID 0 (superuser) accounts).

> **Note:** Make sure the `/var/yp/master.passwd` is neither group nor world readable (mode 600)! Use the `chmod` command, if appropriate.

When you have finished, it is time to initialize the NIS maps! FreeBSD includes a script named `ypinit` to do this for you (see its manual page for more information). Note that this script is available on most UNIX Operating Systems, but not on all. On Digital UNIX/Compaq Tru64 UNIX it is called `ypsetup`. Because we are generating maps for an NIS master, we are going to pass the `-m` option to `ypinit`. To generate the NIS maps, assuming you already performed the steps above, run:

```
ellington# ypinit -m test-domain
Server Type: MASTER Domain: test-domain
Creating an YP server will require that you answer a few questions.
Questions will all be asked at the beginning of the procedure.
Do you want this procedure to quit on non-fatal errors? [y/n: n] n
Ok, please remember to go back and redo manually whatever fails.
If you don't, something might not work.
At this point, we have to construct a list of this domains YP servers.
rod.darktech.org is already known as master server.
Please continue to add any slave servers, one per line. When you are
done with the list, type a <control D>.
master server   :  ellington
next host to add:  coltrane
next host to add:  ^D
The current list of NIS servers looks like this:
ellington
coltrane
Is this correct?  [y/n: y] y

[..output from map generation..]

NIS Map update completed.
```

```
ellington has been setup as an YP master server without any errors.
```

`ypinit` should have created `/var/yp/Makefile` from `/var/yp/Makefile.dist`. When created, this file assumes that you are operating in a single server NIS environment with only FreeBSD machines. Since *test-domain* has a slave server as well, you must edit `/var/yp/Makefile`:

```
ellington# vi /var/yp/Makefile
```

You should comment out the line that says

```
NOPUSH = "True"
```

(if it is not commented out already).

19.9.4.2.3 Setting up a NIS Slave Server

Setting up an NIS slave server is even more simple than setting up the master. Log on to the slave server and edit the file `/etc/rc.conf` as you did before. The only difference is that we now must use the `-s` option when running `ypinit`. The `-s` option requires the name of the NIS master be passed to it as well, so our command line looks like:

```
coltrane# ypinit -s ellington test-domain

Server Type: SLAVE Domain: test-domain Master: ellington

Creating an YP server will require that you answer a few questions.
Questions will all be asked at the beginning of the procedure.

Do you want this procedure to quit on non-fatal errors? [y/n: n]  n

Ok, please remember to go back and redo manually whatever fails.
If you don't, something might not work.
There will be no further questions. The remainder of the procedure
should take a few minutes, to copy the databases from ellington.
Transferring netgroup...
ypxfr: Exiting: Map successfully transferred
Transferring netgroup.byuser...
ypxfr: Exiting: Map successfully transferred
Transferring netgroup.byhost...
ypxfr: Exiting: Map successfully transferred
Transferring master.passwd.byuid...
ypxfr: Exiting: Map successfully transferred
Transferring passwd.byuid...
ypxfr: Exiting: Map successfully transferred
Transferring passwd.byname...
ypxfr: Exiting: Map successfully transferred
Transferring group.bygid...
ypxfr: Exiting: Map successfully transferred
Transferring group.byname...
ypxfr: Exiting: Map successfully transferred
Transferring services.byname...
ypxfr: Exiting: Map successfully transferred
Transferring rpc.bynumber...
```

```
ypxfr: Exiting: Map successfully transferred
Transferring rpc.byname...
ypxfr: Exiting: Map successfully transferred
Transferring protocols.byname...
ypxfr: Exiting: Map successfully transferred
Transferring master.passwd.byname...
ypxfr: Exiting: Map successfully transferred
Transferring networks.byname...
ypxfr: Exiting: Map successfully transferred
Transferring networks.byaddr...
ypxfr: Exiting: Map successfully transferred
Transferring netid.byname...
ypxfr: Exiting: Map successfully transferred
Transferring hosts.byaddr...
ypxfr: Exiting: Map successfully transferred
Transferring protocols.bynumber...
ypxfr: Exiting: Map successfully transferred
Transferring ypservers...
ypxfr: Exiting: Map successfully transferred
Transferring hosts.byname...
ypxfr: Exiting: Map successfully transferred

coltrane has been setup as an YP slave server without any errors.
Don’t forget to update map ypservers on ellington.
```

You should now have a directory called `/var/yp/test-domain`. Copies of the NIS master server’s maps should be in this directory. You will need to make sure that these stay updated. The following `/etc/crontab` entries on your slave servers should do the job:

```
20      *       *       *       *       root   /usr/libexec/ypxfr passwd.byname
21      *       *       *       *       root   /usr/libexec/ypxfr passwd.byuid
```

These two lines force the slave to sync its maps with the maps on the master server. Although these entries are not mandatory, since the master server attempts to ensure any changes to its NIS maps are communicated to its slaves and because password information is vital to systems depending on the server, it is a good idea to force the updates. This is more important on busy networks where map updates might not always complete.

Now, run the command `/etc/netstart` on the slave server as well, which again starts the NIS server.

19.9.4.3 NIS Clients

An NIS client establishes what is called a binding to a particular NIS server using the `ypbind` daemon. `ypbind` checks the system’s default domain (as set by the `domainname` command), and begins broadcasting RPC requests on the local network. These requests specify the name of the domain for which `ypbind` is attempting to establish a binding. If a server that has been configured to serve the requested domain receives one of the broadcasts, it will respond to `ypbind`, which will record the server’s address. If there are several servers available (a master and several slaves, for example), `ypbind` will use the address of the first one to respond. From that point on, the client system will direct all of its NIS requests to that server. `ypbind` will occasionally “ping” the server to make sure it is still up and running. If it fails to receive a reply to one of its pings within a reasonable amount of time, `ypbind` will mark the domain as unbound and begin broadcasting again in the hopes of locating another server.

19.9.4.3.1 Setting Up a NIS Client

Setting up a FreeBSD machine to be a NIS client is fairly straightforward.

1. Edit the file `/etc/rc.conf` and add the following lines in order to set the NIS domainname and start `ypbind` upon network startup:

   ```
   nisdomainname="test-domain"
   nis_client_enable="YES"
   ```

2. To import all possible password entries from the NIS server, remove all user accounts from your `/etc/master.passwd` file and use `vipw` to add the following line to the end of the file:

   ```
   +:::::::::
   ```

   > **Note:** This line will afford anyone with a valid account in the NIS server's password maps an account. There are many ways to configure your NIS client by changing this line. See the netgroups section below for more information. For more detailed reading see O'Reilly's book on `Managing NFS and NIS`.

   > **Note:** You should keep at least one local account (i.e. not imported via NIS) in your `/etc/master.passwd` and this account should also be a member of the group `wheel`. If there is something wrong with NIS, this account can be used to log in remotely, become root, and fix things.

3. To import all possible group entries from the NIS server, add this line to your `/etc/group` file:

   ```
   +:*::
   ```

After completing these steps, you should be able to run `ypcat passwd` and see the NIS server's passwd map.

19.9.5 NIS Security

In general, any remote user can issue an RPC to ypserv(8) and retrieve the contents of your NIS maps, provided the remote user knows your domainname. To prevent such unauthorized transactions, ypserv(8) supports a feature called securenets which can be used to restrict access to a given set of hosts. At startup, ypserv(8) will attempt to load the securenets information from a file called `/var/yp/securenets`.

> **Note:** This path varies depending on the path specified with the `-p` option. This file contains entries that consist of a network specification and a network mask separated by white space. Lines starting with "#" are considered to be comments. A sample securenets file might look like this:

```
# allow connections from local host -- mandatory
127.0.0.1     255.255.255.255
# allow connections from any host
# on the 192.168.128.0 network
192.168.128.0 255.255.255.0
# allow connections from any host
```

```
# between 10.0.0.0 to 10.0.15.255
# this includes the machines in the testlab
10.0.0.0      255.255.240.0
```

If ypserv(8) receives a request from an address that matches one of these rules, it will process the request normally. If the address fails to match a rule, the request will be ignored and a warning message will be logged. If the `/var/yp/securenets` file does not exist, `ypserv` will allow connections from any host.

The `ypserv` program also has support for Wietse Venema's **tcpwrapper** package. This allows the administrator to use the **tcpwrapper** configuration files for access control instead of `/var/yp/securenets`.

> **Note:** While both of these access control mechanisms provide some security, they, like the privileged port test, are vulnerable to "IP spoofing" attacks. All NIS-related traffic should be blocked at your firewall.
>
> Servers using `/var/yp/securenets` may fail to serve legitimate NIS clients with archaic TCP/IP implementations. Some of these implementations set all host bits to zero when doing broadcasts and/or fail to observe the subnet mask when calculating the broadcast address. While some of these problems can be fixed by changing the client configuration, other problems may force the retirement of the client systems in question or the abandonment of `/var/yp/securenets`.
>
> Using `/var/yp/securenets` on a server with such an archaic implementation of TCP/IP is a really bad idea and will lead to loss of NIS functionality for large parts of your network.
>
> The use of the **tcpwrapper** package increases the latency of your NIS server. The additional delay may be long enough to cause timeouts in client programs, especially in busy networks or with slow NIS servers. If one or more of your client systems suffers from these symptoms, you should convert the client systems in question into NIS slave servers and force them to bind to themselves.

19.9.6 Barring Some Users from Logging On

In our lab, there is a machine `basie` that is supposed to be a faculty only workstation. We do not want to take this machine out of the NIS domain, yet the `passwd` file on the master NIS server contains accounts for both faculty and students. What can we do?

There is a way to bar specific users from logging on to a machine, even if they are present in the NIS database. To do this, all you must do is add -*`username`* to the end of the `/etc/master.passwd` file on the client machine, where *`username`* is the username of the user you wish to bar from logging in. This should preferably be done using `vipw`, since `vipw` will sanity check your changes to `/etc/master.passwd`, as well as automatically rebuild the password database when you finish editing. For example, if we wanted to bar user *bill* from logging on to `basie` we would:

```
basie# vipw
[add -bill to the end, exit]
vipw: rebuilding the database...
vipw: done

basie# cat /etc/master.passwd

root:[password]:0:0::0:0:The super-user:/root:/bin/csh
toor:[password]:0:0::0:0:The other super-user:/root:/bin/sh
daemon:*:1:1::0:0:Owner of many system processes:/root:/sbin/nologin
operator:*:2:5::0:0:System &:/:/sbin/nologin
```

```
bin:*:3:7::0:0:Binaries Commands and Source,,,:/:/sbin/nologin
tty:*:4:65533::0:0:Tty Sandbox:/:/sbin/nologin
kmem:*:5:65533::0:0:KMem Sandbox:/:/sbin/nologin
games:*:7:13::0:0:Games pseudo-user:/usr/games:/sbin/nologin
news:*:8:8::0:0:News Subsystem:/:/sbin/nologin
man:*:9:9::0:0:Mister Man Pages:/usr/share/man:/sbin/nologin
bind:*:53:53::0:0:Bind Sandbox:/:/sbin/nologin
uucp:*:66:66::0:0:UUCP pseudo-user:/var/spool/uucppublic:/usr/libexec/uucp/uucico
xten:*:67:67::0:0:X-10 daemon:/usr/local/xten:/sbin/nologin
pop:*:68:6::0:0:Post Office Owner:/nonexistent:/sbin/nologin
nobody:*:65534:65534::0:0:Unprivileged user:/nonexistent:/sbin/nologin
+:::::::::
-bill

basie#
```

19.9.7 Using Netgroups

Contributed by Udo Erdelhoff.

The method shown in the previous section works reasonably well if you need special rules for a very small number of users and/or machines. On larger networks, you *will* forget to bar some users from logging onto sensitive machines, or you may even have to modify each machine separately, thus losing the main benefit of NIS, *centralized* administration.

The NIS developers' solution for this problem is called *netgroups*. Their purpose and semantics can be compared to the normal groups used by UNIX file systems. The main differences are the lack of a numeric id and the ability to define a netgroup by including both user accounts and other netgroups.

Netgroups were developed to handle large, complex networks with hundreds of users and machines. On one hand, this is a Good Thing if you are forced to deal with such a situation. On the other hand, this complexity makes it almost impossible to explain netgroups with really simple examples. The example used in the remainder of this section demonstrates this problem.

Let us assume that your successful introduction of NIS in your laboratory caught your superiors' interest. Your next job is to extend your NIS domain to cover some of the other machines on campus. The two tables contain the names of the new users and new machines as well as brief descriptions of them.

User Name(s)	Description
alpha, beta	Normal employees of the IT department
charlie, delta	The new apprentices of the IT department
echo, foxtrott, golf, ...	Ordinary employees
able, baker, ...	The current interns

Machine Name(s)	Description
war, death, famine, pollution	Your most important servers. Only the IT employees are allowed to log onto these machines.

Machine Name(s)	Description
pride, greed, envy, wrath, lust, sloth	Less important servers. All members of the IT department are allowed to login onto these machines.
one, two, three, four, ...	Ordinary workstations. Only the *real* employees are allowed to use these machines.
trashcan	A very old machine without any critical data. Even the intern is allowed to use this box.

If you tried to implement these restrictions by separately blocking each user, you would have to add one `-user` line to each system's `passwd` for each user who is not allowed to login onto that system. If you forget just one entry, you could be in trouble. It may be feasible to do this correctly during the initial setup, however you *will* eventually forget to add the lines for new users during day-to-day operations. After all, Murphy was an optimist.

Handling this situation with netgroups offers several advantages. Each user need not be handled separately; you assign a user to one or more netgroups and allow or forbid logins for all members of the netgroup. If you add a new machine, you will only have to define login restrictions for netgroups. If a new user is added, you will only have to add the user to one or more netgroups. Those changes are independent of each other; no more "for each combination of user and machine do..." If your NIS setup is planned carefully, you will only have to modify exactly one central configuration file to grant or deny access to machines.

The first step is the initialization of the NIS map netgroup. FreeBSD's ypinit(8) does not create this map by default, but its NIS implementation will support it once it has been created. To create an empty map, simply type

```
ellington# vi /var/yp/netgroup
```

and start adding content. For our example, we need at least four netgroups: IT employees, IT apprentices, normal employees and interns.

```
IT_EMP  (,alpha,test-domain)    (,beta,test-domain)
IT_APP  (,charlie,test-domain)  (,delta,test-domain)
USERS   (,echo,test-domain)     (,foxtrott,test-domain) \
        (,golf,test-domain)
INTERNS (,able,test-domain)     (,baker,test-domain)
```

`IT_EMP`, `IT_APP` etc. are the names of the netgroups. Each bracketed group adds one or more user accounts to it. The three fields inside a group are:

1. The name of the host(s) where the following items are valid. If you do not specify a hostname, the entry is valid on all hosts. If you do specify a hostname, you will enter a realm of darkness, horror and utter confusion.
2. The name of the account that belongs to this netgroup.
3. The NIS domain for the account. You can import accounts from other NIS domains into your netgroup if you are one of the unlucky fellows with more than one NIS domain.

Each of these fields can contain wildcards. See netgroup(5) for details.

> **Note:** Netgroup names longer than 8 characters should not be used, especially if you have machines running other operating systems within your NIS domain. The names are case sensitive; using capital letters for your netgroup names is an easy way to distinguish between user, machine and netgroup names.
>
> Some NIS clients (other than FreeBSD) cannot handle netgroups with a large number of entries. For example, some older versions of SunOS start to cause trouble if a netgroup contains more than 15 *entries*. You can

circumvent this limit by creating several sub-netgroups with 15 users or less and a real netgroup that consists of the sub-netgroups:

```
BIGGRP1  (,joe1,domain)  (,joe2,domain)  (,joe3,domain) [...]
BIGGRP2  (,joe16,domain)  (,joe17,domain) [...]
BIGGRP3  (,joe31,domain)  (,joe32,domain)
BIGGROUP  BIGGRP1 BIGGRP2 BIGGRP3
```

You can repeat this process if you need more than 225 users within a single netgroup.

Activating and distributing your new NIS map is easy:

```
ellington# cd /var/yp
ellington# make
```

This will generate the three NIS maps `netgroup`, `netgroup.byhost` and `netgroup.byuser`. Use ypcat(1) to check if your new NIS maps are available:

```
ellington% ypcat -k netgroup
ellington% ypcat -k netgroup.byhost
ellington% ypcat -k netgroup.byuser
```

The output of the first command should resemble the contents of `/var/yp/netgroup`. The second command will not produce output if you have not specified host-specific netgroups. The third command can be used to get the list of netgroups for a user.

The client setup is quite simple. To configure the server *war*, you only have to start vipw(8) and replace the line

```
+:::::::::
```

with

```
+@IT_EMP:::::::::
```

Now, only the data for the users defined in the netgroup *IT_EMP* is imported into *war*'s password database and only these users are allowed to login.

Unfortunately, this limitation also applies to the ~ function of the shell and all routines converting between user names and numerical user IDs. In other words, `cd ~user` will not work, `ls -l` will show the numerical id instead of the username and `find . -user joe -print` will fail with `No such user`. To fix this, you will have to import all user entries *without allowing them to login onto your servers*.

