The Digital Ecosystems Research Vision: 2010 and Beyond

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Abstract

This paper suggests a set of research problems to be undertaken in the coming Framework Programmes (ICT in CIP, ICT in FP7, …) and their operationalisation. The intent of the paper is to contribute to the definition of the ICT research priorities needed to arrive at a European concept of digital ecosystems that support SMEs and regional development. Recent studies converge towards a research framework that will integrate social science and natural science questions and concerns within an advanced programme of research in computer science and software engineering. The objective of the advanced research programme outlined is to develop an integrated ICT development and ICT adoption strategy that will find its natural expression in the different regions of Europe, advancing them toward the Lisbon Strategy on the Information Society and the Knowledge Economy.

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1 – Introduction

The objective of this paper is to support planning of the Information Society Technologies (IST) Programme within the Seventh Framework Programme (FP7) of research of the European Commission (EC) by proposing a vision for how research in software technologies can contribute to the attainment of the "Lisbon objectives".[1] This vision grows out of the experience of on-going FP6 projects in the "Technologies for Digital Ecosystems" cluster of the "ICT for Enterprise Networking" unit, such as the Digital Business Ecosystem (DBE) Integrated Project (IP), as well as four public workshops organised by the EC and held between October 2002 and May 2005.[2] The research vision presented in this document thus is representative of the four principal groups of stakeholders in the European Knowledge Economy: small and medium-sized enterprises (SMEs) represented by their associations, the European software and knowledge-based service industry, the research community participating in currently funded FP6 projects, and regional/local decision makers represented by their catalysts and agencies. The intended audience are the research communities in e-Business, software engineering, computer science, and social science; regional policy makers; and EC staff.

The paper covers a lot of ground in order to develop the many related ideas and lines of argument that converge toward the digital ecosystem vision. The first section proposes certain priorities and principles of intervention and funding, in particular it stresses the importance of SMEs for the European economy. It also defines the concept of digital ecosystem as a useful metaphor for understanding the dynamics of business networks at the regional and sectoral level and their interaction with and through ICTs. This is followed by a section on "research value chains" and the challenges and opportunities they present for FP research; the emphasis in this section is on the importance of openness as a basis for the cooperation in the formalisation of knowledge within different digital ecosystems. The fourth section summarises the requirements for regional development and ICTs gathered from a number of European regions at a recent workshop on digital ecosystems. The fifth section recounts the main points of the discussion held at the most recent workshop, namely some of the difficult questions surrounding interdisciplinary research and how it could be made more effective. The main question in this section and that stands out as central to the whole paper concerns the difficulty to achieve wide ICT adoption among SMEs, and to define policies and processes that help transform ICT adoption into sustainable economic growth (i.e. Lisbon objectives). The general framework for interdisciplinary research that has been developed up to this point is then explored in the sixth section through four different "research case studies" that begin to address this fundamental question. The seventh section proposes a rationalisation for how digital ecosystems research can leverage communications and formal languages to provide a *practical* answer to the puzzle of regional growth catalysed by ICTs. This leads naturally to an outline of current results and outcomes of one of the projects in the cluster, the Digital Business Ecosystem (DBE) integrated project. The final section summarises the main points and offers an architecture for the Knowledge Economy that encapsulates the arguments developed by the paper.

2 – SMEs and digital ecosystems

We all agree that we need to invest more and better in knowledge and innovation, which are key drivers of economic growth, but it is difficult to reach agreement on priorities. Given the importance

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[1] The Presidency Conclusions, Lisbon European Council, 23-24 March 2000, are generally summarised by the commitment to become "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social inclusion" by 2010.

[2] The first such workshop was held in Bruxelles on 4/10/02 and its focus was the paper by Nachira et al "Toward a network of digital business ecosystems for the local development". The second workshop focused on the role of SMEs and was held in Copenhagen at IST 2002, in November 2002. The final two workshops were held more recently in Bruxelles on 18 April and 18 May 2005 and focused on the needs of the regions and the views of the software industry. More information, links, and minutes can be found at www.digital-ecosystems.org

of SMEs to the European economy,[3] clearly growth of the SME sector and its greater adoption of information and communication technologies (ICTs) would do a lot to progress Europe towards the Lisbon objectives. In fact, entrepreneurship and SMEs have emerged as one of the major engines of economic and social development throughout the world, gradually replacing the managed economy, which characterised Western economies in the three decades after WWII and favoured the concentration of economic/industrial activity in a few large firms. With the acceleration in the pace of scientific discovery, entrepreneurship has come to be seen as a better basis to support innovation than relying on large firms which, in spite of much larger R&D budgets, are more limited by predetermined technological trajectories and lock-in. [4] The role of entrepreneurship has thus changed dramatically and fundamentally, becoming a requisite ingredient generating employment, economic growth and international competitiveness in the global economy.[5]

