Chapter 8
Mobile Communication Networks

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History of Mobile Communication

- 1895 Guglielmo Marconi : first demonstration of wireless telegraphy
- 1907
  - Commercial transatlantic connections
  - Large base stations (30 · 100m high antennas)
- 1915 wireless voice communication New York – San Francisco
- 1920 discovery of short-waves by Marconi: reflection at the ionosphere allows for smaller senders and receivers
- 1926
  - First telephone inside train between Hamburg and Berlin
  - Wires parallel to the rails as antennas

Source: Jochen Schiller, Mobile Communications, Addison Wesley

History: Early Mobile Networks

- 1958 A-Netz in Germany
  - Analog, 160MHz, mobile originated connection establishment only
  - No handover, 80% area coverage, 11000 customers in 1971
- 1972 B-Net in Germany
  - Analog, 160MHz, net-oriented connections possible (location of mobile phone has to be known)
  - Also in A, NL and LUX, 13000 customers in Germany in 1979
- 1986 C-Netz in Germany (until 2000)
  - Analog voice transmission, 450MHz, handover possible,
  - Automatic determination of mobile phone location
  - FAX, modem, X.25, e-mail, 98% area coverage

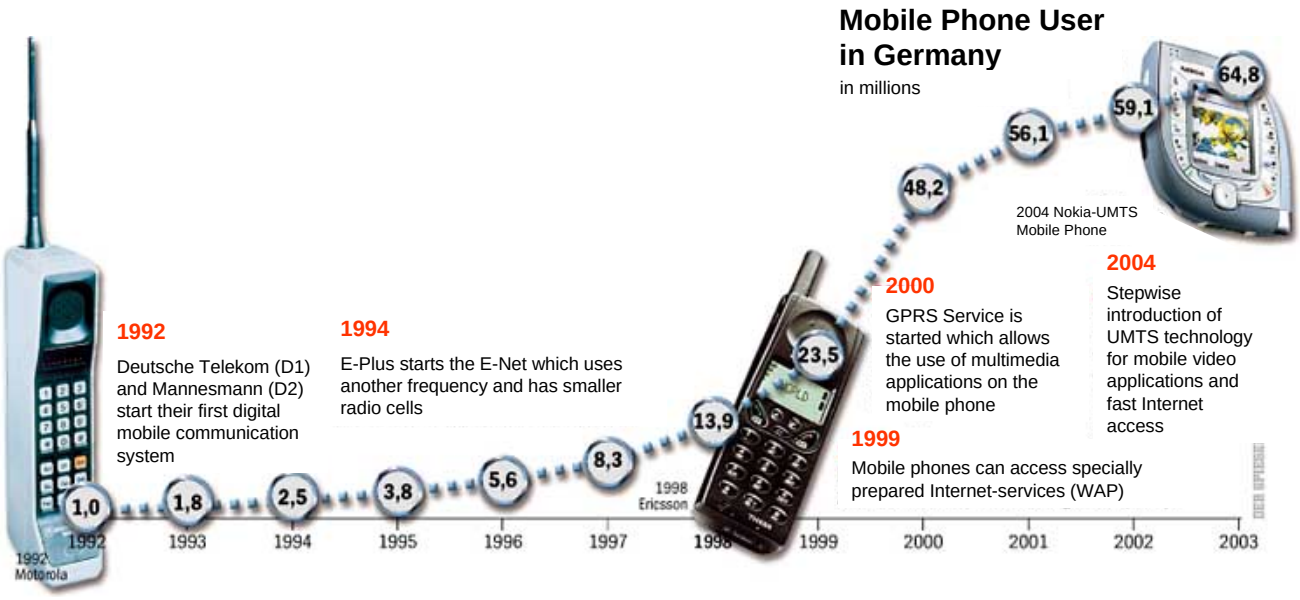
Background and History

- 1992 introduction of GSM
  - In Germany as D1 and D2, digital frequency, 900MHz
  - Automatic localization of subscribers, handover,
  - Cellular structure, roaming
  - Nowadays in more than 170 countries worldwide
  - Data with 9.6kbit/s, FAX, voice, ...
- 1997 wireless local radio networks (WLAN - IEEE802.11)
  - 1999 IEEE 802.11b
  - 2001 IEEE 802.11a
  - 2003 IEEE 802.11g
- 2000 GSM with higher data rates (HSCSD, GPRS)