This can be achieved by adding another line to `/etc/master.passwd`. This line should contain:

`+:::::::::/sbin/nologin`, meaning "Import all entries but replace the shell with `/sbin/nologin` in the imported entries". You can replace any field in the passwd entry by placing a default value in your `/etc/master.passwd`.

Warning: Make sure that the line `+:::::::::/sbin/nologin` is placed after `+@IT_EMP:::::::::`. Otherwise, all user accounts imported from NIS will have /sbin/nologin as their login shell.

After this change, you will only have to change one NIS map if a new employee joins the IT department. You could use a similar approach for the less important servers by replacing the old `+:::::::::` in their local version of `/etc/master.passwd` with something like this:

```
+@IT_EMP:::::::::
+@IT_APP:::::::::
+:::::::::/sbin/nologin
```

The corresponding lines for the normal workstations could be:

```
+@IT_EMP:::::::::
+@USERS:::::::::
+:::::::::/sbin/nologin
```

And everything would be fine until there is a policy change a few weeks later: The IT department starts hiring interns. The IT interns are allowed to use the normal workstations and the less important servers; and the IT apprentices are allowed to login onto the main servers. You add a new netgroup IT_INTERN, add the new IT interns to this netgroup and start to change the config on each and every machine... As the old saying goes: "Errors in centralized planning lead to global mess".

NIS' ability to create netgroups from other netgroups can be used to prevent situations like these. One possibility is the creation of role-based netgroups. For example, you could create a netgroup called *BIGSRV* to define the login restrictions for the important servers, another netgroup called *SMALLSRV* for the less important servers and a third netgroup called *USERBOX* for the normal workstations. Each of these netgroups contains the netgroups that are allowed to login onto these machines. The new entries for your NIS map netgroup should look like this:

```
BIGSRV    IT_EMP  IT_APP
SMALLSRV  IT_EMP  IT_APP  ITINTERN
USERBOX   IT_EMP  ITINTERN USERS
```

This method of defining login restrictions works reasonably well if you can define groups of machines with identical restrictions. Unfortunately, this is the exception and not the rule. Most of the time, you will need the ability to define login restrictions on a per-machine basis.

Machine-specific netgroup definitions are the other possibility to deal with the policy change outlined above. In this scenario, the `/etc/master.passwd` of each box contains two lines starting with "+". The first of them adds a netgroup with the accounts allowed to login onto this machine, the second one adds all other accounts with `/sbin/nologin` as shell. It is a good idea to use the ALL-CAPS version of the machine name as the name of the netgroup. In other words, the lines should look like this:

```
+@BOXNAME:::::::::
+:::::::::/sbin/nologin
```

Once you have completed this task for all your machines, you will not have to modify the local versions of `/etc/master.passwd` ever again. All further changes can be handled by modifying the NIS map. Here is an example of a possible netgroup map for this scenario with some additional goodies.

```
# Define groups of users first
IT_EMP    (,alpha,test-domain)    (,beta,test-domain)
IT_APP    (,charlie,test-domain)  (,delta,test-domain)
DEPT1     (,echo,test-domain)     (,foxtrott,test-domain)
DEPT2     (,golf,test-domain)     (,hotel,test-domain)
DEPT3     (,india,test-domain)    (,juliet,test-domain)
```

```
ITINTERN  (,kilo,test-domain)     (,lima,test-domain)
D_INTERNS (,able,test-domain)     (,baker,test-domain)
#
# Now, define some groups based on roles
USERS     DEPT1   DEPT2     DEPT3
BIGSRV    IT_EMP  IT_APP
SMALLSRV  IT_EMP  IT_APP    ITINTERN
USERBOX   IT_EMP  ITINTERN  USERS
#
# And a groups for a special tasks
# Allow echo and golf to access our anti-virus-machine
SECURITY  IT_EMP  (,echo,test-domain)  (,golf,test-domain)
#
# machine-based netgroups
# Our main servers
WAR       BIGSRV
FAMINE    BIGSRV
# User india needs access to this server
POLLUTION  BIGSRV  (,india,test-domain)
#
# This one is really important and needs more access restrictions
DEATH     IT_EMP
#
# The anti-virus-machine mentioned above
ONE       SECURITY
#
# Restrict a machine to a single user
TWO       (,hotel,test-domain)
# [...more groups to follow]
```

If you are using some kind of database to manage your user accounts, you should be able to create the first part of the map with your database's report tools. This way, new users will automatically have access to the boxes.

One last word of caution: It may not always be advisable to use machine-based netgroups. If you are deploying a couple of dozen or even hundreds of identical machines for student labs, you should use role-based netgroups instead of machine-based netgroups to keep the size of the NIS map within reasonable limits.

19.9.8 Important Things to Remember

There are still a couple of things that you will need to do differently now that you are in an NIS environment.

- Every time you wish to add a user to the lab, you must add it to the master NIS server *only*, and *you must remember to rebuild the NIS maps*. If you forget to do this, the new user will not be able to login anywhere except on the NIS master. For example, if we needed to add a new user "jsmith" to the lab, we would:

  ```
  # pw useradd jsmith
  # cd /var/yp
  # make test-domain
  ```

  You could also run `adduser jsmith` instead of `pw useradd jsmith`.

- *Keep the administration accounts out of the NIS maps*. You do not want to be propagating administrative accounts and passwords to machines that will have users that should not have access to those accounts.
- *Keep the NIS master and slave secure, and minimize their downtime*. If somebody either hacks or simply turns off these machines, they have effectively rendered many people without the ability to login to the lab.

  This is the chief weakness of any centralized administration system. If you do not protect your NIS servers, you will have a lot of angry users!

19.9.9 NIS v1 Compatibility

FreeBSD's **ypserv** has some support for serving NIS v1 clients. FreeBSD's NIS implementation only uses the NIS v2 protocol, however other implementations include support for the v1 protocol for backwards compatibility with older systems. The **ypbind** daemons supplied with these systems will try to establish a binding to an NIS v1 server even though they may never actually need it (and they may persist in broadcasting in search of one even after they receive a response from a v2 server). Note that while support for normal client calls is provided, this version of ypserv does not handle v1 map transfer requests; consequently, it cannot be used as a master or slave in conjunction with older NIS servers that only support the v1 protocol. Fortunately, there probably are not any such servers still in use today.

19.9.10 NIS Servers That Are Also NIS Clients

Care must be taken when running ypserv in a multi-server domain where the server machines are also NIS clients. It is generally a good idea to force the servers to bind to themselves rather than allowing them to broadcast bind requests and possibly become bound to each other. Strange failure modes can result if one server goes down and others are dependent upon it. Eventually all the clients will time out and attempt to bind to other servers, but the delay involved can be considerable and the failure mode is still present since the servers might bind to each other all over again.

You can force a host to bind to a particular server by running `ypbind` with the `-S` flag. If you do not want to do this manually each time you reboot your NIS server, you can add the following lines to your `/etc/rc.conf`:

```
nis_client_enable="YES" # run client stuff as well
nis_client_flags="-S NIS domain,server"
```

See ypbind(8) for further information.

19.9.11 Password Formats

One of the most common issues that people run into when trying to implement NIS is password format compatibility. If your NIS server is using DES encrypted passwords, it will only support clients that are also using DES. For example, if you have Solaris NIS clients in your network, then you will almost certainly need to use DES encrypted passwords.

To check which format your servers and clients are using, look at `/etc/login.conf`. If the host is configured to use DES encrypted passwords, then the `default` class will contain an entry like this:

```
default:\
:passwd_format=des:\
```

```
:copyright=/etc/COPYRIGHT:\
[Further entries elided]
```

Other possible values for the `passwd_format` capability include `blf` and `md5` (for Blowfish and MD5 encrypted passwords, respectively).

If you have made changes to `/etc/login.conf`, you will also need to rebuild the login capability database, which is achieved by running the following command as `root`:

```
# cap_mkdb /etc/login.conf
```

> **Note:** The format of passwords already in `/etc/master.passwd` will not be updated until a user changes their password for the first time *after* the login capability database is rebuilt.

Next, in order to ensure that passwords are encrypted with the format that you have chosen, you should also check that the `crypt_default` in `/etc/auth.conf` gives precedence to your chosen password format. To do this, place the format that you have chosen first in the list. For example, when using DES encrypted passwords, the entry would be:

```
crypt_default = des blf md5
```

Having followed the above steps on each of the FreeBSD based NIS servers and clients, you can be sure that they all agree on which password format is used within your network. If you have trouble authenticating on an NIS client, this is a pretty good place to start looking for possible problems. Remember: if you want to deploy an NIS server for a heterogenous network, you will probably have to use DES on all systems because it is the lowest common standard.

19.10 DHCP

Written by Greg Sutter.

19.10.1 What Is DHCP?

DHCP, the Dynamic Host Configuration Protocol, describes the means by which a system can connect to a network and obtain the necessary information for communication upon that network. FreeBSD uses the ISC (Internet Software Consortium) DHCP implementation, so all implementation-specific information here is for use with the ISC distribution.

19.10.2 What This Section Covers

This section describes both the client-side and server-side components of the ISC DHCP system. The client-side program, `dhclient`, comes integrated within FreeBSD, and the server-side portion is available from the `net/isc-dhcp3` port. The dhclient(8), dhcp-options(5), and dhclient.conf(5) manual pages, in addition to the references below, are useful resources.

19.10.3 How It Works

When `dhclient`, the DHCP client, is executed on the client machine, it begins broadcasting requests for configuration information. By default, these requests are on UDP port 68. The server replies on UDP 67, giving the client an IP address and other relevant network information such as netmask, router, and DNS servers. All of this information comes in the form of a DHCP "lease" and is only valid for a certain time (configured by the DHCP server maintainer). In this manner, stale IP addresses for clients no longer connected to the network can be automatically reclaimed.

DHCP clients can obtain a great deal of information from the server. An exhaustive list may be found in dhcp-options(5).

19.10.4 FreeBSD Integration

FreeBSD fully integrates the ISC DHCP client, `dhclient`. DHCP client support is provided within both the installer and the base system, obviating the need for detailed knowledge of network configurations on any network that runs a DHCP server. `dhclient` has been included in all FreeBSD distributions since 3.2.

DHCP is supported by **sysinstall**. When configuring a network interface within sysinstall, the first question asked is, "Do you want to try DHCP configuration of this interface?" Answering affirmatively will execute `dhclient`, and if successful, will fill in the network configuration information automatically.

There are two things you must do to have your system use DHCP upon startup:

- Make sure that the `bpf` device is compiled into your kernel. To do this, add `pseudo-device bpf` to your kernel configuration file, and rebuild the kernel. For more information about building kernels, see Chapter 9.

  The `bpf` device is already part of the `GENERIC` kernel that is supplied with FreeBSD, so if you do not have a custom kernel, you should not need to create one in order to get DHCP working.

  > **Note:** For those who are particularly security conscious, you should be warned that `bpf` is also the device that allows packet sniffers to work correctly (although they still have to be run as `root`). `bpf` *is* required to use DHCP, but if you are very sensitive about security, you probably should not add `bpf` to your kernel in the expectation that at some point in the future you will be using DHCP.

- Edit your `/etc/rc.conf` to include the following:

  ```
  ifconfig_fxp0="DHCP"
  ```

  > **Note:** Be sure to replace `fxp0` with the designation for the interface that you wish to dynamically configure, as described in Section 6.8.

  If you are using a different location for `dhclient`, or if you wish to pass additional flags to `dhclient`, also include the following (editing as necessary):

  ```
  dhcp_program="/sbin/dhclient"
  dhcp_flags=""
  ```

The DHCP server, `dhcpd`, is included as part of the `net/isc-dhcp3` port in the ports collection. This port contains the full ISC DHCP distribution, consisting of client, server, relay agent and documentation.

19.10.5 Files

- `/etc/dhclient.conf`

  `dhclient` requires a configuration file, `/etc/dhclient.conf`. Typically the file contains only comments, the defaults being reasonably sane. This configuration file is described by the dhclient.conf(5) manual page.

- `/sbin/dhclient`

  `dhclient` is statically linked and resides in `/sbin`. The dhclient(8) manual page gives more information about `dhclient`.

- `/sbin/dhclient-script`

  `dhclient-script` is the FreeBSD-specific DHCP client configuration script. It is described in dhclient-script(8), but should not need any user modification to function properly.

- `/var/db/dhclient.leases`

  The DHCP client keeps a database of valid leases in this file, which is written as a log. dhclient.leases(5) gives a slightly longer description.

19.10.6 Further Reading

The DHCP protocol is fully described in RFC 2131 (http://www.freesoft.org/CIE/RFC/2131/). An informational resource has also been set up at dhcp.org (http://www.dhcp.org/).

19.10.7 Installing and Configuring a DHCP Server

19.10.7.1 What This Section Covers

This section provides information on how to configure a FreeBSD system to act as a DHCP server using the ISC (Internet Software Consortium) implementation of the DHCP suite.

The server portion of the suite is not provided as part of FreeBSD, and so you will need to install the `net/isc-dhcp3` port to provide this service. See Chapter 4 for more information on using the ports collection.

19.10.7.2 DHCP Server Installation

In order to configure your FreeBSD system as a DHCP server, you will need to ensure that the bpf(4) device is compiled into your kernel. To do this, add `pseudo-device bpf` to your kernel configuration file, and rebuild the kernel. For more information about building kernels, see Chapter 9.

The `bpf` device is already part of the `GENERIC` kernel that is supplied with FreeBSD, so you do not need to create a custom kernel in order to get DHCP working.

> **Note:** Those who are particularly security conscious should note that `bpf` is also the device that allows packet sniffers to work correctly (although such programs still need privileged access). `bpf` *is* required to use DHCP, but if you are very sensitive about security, you probably should not include `bpf` in your kernel purely because you expect to use DHCP at some point in the future.

The next thing that you will need to do is edit the sample `dhcpd.conf` which was installed by the `net/isc-dhcp3` port. By default, this will be `/usr/local/etc/dhcpd.conf.sample`, and you should copy this to `/usr/local/etc/dhcpd.conf` before proceeding to make changes.

19.10.7.3 Configuring the DHCP Server

`dhcpd.conf` is comprised of declarations regarding subnets and hosts, and is perhaps most easily explained using an example :

```
option domain-name "example.com";❶
option domain-name-servers 192.168.4.100;❷
option subnet-mask 255.255.255.0;❸

default-lease-time 3600;❹
max-lease-time 86400;❺
ddns-update-style none;❻

subnet 192.168.4.0 netmask 255.255.255.0 {
  range 192.168.4.129 192.168.4.254;❼
  option routers 192.168.4.1;❽
}

host mailhost {
  hardware ethernet 02:03:04:05:06:07;❾
  fixed-address mailhost.example.com;(10)
}
```

❶ This option specifies the domain that will be provided to clients as the default search domain. See resolv.conf(5) for more information on what this means.

❷ This option specifies a comma separated list of DNS servers that the client should use.

❸ The netmask that will be provided to clients.

❹ A client may request a specific length of time that a lease will be valid. Otherwise the server will assign a lease with this expiry value (in seconds).

❺ This is the maximum length of time that the server will lease for. Should a client request a longer lease, a lease will be issued, although it will only be valid for `max-lease-time` seconds.

❻ This option specifies whether the DHCP server should attempt to update DNS when a lease is accepted or released. In the ISC implementation, this option is *required*.

❼ This denotes which IP addresses should be used in the pool reserved for allocating to clients. IP addresses between, and including, the ones stated are handed out to clients.

❽ Declares the default gateway that will be provided to clients.

❾ The hardware MAC address of a host (so that the DHCP server can recognize a host when it makes a request).

(10) Specifies that the host should always be given the same IP address. Note that a hostname is OK here, since the DHCP server will resolve the hostname itself before returning the lease information.

Once you have finished writing your `dhcpd.conf`, you can proceed to start the server by issuing the following command:

```
# /usr/local/etc/rc.d/isc-dhcpd.sh start
```

Should you need to make changes to the configuration of your server in the future, it is important to note that sending a `SIGHUP` signal to **dhcpd** does *not* result in the configuration being reloaded, as it does with most daemons. You will need to send a `SIGTERM` signal to stop the process, and then restart it using the command above.

19.10.7.4 Files

- `/usr/local/sbin/dhcpd`

  dhcpd is statically linked and resides in `/usr/local/sbin`. The dhcpd(8) manual page installed with the port gives more information about **dhcpd**.

- `/usr/local/etc/dhcpd.conf`

  dhcpd requires a configuration file, `/usr/local/etc/dhcpd.conf` before it will start providing service to clients. This file needs to contain all the information that should be provided to clients that are being serviced, along with information regarding the operation of the server. This configuration file is described by the dhcpd.conf(5) manual page installed by the port.

- `/var/db/dhcpd.leases`

  The DHCP server keeps a database of leases it has issued in this file, which is written as a log. The manual page dhcpd.leases(5), installed by the port gives a slightly longer description.

- `/usr/local/sbin/dhcrelay`

  dhcrelay is used in advanced environments where one DHCP server forwards a request from a client to another DHCP server on a separate network. The dhcrelay(8) manual page provided with the port contains more detail.

19.11 DNS

Contributed by Chern Lee.