The challenge of engaging SMEs

Given the importance of SMEs to the European economy the challenge we face can be separated into two overarching objectives:

- Enable European SME ICT providers to gain competiveness in the software market.
- Provide e-business software solutions able to self-adapt to the needs of local SMEs, fostering ICT adoption and economic growth in local innovation nodes.

For the implementation of EC research policy these objectives translate into two important but separate issues revolving around the question of how to engage SMEs actively and sustainably in research-led activities:

- SME involvement in research, and
- SME take-up of research results.

To an extent the two are linked in that an SME involved in a project has a demonstrable interest in the technology and is more likely to be involved in exploitation, although this link is by no means certain and some SME participants could be pure research performers rather than users. However, the focus in terms of official data seems to be always on participation and not on innovation and exploitation. Studies and assessments are finding a good involvement of SMEs in FP research, but little independent analysis is made about the take-up of results. The Technology Implementation Plans and Use and Dissemination Plans that were a response to criticisms of earlier FPs about exploitation are not providing the data that was envisaged. While 5-year assessments of the early Framework Programmes (Davignon 1996)[6] and (Majo 1999)[7] criticised the lack of involvement of SMEs and the lack of exploitation of results, more recent assessments (Ormala 2003)[8] have tended to focus on strengthening the research capability and ignoring the specific outcomes of individual projects. The

[3] SMEs are 99.7% of companies in Europe, accounting for approximately 50% of Europe's GDP. 93% have less than 10 employees (www.ueapme.org).

[4] Audretsch, D B, and Thurik, A R, "What's New about the New Economy? Sources of Growth in the Managed and Entrepreneurial Economies", ERIM Report ERS-2000-45-STR, November 2000. www.erim.eur.nl

[5] Observatory of European SMEs report "SMEs in Europe 2003". http://europa.eu.int/comm/enterprise/enterprise_policy/analysis/observatory_en.htm

[6] http://www.cordis.lu/esprit/src/monitor.htm

[7] http://www.cordis.lu/fp5/monitoring/prevrep.htm

[8] On SME participation the Ormala 2003 report (http://europa.eu.int/comm/research/reports/2004/fya_en.html) says on Page 6: "Recommendation 3: The industrial orientation and participation in the Framework Programme must be enhanced. This requires restoring industrial relevance and leadership in programmes aimed at innovation and competitiveness. In particular, hightech SMEs should be able to find direct participation more attractive". And on Page 11: "The majority of National Contact Points (NCPs) perceive FP6 to be attractive to public researchers, but not so attractive to industry and SMEs. Several find FP6 less attractive to SMEs than FP5".

research community is seen as the "user" of FP funds and the achievement of the ERA as the objective. While the 2003 assessment rightly emphasises the non-linear and organic nature of the link between research and innovation, it would be useful to study the relationship between the "routes to market" described in project proposals to justify the funding and the actual project outcomes. It is generally felt that many projects fail to achieve their stated objectives especially where evaluation focuses on the short-term outcomes—or at least there is a failure to implement the innovation process that is assumed to follow on from research. This lack of buy-in of most user-SMEs is related to the insufficient network capabilities available to them. They often cannot judge the potential benefits of technology, nor can they compare with others. As the Framework Programmes offer very limited help on this, they feel disconnected and cannot catch up.

Digital ecosystems and sustainable growth

This paper outlines an approach at research and SME engagement that has taken form over the past several years in the ICT for Enterprise Networking unit and that now groups several projects under the same cluster, Technologies for Digital Ecosystems. The original discussion paper published by the then e-Business Unit[9] developed a complex conceptual framework for describing the interactions between firms, technology, and knowledge inspired by biological ecosystems. Building on previous work,[10] the original paper on digital ecosystems developed several points relevant to the formalisation of knowledge for and by SMEs through ICTs to enable the creation of an open-source environment that could support the continuous evolution of business models and software services. In particular, it called for self-organisation and evolutionary models from Biology to be applied to software, based on the assumption that such "biological" behaviour of the software, if attained, is likely to optimise the catalytic function of the ICTs in question for socio-economic growth and innovation. Fig. 1 captures the main ideas at a high level.