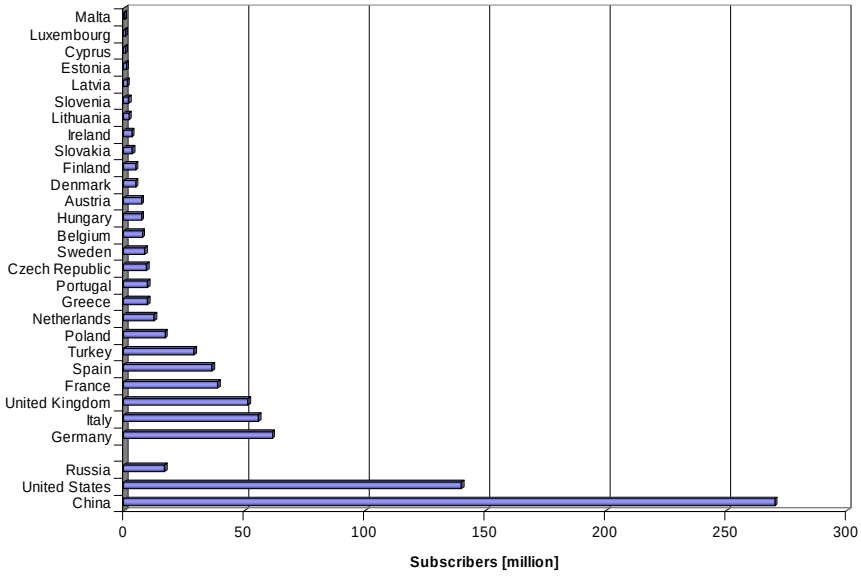
Background and History

- 2000 UMTS auctions
- 2001 introduction of 3G systems
  - CDMA2000 in Korea
  - UMTS in Europe, FOMA in Japan
- 2001 wireless „Metropolitan Area Networks“
  - IEEE 802.16 - MAN
  - 2001 IEEE 802.16-2001
  - 2004 IEEE 802.16-2004
- 2004 introduction of 3G in Germany
  - PC Card for UMTS
  - Services are still under development

Growth of Mobile Communication Systems



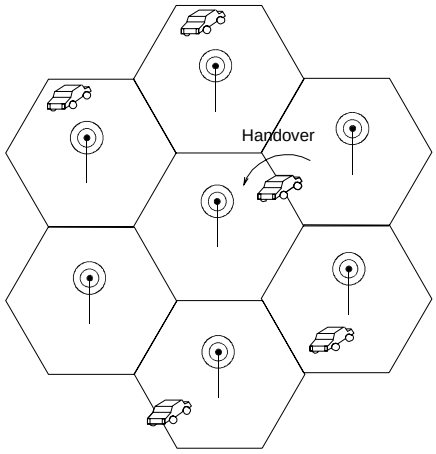
Mobile Subscribers (4Q2003)



Source: European Mobile Communications Report 1/2004

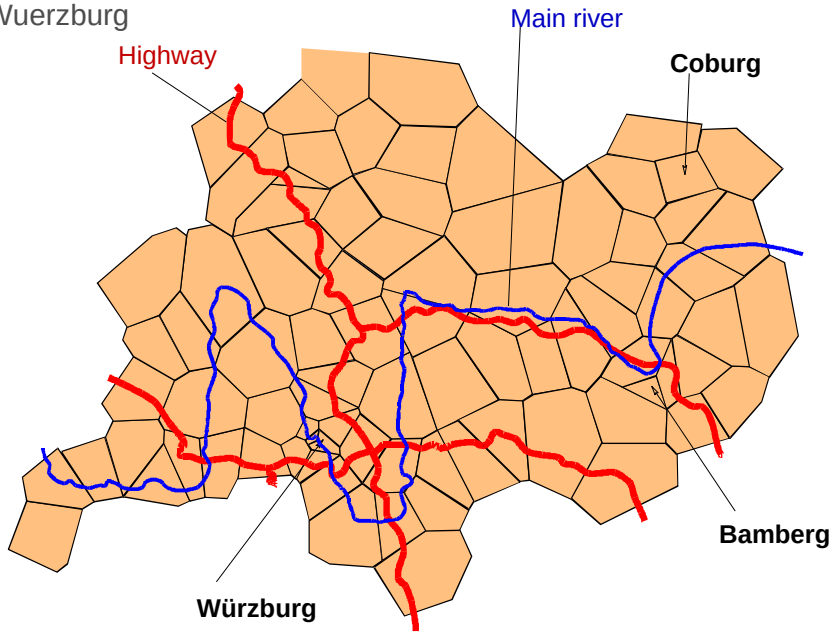
Cellular Network Concept (McDonald, AT&T, 1978)