19.11.1 Overview

FreeBSD utilizes, by default, a version of BIND (Berkeley Internet Name Domain), which is the most common implementation of the DNS protocol. DNS is the protocol through which names are mapped to IP addresses, and vice versa. For example, a query for `www.FreeBSD.org` will receive a reply with the IP address of The FreeBSD Project's web server, whereas, a query for `ftp.FreeBSD.org` will return the IP address of the corresponding FTP machine. Likewise, the opposite can happen. A query for an IP address can resolve its hostname. It is not necessary to run a name server to perform DNS lookups on a system.

DNS is coordinated across the Internet through a somewhat complex system of authoritative root name servers, and other smaller-scale name servers who host and cache individual domain information.

This document refers to BIND 8.x, as it is the stable version used in FreeBSD. BIND 9.x in FreeBSD can be installed through the `net/bind9` port.

RFC1034 and RFC1035 dictate the DNS protocol.

Currently, BIND is maintained by the Internet Software Consortium (www.isc.org) (http://www.isc.org/).

19.11.2 Terminology

To understand this document, some terms related to DNS must be understood.

Term	Definition
Forward DNS	Mapping of hostnames to IP addresses
Origin	Refers to the domain covered in a particular zone file
named, BIND, name server	Common names for the BIND name server package within FreeBSD
Resolver	A system process through which a machine queries a name server for zone information
Reverse DNS	The opposite of forward DNS; mapping of IP addresses to hostnames
Root zone	The beginning of the Internet zone hierarchy. All zones fall under the root zone, similar to how all files in a file system fall under the root directory.
Zone	An individual domain, subdomain, or portion of the DNS administered by the same authority

Examples of zones:

- `.` is the root zone
- `org.` is a zone under the root zone
- `example.org` is a zone under the `org.` zone
- `foo.example.org.` is a subdomain, a zone under the `example.org.` zone

- `1.2.3.in-addr.arpa` is a zone referencing all IP addresses which fall under the 3.2.1.* IP space.

As one can see, the more specific part of a hostname appears to its left. For example, `example.org.` is more specific than `org.`, as `org.` is more specific than the root zone. The layout of each part of a hostname is much like a filesystem: the `/dev` directory falls within the root, and so on.

19.11.3 Reasons to Run a Name Server

Name servers usually come in two forms: an authoritative name server, and a caching name server.

An authoritative name server is needed when:

- one wants to serve DNS information to the world, replying authoritatively to queries.
- a domain, such as `example.org`, is registered and IP addresses need to be assigned to hostnames under it.
- an IP address block requires reverse DNS entries (IP to hostname).
- a backup name server, called a slave, must reply to queries when the primary is down or inaccessible.

A caching name server is needed when:

- a local DNS server may cache and respond more quickly than querying an outside name server.
- a reduction in overall network traffic is desired (DNS traffic has been measured to account for 5% or more of total Internet traffic).

When one queries for `www.FreeBSD.org`, the resolver usually queries the uplink ISP's name server, and retrieves the reply. With a local, caching DNS server, the query only has to be made once to the outside world by the caching DNS server. Every additional query will not have to look to the outside of the local network, since the information is cached locally.

19.11.4 How It Works

In FreeBSD, the BIND daemon is called **named** for obvious reasons.

File	Description
named	the BIND daemon
`ndc`	name daemon control program
`/etc/namedb`	directory where BIND zone information resides
`/etc/namedb/named.conf`	daemon configuration file

Zone files are usually contained within the `/etc/namedb` directory, and contain the DNS zone information served by the name server.

19.11.5 Starting BIND

Since BIND is installed by default, configuring it all is relatively simple.

To ensure the named daemon is started at boot, put the following modifications in `/etc/rc.conf`:

```
named_enable="YES"
```

To start the daemon manually (after configuring it)

```
# ndc start
```

19.11.6 Configuration Files

19.11.6.1 Using make-localhost

Be sure to:

```
# cd /etc/namedb
# sh make-localhost
```

to properly create the local reverse DNS zone file in `/etc/namedb/localhost.rev`.

19.11.6.2 /etc/namedb/named.conf

```
// $FreeBSD$
//
// Refer to the named(8) manual page for details.  If you are ever going
// to setup a primary server, make sure you've understood the hairy
// details of how DNS is working.  Even with simple mistakes, you can
// break connectivity for affected parties, or cause huge amount of
// useless Internet traffic.

options {
        directory "/etc/namedb";

// In addition to the "forwarders" clause, you can force your name
// server to never initiate queries of its own, but always ask its
// forwarders only, by enabling the following line:
//
//      forward only;

// If you've got a DNS server around at your upstream provider, enter
// its IP address here, and enable the line below.  This will make you
// benefit from its cache, thus reduce overall DNS traffic in the
Internet.
/*
        forwarders {
                127.0.0.1;
        };
*/
```

Just as the comment says, to benefit from an uplink's cache, `forwarders` can be enabled here. Under normal circumstances, a name server will recursively query the Internet looking at certain name servers until it finds the answer it is looking for. Having this enabled will have it query the uplink's name server (or name server provided) first, taking advantage of its cache. If the uplink name server in question is a heavily trafficked, fast name server, enabling this may be worthwhile.

> **Warning:** `127.0.0.1` will *not* work here. Change this IP address to a name server at your uplink.

```
        /*
         * If there is a firewall between you and name servers you want
         * to talk to, you might need to uncomment the query-source
         * directive below.  Previous versions of BIND always asked
         * questions using port 53, but BIND 8.1 uses an unprivileged
         * port by default.
         */
        // query-source address * port 53;

        /*
         * If running in a sandbox, you may have to specify a different
         * location for the dumpfile.
         */
        // dump-file "s/named_dump.db";
};

// Note: the following will be supported in a future release.
/*
host { any; } {
        topology {
                127.0.0.0/8;
        };
};
*/

// Setting up secondaries is way easier and the rough picture for this
// is explained below.
//
// If you enable a local name server, don't forget to enter 127.0.0.1
// into your /etc/resolv.conf so this server will be queried first.
// Also, make sure to enable it in /etc/rc.conf.

zone "." {
        type hint;
        file "named.root";
};

zone "0.0.127.IN-ADDR.ARPA" {
        type master;
        file "localhost.rev";
};

zone
"0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.IP6.INT" {
        type master;
        file "localhost.rev";
```

```
};

// NB: Do not use the IP addresses below, they are faked, and only
// serve demonstration/documentation purposes!
//
// Example secondary config entries.  It can be convenient to become
// a secondary at least for the zone where your own domain is in.  Ask
// your network administrator for the IP address of the responsible
// primary.
//
// Never forget to include the reverse lookup (IN-ADDR.ARPA) zone!
// (This is the first bytes of the respective IP address, in reverse
// order, with ".IN-ADDR.ARPA" appended.)
//
// Before starting to setup a primary zone, better make sure you fully
// understand how DNS and BIND works, however.  There are sometimes
// unobvious pitfalls.  Setting up a secondary is comparably simpler.
//
// NB: Don't blindly enable the examples below. :-)  Use actual names
// and addresses instead.
//
// NOTE!!! FreeBSD runs bind in a sandbox (see named_flags in rc.conf).
// The directory containing the secondary zones must be write accessible
// to bind.  The following sequence is suggested:
//
//      mkdir /etc/namedb/s
//      chown bind:bind /etc/namedb/s
//      chmod 750 /etc/namedb/s
```

For more information on running BIND in a sandbox, see Running named in a sandbox.

```
/*
zone "example.com" {
        type slave;
        file "s/example.com.bak";
        masters {
                192.168.1.1;
        };
};

zone "0.168.192.in-addr.arpa" {
        type slave;
        file "s/0.168.192.in-addr.arpa.bak";
        masters {
                192.168.1.1;
        };
};
*/
```

In `named.conf`, these are examples of slave entries for a forward and reverse zone.

For each new zone served, a new zone entry must be added to `named.conf`

For example, the simplest zone entry for `example.org` can look like:

```
zone "example.org" {
type master;
file "example.org";
};
```

The zone is a master, as indicated by the `type` statement, holding its zone information in `/etc/namedb/example.org` indicated by the `file` statement.

```
zone "example.org" {
type slave;
file "example.org";
};
```

In the slave case, the zone information is transferred from the master name server for the particular zone, and saved in the file specified. If and when the master server dies or is unreachable, the slave name server will have the transferred zone information and will be able to serve it.

19.11.6.3 Zone Files

An example master zone file for `example.org` (existing within `/etc/namedb/example.org`) is as follows:

```
$TTL 3600

example.org. IN SOA ns1.example.org. admin.example.org. (
                        5               ; Serial
                        10800           ; Refresh
                        3600            ; Retry
                        604800          ; Expire
                        86400 )         ; Minimum TTL

; DNS Servers
@       IN NS           ns1.example.org.
@       IN NS           ns2.example.org.

; Machine Names
localhost       IN A    127.0.0.1
ns1             IN A    3.2.1.2
ns2             IN A    3.2.1.3
mail            IN A    3.2.1.10
@               IN A    3.2.1.30

; Aliases
www             IN CNAME        @

; MX Record
@               IN MX   10      mail.example.org.
```

Note that every hostname ending in a “.” is an exact hostname, whereas everything without a trailing “.” is referenced to the origin. For example, `www` is translated into `www + origin`. In our fictitious zone file, our origin is `example.org.`, so `www` would translate to `www.example.org.`

The format of a zone file follows:

```
recordname      IN recordtype   value
```

The most commonly used DNS records:

SOA

: start of zone authority

NS

: an authoritative name server

A

: A host address

CNAME

: the canonical name for an alias

MX

: mail exchanger

PTR

: a domain name pointer (used in reverse DNS)

```
example.org. IN SOA ns1.example.org. admin.example.org. (
                        5               ; Serial
                        10800           ; Refresh after 3 hours
                        3600            ; Retry after 1 hour
                        604800          ; Expire after 1 week
                        86400 )         ; Minimum TTL of 1 day
```

`example.org.`

: the domain name, also the origin for this zone file.

`ns1.example.org.`

: the primary/authoritative name server for this zone

`admin.example.org.`

: the responsible person for this zone, email address with @ replaced. (<`admin@example.org`> becomes `admin.example.org`)

`5`

: the serial number of the file. this must be incremented each time the zone file is modified. Nowadays, many admins prefer a `yyyymmddrr` format for the serial number. 2001041002 would mean last modified 04/10/2001, the latter 02 being the second time the zone file has been modified this day. The serial number is important as it alerts slave name servers for a zone when it is updated.

```
@       IN NS           ns1.example.org.
```

This is an NS entry. Every name server that is going to reply authoritatively for the zone must have one of these entries. The @ as seen here could have been example.org. The @ translates to the origin.

```
localhost       IN A    127.0.0.1
ns1             IN A    3.2.1.2
ns2             IN A    3.2.1.3
mail            IN A    3.2.1.10
@               IN A    3.2.1.30
```

The A record indicates machine names. As seen above, ns1.example.org would resolve to 3.2.1.2. Again, the origin symbol, @, is used here, thus meaning example.org would resolve to 3.2.1.30.

```
www             IN CNAME        @
```

The canonical name record is usually used for giving aliases to a machine. In the example, www is aliased to the machine addressed to the origin, or example.org (3.2.1.30). CNAMEs can be used to provide alias hostnames, or round robin one hostname among multiple machines.

```
@               IN MX   10      mail.example.org.
```

The MX record indicates which mail servers are responsible for handling incoming mail for the zone. mail.example.org is the hostname of the mail server, and 10 being the priority of that mail server.

One can have several mail servers, with priorities of 3, 2, 1. A mail server attempting to deliver to example.org would first try the highest priority MX, then the second highest, etc, until the mail can be properly delivered.

For in-addr.arpa zone files (reverse DNS), the same format is used, except with PTR entries instead of A or CNAME.

```
$TTL 3600

1.2.3.in-addr.arpa. IN SOA ns1.example.org. admin.example.org. (
                        5               ; Serial
                        10800           ; Refresh
                        3600            ; Retry
                        604800          ; Expire
                        3600 )          ; Minimum

@       IN NS   ns1.example.org.
@       IN NS   ns2.example.org.

2       IN PTR  ns1.example.org.
3       IN PTR  ns2.example.org.
10      IN PTR  mail.example.org.
30      IN PTR  example.org.
```

This file gives the proper IP address to hostname mappings of our above fictitious domain.

19.11.7 Caching Name Server

A caching name server is a name server that is not authoritative for any zones. It simply asks queries of its own, and remembers them for later use. To set one up, just configure the name server as usual, omitting any inclusions of zones.

19.11.8 Running named in a Sandbox

For added security you may want to run named(8) as an unprivileged user, and configure it to chroot(8) into a sandbox directory. This makes everything outside of the sandbox inaccessible to the **named** daemon. Should **named** be compromised, this will help to reduce the damage that can be caused. By default, FreeBSD has a user and a group called `bind`, intended for this use.

> **Note:** Various people would recommend that instead of configuring **named** to `chroot`, you should run **named** inside a jail(8). This section does not attempt to cover this situation.

Since **named** will not be able to access anything outside of the sandbox (such as shared libraries, log sockets, and so on), there are a number of steps that need to be followed in order to allow **named** to function correctly. In the following checklist, it is assumed that the path to the sandbox is `/etc/namedb` and that you have made no prior modifications to the contents of this directory. Perform the following steps as `root`.

- Create all directories that **named** expects to see:

  ```
  # cd /etc/namedb
  # mkdir -p bin dev etc var/tmp var/run master slave
  # chown bind:bind slave var/*❶
  ```

  ❶ **named** only needs write access to these directories, so that is all we give it.

- Rearrange and create basic zone and configuration files:

  ```
  # cp /etc/localtime etc❶
  # mv named.conf etc && ln -sf etc/named.conf
  # mv named.root master
  # sh make-localhost && mv localhost.rev localhost-v6.rev master
  # cat > master/named.localhost
  $ORIGIN localhost.
  $TTL 6h
  @ IN SOA localhost. postmaster.localhost. (
  1 ; serial
  3600 ; refresh
  1800 ; retry
  604800 ; expiration
  3600 ) ; minimum
  IN NS localhost.
  IN A 127.0.0.1
  ^D
  ```

  ❶ This allows **named** to log the correct time to syslogd(8)

- If you are running a version of FreeBSD prior to 4.9-RELEASE, build a statically linked copy of **named-xfer**, and copy it into the sandbox:

  ```
  # cd /usr/src/lib/libisc
  # make cleandir && make cleandir && make depend && make all
  # cd /usr/src/lib/libbind
  ```

```
# make cleandir && make cleandir && make depend && make all
# cd /usr/src/libexec/named-xfer
# make cleandir && make cleandir && make depend && make NOSHARED=yes all
# cp named-xfer /etc/namedb/bin && chmod 555 /etc/namedb/bin/named-xfer❶
```

After your statically linked `named-xfer` is installed some cleaning up is required, to avoid leaving stale copies of libraries or programs in your source tree:

```
# cd /usr/src/lib/libisc
# make cleandir
# cd /usr/src/lib/libbind
# make cleandir
# cd /usr/src/libexec/named-xfer
# make cleandir
```

❶ This step has been reported to fail occasionally. If this happens to you, then issue the command:

```
# cd /usr/src && make cleandir && make cleandir
```

and delete your `/usr/obj` tree:

```
# rm -fr /usr/obj && mkdir /usr/obj
```

This will clean out any "cruft" from your source tree, and retrying the steps above should then work.

If you are running FreeBSD version 4.9-RELEASE or later, then the copy of `named-xfer` in `/usr/libexec` is statically linked by default, and you can simply use cp(1) to copy it into your sandbox.

- Make a `dev/null` that **named** can see and write to:

```
# cd /etc/namedb/dev && mknod null c 2 2
# chmod 666 null
```

- Symlink `/var/run/ndc` to `/etc/namedb/var/run/ndc`:

```
# ln -sf /etc/namedb/var/run/ndc /var/run/ndc
```

> **Note:** This simply avoids having to specify the `-c` option to ndc(8) every time you run it. Since the contents of /var/run are deleted on boot, if this is something that you find useful you may wish to add this command to root's crontab, making use of the `@reboot` option. See crontab(5) for more information regarding this.

- Configure syslogd(8) to create an extra `log` socket that **named** can write to. To do this, add `-l /etc/namedb/dev/log` to the `syslogd_flags` variable in `/etc/rc.conf`.
- Arrange to have **named** start and `chroot` itself to the sandbox by adding the following to `/etc/rc.conf`:

```
named_enable="YES"
named_flags="-u bind -g bind -t /etc/namedb /etc/named.conf"
```

> **Note:** Note that the configuration file */etc/named.conf* is denoted by a full pathname *relative to the sandbox*, i.e. in the line above, the file referred to is actually `/etc/namedb/etc/named.conf`.

The next step is to edit `/etc/namedb/etc/named.conf` so that **named** knows which zones to load and where to find them on the disk. There follows a commented example (anything not specifically commented here is no different from the setup for a DNS server not running in a sandbox):

```
options {
        directory "/";❶
        named-xfer "/bin/named-xfer";❷
        version ""; // Don't reveal BIND version
        query-source address * port 53;
};
// ndc control socket
controls {
        unix "/var/run/ndc" perm 0600 owner 0 group 0;
};
// Zones follow:
zone "localhost" IN {
        type master;
        file "master/named.localhost";❸
        allow-transfer { localhost; };
        notify no;
};
zone "0.0.127.in-addr.arpa" IN {
        type master;
        file "master/localhost.rev";
        allow-transfer { localhost; };
        notify no;
};
zone "0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.0.ip6.int" {
type master;
file "master/localhost-v6.rev";
allow-transfer { localhost; };
notify no;
};
zone "." IN {
        type hint;
        file "master/named.root";
};
zone "private.example.net" in {
        type master;
        file "master/private.example.net.db";
allow-transfer { 192.168.10.0/24; };
};
zone "10.168.192.in-addr.arpa" in {
        type slave;
        masters { 192.168.10.2; };
        file "slave/192.168.10.db";❹
};
```

❶ The `directory` statement is specified as `/`, since all files that **named** needs are within this directory (recall that this is equivalent to a "normal" user's `/etc/namedb`.