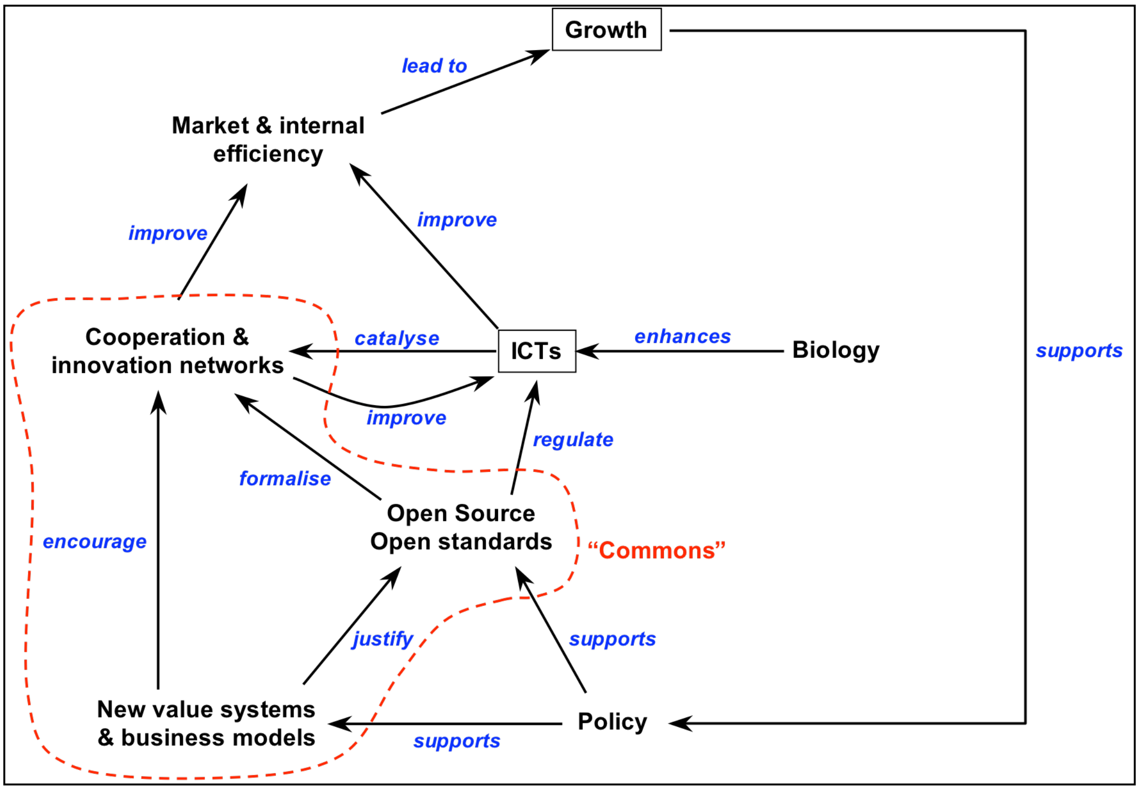

Fig. 1 Flow diagram for growth catalysed by ICTs

[9] Nachira, F, et al. (2002). "Toward a network of digital business ecosystems fostering the local development", http://www.europa.eu.int/information_society/topics/ebusiness/godigital/sme_research/index_en.htm

[10] Moore, J (1996). *The death of competition: leadership and strategy in the age of business ecosystems*, New York, Harperbusiness.

In the case of digital ecosystems, success or failure will be very evident as the ecosystems will either survive and grow beyond the period of project funding or will wither and die, possibly being replaced by some other form of technology, which might for example be proprietary and cause *de facto* standards to replace the initially envisaged *de jure* ones that underpin open competition by enabling compatibility between compliant products. As an engagement strategy, engineering early take-up and funding can leave itself open to the risk that we end up supporting both "losers" and "winners". However, supporting early ecosystem contributors with funding in order to promote a nascent community until such time as sufficient commercial forces exist to support a sustainable ecosystem suggests an alternative model. The bootstrap phase should focus on high-potential SMEs[11] and gradually bring in SMEs with lower IT skills as the ecosystems become better defined.[12] This will minimise situations where some companies flourish in such a protected environment but will fail once the support ends.