- Reason: Number of available frequencies is very limited (z.B. 124 frequency pairs in GSM)
- Solution: Segmentation of service area into cells
  - Spatial reuse of available frequencies (frequency reuse)
  - Introduction of regions concerning the reuse of frequencies
  - Handover or handoff: transfer of connection (control) crossing the cell border

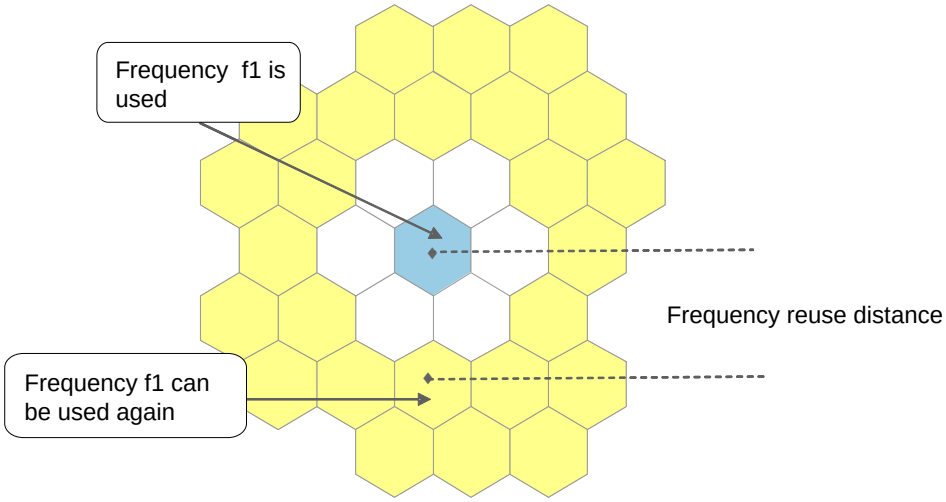


Realistic Example of a Segmentation into Cells

- Region of Wuerzburg



Frequency Reuse Distance

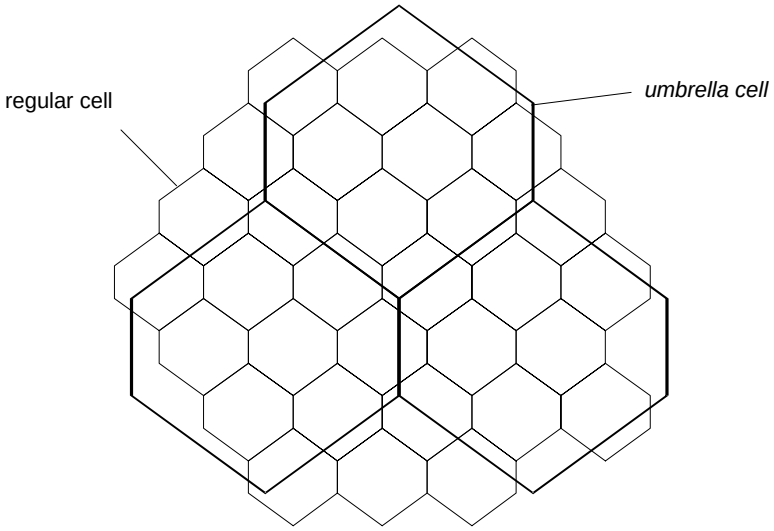


- Consequence of segmenting the service area into cells
- With frequency multiplexing a number of frequencies is allocated to every cell
- Sufficiently large frequency reuse distance to minimize interferences

Frequency Allocation Method

- The existing frequencies (channel pairs) must be assigned to the cells of a cellular group according to a certain frequency allocation method
- Frequency allocation method:
  - *Static frequency allocation*
  - *Allocation with borrowing policy*: possibility for a highly loaded cell to borrow a channel from a neighboring less loaded cell
  - *Dynamic frequency allocation*: a new frequency requirement station emerges with every new connection; thereafter the frequency allocation has to be adapted
- Frequency allocation methods are in general complex (algorithm is NP complete)