❷ Specifies the full path to the `named-xfer` binary (from **named**'s frame of reference). This is necessary since **named** is compiled to look for `named-xfer` in `/usr/libexec` by default.

❸ Specifies the filename (relative to the `directory` statement above) where **named** can find the zonefile for this zone.

❹ Specifies the filename (relative to the `directory` statement above) where **named** should write a copy of the zonefile for this zone after successfully transferring it from the master server. This is why we needed to change the ownership of the directory `slave` to `bind` in the setup stages above.

After completing the steps above, either reboot your server or restart syslogd(8) and start named(8), making sure to use the new options specified in `syslogd_flags` and `named_flags`. You should now be running a sandboxed copy of **named**!

19.11.9 Security

Although BIND is the most common implementation of DNS, there is always the issue of security. Possible and exploitable security holes are sometimes found.

It is a good idea to subscribe to CERT (http://www.cert.org/) and freebsd-security-notifications (../handbook/eresources.html#ERESOURCES-MAIL) to stay up to date with the current Internet and FreeBSD security issues.

> **Tip:** If a problem arises, keeping sources up to date and having a fresh build of named would not hurt.

19.11.10 Further Reading

BIND/named manual pages: ndc(8) named(8) named.conf(5)

- Official ISC Bind Page (http://www.isc.org/products/BIND/)
- BIND FAQ (http://www.nominum.com/getOpenSourceResource.php?id=6)
- O'Reilly DNS and BIND 4th Edition (http://www.oreilly.com/catalog/dns4/)
- RFC1034 - Domain Names - Concepts and Facilities (ftp://ftp.isi.edu/in-notes/rfc1034.txt)
- RFC1035 - Domain Names - Implementation and Specification (ftp://ftp.isi.edu/in-notes/rfc1035.txt)

19.12 NTP

Contributed by Tom Hukins.

19.12.1 Overview

Over time, a computer's clock is prone to drift. As time passes, the computer's clock becomes less accurate. NTP (Network Time Protocol) is one way to ensure your clock is right.

Many Internet services rely on, or greatly benefit from, computers' clocks being accurate. For example, a Web server may receive requests to send a file if it has modified since a certain time. Services such as cron(8) run commands at a given time. If the clock is inaccurate, these commands may not run when expected.

FreeBSD ships with the ntpd(8) NTP server which can be used to query other NTP servers to set the clock on your machine or provide time services to others.

19.12.2 Choosing Appropriate NTP Servers

In order to synchronize your clock, you will need to find one or more NTP servers to use. Your network administrator or ISP may have set up an NTP server for this purpose—check their documentation to see if this is the case. There is a list of publicly accessible NTP servers (http://www.eecis.udel.edu/~mills/ntp/servers.html) which you can use to find an NTP server near to you. Make sure you are aware of the policy for any servers you choose, and ask for permission if required.

Choosing several unconnected NTP servers is a good idea in case one of the servers you are using becomes unreachable or its clock is unreliable. ntpd(8) uses the responses it receives from other servers intelligently—it will favor unreliable servers less than reliable ones.

19.12.3 Configuring Your Machine

19.12.3.1 Basic Configuration

If you only wish to synchronize your clock when the machine boots up, you can use ntpdate(8). This may be appropriate for some desktop machines which are frequently rebooted and only require infrequent synchronization, but most machines should run ntpd(8).

Using ntpdate(8) at boot time is also a good idea for machines that run ntpd(8). The ntpd(8) program changes the clock gradually, whereas ntpdate(8) sets the clock, no matter how great the difference between a machine's current clock setting and the correct time.

To enable ntpdate(8) at boot time, add `ntpdate_enable="YES"` to `/etc/rc.conf`. You will also need to specify all servers you wish to synchronize with and any flags to be passed to ntpdate(8) in `ntpdate_flags`.

19.12.3.2 General Configuration

NTP is configured by the `/etc/ntp.conf` file in the format described in ntp.conf(5). Here is a simple example:

```
server ntplocal.example.com prefer
server timeserver.example.org
server ntp2a.example.net

driftfile /var/db/ntp.drift
```

The `server` option specifies which servers are to be used, with one server listed on each line. If a server is specified with the `prefer` argument, as with `ntplocal.example.com`, that server is preferred over other servers. A response from a preferred server will be discarded if it differs significantly from other servers' responses, otherwise it will be used without any consideration to other responses. The `prefer` argument is normally used for NTP servers that are known to be highly accurate, such as those with special time monitoring hardware.

The `driftfile` option specifies which file is used to store the system clock's frequency offset. The ntpd(8) program uses this to automatically compensate for the clock's natural drift, allowing it to maintain a reasonably correct setting even if it is cut off from all external time sources for a period of time.

The `driftfile` option specifies which file is used to store information about previous responses from the NTP servers you are using. This file contains internal information for NTP. It should not be modified by any other process.

19.12.3.3 Controlling Access to Your Server

By default, your NTP server will be accessible to all hosts on the Internet. The `restrict` option in `/etc/ntp.conf` allows you to control which machines can access your server.

If you want to deny all machines from accessing your NTP server, add the following line to `/etc/ntp.conf`:

```
restrict default ignore
```

If you only want to allow machines within your own network to synchronize their clocks with your server, but ensure they are not allowed to configure the server or used as peers to synchronize against, add

```
restrict 192.168.1.0 mask 255.255.255.0 notrust nomodify notrap
```

instead, where `192.168.1.0` is an IP address on your network and `255.255.255.0` is your network's netmask.

`/etc/ntp.conf` can contain multiple `restrict` options. For more details, see the `Access Control Support` subsection of ntp.conf(5).

19.12.4 Running the NTP Server

To ensure the NTP server is started at boot time, add the line `xntpd_enable="YES"` to `/etc/rc.conf`. If you wish to pass additional flags to ntpd(8), edit the `xntpd_flags` parameter in `/etc/rc.conf`.

To start the server without rebooting your machine, run `ntpd` being sure to specify any additional parameters from `xntpd_flags` in `/etc/rc.conf`. For example:

```
# ntpd -p /var/run/ntpd.pid
```

> **Note:** Under FreeBSD 5.X, various options in `/etc/rc.conf` have been renamed. Thus, you have to replace every instance of `xntpd` with `ntpd` in the options above.

19.12.5 Using ntpd with a Temporary Internet Connection

The ntpd(8) program does not need a permanent connection to the Internet to function properly. However, if you have a temporary connection that is configured to dial out on demand, it is a good idea to prevent NTP traffic from triggering a dial out or keeping the connection alive. If you are using user PPP, you can use `filter` directives in `/etc/ppp/ppp.conf`. For example:

```
 set filter dial 0 deny udp src eq 123
 # Prevent NTP traffic from initiating dial out
```

```
set filter dial 1 permit 0 0
set filter alive 0 deny udp src eq 123
# Prevent incoming NTP traffic from keeping the connection open
set filter alive 1 deny udp dst eq 123
# Prevent outgoing NTP traffic from keeping the connection open
set filter alive 2 permit 0/0 0/0
```

For more details see the `PACKET FILTERING` section in ppp(8) and the examples in `/usr/share/examples/ppp/`.

> **Note:** Some Internet access providers block low-numbered ports, preventing NTP from functioning since replies never reach your machine.

19.12.6 Further Information

Documentation for the NTP server can be found in `/usr/share/doc/ntp/` in HTML format.

19.13 Network Address Translation

Contributed by Chern Lee.

19.13.1 Overview

FreeBSD's Network Address Translation daemon, commonly known as natd(8) is a daemon that accepts incoming raw IP packets, changes the source to the local machine and re-injects these packets back into the outgoing IP packet stream. natd(8) does this by changing the source IP address and port such that when data is received back, it is able to determine the original location of the data and forward it back to its original requester.

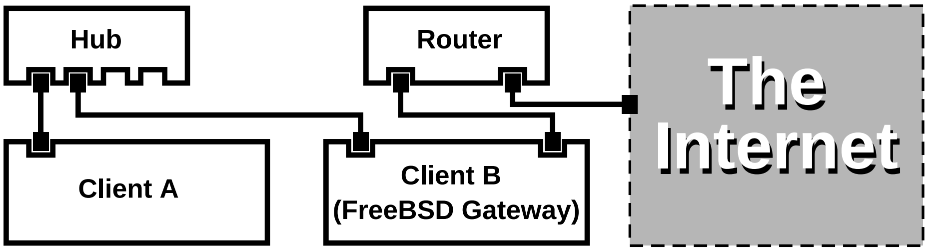
The most common use of NAT is to perform what is commonly known as Internet Connection Sharing.

19.13.2 Setup

Due to the diminishing IP space in IPv4, and the increased number of users on high-speed consumer lines such as cable or DSL, people are increasingly in need of an Internet Connection Sharing solution. The ability to connect several computers online through one connection and IP address makes natd(8) a reasonable choice.

Most commonly, a user has a machine connected to a cable or DSL line with one IP address and wishes to use this one connected computer to provide Internet access to several more over a LAN.

To do this, the FreeBSD machine on the Internet must act as a gateway. This gateway machine must have two NICs—one for connecting to the Internet router, the other connecting to a LAN. All the machines on the LAN are connected through a hub or switch.



A setup like this is commonly used to share an Internet connection. One of the LAN machines is connected to the Internet. The rest of the machines access the Internet through that "gateway" machine.

19.13.3 Configuration

The following options must be in the kernel configuration file:

```
options IPFIREWALL
options IPDIVERT
```

Additionally, at choice, the following may also be suitable:

```
options IPFIREWALL_DEFAULT_TO_ACCEPT
options IPFIREWALL_VERBOSE
```

The following must be in `/etc/rc.conf`:

```
gateway_enable="YES"
firewall_enable="YES"
firewall_type="OPEN"
natd_enable="YES"
natd_interface="fxp0"
natd_flags=""
```

gateway_enable="YES"	Sets up the machine to act as a gateway. Running `sysctl net.inet.ip.forwarding=1` would have the same effect.
firewall_enable="YES"	Enables the firewall rules in `/etc/rc.firewall` at boot.
firewall_type="OPEN"	This specifies a predefined firewall ruleset that allows anything in. See `/etc/rc.firewall` for additional types.
natd_interface="fxp0"	Indicates which interface to forward packets through (the interface connected to the Internet).
natd_flags=""	Any additional configuration options passed to natd(8) on boot.

Having the previous options defined in `/etc/rc.conf` would run `natd -interface fxp0` at boot. This can also be run manually.

Each machine and interface behind the LAN should be assigned IP address numbers in the private network space as defined by RFC 1918 (ftp://ftp.isi.edu/in-notes/rfc1918.txt) and have a default gateway of the **natd** machine's internal IP address.

For example, client `A` and `B` behind the LAN have IP addresses of `192.168.0.2` and `192.168.0.3`, while the natd machine's LAN interface has an IP address of `192.168.0.1`. Client `A` and `B`'s default gateway must be set to that of the **natd** machine, `192.168.0.1`. The **natd** machine's external, or Internet interface does not require any special modification for natd(8) to work.

19.13.4 Port Redirection

The drawback with natd(8) is that the LAN clients are not accessible from the Internet. Clients on the LAN can make outgoing connections to the world but cannot receive incoming ones. This presents a problem if trying to run Internet services on one of the LAN client machines. A simple way around this is to redirect selected Internet ports on the **natd** machine to a LAN client.

For example, an IRC server runs on client `A`, and a web server runs on client `B`. For this to work properly, connections received on ports 6667 (IRC) and 80 (web) must be redirected to the respective machines.

The `-redirect_port` must be passed to natd(8) with the proper options. The syntax is as follows:

```
 -redirect_port proto targetIP:targetPORT[-targetPORT]
             [aliasIP:]aliasPORT[-aliasPORT]
             [remoteIP[:remotePORT[-remotePORT]]]
```

In the above example, the argument should be:

```
-redirect_port tcp 192.168.0.2:6667 6667
-redirect_port tcp 192.168.0.3:80 80
```

This will redirect the proper *tcp* ports to the LAN client machines.

The `-redirect_port` argument can be used to indicate port ranges over individual ports. For example, *`tcp 192.168.0.2:2000-3000 2000-3000`* would redirect all connections received on ports 2000 to 3000 to ports 2000 to 3000 on client `A`.

These options can be used when directly running natd(8) or placed within the `natd_flags=""` option in `/etc/rc.conf`.

For further configuration options, consult natd(8)

19.13.5 Address Redirection

Address redirection is useful if several IP addresses are available, yet they must be on one machine. With this, natd(8) can assign each LAN client its own external IP address. natd(8) then rewrites outgoing packets from the LAN clients with the proper external IP address and redirects all traffic incoming on that particular IP address back to the specific LAN client. This is also known as static NAT. For example, the IP addresses `128.1.1.1`, `128.1.1.2`, and `128.1.1.3` belong to the **natd** gateway machine. `128.1.1.1` can be used as the **natd** gateway machine's external IP address, while `128.1.1.2` and `128.1.1.3` are forwarded back to LAN clients `A` and `B`.

The `-redirect_address` syntax is as follows:

```
-redirect_address localIP publicIP
```

localIP	The internal IP address of the LAN client.
publicIP	The external IP address corresponding to the LAN client.

In the example, this argument would read:

```
-redirect_address 192.168.0.2 128.1.1.2
-redirect_address 192.168.0.3 128.1.1.3
```

Like `-redirect_port`, these arguments are also placed within the `natd_flags=""` option of `/etc/rc.conf`. With address redirection, there is no need for port redirection since all data received on a particular IP address is redirected.

The external IP addresses on the **natd** machine must be active and aliased to the external interface. Look at rc.conf(5) to do so.

19.14 The inetd "Super-Server"

Contributed by Chern Lee.

19.14.1 Overview

inetd(8) is referred to as the "Internet Super-Server" because it manages connections for several daemons. Programs that provide network service are commonly known as daemons. **inetd** serves as a managing server for other daemons. When a connection is received by **inetd**, it determines which daemon the connection is destined for, spawns the particular daemon and delegates the socket to it. Running one instance of **inetd** reduces the overall system load as compared to running each daemon individually in stand-alone mode.

Primarily, **inetd** is used to spawn other daemons, but several trivial protocols are handled directly, such as **chargen**, **auth**, and **daytime**.

This section will cover the basics in configuring **inetd** through its command-line options and its configuration file, `/etc/inetd.conf`.

19.14.2 Settings

inetd is initialized through the `/etc/rc.conf` system. The `inetd_enable` option is set to "NO" by default, but is often times turned on by **sysinstall** with the medium security profile. Placing:

```
inetd_enable="YES"
```

or

```
inetd_enable="NO"
```

into `/etc/rc.conf` can enable or disable **inetd** starting at boot time.

Additionally, different command-line options can be passed to **inetd** via the `inetd_flags` option.

19.14.3 Command-Line Options

inetd synopsis:

```
inetd [-d] [-l] [-w] [-W] [-c maximum] [-C rate] [-a address | hostname] [-p filename]
[-R rate] [configuration file]
```

-d

Turn on debugging.

-l

Turn on logging of successful connections.

-w

Turn on TCP Wrapping for external services (on by default).

-W

Turn on TCP Wrapping for internal services which are built into **inetd** (on by default).

-c maximum

Specify the default maximum number of simultaneous invocations of each service; the default is unlimited. May be overridden on a per-service basis with the `max-child` parameter.

-C rate

Specify the default maximum number of times a service can be invoked from a single IP address in one minute; the default is unlimited. May be overridden on a per-service basis with the `max-connections-per-ip-per-minute` parameter.

-R rate

Specify the maximum number of times a service can be invoked in one minute; the default is 256. A rate of 0 allows an unlimited number of invocations.

-a

Specify one specific IP address to bind to. Alternatively, a hostname can be specified, in which case the IPv4 or IPv6 address which corresponds to that hostname is used. Usually a hostname is specified when **inetd** is run inside a jail(8), in which case the hostname corresponds to the jail(8) environment.

When hostname specification is used and both IPv4 and IPv6 bindings are desired, one entry with the appropriate protocol type for each binding is required for each service in `/etc/inetd.conf`. For example, a TCP-based service would need two entries, one using "tcp4" for the protocol and the other using "tcp6".

-p

Specify an alternate file in which to store the process ID.

These options can be passed to **inetd** using the `inetd_flags` option in `/etc/rc.conf`. By default, `inetd_flags` is set to "-wW", which turns on TCP wrapping for **inetd**'s internal and external services. For novice users, these parameters usually do not need to be modified or even entered in `/etc/rc.conf`.

Note: An external service is a daemon outside of **inetd**, which is invoked when a connection is received for it. On the other hand, an internal service is one that **inetd** has the facility of offering within itself.