Toward a sustainable network of digital ecosystems

The workshops in Copenhagen and Brussels since 2002 have clearly identified the importance of local actors (a.k.a. Regional Catalysts) and the projects in the Digital Ecosystems Cluster are rapidly gathering experience and empirical knowledge about methods and practices for engaging the value chain from research to the end-user. It would be good if more regions could be involved in the innovation and technology adoption role in future initiatives and projects, although this may make the preparation process more cumbersome and expensive. Early results from empirical research carried out with SMEs in the regions have demonstrated that the 'openness' of ecosystem development itself is a key quality. The quality of openness refers not only to disclosing software source code, it includes the broader processes relating to software and infrastructure development, and also to modes of governance through which the ecosystem will be sustained. Including SMEs and their representatives within ecosystem governance is a potentially important method of engaging SMEs and structurally supporting both involvement in research and take-up of research results. In addition, it would be helpful to coordinate formally the Structural Funds with the Digital Ecosystems development so that regional involvement can be easily "programmed" into regional plans. The same could be said for the new "ICT Policy Support Programme" of the Competitiveness and Innovation framework Programme (CIP). Existing networks aiming at the digital development of SMEs should be leveraged and extended, as this will combine the technology strengths with the organisational ones. From the point of view of public perception the various Commission initiatives should be seen to be genuinely complementary, tightly coordinated, and reinforcing each other in a long-term and sustained strategic push. In this regard, the involvement of a network of pilot regions, which complement the initiatives taken at European level with deployment and dissemination initiatives and implementing the principle of subsidiarity, is crucial.

3 – Engaging the value chain: from research to end-user

Understanding the diverse ways in which value is perceived and derived at each point in this chain is a process that has to develop over time. Empirically testing and confirming the value of new and established research ideas is an iterative process that involves strong cross-communication across diverse project participants in projects and initiatives, especially as concerns cross-disciplinary dialogue. A base of empirical knowledge has been gathered by the Digital Ecosystems Cluster and

[11] In the DBE project potential adopters are divided into four groups: "Drivers" are interested in engaging and have the ability to do so; "Discoverers" are interested but do not necessarily have the IT skills; "Implementers" have the skills but are more conservative regarding their business models; and regular "Users" are low IT-skills SMEs who will only follow if they see a clear business advantage that justifies the investment in training etc.

[12] Another relevant reference is the "7-Step Process" recommended by UEAPME (Union Europeenne de l'Artisanat et des Petites et Moyennes Entreprises, www.ueapme.org); see UEAPME presentation at http://www.digital-ecosystems.org/events/2005.04/workshop_3ya1.html

from that base a number of key areas of concern have been identified as relevant to all project participants—from SMEs, to large corporations, to academic institutions—as discussed in the rest of this paper.

Models and standards for digital ecosystems

A coordinated funding strategy may be interpreted as implying the development of a single functional reference model for e-Business applications and software. Instead, the architecture of digital ecosystems differentiates between several modelling levels. As will be discussed more fully in the next sections, this makes it possible to find a balance between cooperation and competition. At the lowest, most general levels, common business modelling language meta-models are shared across Europe and across industry sectors. Individual sectors and regions, however, will have the tools to develop their own sector-specific and regional models. Individual companies can then develop their own business models that conform to the more general standards while reusing the generic models. Since model adoption cannot be enforced in a real market environment SMEs should be allowed to have their own reference models. Assuming that services will share the same model is an unreachable myth. It is more realistic to expect that any SME can adopt and publish a model. Clusters of adoptions are likely to form around functional models, similar to the way in which standards adoption takes place. People will converge around the most used functional models because it will ease migration for themselves and their customers.