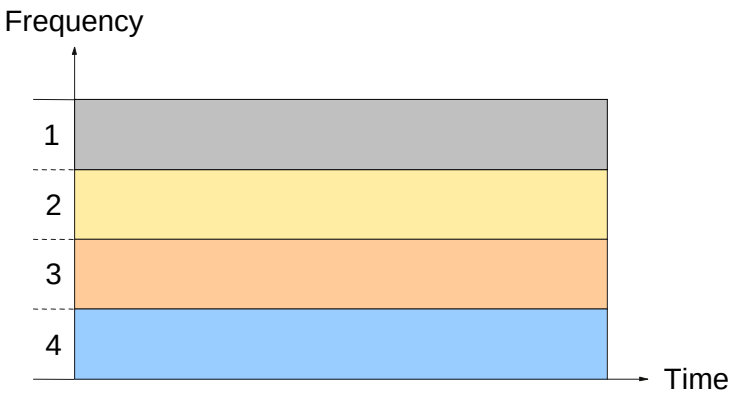
Micro Cells, Macro Cells and Umbrella Cells



- Enhancement of the cellular concept
- Hierarchical systems for reducing the signaling effort

Multiplexing Schemes in Mobile Communication Networks

- **FDMA** ***(Frequency Division Multiple Access)***
  - Separated, non overlapping frequency bands
  - Exclusive allocation of one frequency for the whole duration of a connection

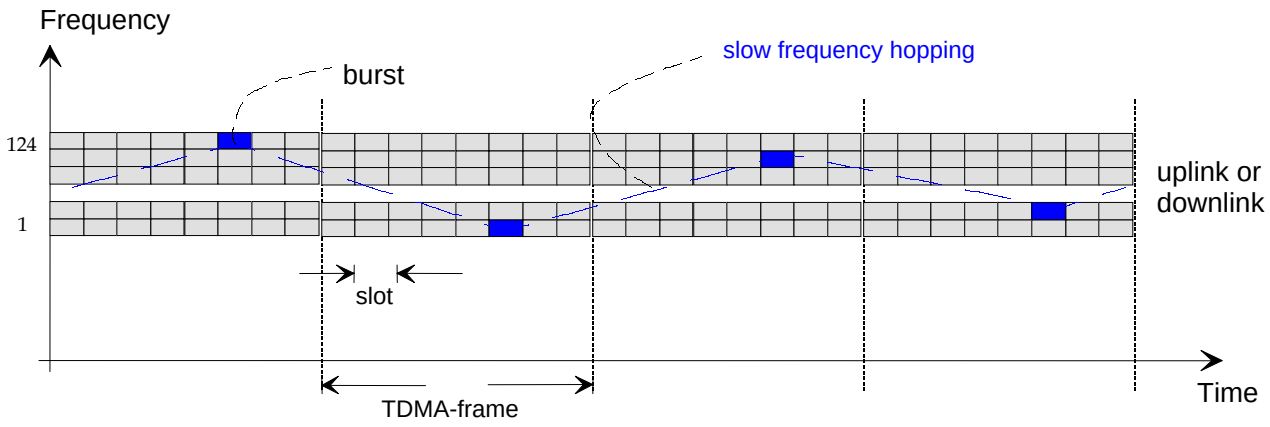


FDMA/TDMA & Frequency Hopping

- **FDMA/TDMA** (***Frequency/Time Division Multiple Access***)
  - Frequency band segmented into time slots
  - Combination of time and frequency division multiplex
  - Used in GSM systems – combined with frequency hopping

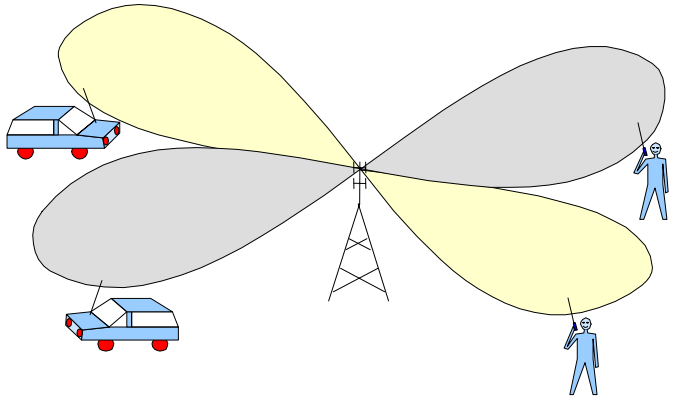
- **Frequency hopping**
  - Change of frequency band every time frame according to predefined hopping sequence
  - Improved robustness against frequency selective fading and interference
  - Technically complex