19.14.4 `inetd.conf`

Configuration of **inetd** is controlled through the `/etc/inetd.conf` file.

When a modification is made to `/etc/inetd.conf`, **inetd** can be forced to re-read its configuration file by sending a HangUP signal to the **inetd** process as shown:

Example 19-4. Sending inetd a HangUP Signal

```
# kill -HUP ‘cat /var/run/inetd.pid‘
```

Each line of the configuration file specifies an individual daemon. Comments in the file are preceded by a “#”. The format of `/etc/inetd.conf` is as follows:

```
service-name
socket-type
protocol
{wait|nowait}[/max-child[/max-connections-per-ip-per-minute]]
user[:group][/login-class]
server-program
server-program-arguments
```

An example entry for the **ftpd** daemon using IPv4:

```
ftp     stream  tcp     nowait  root    /usr/libexec/ftpd       ftpd -l
```

service-name

This is the service name of the particular daemon. It must correspond to a service listed in `/etc/services`. This determines which port **inetd** must listen to. If a new service is being created, it must be placed in `/etc/services` first.

socket-type

Either `stream`, `dgram`, `raw`, or `seqpacket`. `stream` must be used for connection-based, TCP daemons, while `dgram` is used for daemons utilizing the UDP transport protocol.

protocol

One of the following:

Protocol	Explanation
tcp, tcp4	TCP IPv4
udp, udp4	UDP IPv4
tcp6	TCP IPv6
udp6	UDP IPv6

Protocol	Explanation
tcp46	Both TCP IPv4 and v6
udp46	Both UDP IPv4 and v6

{wait|nowait}[/max-child[/max-connections-per-ip-per-minute]]

`wait|nowait` indicates whether the daemon invoked from **inetd** is able to handle its own socket or not. `dgram` socket types must use the wait option, while stream socket daemons, which are usually multi-threaded, should use `nowait`. `wait` usually hands off multiple sockets to a single daemon, while `nowait` spawns a child daemon for each new socket.

The maximum number of child daemons **inetd** may spawn can be set using the `max-child` option. If a limit of ten instances of a particular daemon is needed, a `/10` would be placed after `nowait`.

In addition to `max-child`, another option limiting the maximum connections from a single place to a particular daemon can be enabled. `max-connections-per-ip-per-minute` does just this. A value of ten here would limit any particular IP address connecting to a particular service to ten attempts per minute. This is useful to prevent intentional or unintentional resource consumption and Denial of Service (DoS) attacks to a machine.

In this field, `wait` or `nowait` is mandatory. `max-child` and `max-connections-per-ip-per-minute` are optional.

A stream-type multi-threaded daemon without any `max-child` or `max-connections-per-ip-per-minute` limits would simply be: `nowait`

The same daemon with a maximum limit of ten daemons would read: `nowait/10`

Additionally, the same setup with a limit of twenty connections per IP address per minute and a maximum total limit of ten child daemons would read: `nowait/10/20`

These options are all utilized by the default settings of the **fingerd** daemon, as seen here:

```
finger stream  tcp     nowait/3/10 nobody /usr/libexec/fingerd fingerd -s
```

user

The user is the username that the particular daemon should run as. Most commonly, daemons run as the `root` user. For security purposes, it is common to find some servers running as the `daemon` user, or the least privileged `nobody` user.

server-program

The full path of the daemon to be executed when a connection is received. If the daemon is a service provided by **inetd** internally, then `internal` should be used.

server-program-arguments

This works in conjunction with `server-program` by specifying the arguments, starting with argv[0], passed to the daemon on invocation. If **mydaemon -d** is the command line, `mydaemon -d` would be the value of `server program arguments`. Again, if the daemon is an internal service, use `internal` here.

19.14.5 Security

Depending on the security profile chosen at install, many of **inetd**'s daemons may be enabled by default. If there is no apparent need for a particular daemon, disable it! Place a "`#`" in front of the daemon in question, and send a hangup signal to inetd. Some daemons, such as **fingerd**, may not be desired at all because they provide an attacker with too much information.

Some daemons are not security-conscious and have long, or non-existent timeouts for connection attempts. This allows an attacker to slowly send connections to a particular daemon, thus saturating available resources. It may be a good idea to place `ip-per-minute` and `max-child` limitations on certain daemons.

By default, TCP wrapping is turned on. Consult the hosts_access(5) manual page for more information on placing TCP restrictions on various **inetd** invoked daemons.

19.14.6 Miscellaneous

daytime, **time**, **echo**, **discard**, **chargen**, and **auth** are all internally provided services of **inetd**.

The **auth** service provides identity (ident, identd) network services, and is configurable to a certain degree.

Consult the inetd(8) manual page for more in-depth information.

19.15 Parallel Line IP (PLIP)

PLIP lets us run TCP/IP between parallel ports. It is useful on machines without network cards, or to install on laptops. In this section, we will discuss:

- Creating a parallel (laplink) cable.
- Connecting two computers with PLIP.

19.15.1 Creating a Parallel Cable

You can purchase a parallel cable at most computer supply stores. If you cannot do that, or you just want to know how it is done, the following table shows how to make one out of a normal parallel printer cable.

Table 19-1. Wiring a Parallel Cable for Networking

A-name	A-End	B-End	Descr.	Post/Bit
DATA0 -ERROR	2 15	15 2	Data	0/0x01 1/0x08
DATA1 +SLCT	3 13	13 3	Data	0/0x02 1/0x10
DATA2 +PE	4 12	12 4	Data	0/0x04 1/0x20
DATA3 -ACK	5 10	10 5	Strobe	0/0x08 1/0x40

A-name	A-End	B-End	Descr.	Post/Bit
DATA4 BUSY	6 11	11 6	Data	0/0x10 1/0x80
GND	18-25	18-25	GND	-

19.15.2 Setting Up PLIP

First, you have to get a laplink cable. Then, confirm that both computers have a kernel with lpt(4) driver support:

```
# grep lp /var/run/dmesg.boot
lpt0: <Printer> on ppbus0
lpt0: Interrupt-driven port
```

The parallel port must be an interrupt driven port, under FreeBSD 4.X, you should have a line similar to the the following on in your kernel configuration file:

```
device ppc0 at isa? irq 7
```

Under FreeBSD 5.X, the `/boot/device.hints` file should contain the following lines:

```
hint.ppc.0.at="isa"
hint.ppc.0.irq="7"
```

Then check if the kernel configuration file has a `device plip` line or if the `plip.ko` kernel module is loaded. In both cases the parallel networking interface shoud appears when you directly use the ifconfig(8) command. Under FreeBSD 4.X like this:

```
# ifconfig lp0
lp0: flags=8810<POINTOPOINT,SIMPLEX,MULTICAST> mtu 1500
```

and for FreeBSD 5.X:

```
# ifconfig plip0
plip0: flags=8810<POINTOPOINT,SIMPLEX,MULTICAST> mtu 1500
```

> **Note:** The device name used for parallel interface is different between FreeBSD 4.X (`lpX`) and FreeBSD 5.X (`plipX`).

Plug in the laplink cable into the parallel interface on both computers.

Configure the network interface parameters on both sites as `root`. For example, if you want connect the host `host1` running FreeBSD 4.X with `host2` running FreeBSD 5.X:

```
                 host1 <-----> host2
IP Address    10.0.0.1      10.0.0.2
```

Configure the interface on `host1` by doing:

```
# ifconfig lp0 10.0.0.1 10.0.0.2
```

Configure the interface on `host2` by doing:

```
# ifconfig plip0 10.0.0.2 10.0.0.1
```

You now should have a working connection. Please read the manual pages lp(4) and lpt(4) for more details.

You should also add both hosts to `/etc/hosts`:

```
127.0.0.1               localhost.my.domain localhost
10.0.0.1                host1.my.domain host1
10.0.0.2                host2.my.domain
```

To confirm the connection works, go to each host and ping the other. For example, on `host1`:

```
# ifconfig lp0
lp0: flags=8851<UP,POINTOPOINT,RUNNING,SIMPLEX,MULTICAST> mtu 1500
        inet 10.0.0.1 --> 10.0.0.2 netmask 0xff000000
# netstat -r
Routing tables

Internet:
Destination        Gateway          Flags     Refs     Use      Netif Expire
host2              host1              UH          0       0       lp0
# ping -c 4 host2
PING host2 (10.0.0.2): 56 data bytes
64 bytes from 10.0.0.2: icmp_seq=0 ttl=255 time=2.774 ms
64 bytes from 10.0.0.2: icmp_seq=1 ttl=255 time=2.530 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=255 time=2.556 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=255 time=2.714 ms

--- host2 ping statistics ---
4 packets transmitted, 4 packets received, 0% packet loss
round-trip min/avg/max/stddev = 2.530/2.643/2.774/0.103 ms
```

19.16 IPv6

Originally Written by Aaron Kaplan. Restructured and Added by Tom Rhodes.

IPv6 (also know as IPng "IP next generation") is the new version of the well known IP protocol (also know as IPv4). Like the other current *BSD systems, FreeBSD includes the KAME IPv6 reference implementation. So your FreeBSD system comes with all you will need to experiment with IPv6. This section focuses on getting IPv6 configured and running.

In the early 1990s, people became aware of the rapidly diminishing address space of IPv4. Given the expansion rate of the Internet there were two major concerns:

- Running out of addresses. Today this is not so much of a concern anymore since private address spaces (`10.0.0.0/8`, `192.168.0.0/24`, etc.) and Network Address Translation (NAT) are being employed.
- Router table entries were getting too large. This is still a concern today.

IPv6 deals with these and many other issues:

- 128 bit address space. In other words theoretically there are 340,282,366,920,938,463,463,374,607,431,768,211,456 addresses available. This means there are approximately 6.67 * 10^27 IPv6 addresses per square meter on our planet.
- Routers will only store network aggregation addresses in their routing tables thus reducing the average space of a routing table to 8192 entries.

There are also lots of other useful features of IPv6 such as:

- Address autoconfiguration (RFC2462)
- Anycast addresses ("one-out-of many")
- Mandatory multicast addresses
- IPsec (IP security)
- Simplified header structure
- Mobile IP
- IPv4-to-IPv6 transition mechanisms

For more information see:

- IPv6 overview at Sun.com (http://www.sun.com)
- IPv6.org (http://www.ipv6.org)
- KAME.net (http://www.kame.net)
- 6bone.net (http://www.6bone.net)

19.16.1 Background on IPv6 Addresses

There are different types of IPv6 addresses: Unicast, Anycast and Multicast.

Unicast addresses are the well known addresses. A packet sent to a unicast address arrives exactly at the interface belonging to the address.

Anycast addresses are syntactically indistinguishable from unicast addresses but they address a group of interfaces. The packet destined for an anycast address will arrive at the nearest (in router metric) interface. Anycast addresses may only be used by routers.

Multicast addresses identify a group of interfaces. A packet destined for a multicast address will arrive at all interfaces belonging to the multicast group.

> **Note:** The IPv4 broadcast address (usually `xxx.xxx.xxx.255`) is expressed by multicast addresses in IPv6.

Reserved IPv6 addresses:

```
ipv6-address  prefixlength(Bits) description Notes

:: 128 Bits unspecified cf. 0.0.0.0 in IPv4 address
::1 128 Bits loopback address cf. 127.0.0.1 in IPv4
::00:xx:xx:xx:xx 96 Bits embedded IPv4 The lower 32 bits are the
```

```
address IPv4 address. Also called
“IPv4 compatible IPv6
address”
::ff:xx:xx:xx:xx 96 Bits IPv4 mapped     The lower 32 bits are the
IPv6 address IPv4 address. For hosts
which do not support IPv6
fe80:: - feb:: 10 Bits link-local cf. loopback address in
IPv4
fec0:: - fef:: 10 Bits site-local
ff:: 8 Bits multicast
001 (base 2) 3 Bits global unicast All global unicast
addresses are assigned from
this pool. The first 3 Bits
are “001”.
```

19.16.2 Reading IPv6 Addresses

The canonical form is represented as: `x:x:x:x:x:x:x:x`, each “x” being a 16 Bit hex value. For example `FEBC:A574:382B:23C1:AA49:4592:4EFE:9982`

Often an address will have long substrings of all zeros therefore each such substring can be abbreviated by “::”. For example `fe80::1` corresponds to the canonical form `fe80:0000:0000:0000:0000:0000:0000:0001`

A third form is to write the last 32 Bit part in the well known (decimal) IPv4 style with dots “.” as separators. For example `2002::10.0.0.1` corresponds to the (hexadecimal) canonical representation `2002:0000:0000:0000:0000:0000:0a00:0001` which in turn is equivalent to writing `2002::a00:1`

By now the reader should be able to understand the following:

```
# ifconfig
```

```
rl0: flags=8943<UP,BROADCAST,RUNNING,PROMISC,SIMPLEX,MULTICAST> mtu 1500
         inet 10.0.0.10 netmask 0xffffff00 broadcast 10.0.0.255
         inet6 fe80::200:21ff:fe03:8e1%rl0 prefixlen 64 scopeid 0x1
         ether 00:00:21:03:08:e1
         media: Ethernet autoselect (100baseTX )
         status: active
```

`fe80::200:21ff:fe03:8e1%rl0` is an auto configured link-local address. It includes the scrambled Ethernet MAC as part of the auto configuration.

For further information on the structure of IPv6 addresses see RFC2373.

19.16.3 Getting Connected

Currently there are four ways to connect to other IPv6 hosts and networks:

- Join the experimental 6bone
- Getting an IPv6 network from your upstream provider. Talk to your Internet provider for instructions.
- Tunnel via 6-to-4

- Use the freenet6 port if you are on a dial-up connection.

Here we will talk on how to connect to the 6bone since it currently seems to be the most popular way.

First take a look at the 6bone site and find a 6bone connection nearest to you. Write to the responsible person and with a little bit of luck you will be given instructions on how to set up your connection. Usually this involves setting up a GRE (gif) tunnel.

Here is a typical example on setting up a gif(4) tunnel:

```
# ifconfig gif0 create
# ifconfig gif0
gif0: flags=8010<POINTOPOINT,MULTICAST> mtu 1280
# ifconfig gif0 tunnel MY_IPv4_ADDR  HIS_IPv4_ADDR
# ifconfig gif0 inet6 alias MY_ASSIGNED_IPv6_TUNNEL_ENDPOINT_ADDR
```

Replace the capitalized words by the information you received from the upstream 6bone node.

This establishes the tunnel. Check if the tunnel is working by ping6(8) 'ing `ff02::1%gif0`. You should receive two ping replies.

> **Note:** In case you are intrigued by the address `ff02:1%gif0`, this is a multicast address. `%gif0` states that the multicast address at network interface `gif0` is to be used. Since we `ping` a multicast address the other endpoint of the tunnel should reply as well).

By now setting up a route to your 6bone uplink should be rather straightforward:

```
# route add -inet6 default -interface gif0
# ping6 -n MY_UPLINK

# traceroute6 www.jp.FreeBSD.org
(3ffe:505:2008:1:2a0:24ff:fe57:e561) from 3ffe:8060:100::40:2, 30 hops max, 12 byte packets
     1  atnet-meta6  14.147 ms  15.499 ms  24.319 ms
     2  6bone-gw2-ATNET-NT.ipv6.tilab.com  103.408 ms  95.072 ms *
     3  3ffe:1831:0:ffff::4  138.645 ms  134.437 ms  144.257 ms
     4  3ffe:1810:0:6:290:27ff:fe79:7677  282.975 ms  278.666 ms  292.811 ms
     5  3ffe:1800:0:ff00::4  400.131 ms  396.324 ms  394.769 ms
     6  3ffe:1800:0:3:290:27ff:fe14:cdee  394.712 ms  397.19 ms  394.102 ms
```

This output will differ from machine to machine. By now you should be able to reach the IPv6 site www.kame.net (http://www.kame.net) and see the dancing tortoise — that is if you have a IPv6 enabled browser such as `www/mozilla`.

19.16.4 DNS in the IPv6 World

There are two new types of DNS records for IPv6:

- AAAA records,
- A6 records

Using AAAA records is straightforward. Assign your hostname to the new IPv6 address you just got by adding:

```
MYHOSTNAME           AAAA    MYIPv6ADDR
```

To your primary zone DNS file. In case you do not serve your own DNS zones ask your DNS provider. Current versions of **bind** (version 8.3 and 9) support AAAA records.

Chapter 20 Electronic Mail

Original work by Bill Lloyd. Rewritten by Jim Mock.

20.1 Synopsis

"Electronic Mail", better known as email, is one of the most widely used forms of communication today. This chapter provides a basic introduction to running a mail server on FreeBSD. However, it is not a complete reference and in fact many important considerations are omitted. For more complete coverage of the subject, the reader is referred to the many excellent books listed in Appendix B.

After reading this chapter, you will know:

- What software components are involved in sending and receiving electronic mail.
- Where basic **sendmail** configuration files are located in FreeBSD.
- How to block spammers from illegally using your mail server as a relay.
- How to install and configure an alternate mail transfer agent on your system, replacing **sendmail**.
- How to troubleshoot common mail server problems.
- How to use SMTP with UUCP.
- How to use mail with a dialup connection.
- How to configure SMTP Authentication for added security.