Science can lead industry, but we should evaluate projects from an industrial perspective

While the conclusions of the IST 2002 Copenhagen conference emphasise that SMEs "…sought business solutions more than a specific technological one", this is more an issue about the exploitation and presentation of research, which should be done in terms of business applications and benefits rather than raw technological achievements. There is a danger in the apparently logical "let industry drive research" approach that industry will focus on only short-term goals and working within known paradigms. An important role of the scientific researcher is to show industry things that they have never before dreamed of. Science should not be afraid to lead industry. However, science for its own sake is more the realm of academic institutions, whereas the FP interventions have a definite and fundamental purpose to increase the competitiveness of EU industry. Thus projects need to be rooted in a realistic possibility of achieving some business improvement and this innovation and exploitation aspect should be an important part of the overall project plan. In digital ecosystems scientific research, the results require careful nurturing. The central metaphor of the "ecosystem" takes its inspiration from Biology but there are also contact points with Physics and with Mathematics. Often perceived as interesting but too "high-brow" by SMEs, results from science are also difficult for project participants from different research disciplines to absorb and put in context. This level of inter-communication is thus a challenge not only from Science to SMEs but also between scientific disciplines, in particular between science and social science subject areas, which are both important in digital ecosystems.

Get nearer the market while remaining pre-competitive

We understand that industry wants ready-to-apply technologies and is put off by risks, uncertainties, and the long time scales of research, but by furthering research alone, without developing practical applications, we worsen the innovation gap between research and exploitation. To some extent this is a consequence of the application to Framework Programmes of the original Treaty of Rome and the need to avoid public-sector interference in the marketplace. As a consequence, "pre-competitive" research has come to be interpreted as "far-from-market". Because much of such research is carried out by universities and is in the public domain, a perception has developed that "near-market" is only really competitive when the technology is proprietary.

In the field of Digital Ecosystems non-proprietary intellectual property does not distort competition and should be regarded as competitively neutral (other than for those companies that would seek to dominate the market). Thus Digital Ecosystems could include application development, demonstrations, and even early-stage support for user communities, provided that they are open and competitively neutral. There are technologies, such as the Internet, where only after the early and obvious use has been established does the real exploitation potential start to be seen. Thus early use and familiarity can actually be a pre-requisite of a quick and comprehensive uptake of a technology. If this use is funded it should not matter, provided always that such funding is not anti-competitive.

Understanding the economic potential of Open Source is a particularly challenging research area. Views of Open Source which describe it as "far-from-market" as opposed to "near-to-market" are limiting, and economic and business models surrounding Open Source standards and software development are not yet well-understood, as has been argued in a growing number of social science journals and initiatives.[13,14] Benkler, for instance, looks at Open Source from the point of view of New Institutional Economics and characterises its rise as deriving directly from the lower transaction costs afforded by certain implementations of ICTs. Since Open Source, in turn, decreases transaction costs, its role as an economic mode of production is self-reinforcing.[15] This view is not universally agreed even among academics and Open Source supporters, as discussed more fully below, suggesting that the role of Open Source is a subject of current intense debate that should remain a focus of research in FP7.

The role of knowledge sharing in digital ecosystems

As the introduction of a disruptive technology involves many and various players, some of whom may not be involved in a technological sense, such as legislators, their networking and dialogue is an important infrastructural consideration in order to pave the way for a coordinated introduction of a new technology, rather than a collision with unintended barriers. While the Digital Ecosystems will each have their user communities, it could be advantageous to envisage more distributed ways to share the knowledge among the wider community affected.[16]

In the digital ecosystem approach, the shared knowledge, common models, and training modules are considered a form of human capital accumulated, formalised, and embedded within the digital ecosystems. The sharing of ideas allows the collaborative development of applications, but also the building of compatible behaviours and a shared perception of reality, forming a common identity and facilitating engagement at a "community" level. Open-source learning technology in which SME participants can share and develop ideas relating to service composition and potential business scenarios forms an ever-growing resource embedded within the digital ecosystem infrastructure.

Lessons from the early experiences of the new instruments

It seems that there has been a general problem with Integrated Projects[17] in that potential users have misunderstood "critical mass" to be simply large, while missing the concept of "integrated" in terms of the scope of the projects integrating research value chains. It would perhaps help to emphasise this point if more prominence were given to the involvement of regions, SME "Drivers",[18] and end-users so as to integrate demonstration and application development into Integrated Projects, even if the funding is limited in terms of how close it can go to the marketplace.

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[13] Benkler, Y (2004). "Sharing Nicely: On Shareable Goods and the Emergence of Sharing as a modality of Economic Production", *Yale Law Journal*, Vol 114, pp 273-358.