Frequency Hopping



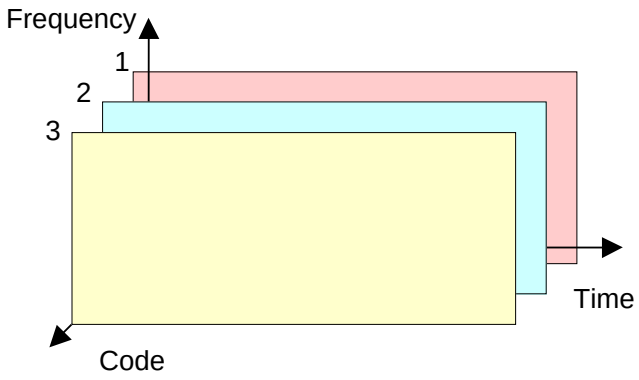
Multiplexing Schemes in Mobile Communication Networks

- **SDMA (*Space Division Multiple Access*)**
  - Separating medium is the space, in which multiplexing is realized by directed (smart) antennas
  - Steering of smart antennas (adaptive antenna arrays) is normally done electronically and not mechanically
  - Combination with FDMA/TDMA or CDMA possible



Multiplexing Schemes in Mobile Communication Networks

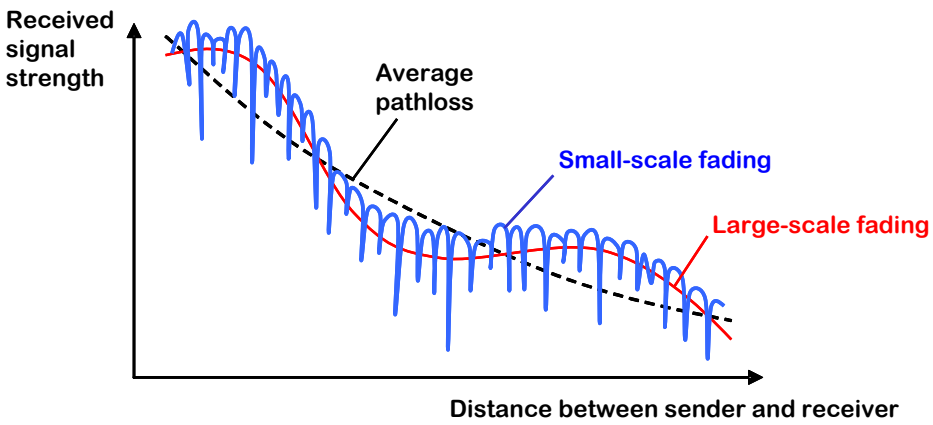
- **CDMA (*Code Division Multiple Access*)**
  - Used in cdmaOne and in UMTS
  - Uses orthogonal codes
  - Receiver filters the appropriate signal in the code space
  - Signals from other stations seen as noise



Radio Propagation

- Radio waves are influenced by the following effects:
  - **Reflections** are caused by objects in the propagation path which are very large in comparison to the wave length (e.g. the surface of a building)
  - **Diffractions** are caused by objects of sizes approximately equal to the wave length
  - **Shadowing effects** are caused by impenetrable obstacles in the line of sight

Radio Propagation



- **Small-scale fading:** due to small changes in position;
  the sum of the phases of the received signal is nearly random because of the multipath propagation. Variation of the received signal strength by approx. 30-40 dB
- **Large-scale fading:** on larger distances;
  the mean received signal strength decreases gradually because of propagation loss

Simple Radio Propagation Model

$$PL(d) = PL(d_0) + 10\, n \log(d/d_0) + X_\sigma \quad \text{(in dB)}$$

PL:	path loss as mean received signal strength
d:	distance between sender and receiver
n:	path loss exponent (in free space n = 2, typical n ≤ 4)
d_0 :	reference distance (1 km on macro cells, 100 m on micro cells)
X_σ :	lognormal shadowing, Gaussian RV with mean 0 dB