Before reading this chapter, you should:

- Properly set up your network connection (Chapter 19).
- Properly set up the DNS information for your mail host (Chapter 19).
- Know how to install additional third-party software (Chapter 4).

20.2 Using Electronic Mail

There are five major parts involved in an email exchange. They are: the user program, the server daemon, DNS, a POP or IMAP daemon, and of course, the mailhost itself.

20.2.1 The User Program

This includes command line programs such as **mutt**, **pine**, **elm**, and **mail**, and GUI programs such as **balsa**, **xfmail** to name a few, and something more "sophisticated" like a WWW browser. These programs simply pass off the email transactions to the local "mailhost", either by calling one of the server daemons available or delivering it over TCP.

20.2.2 Mailhost Server Daemon

This is usually **sendmail** (by default with FreeBSD) or one of the other mail server daemons such as **qmail**, **postfix**, or **exim**. There are others, but those are the most widely used.

The server daemon usually has two functions—it looks after receiving incoming mail and delivers outgoing mail. It does not allow you to connect to it via POP or IMAP to read your mail. You need an additional daemon for that.

Be aware that some older versions of **sendmail** have some serious security problems, however as long as you run a current version of it you should not have any problems. As always, it is a good idea to stay up-to-date with any software you run.

20.2.3 Email and DNS

The Domain Name System (DNS) and its daemon `named` play a large role in the delivery of email. In order to deliver mail from your site to another, the server daemon will look up the site in the DNS to determine the host that will receive mail for the destination.

It works the same way when you have mail sent to you. The DNS contains the database mapping hostname to an IP address, and a hostname to mailhost. The IP address is specified in an A record. The MX (Mail eXchanger) record specifies the mailhost that will receive mail for you. If you do not have an MX record for your hostname, the mail will be delivered directly to your host.

20.2.4 Receiving Mail

Receiving mail for your domain is done by the mail host. It will collect mail sent to you and store it for reading or pickup. In order to pick the stored mail up, you will need to connect to the mail host. This is done by either using POP or IMAP. If you want to read mail directly on the mail host, then a POP or IMAP server is not needed.

If you want to run a POP or IMAP server, there are two things you need to do:

1. Get a POP or IMAP daemon from the ports collection (../../../../ports/mail.html) and install it on your system.
2. Modify `/etc/inetd.conf` to load the POP or IMAP server.

20.2.5 The Mail Host

The mail host is the name given to a server that is responsible for delivering and receiving mail for your host, and possibly your network.

20.3 sendmail Configuration

Contributed by Christopher Shumway.

sendmail(8) is the default Mail Transfer Agent (MTA) in FreeBSD. **sendmail**’s job is to accept mail from Mail User Agents (MUA) and deliver it to the appropriate mailer as defined by its configuration file. **sendmail** can also accept network connections and deliver mail to local mailboxes or deliver it to another program.

sendmail uses the following configuration files:

Filename	Function
`/etc/mail/access`	**sendmail** access database file
`/etc/mail/aliases`	Mailbox aliases
`/etc/mail/local-host-names`	Lists of hosts **sendmail** accepts mail for
`/etc/mail/mailer.conf`	Mailer program configuration
`/etc/mail/mailertable`	Mailer delivery table
`/etc/mail/sendmail.cf`	**sendmail** master configuration file
`/etc/mail/virtusertable`	Virtual users and domain tables

20.3.1 `/etc/mail/access`

The access database defines what host(s) or IP addresses have access to the local mail server and what kind of access they have. Hosts can be listed as `OK`, `REJECT`, `RELAY` or simply passed to **sendmail**'s error handling routine with a given mailer error. Hosts that are listed as `OK`, which is the default, are allowed to send mail to this host as long as the mail's final destination is the local machine. Hosts that are listed as `REJECT` are rejected for all mail connections. Hosts that have the `RELAY` option for their hostname are allowed to send mail for any destination through this mail server.

Example 20-1. Configuring the sendmail Access Database

```
cyberspammer.com                550 We don't accept mail from spammers
FREE.STEALTH.MAILER@            550 We don't accept mail from spammers
another.source.of.spam          REJECT
okay.cyberspammer.com           OK
128.32                          RELAY
```

In this example we have five entries. Mail senders that match the left hand side of the table are affected by the action on the right side of the table. The first two examples give an error code to **sendmail**'s error handling routine. The message is printed to the remote host when a mail matches the left hand side of the table. The next entry rejects mail from a specific host on the Internet, `another.source.of.spam`. The next entry accepts mail connections from a host `okay.cyberspammer.com`, which is more exact than the `cyberspammer.com` line above. More specific matches override less exact matches. The last entry allows relaying of electronic mail from hosts with an IP address that begins with `128.32`. These hosts would be able to send mail through this mail server that are destined for other mail servers.

When this file is updated, you need to run `make` in `/etc/mail/` to update the database.

20.3.2 `/etc/mail/aliases`

The aliases database contains a list of virtual mailboxes that are expanded to other user(s), files, programs or other aliases. Here are a few examples that can be used in `/etc/mail/aliases`:

Example 20-2. Mail Aliases

```
root: localuser
```

```
ftp-bugs: joe,eric,paul
bit.bucket:  /dev/null
procmail: "|/usr/local/bin/procmail"
```

The file format is simple; the mailbox name on the left side of the colon is expanded to the target(s) on the right. The first example simply expands the mailbox `root` to the mailbox `localuser`, which is then looked up again in the aliases database. If no match is found, then the message is delivered to the local user `localuser`. The next example shows a mail list. Mail to the mailbox `ftp-bugs` is expanded to the three local mailboxes `joe`, `eric`, and `paul`. Note that a remote mailbox could be specified as `user@example.com`. The next example shows writing mail to a file, in this case `/dev/null`. The last example shows sending mail to a program, in this case the mail message is written to the standard input of `/usr/local/bin/procmail` through a UNIX pipe.

When this file is updated, you need to run `make` in `/etc/mail/` to update the database.

20.3.3 `/etc/mail/local-host-names`

This is a list of hostnames sendmail(8) is to accept as the local host name. Place any domains or hosts that **sendmail** is to be receiving mail for. For example, if this mail server was to accept mail for the domain `example.com` and the host `mail.example.com`, its `local-host-names` might look something like this:

```
example.com
mail.example.com
```

When this file is updated, sendmail(8) needs to be restarted to read the changes.

20.3.4 `/etc/mail/sendmail.cf`

sendmail's master configuration file, `sendmail.cf` controls the overall behavior of **sendmail**, including everything from rewriting e-mail addresses to printing rejection messages to remote mail servers. Naturally, with such a diverse role, this configuration file is quite complex and its details are a bit out of the scope of this section. Fortunately, this file rarely needs to be changed for standard mail servers.

The master **sendmail** configuration file can be built from m4(1) macros that define the features and behavior of **sendmail**. Please see `/usr/src/contrib/sendmail/cf/README` for some of the details.

When changes to this file are made, **sendmail** needs to be restarted for the changes to take effect.

20.3.5 `/etc/mail/virtusertable`

The `virtusertable` maps mail addresses for virtual domains and mailboxes to real mailboxes. These mailboxes can be local, remote, aliases defined in `/etc/mail/aliases` or files.

Example 20-3. Example Virtual Domain Mail Map

```
root@example.com                root
postmaster@example.com          postmaster@noc.example.net
@example.com                    joe
```

In the above example, we have a mapping for a domain `example.com`. This file is processed in a first match order down the file. The first item maps `root@example.com` to the local mailbox `root`. The next entry maps postmaster@example.com to the mailbox postmaster on the host noc.example.net. Finally, if nothing from example.com has matched so far, it will match the last mapping, which matches every other mail message addressed to someone at example.com. This will be mapped to the local mailbox joe.

20.4 Changing Your Mail Transfer Agent

Written by Andrew Boothman. Information taken from e-mails written by Gregory Neil Shapiro.

As already mentioned, FreeBSD comes with **sendmail** already installed as your MTA (Mail Transfer Agent). Therefore by default it is in charge of your outgoing and incoming mail.

However, for a variety of reasons, some system administrators want to change their system's MTA. These reasons range from simply wanting to try out another MTA to needing a specific feature or package which relies on another mailer. Fortunately, whatever the reason, FreeBSD makes it easy to make the change.

20.4.1 Install a New MTA

You have a wide choice of MTAs available. A good starting point is the FreeBSD Ports Collection where you will be able to find many. Of course you are free to use any MTA you want from any location, as long as you can make it run under FreeBSD.

Start by installing your new MTA. Once it is installed it gives you a chance to decide if it really fulfills your needs, and also gives you the opportunity to configure your new software before getting it to take over from **sendmail**. When doing this, you should be sure that installing the new software will not attempt to overwrite system binaries such as /usr/bin/sendmail. Otherwise, your new mail software has essentially been put into service before you have configured it.

Please refer to your chosen MTA's documentation for information on how to configure the software you have chosen.

20.4.2 Disable sendmail

The procedure used to start **sendmail** changed significantly between 4.5-RELEASE and 4.6-RELEASE. Therefore, the procedure used to disable it is subtly different.

20.4.2.1 FreeBSD 4.5-STABLE before 2002/4/4 and Earlier (Including 4.5-RELEASE and Earlier)

Enter:

```
sendmail_enable="NO"
```

into /etc/rc.conf. This will disable **sendmail**'s incoming mail service, but if /etc/mail/mailer.conf (see below) is not changed, **sendmail** will still be used to send e-mail.

20.4.2.2 FreeBSD 4.5-STABLE after 2002/4/4 (Including 4.6-RELEASE and Later)

In order to completely disable **sendmail** you must use

```
sendmail_enable="NONE"
```

in `/etc/rc.conf`.

> **Warning:** If you disable **sendmail**'s outgoing mail service in this way, it is important that you replace it with a fully working alternative mail delivery system. If you choose not to, system functions such as periodic(8) will be unable to deliver their results by e-mail as they would normally expect to. Many parts of your system may expect to have a functional **sendmail**-compatible system. If applications continue to use **sendmail**'s binaries to try and send e-mail after you have disabled them, mail could go into an inactive **sendmail** queue, and never be delivered.

If you only want to disable **sendmail**'s incoming mail service, you should set

```
sendmail_enable="NO"
```

in `/etc/rc.conf`. More information on **sendmail**'s startup options is available from the rc.sendmail(8) manual page.

20.4.3 Running Your New MTA on Boot

You may have a choice of two methods for running your new MTA on boot, again depending on what version of FreeBSD you are running.

20.4.3.1 FreeBSD 4.5-STABLE before 2002/4/11 (Including 4.5-RELEASE and Earlier)

Add a script to `/usr/local/etc/rc.d/` that ends in `.sh` and is executable by `root`. The script should accept `start` and `stop` parameters. At startup time the system scripts will execute the command

```
/usr/local/etc/rc.d/supermailer.sh start
```

which you can also use to manually start the server. At shutdown time, the system scripts will use the `stop` option, running the command

```
/usr/local/etc/rc.d/supermailer.sh stop
```

which you can also use to manually stop the server while the system is running.

20.4.3.2 FreeBSD 4.5-STABLE after 2002/4/11 (Including 4.6-RELEASE and Later)

With later versions of FreeBSD, you can use the above method or you can set

```
mta_start_script="filename"
```

in `/etc/rc.conf`, where *`filename`* is the name of some script that you want executed at boot to start your MTA.

20.4.4 Replacing sendmail as the System's Default Mailer

The program **sendmail** is so ubiquitous as standard software on UNIX systems that some software just assumes it is already installed and configured. For this reason, many alternative MTA's provide their own compatible implementations of the **sendmail** command-line interface; this facilitates using them as "drop-in" replacements for **sendmail**.

Therefore, if you are using an alternative mailer, you will need to make sure that software trying to execute standard **sendmail** binaries such as `/usr/bin/sendmail` actually executes your chosen mailer instead. Fortunately, FreeBSD provides a system called mailwrapper(8) that does this job for you.

When **sendmail** is operating as installed, you will find something like the following in `/etc/mail/mailer.conf`:

```
sendmail  /usr/libexec/sendmail/sendmail
send-mail /usr/libexec/sendmail/sendmail
mailq /usr/libexec/sendmail/sendmail
newaliases /usr/libexec/sendmail/sendmail
hoststat /usr/libexec/sendmail/sendmail
purgestat /usr/libexec/sendmail/sendmail
```

This means that when any of these common commands (such as `sendmail` itself) are run, the system actually invokes a copy of mailwrapper named `sendmail`, which checks `mailer.conf` and executes `/usr/libexec/sendmail/sendmail` instead. This system makes it easy to change what binaries are actually executed when these default `sendmail` functions are invoked.

Therefore if you wanted `/usr/local/supermailer/bin/sendmail-compat` to be run instead of **sendmail**, you could change `/etc/mail/mailer.conf` to read:

```
sendmail  /usr/local/supermailer/bin/sendmail-compat
send-mail /usr/local/supermailer/bin/sendmail-compat
mailq /usr/local/supermailer/bin/mailq-compat
newaliases /usr/local/supermailer/bin/newaliases-compat
hoststat /usr/local/supermailer/bin/hoststat-compat
purgestat /usr/local/supermailer/bin/purgestat-compat
```

20.4.5 Finishing

Once you have everything configured the way you want it, you should either kill the **sendmail** processes that you no longer need and start the processes belonging to your new software, or simply reboot. Rebooting will also give you the opportunity to ensure that you have correctly configured your system to start your new MTA automatically on boot.

20.5 Troubleshooting

1. Why do I have to use the FQDN for hosts on my site?

You will probably find that the host is actually in a different domain; for example, if you are in `foo.bar.edu` and you wish to reach a host called `mumble` in the `bar.edu` domain, you will have to refer to it by the fully-qualified domain name, `mumble.bar.edu`, instead of just `mumble`.

Traditionally, this was allowed by BSD BIND resolvers. However the current version of **BIND** that ships with FreeBSD no longer provides default abbreviations for non-fully qualified domain names other than the domain you are in. So an unqualified host `mumble` must either be found as `mumble.foo.bar.edu`, or it will be searched for in the root domain.

This is different from the previous behavior, where the search continued across `mumble.bar.edu`, and `mumble.edu`. Have a look at RFC 1535 for why this was considered bad practice, or even a security hole.

As a good workaround, you can place the line:

```
search foo.bar.edu bar.edu
```

instead of the previous:

```
domain foo.bar.edu
```

into your `/etc/resolv.conf`. However, make sure that the search order does not go beyond the "boundary between local and public administration", as RFC 1535 calls it.

2. sendmail says `mail loops back to myself`

This is answered in the **sendmail** FAQ as follows:

```
I am getting "Local configuration error" messages, such as:

553 relay.domain.net config error: mail loops back to myself
554 <user@domain.net>... Local configuration error

How can I solve this problem?

You have asked mail to the domain (e.g., domain.net) to be
forwarded to a specific host (in this case, relay.domain.net)
by using an MX record, but the relay machine does not recognize
itself as domain.net. Add domain.net to /etc/mail/local-host-names
(if you are using FEATURE(use_cw_file)) or add "Cw domain.net"
to /etc/mail/sendmail.cf.
```

The **sendmail** FAQ can be found at http://www.sendmail.org/faq/ and is recommended reading if you want to do any "tweaking" of your mail setup.

3. How can I run a mail server on a dial-up PPP host?

You want to connect a FreeBSD box on a LAN to the Internet. The FreeBSD box will be a mail gateway for the LAN. The PPP connection is non-dedicated.

There are at least two ways to do this. One way is to use UUCP.

Another way is to get a full-time Internet server to provide secondary MX services for your domain. For example, if your company's domain is `example.com` and your Internet service provider has set `example.net` up to provide secondary MX services to your domain:

```
example.com.          MX        10      example.com.
                      MX        20      example.net.
```

Only one host should be specified as the final recipient (add `Cw example.com` in `/etc/mail/sendmail.cf` on `example.com`).

When the sending `sendmail` is trying to deliver the mail it will try to connect to you (`example.com`) over the modem link. It will most likely time out because you are not online. The program **sendmail** will automatically deliver it to the secondary MX site, i.e. your Internet provider (`example.net`). The secondary MX site will then periodically try to connect to your host and deliver the mail to the primary MX host (`example.com`).

You might want to use something like this as a login script:

```
#!/bin/sh
# Put me in /usr/local/bin/pppmyisp
( sleep 60 ; /usr/sbin/sendmail -q ) &
/usr/sbin/ppp -direct pppmyisp
```

If you are going to create a separate login script for a user you could use `sendmail -qRexample.com` instead in the script above. This will force all mail in your queue for `example.com` to be processed immediately.