[14] Simon Forge, SCF Associates Ltd (2004). "Open Source Software: Importance for Europe—What Future Does OSS Hold for Europe Today?" Study for IPTS/JRC/EC. http://www.jrc.es/home/report/english/articles/vol85/ICT3E856.htm

[15] Benkler, Y (2002). "Coase's Penguin, or, Linux and *The Nature of the Firm*", *Yale Law Journal*, Vol 112, pp 369-446.

[16] For example the UK Department of Trade and Industry currently has a programme to set up 30 online-based 'Knowledge Transfer Networks for this purpose (see http://www.dti.gov.uk/ktn/)

[17] See FP6 mid-term evaluation (Marimon) report Page 3 Item 4. ftp://ftp.cordis.lu/pub/documents_r5/natdir0000033/s_6082005_20050214_184834_ADS0006763en.pdf

[18] See footnote 11

For example, the DBE integrated project has, through refocusing its distinctive engagement and training strategy, placed the regions and SME engagement at the forefront of its work. Regional catalysts have established networks of interest within their regions that have taken into account the varying nature of "credibility flags" in each local area. Having successfully created a considerable level of interest among SME software companies, the process of selecting Drivers has been carried out through extensive one-to-one interaction and through "engagement workshops". The "management of expectations" is a key concept in the engagement process, mainly in the first regions. The Regional Catalysts must have clear knowledge of the status of the platform (i.e. of the different software components) at the time the different actors are engaged (Drivers, Implementers, ...). The concept of the DBE is very attractive to SMEs and indeed they would like to experiment with it but they are not able to do it yet and they do not know exactly when they will be. This may be a point that only the first Regional Catalysts will face. It is also related to the "credibility flags" mentioned above. It is very important to explain to the SMEs as accurately as possible what componets for what functionality they will find on Sourceforge available for download.

Concepts relating to digital ecosystems are complex and cutting-edge and so communication has required careful planning, with regions passing on their experience of engagement events as they take place in order to incorporate and build upon good practice. A considerable body of empirical understanding has now been captured on SME engagement both at Driver and community levels. One of the most important aspects of the engagement process has been to incorporate the viewpoints, feedback and opinions of SMEs at every stage. Understanding and incorporating the viewpoints of SMEs in each of the regions is a process that was supported by a recent workshop held in Bruxelles for the Digital Ecosystems Cluster, outcomes from which are described in the following section.

4 – The regional point of view

The workshop held in Bruxelles on 18 April 2005, "Digital Ecosystems: Re-tuning the requirements after 3 years" involved several European regions, representatives of SME associations, and representatives of the academic research community and of industry. The discussions and the conclusions reached during the workshop were summarised and then distributed among the participants.[19] The final text approved through this open process included the following conclusions:

- *Global solutions with a local input and sector approach*. The operation of SMEs is still strongly related to their local regions. But the solutions to be provided need to be developed on a European scale, with sector-specific implementations that can be adapted and tuned according to local customs. SMEs need a local support infrastructure to implement those solutions in their business operations.
- *No single point of failure and control*. Digital ecosystems should not be dependent upon any single instance or actor. From the technology point of view this refers especially to the utilisation of P2P technologies, and from the organisational perspective to balanced and decentralised governance models.
- *Commitment to Open Source and Open Standards*. The infrastructure of a digital ecosystem should be based on open-source technologies and open standards. Open standards mean open access to the specifications and free use of the standards.
- *Long-term credibility and attractive brand*. When aiming at piloting new technology with real business, the sustainability of the technology in use is a central success factor. Long-term credibility is crucial for adoption by SMEs and can be enhanced by several measures, including EC instruments, but especially by having support from large players in the software industry, from large established development communities and/or from standardisation organisations.
- *Utilisation of proven technologies*. The infrastructure should reuse whenever possible standards and technologies and should build on top of previous successful research and development.

[19] See www.digital-ecosystems.org for the minutes of this workshop.

However, in the areas where new technologies are deemed necessary, they should provide enough competitive advantage against existing integration solutions and emerging proprietary products to justify the cost of switching.