A further refinement of the situation is as follows:

Message stolen from the FreeBSD Internet service provider's mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-isp).

```
> we provide the secondary MX for a customer. The customer connects to
> our services several times a day automatically to get the mails to
> his primary MX (We do not call his site when a mail for his domains
> arrived). Our sendmail sends the mailqueue every 30 minutes. At the
> moment he has to stay 30 minutes online to be sure that all mail is
> gone to the primary MX.
>
> Is there a command that would initiate sendmail to send all the mails
> now? The user has not root-privileges on our machine of course.

In the "privacy flags" section of sendmail.cf, there is a
definition Opgoaway,restrictqrun

Remove restrictqrun to allow non-root users to start the queue processing.
You might also like to rearrange the MXs. We are the 1st MX for our
customers like this, and we have defined:

# If we are the best MX for a host, try directly instead of generating
# local config error.
OwTrue

That way a remote site will deliver straight to you, without trying
the customer connection.  You then send to your customer.  Only works for
"hosts", so you need to get your customer to name their mail
machine "customer.com" as well as
"hostname.customer.com" in the DNS.  Just put an A record in
the DNS for "customer.com".
```

4. Why do I keep getting `Relaying Denied` errors when sending mail from other hosts?

In default FreeBSD installations, **sendmail** is configured to only send mail from the host it is running on. For example, if a POP3 server is installed, then users will be able to check mail from school, work, or other remote locations but they still will not be able to send outgoing emails from outside locations. Typically, a few moments after the attempt, an email will be sent from **MAILER-DAEMON** with a `5.7 Relaying Denied` error message.

There are several ways to get around this. The most straightforward solution is to put your ISP's address in a relay-domains file at `/etc/mail/relay-domains`. A quick way to do this would be:

```
# echo "your.isp.example.com" > /etc/mail/relay-domains
```

After creating or editing this file you must restart **sendmail**. This works great if you are a server administrator and do not wish to send mail locally, or would like to use a point and click client/system on another machine or even another ISP. It is also very useful if you only have one or two email accounts set up. If there is a large number of addresses to add, you can simply open this file in your favorite text editor and then add the domains, one per line:

```
your.isp.example.com
other.isp.example.net
users-isp.example.org
www.example.org
```

Now any mail sent through your system, by any host in this list (provided the user has an account on your system), will succeed. This is a very nice way to allow users to send mail from your system remotely without allowing people to send SPAM through your system.

20.6 Advanced Topics

The following section covers more involved topics such as mail configuration and setting up mail for your entire domain.

20.6.1 Basic Configuration

Out of the box, you should be able to send email to external hosts as long as you have set up `/etc/resolv.conf` or are running your own name server. If you would like to have mail for your host delivered to the MTA (e.g., **sendmail**) on your own FreeBSD host, there are two methods:

- Run your own name server and have your own domain. For example, `FreeBSD.org`
- Get mail delivered directly to your host. This is done by delivering mail directly to the current DNS name for your machine. For example, `example.FreeBSD.org`.

Regardless of which of the above you choose, in order to have mail delivered directly to your host, it must have a permanent static IP address (not a dynamic address, as with most PPP dial-up configurations). If you are behind a firewall, it must pass SMTP traffic on to you. If you want to receive mail directly at your host, you need to be sure of either of two things:

- Make sure that the (lowest-numbered) MX record in your DNS points to your host's IP address.

- Make sure there is no MX entry in your DNS for your host.

Either of the above will allow you to receive mail directly at your host.

Try this:

```
# hostname
example.FreeBSD.org
# host example.FreeBSD.org
example.FreeBSD.org has address 204.216.27.XX
```

If that is what you see, mail directly to <yourlogin@example.FreeBSD.org> should work without problems (assuming **sendmail** is running correctly on `example.FreeBSD.org`).

If instead you see something like this:

```
# host example.FreeBSD.org
example.FreeBSD.org has address 204.216.27.XX
example.FreeBSD.org mail is handled (pri=10) by hub.FreeBSD.org
```

All mail sent to your host (`example.FreeBSD.org`) will end up being collected on `hub` under the same username instead of being sent directly to your host.

The above information is handled by your DNS server. The DNS record that carries mail routing information is the *M*ail e*X*change entry. If no MX record exists, mail will be delivered directly to the host by way of its IP address.

The MX entry for `freefall.FreeBSD.org` at one time looked like this:

```
freefall MX 30 mail.crl.net
freefall MX 40 agora.rdrop.com
freefall MX 10 freefall.FreeBSD.org
freefall MX 20 who.cdrom.com
```

As you can see, `freefall` had many MX entries. The lowest MX number is the host that receives mail directly if available; if it is not accessible for some reason, the others (sometimes called "backup MXes") accept messages temporarily, and pass it along when a lower-numbered host becomes available, eventually to the lowest-numbered host.

Alternate MX sites should have separate Internet connections from your own in order to be most useful. Your ISP or another friendly site should have no problem providing this service for you.

20.6.2 Mail for Your Domain

In order to set up a "mailhost" (a.k.a. mail server) you need to have any mail sent to various workstations directed to it. Basically, you want to "claim" any mail for any hostname in your domain (in this case `*.FreeBSD.org`) and divert it to your mail server so your users can receive their mail on the master mail server.

To make life easiest, a user account with the same *username* should exist on both machines. Use adduser(8) to do this.

The mailhost you will be using must be the designated mail exchanger for each workstation on the network. This is done in your DNS configuration like so:

```
example.FreeBSD.org A 204.216.27.XX ; Workstation
MX 10 hub.FreeBSD.org ; Mailhost
```

This will redirect mail for the workstation to the mailhost no matter where the A record points. The mail is sent to the MX host.

You cannot do this yourself unless you are running a DNS server. If you are not, or cannot run your own DNS server, talk to your ISP or whoever provides your DNS.

If you are doing virtual email hosting, the following information will come in handy. For this example, we will assume you have a customer with his own domain, in this case `customer1.org`, and you want all the mail for `customer1.org` sent to your mailhost, `mail.myhost.com`. The entry in your DNS should look like this:

```
customer1.org MX 10 mail.myhost.com
```

You do *not* need an A record for `customer1.org` if you only want to handle email for that domain.

> **Note:** Be aware that pinging `customer1.org` will not work unless an A record exists for it.

The last thing that you must do is tell **sendmail** on your mailhost what domains and/or hostnames it should be accepting mail for. There are a few different ways this can be done. Either of the following will work:

- Add the hosts to your `/etc/mail/local-host-names` file if you are using the `FEATURE(use_cw_file)`. If you are using a version of **sendmail** earlier than 8.10, the file is `/etc/sendmail.cw`.
- Add a `Cwyour.host.com` line to your `/etc/sendmail.cf` or `/etc/mail/sendmail.cf` if you are using **sendmail** 8.10 or higher.

20.7 SMTP with UUCP

The **sendmail** configuration that ships with FreeBSD is designed for sites that connect directly to the Internet. Sites that wish to exchange their mail via UUCP must install another sendmail configuration file.

Tweaking `/etc/mail/sendmail.cf` manually is an advanced topic. **sendmail** version 8 generates config files via m4(1) preprocessing, where the actual configuration occurs on a higher abstraction level. The m4(1) configuration files can be found under `/usr/src/usr.sbin/sendmail/cf`.

If you did not install your system with full sources, the sendmail config stuff has been broken out into a separate source distribution tarball. Assuming you have your FreeBSD source code CDROM mounted, do:

```
# cd /cdrom/src
# cat scontrib.?? | tar xzf - -C /usr/src/contrib/sendmail
```

This extracts to only a few hundred kilobytes. The file `README` in the `cf` directory can serve as a basic introduction to m4 configuration.

The best way to support UUCP delivery is to use the `mailertable` feature. This creates a database that **sendmail** can use to make routing decisions.

First, you have to create your `.mc` file. The directory `/usr/src/usr.sbin/sendmail/cf/cf` contains a few examples. Assuming you have named your file `foo.mc`, all you need to do in order to convert it into a valid `sendmail.cf` is:

```
# cd /usr/src/usr.sbin/sendmail/cf/cf
# make foo.cf
# cp foo.cf /etc/mail/sendmail.cf
```

A typical `.mc` file might look like:

```
VERSIONID('Your version number') OSTYPE(bsd4.4)

FEATURE(accept_unresolvable_domains)
FEATURE(nocanonify)
FEATURE(mailertable, 'hash -o /etc/mail/mailertable')

define('UUCP_RELAY', your.uucp.relay)
define('UUCP_MAX_SIZE', 200000)
define('confDONT_PROBE_INTERFACES')

MAILER(local)
MAILER(smtp)
MAILER(uucp)

Cw    your.alias.host.name
Cw    youruucpnodename.UUCP
```

The lines containing `accept_unresolvable_domains`, `nocanonify`, and `confDONT_PROBE_INTERFACES` features will prevent any usage of the DNS during mail delivery. The `UUCP_RELAY` clause is needed to support UUCP delivery. Simply put an Internet hostname there that is able to handle .UUCP pseudo-domain addresses; most likely, you will enter the mail relay of your ISP there.

Once you have this, you need an `/etc/mail/mailertable` file. If you have only one link to the outside that is used for all your mails, the following file will suffice:

```
#
# makemap hash /etc/mail/mailertable.db < /etc/mail/mailertable
.                             uucp-dom:your.uucp.relay
```

A more complex example might look like this:

```
#
# makemap hash /etc/mail/mailertable.db < /etc/mail/mailertable
#
horus.interface-business.de   uucp-dom:horus
.interface-business.de        uucp-dom:if-bus
interface-business.de         uucp-dom:if-bus
.heep.sax.de                  smtp8:%1
horus.UUCP                    uucp-dom:horus
if-bus.UUCP                   uucp-dom:if-bus
.                             uucp-dom:
```

The first three lines handle special cases where domain-addressed mail should not be sent out to the default route, but instead to some UUCP neighbor in order to “shortcut” the delivery path. The next line handles mail to the local Ethernet domain that can be delivered using SMTP. Finally, the UUCP neighbors are mentioned in the .UUCP pseudo-domain notation, to allow for a *`uucp-neighbor`* `!`*`recipient`* override of the default rules. The last line is always a single dot, matching everything else, with UUCP delivery to a UUCP neighbor that serves as your universal mail gateway to the world. All of the node names behind the `uucp-dom:` keyword must be valid UUCP neighbors, as you can verify using the command `uuname`.

As a reminder that this file needs to be converted into a DBM database file before use. The command line to accomplish this is best placed as a comment at the top of the mailertable. You always have to execute this command each time you change your mailertable.

Final hint: if you are uncertain whether some particular mail routing would work, remember the `-bt` option to **sendmail**. It starts **sendmail** in *address test mode*; simply enter `3,0`, followed by the address you wish to test for the mail routing. The last line tells you the used internal mail agent, the destination host this agent will be called with, and the (possibly translated) address. Leave this mode by typing **Ctrl**+**D**.

```
% sendmail -bt
ADDRESS TEST MODE (ruleset 3 NOT automatically invoked)
Enter <ruleset> <address>
> 3,0 foo@example.com
canonify           input: foo @ example . com
...
parse            returns: $# uucp-dom $@ your.uucp.relay $: foo < @ example . com . >
> ^D
```

20.8 Using Mail with a Dialup Connection

If you have a static IP address, you should not need to adjust anything from the defaults. Set your host name to your assigned Internet name and **sendmail** will do the rest.

If you have a dynamically assigned IP number and use a dialup PPP connection to the Internet, you will probably have a mailbox on your ISPs mail server. Let's assume your ISP's domain is `example.net`, and that your user name is `user`, you have called your machine `bsd.home`, and your ISP has told you that you may use `relay.example.net` as a mail relay.

In order to retrieve mail from your mailbox, you must install a retrieval agent. The **fetchmail** utility is a good choice as it supports many different protocols. Usually, your ISP will provide POP3. If you are using user-PPP, you can automatically fetch your mail when an Internet connection is established with the following entry in `/etc/ppp/ppp.linkup`:

```
MYADDR:
!bg su user -c fetchmail
```

If you are using **sendmail** (as shown below) to deliver mail to non-local accounts, you probably want to have **sendmail** process your mailqueue as soon as your Internet connection is established. To do this, put this command after the `fetchmail` command in `/etc/ppp/ppp.linkup`.

```
  !bg su user -c "sendmail -q"
```

Assume that you have an account for `user` on `bsd.home`. In the home directory of `user` on `bsd.home`, create a `.fetchmailrc` file:

```
poll example.net protocol pop3 fetchall pass MySecret
```

This file should not be readable by anyone except `user` as it contains the password `MySecret`.

In order to send mail with the correct `from:` header, you must tell **sendmail** to use `user@example.net` rather than `user@bsd.home`. You may also wish to tell **sendmail** to send all mail via `relay.example.net`, allowing quicker mail transmission.

The following `.mc` file should suffice:

```
VERSIONID('bsd.home.mc version 1.0')
OSTYPE(bsd4.4)dnl
FEATURE(nouucp)dnl
MAILER(local)dnl
MAILER(smtp)dnl
Cwlocalhost
Cwbsd.home
MASQUERADE_AS('example.net')dnl
FEATURE(allmasquerade)dnl
FEATURE(masquerade_envelope)dnl
FEATURE(nocanonify)dnl
FEATURE(nodns)dnl
define('SMART_HOST', 'relay.example.net')
Dmbsd.home
define('confDOMAIN_NAME','bsd.home')dnl
define('confDELIVERY_MODE','deferred')dnl
```

Refer to the previous section for details of how to turn this `.mc` file into a `sendmail.cf` file. Also, do not forget to restart **sendmail** after updating `sendmail.cf`.

20.9 SMTP Authentication

Having SMTP Authentication in place on your mail server has a number of benefits. SMTP Authentication can add another layer of security to **sendmail**, and has the benefit of giving mobile users who switch hosts the ability to use the same mail server without the need to reconfigure their mail client settings each time.

1. Install `security/cyrus-sasl` from the ports. You can find this port in `security/cyrus-sasl`. `security/cyrus-sasl` has a number of compile time options to choose from and, for the method we will be using here, make sure to select the `pwcheck` option.

2. After installing `security/cyrus-sasl`, edit `/usr/local/lib/sasl/Sendmail.conf` (or create it if it does not exist) and add the following line:

   ```
   pwcheck_method: passwd
   ```

   This method will enable **sendmail** to authenticate against your FreeBSD `passwd` database. This saves the trouble of creating a new set of usernames and passwords for each user that needs to use SMTP authentication, and keeps the login and mail password the same.

3. Now edit `/etc/make.conf` and add the following lines:

   ```
   SENDMAIL_CFLAGS=-I/usr/local/include/sasl1 -DSASL
   SENDMAIL_LDFLAGS=-L/usr/local/lib
   SENDMAIL_LDADD=-lsasl
   ```

   These lines will give **sendmail** the proper configuration options for linking to `cyrus-sasl` at compile time. Make sure that `cyrus-sasl` has been installed before recompiling **sendmail**.

4. Recompile **sendmail** by executing the following commands:

```
# cd /usr/src/usr.sbin/sendmail
# make cleandir
# make obj
# make
# make install
```

   The compile of **sendmail** should not have any problems if `/usr/src` has not been changed extensively and the shared libraries it needs are available.

5. After **sendmail** has been compiled and reinstalled, edit your `/etc/mail/freebsd.mc` file (or whichever file you use as your `.mc` file. Many administrators choose to use the output from hostname(1) as the `.mc` file for uniqueness). Add these lines to it:

```
dnl set SASL options
TRUST_AUTH_MECH(‘GSSAPI DIGEST-MD5 CRAM-MD5 LOGIN’)dnl
define(‘confAUTH_MECHANISMS’, ‘GSSAPI DIGEST-MD5 CRAM-MD5 LOGIN’)dnl
define(‘confDEF_AUTH_INFO’, ‘/etc/mail/auth-info’)dnl
```

   These options configure the different methods available to **sendmail** for authenticating users. If you would like to use a method other than **pwcheck**, please see the included documentation.

6. Finally, run make(1) while in `/etc/mail`. That will run your new `.mc` file and create a `.cf` file named `freebsd.cf` (or whatever name you have used for your `.mc` file). Then use the command `make install restart`, which will copy the file to `sendmail.cf`, and will properly restart **sendmail**. For more information about this process, you should refer to `/etc/mail/Makefile`.

If all has gone correctly, you should be able to enter your login information into the mail client and send a test message. For further investigation, set the `LogLevel` of **sendmail** to 13 and watch `/var/log/maillog` for any errors.

You may wish to add the following lines to `/etc/rc.conf` so this service will be available after every system boot:

```
sasl_pwcheck_enable="YES"
sasl_pwcheck_program="/usr/local/sbin/pwcheck"
```

This will ensure the initialization of SMTP_AUTH upon system boot.

For more information, please see the **sendmail** page regarding SMTP authentication (http://www.sendmail.org/~ca/email/auth.html).

Chapter 21 The Cutting Edge

Restructured, reorganized, and parts updated by Jim Mock. Original work by Jordan Hubbard, Poul-Henning Kamp, John Polstra, and Nik Clayton.

21.1 Synopsis

FreeBSD is under constant development between releases. For people who want to be on the cutting edge, there are several easy mechanisms for keeping your system in sync with the latest developments. Be warned—the cutting edge is not for everyone! This chapter will help you decide if you want to track the development system, or stick with one of the released versions.

After reading this chapter, you will know:

- The difference between the two development branches: FreeBSD-STABLE and FreeBSD-CURRENT.
- How to keep your system up to date with **CVSup**, **CVS**, or **CTM**.
- How to rebuild and reinstall the entire base system with `make world`.

Before reading this chapter, you should:

- Properly set up your network connection (Chapter 19).
- Know how to install additional third-party software (Chapter 4).

21.2 FreeBSD-CURRENT vs. FreeBSD-STABLE

There are two development branches to FreeBSD: FreeBSD-CURRENT and FreeBSD-STABLE. This section will explain a bit about each and describe how to keep your system up-to-date with each respective tree. FreeBSD-CURRENT will be discussed first, then FreeBSD-STABLE.