- *Simple on the surface, performant technology underneath*. The use of the technology should be simple and easily integrated into the daily operating mode of the SMEs; the underlying technology should enable the SMEs to interact efficiently with other, bigger systems (interoperability) and provide the savings the SMEs are looking for.
- *Sufficient trust and identity management and data security*. The major current unresolved questions seem to be in the area of trust and security. The absence of reliable and robust solutions to be applied within a distributed P2P architecture could greatly slow down the diffusion and prevent the full realisation of the benefits of the concept of digital business ecosystem.
- *Proven business cases and benefits for service providers and service users*. The bootstrap of services in a digital business ecosystem is based on the attractive business cases for service providers and consumers. The business benefits should be clearly demonstrated and widely communicated to the SMEs in different regions and opportunity spaces.
- *Allows open entry to new territorial markets*. The benefits of the infrastructure can be fully realised only when a critical mass of providers and consumers have joined as users. Highly skilled and hi-tech companies may be chosen to lead this implementation, but to reach critical mass the territorial pilots should be widened to cross-European initiatives, involving a much wider array of enterprises.

Functional requirements

Based on the in-depth analysis of the ICT needs of the pilot regions (i.e. over 400 SMEs in the Tampere Region) and the input from SME associations (such as the UEAPME small enterprise analysis), the key software service needs of SMEs can be summarised as follows:

- Providing cost and time savings in the daily operations, with the recognition of the need to change their way of working to take full advantage of the new management systems
- Improving customer relationships management: services that make the sales, marketing and customer care processes and interaction with customers more effective
- Improving internal communication: services such as intranet, collaborative team work, remote work and project management
- Exchange of information between companies: services such as electronic invoices, technical and sales documents
- The IT-infrastructure for SMEs must be easy to use and to maintain. There is a growing need for local IT-caretaker services that would provide services such as installation, upgradings and trouble-shooting.
- Seamless cooperation between large and small operators, governments and businesses, allowing full interoperability

In general, the regional interests towards digital ecosystems proved to be quite coherent. Based on the regional presentations and the subsequent roundtable discussion, the following aspects can be highlighted as common elements in the regional approaches presented:

- Strong focus on the development of the SME sector
- Mechanisms for sharing and open diffusion of knowledge within local clusters of SMEs, helped by the interaction and Europe-wide cooperation between regional networks.
- Interaction of such local networks and local communities with larger ones already in place; stronger interaction between SME associations structures and open source communities
- Linking eGovernment with SMEs
- Need for strong business cases demonstrating the benefits of the concept of Digital Ecosystem

- Need for easy-to-use services with high user value. Current work on Digital Ecosystems has mainly focused on the development of the infrastructure. Without integrated services, however, the ecosystem is empty and the technology practically useless.
- Shared interest and support for Open Source
- Promotion of the knowledge "embedded" within local territories, and the recognised need to share knowledge and best practices through information and education programs (coaching).

Non-functional requirements

From the multidisciplinary research activities performed by the projects of the cluster "Technologies for Digital Ecosystems" some elements have emerged:

- The development of models which could be used directly by SMEs, without intermediaries
- The necessity to approach SMEs differently by category, by sector, by size, and by existing ICT level. Micro-companies need a different approach to medium-sized ones.
- The need of new paradigms that allow the delivery of intermediate results through a gradual and evolutionary approach

5 – Interdisciplinary research as a fundamental challenge for FP7

At the second workshop held in Bruxelles on 18 May 2005, "Towards a network of Digital Ecosystems: Which technology, which research and which instruments?" a wide-ranging discussion on methodology and research approaches was held. The attendance at this second workshop was divided evenly between representatives of the software industry, academic institutions, and regional players. The following pages recount the main points covered, which began with an in-depth discussion of interdisciplinarity.

The challenge of interdisciplinarity

Whereas there is growing agreement over the importance of the SME sector, unfortunately the link between ICTs and regional growth remains difficult to establish operationally, and ICT adoption for most SMEs continues to be elusive. These facts suggest that greater attention needs to be placed on the integration of information systems with socio-economic systems, in both research and applications.

Whilst this aim can be agreed upon in principle, collaboration between the diverse subject disciplines required to address these issues is not easily achieved. The model for interdisciplinary collaboration that has been created within the digital ecosystems initiatives was designed to focus project participants on common areas of concern through the design of integrated workpackages. Different traditions, disciplines and approaches have very different ideas of relevance and often operate according to very different philosophies or world-views. These differences have been understood as extremely positive and, whilst they can give rise to fundamental differences of opinion, the process of reaching an operational consensus is an enriching one. Remaining conscious of the fundamental basis or premises upon which research traditions are constructed was an issue that was raised at the Brussels workshop and is one which has been a requisite aspect of interdisciplinary communications in the digital ecosystems research area.