21.2.1 Staying Current with FreeBSD

As you read this, keep in mind that FreeBSD-CURRENT is the "bleeding edge" of FreeBSD development. FreeBSD-CURRENT users are expected to have a high degree of technical skill, and should be capable of solving difficult system problems on their own. If you are new to FreeBSD, think twice before installing it.

21.2.1.1 What Is FreeBSD-CURRENT?

FreeBSD-CURRENT is the latest working sources for FreeBSD. This includes work in progress, experimental changes, and transitional mechanisms that might or might not be present in the next official release of the software. While many FreeBSD developers compile the FreeBSD-CURRENT source code daily, there are periods of time when the sources are not buildable. These problems are resolved as expeditiously as possible, but whether or not FreeBSD-CURRENT brings disaster or greatly desired functionality can be a matter of which exact moment you grabbed the source code in!

21.2.1.2 Who Needs FreeBSD-CURRENT?

FreeBSD-CURRENT is made available for 3 primary interest groups:

1. Members of the FreeBSD group who are actively working on some part of the source tree and for whom keeping "current" is an absolute requirement.
2. Members of the FreeBSD group who are active testers, willing to spend time solving problems in order to ensure that FreeBSD-CURRENT remains as sane as possible. These are also people who wish to make topical suggestions on changes and the general direction of FreeBSD, and submit patches to implement them.
3. Those who merely wish to keep an eye on things, or to use the current sources for reference purposes (e.g. for *reading*, not running). These people also make the occasional comment or contribute code.

21.2.1.3 What Is FreeBSD-CURRENT *Not*?

1. A fast-track to getting pre-release bits because you heard there is some cool new feature in there and you want to be the first on your block to have it. Being the first on the block to get the new feature means that you're the first on the block to get the new bugs.
2. A quick way of getting bug fixes. Any given version of FreeBSD-CURRENT is just as likely to introduce new bugs as to fix existing ones.
3. In any way "officially supported". We do our best to help people genuinely in one of the 3 "legitimate" FreeBSD-CURRENT groups, but we simply *do not have the time* to provide tech support. This is not because we are mean and nasty people who do not like helping people out (we would not even be doing FreeBSD if we were). We simply cannot answer hundreds messages a day *and* work on FreeBSD! Given the choice between improving FreeBSD and answering lots of questions on experimental code, the developers opt for the former.

21.2.1.4 Using FreeBSD-CURRENT

1. Join the freebsd-current (http://lists.FreeBSD.org/mailman/listinfo/freebsd-current) and the cvs-all (http://lists.FreeBSD.org/mailman/listinfo/cvs-all) lists. This is not just a good idea, it is *essential*. If you are not on the *freebsd-current (http://lists.FreeBSD.org/mailman/listinfo/freebsd-current)* list, you will not see the comments that people are making about the current state of the system and thus will probably end up stumbling over a lot of problems that others have already found and solved. Even more importantly, you will miss out on important bulletins which may be critical to your system's continued health.

   The cvs-all (http://lists.FreeBSD.org/mailman/listinfo/cvs-all) list will allow you to see the commit log entry for each change as it is made along with any pertinent information on possible side-effects.

   To join these lists, or one of the others available go to http://lists.FreeBSD.org/mailman/listinfo and click on the list that you wish to subscribe to. Instructions on the rest of the procedure are available there.

2. Grab the sources from a FreeBSD mirror site. You can do this in one of two ways:

   a. Use the cvsup program with the `supfile` named `standard-supfile` available from `/usr/share/examples/cvsup`. This is the most recommended method, since it allows you to grab the entire collection once and then only what has changed from then on. Many people run `cvsup` from `cron` and keep their sources up-to-date automatically. You have to customize the sample `supfile` above, and configure cvsup for your environment.

b. Use the **CTM** facility. If you have very bad connectivity (high price connections or only email access) **CTM** is an option. However, it is a lot of hassle and can give you broken files. This leads to it being rarely used, which again increases the chance of it not working for fairly long periods of time. We recommend using **CVSup** for anybody with a 9600 bps modem or faster connection.

3. If you are grabbing the sources to run, and not just look at, then grab *all* of FreeBSD-CURRENT, not just selected portions. The reason for this is that various parts of the source depend on updates elsewhere, and trying to compile just a subset is almost guaranteed to get you into trouble.

   Before compiling FreeBSD-CURRENT, read the `Makefile` in `/usr/src` carefully. You should at least run a make world the first time through as part of the upgrading process. Reading the FreeBSD-CURRENT mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-current) and `/usr/src/UPDATING` will keep you up-to-date on other bootstrapping procedures that sometimes become necessary as we move toward the next release.

4. Be active! If you are running FreeBSD-CURRENT, we want to know what you have to say about it, especially if you have suggestions for enhancements or bug fixes. Suggestions with accompanying code are received most enthusiastically!

21.2.2 Staying Stable with FreeBSD

21.2.2.1 What Is FreeBSD-STABLE?

FreeBSD-STABLE is our development branch from which major releases are made. Changes go into this branch at a different pace, and with the general assumption that they have first gone into FreeBSD-CURRENT for testing. This is *still* a development branch, however, and this means that at any given time, the sources for FreeBSD-STABLE may or may not be suitable for any particular purpose. It is simply another engineering development track, not a resource for end-users.

21.2.2.2 Who Needs FreeBSD-STABLE?

If you are interested in tracking or contributing to the FreeBSD development process, especially as it relates to the next "point" release of FreeBSD, then you should consider following FreeBSD-STABLE.

While it is true that security fixes also go into the FreeBSD-STABLE branch, you do not *need* to track FreeBSD-STABLE to do this. Every security advisory for FreeBSD explains how to fix the problem for the releases it affects [1] , and tracking an entire development branch just for security reasons is likely to bring in a lot of unwanted changes as well.

Although we endeavor to ensure that the FreeBSD-STABLE branch compiles and runs at all times, this cannot be guaranteed. In addition, while code is developed in FreeBSD-CURRENT before including it in FreeBSD-STABLE, more people run FreeBSD-STABLE than FreeBSD-CURRENT, so it is inevitable that bugs and corner cases will sometimes be found in FreeBSD-STABLE that were not apparent in FreeBSD-CURRENT.

For these reasons, we do *not* recommend that you blindly track FreeBSD-STABLE, and it is particularly important that you do not update any production servers to FreeBSD-STABLE without first thoroughly testing the code in your development environment.

If you do not have the resources to do this then we recommend that you run the most recent release of FreeBSD, and use the binary update mechanism to move from release to release.

21.2.2.3 Using FreeBSD-STABLE

1. Join the freebsd-stable (http://lists.FreeBSD.org/mailman/listinfo/freebsd-stable) list. This will keep you informed of build-dependencies that may appear in FreeBSD-STABLE or any other issues requiring special attention. Developers will also make announcements in this mailing list when they are contemplating some controversial fix or update, giving the users a chance to respond if they have any issues to raise concerning the proposed change.

   The cvs-all (http://lists.FreeBSD.org/mailman/listinfo/cvs-all) list will allow you to see the commit log entry for each change as it is made along with any pertinent information on possible side-effects.

   To join these lists, or one of the others available go to http://lists.FreeBSD.org/mailman/listinfo and click on the list that you wish to subscribe to. Instructions on the rest of the procedure are available there.

2. If you are installing a new system and want it to be as stable as possible, you can simply grab the latest dated branch snapshot from ftp://releng4.FreeBSD.org/pub/FreeBSD/ and install it like any other release.

   If you are already running a previous release of FreeBSD and wish to upgrade via sources then you can easily do so from FreeBSD mirror site. This can be done in one of two ways:

   a. Use the cvsup program with the `supfile` named `stable-supfile` from the directory `/usr/share/examples/cvsup`. This is the most recommended method, since it allows you to grab the entire collection once and then only what has changed from then on. Many people run `cvsup` from `cron` to keep their sources up-to-date automatically. You have to customize the sample `supfile` above, and configure cvsup for your environment.

   b. Use the **CTM** facility. If you do not have a fast and inexpensive connection to the Internet, this is the method you should consider using.

3. Essentially, if you need rapid on-demand access to the source and communications bandwidth is not a consideration, use `cvsup` or `ftp`. Otherwise, use **CTM**.

4. Before compiling FreeBSD-STABLE, read the `Makefile` in `/usr/src` carefully. You should at least run a make world the first time through as part of the upgrading process. Reading the FreeBSD-STABLE mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-stable) and `/usr/src/UPDATING` will keep you up-to-date on other bootstrapping procedures that sometimes become necessary as we move toward the next release.

21.3 Synchronizing Your Source

There are various ways of using an Internet (or email) connection to stay up-to-date with any given area of the FreeBSD project sources, or all areas, depending on what interests you. The primary services we offer are Anonymous CVS, CVSup, and CTM.

> **Warning:** While it is possible to update only parts of your source tree, the only supported update procedure is to update the entire tree and recompile both userland (i.e., all the programs that run in user space, such as those in `/bin` and `/sbin`) and kernel sources. Updating only part of your source tree, only the kernel, or only userland will often result in problems. These problems may range from compile errors to kernel panics or data corruption.

Anonymous CVS and **CVSup** use the *pull* model of updating sources. In the case of **CVSup** the user (or a `cron` script) invokes the `cvsup` program, and it interacts with a `cvsupd` server somewhere to bring your files up-to-date. The updates you receive are up-to-the-minute and you get them when, and only when, you want them. You can easily restrict your updates to the specific files or directories that are of interest to you. Updates are generated on the fly by the server, according to what you have and what you want to have. **Anonymous CVS** is quite a bit more simplistic than **CVSup** in that it is just an extension to **CVS** which allows it to pull changes directly from a remote CVS repository. **CVSup** can do this far more efficiently, but **Anonymous CVS** is easier to use.

CTM, on the other hand, does not interactively compare the sources you have with those on the master archive or otherwise pull them across. Instead, a script which identifies changes in files since its previous run is executed several times a day on the master CTM machine, any detected changes being compressed, stamped with a sequence-number and encoded for transmission over email (in printable ASCII only). Once received, these "CTM deltas" can then be handed to the ctm_rmail(1) utility which will automatically decode, verify and apply the changes to the user's copy of the sources. This process is far more efficient than **CVSup**, and places less strain on our server resources since it is a *push* rather than a *pull* model.

There are other trade-offs, of course. If you inadvertently wipe out portions of your archive, **CVSup** will detect and rebuild the damaged portions for you. **CTM** will not do this, and if you wipe some portion of your source tree out (and do not have it backed up) then you will have to start from scratch (from the most recent CVS "base delta") and rebuild it all with **CTM** or, with **Anonymous CVS**, simply delete the bad bits and resync.

21.4 Using `make world`

Once you have synchronized your local source tree against a particular version of FreeBSD (FreeBSD-STABLE, FreeBSD-CURRENT, and so on) you can then use the source tree to rebuild the system.

> **Take a Backup:** It cannot be stressed enough how important it is to take a backup of your system *before* you do this. While rebuilding the world is (as long as you follow these instructions) an easy task to do, there will inevitably be times when you make mistakes, or when mistakes made by others in the source tree render your system unbootable.
>
> Make sure you have taken a backup. And have a fixit floppy to hand. You will probably never have to use it, but it is better to be safe than sorry!

> **Subscribe to the Right Mailing List:** The FreeBSD-STABLE and FreeBSD-CURRENT branches are, by their nature, *in development*. People that contribute to FreeBSD are human, and mistakes occasionally happen.

Sometimes these mistakes can be quite harmless, just causing your system to print a new diagnostic warning. Or the change may be catastrophic, and render your system unbootable or destroy your file systems (or worse).

If problems like these occur, a "heads up" is posted to the appropriate mailing list, explaining the nature of the problem and which systems it affects. And an "all clear" announcement is posted when the problem has been solved.

If you try to track FreeBSD-STABLE or FreeBSD-CURRENT and do not read the FreeBSD-STABLE mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-stable) or the FreeBSD-CURRENT mailing list (http://lists.FreeBSD.org/mailman/listinfo/freebsd-current) respectively, then you are asking for trouble.

21.4.1 Read `/usr/src/UPDATING`

Before you do anything else, read `/usr/src/UPDATING` (or the equivalent file wherever you have a copy of the source code). This file should contain important information about problems you might encounter, or specify the order in which you might have to run certain commands. If `UPDATING` contradicts something you read here, `UPDATING` takes precedence.

> **Important:** Reading `UPDATING` is not an acceptable substitute for subscribing to the correct mailing list, as described previously. The two requirements are complementary, not exclusive.

21.4.2 Check `/etc/make.conf`

Examine the files `/etc/defaults/make.conf` and `/etc/make.conf`. The first contains some default defines – most of which are commented out. To make use of them when you rebuild your system from source, add them to `/etc/make.conf`. Keep in mind that anything you add to `/etc/make.conf` is also used every time you run `make`, so it is a good idea to set them to something sensible for your system.

A typical user will probably want to copy the `CFLAGS` and `NOPROFILE` lines found in `/etc/defaults/make.conf` to `/etc/make.conf` and uncomment them.

Examine the other definitions (`COPTFLAGS`, `NOPORTDOCS` and so on) and decide if they are relevant to you.

21.4.3 Update the Files in `/etc`

The `/etc` directory contains a large part of your system's configuration information, as well as scripts that are run at system startup. Some of these scripts change from version to version of FreeBSD.

Some of the configuration files are also used in the day to day running of the system. In particular, `/etc/group`.

There have been occasions when the installation part of "make world" has expected certain usernames or groups to exist. When performing an upgrade it is likely that these users or groups did not exist. This caused problems when upgrading.

A recent example of this is when the `smmsp` user was added. Users had the installation process fail for them when mtree(8) was trying to create `/var/spool/clientmqueue`.

The solution is to examine `/usr/src/etc/group` and compare its list of groups with your own. If there are any groups in the new file that are not in your file then copy them over. Similarly, you should rename any groups in `/etc/group` which have the same GID but a different name to those in `/usr/src/etc/group`.

Since 4.6-RELEASE you can run mergemaster(8) in pre-buildworld mode by providing the `-p` option. This will compare only those files that are essential for the success of `buildworld` or `installworld`. If your old version of `mergemaster` does not support `-p`, use the new version in the source tree when running for the first time:

```
# cd /usr/src/usr.sbin/mergemaster
# ./mergemaster.sh -p
```

> **Tip:** If you are feeling particularly paranoid, you can check your system to see which files are owned by the group you are renaming or deleting:
>
> ```
> # find / -group GID -print
> ```
>
> will show all files owned by group *`GID`* (which can be either a group name or a numeric group ID).

21.4.4 Drop to Single User Mode

You may want to compile the system in single user mode. Apart from the obvious benefit of making things go slightly faster, reinstalling the system will touch a lot of important system files, all the standard system binaries, libraries, include files and so on. Changing these on a running system (particularly if you have active users on the system at the time) is asking for trouble.

Another method is to compile the system in multi-user mode, and then drop into single user mode for the installation. If you would like to do it this way, simply hold off on the following steps until the build has completed. You can postpone dropping to single user mode until you have to `installkernel` or `installworld`.

As the superuser, you can execute:

```
# shutdown now
```

from a running system, which will drop it to single user mode.

Alternatively, reboot the system, and at the boot prompt, enter the `-s` flag. The system will then boot single user. At the shell prompt you should then run:

```
# fsck -p
# mount -u /
# mount -a -t ufs
# swapon -a
```

This checks the file systems, remounts `/` read/write, mounts all the other UFS file systems referenced in `/etc/fstab` and then turns swapping on.

> **Note:** If your CMOS clock is set to local time and not to GMT (this is true if the output of the date(1) command does not show the correct time and zone), you may also need to run the following command:
>
> ```
> # adjkerntz -i
> ```

This will make sure that your local time-zone settings get set up correctly — without this, you may later run into some problems.

21.4.5 Remove /usr/obj

As parts of the system are rebuilt they are placed in directories which (by default) go under `/usr/obj`. The directories shadow those under `/usr/src`.

You can speed up the "make world" process, and possibly save yourself some dependency headaches by removing this directory as well.

Some files below `/usr/obj` may have the immutable flag set (see chflags(1) for more information) which must be removed first.

```
# cd /usr/obj
# chflags -R noschg *
# rm -rf *
```

21.4.6 Recompile the Source

21.4.6.1 Saving the Output

It is a good idea to save the output you get from running make(1) to another file. If something goes wrong you will have a copy of the error message. While this might not help you in diagnosing what has gone wrong, it can help others if you post your problem to one of the FreeBSD mailing lists.

The easiest way to do this is to use the script(1) command, with a parameter that specifies the name of the file to save all output to. You would do this immediately before rebuilding the world, and then type **exit** when the process has finished.

```
# script /var/tmp/mw.out
Script started, output file is /var/tmp/mw.out
# make TARGET
... compile, compile, compile ...
# exit
Script done, ...
```

If you do this, *do not* save the output in `/tmp`. This directory may be cleared next time you reboot. A better place to store it is in `/var/tmp` (as in the previous example) or in `root`'s home directory.

21.4.6.2 Compile the Base System

You must be in the `/usr/src` directory:

```
# cd /usr/src
```

(unless, of course, your source code is elsewhere, in which case change to that directory instead).