User-centred design

We should take inspiration from the success of the user-centred design paradigm in the wide array of industries to which it was applied. The question, however, is not how can we make technology fit better in the personal and professional lives of the citizens. Ambient intelligence and virtual enterprises are worthwhile endeavours but their focus and rationale revolve around the concept of functional or instrumental optimisation. Functional optimisation addresses very well the technological part of the problem, but does not pay enough attention to the intentions of the users and the structure and dynamics of social groups and user communities. Given the very significant investments in user studies and user tests by the private sector,[20] it would be inaccurate and unfair to claim that the importance of this issue has not been recognised (although size of effort is not necessarily the same as methodological soundness or of capacity of others within the firm to assimilate or act on results). The problem, rather, is how user-centred design for products might be related to ICT adoption for economic growth on a regional scale.

The need to understand scale

The regional scale[21] seems small and parochial if we compare it to the globalising market outlook of many multinational corporations, but appears large if we think of the heterogeneity of a region's business and social environments. The blending of the market concerns of technological production with the lives of private citizens and with the business practices of SMEs in various parts of the world clearly points to the need to develop methods of analysis and a strategy for action that can properly account for and even leverage diversity and localisation in social and economic life. Within the FPs this position is reflected by the large number of socio-economic research projects that were funded, especially in FP4 and FP5.

In the early experiences a practical and theoretical emphasis on "contact points" and "events" has been key to overcoming questions of scale. In traditional social analysis, society is often divided up into tiers to reflect differences in scale, for example, micro, mezzo and macro. Although in many cases this model provides a useful basis for discussing questions of, for example, institutional power, it is equally important to understand how links are formed and relationships fostered across these levels. In this way, "events" can form an important way of understanding and achieving interaction between actors who are considered "distant" either geographically, across social strata or in any other recognised terms. For example, engagement events and workshops, or even on-line discussion forums when they form part of a co-ordinated approach, can act as tangible "contact points" between people working at regional level, project level and those working for the Commission. By focusing on what forms tangible and sustainable links between significant actors—regardless of size or scale—it is possible to concentrate both operationally and analytically on what binds actors together and, conversely, what keeps them apart. In this way, individual technologies, a series of events, a contract, or an enigmatic leader can all potentially be understood to form a common link between actors. Whether they are or not is always an empirical question according to this approach and not a structural characteristic of society. This approach, derived from Actor Network Theory,[22,23] can be used to understand network, group and local economy formation and is particularly relevant to the study of technology.

Lessons learned from integrated interdisciplinary collaboration

Why, then, is the sense that we do not understand the ICT adoption process still lingering? Why do the Lisbon objectives, half-way to the target year of 2010 since the time they were formulated in 2000, still seem so far away? How can research in IST contribute?

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[20] For example, Intel has a whole department devoted to the anthropological and sociological study of users of technologies, the People and Practices Group. Philips Design, one of the business units of Philips, numbers 500 and includes a large proportion of sociologists, interaction designers, and experts in user testing. Sony, Apple, Microsoft and most other technology companies have established similar groups of experts, some to balance their original technocentric perspectives, others since their inception.

[21] Where, by a "region" we consider a territory whose economy could be considered to behave like a businesss ecosystem and is affected by the industrial policy and regulations of a governance body. Its size depends from the structure of its economy and its institutions, but on average it can range from a few hundred thousand to a few million citizens and 10,000-20,000 SMEs.

[22] Callon, M (1998). "Introduction: The Embeddedness of Economic Markets in Economics", in Callon, M (ed.) *The Laws of the Markets*, Blackwell: Oxford.

[23] Latour, B. (1991). "Technology is Society Made Durable", in Law, J (ed.) *A Sociology of Monsters* Routledge: London.

The problem is not one of lack of clear objectives or strong resolve; rather, it is one of disciplinary fragmentation. This fragmentation makes sense both within academia and large industry because in both these institutions problems are decomposed into workable parts and the ROI is measured in either publications or product innovation (or both). Clearly, however, excellence in academic research and "killer apps" are not doing enough to address the challenges posed by the Lisbon objectives.[24] There is little or no incentive, either within the academic system or in private industry, to build on past funded research results, which therefore remain largely unused. The main obstacle is the challenge posed by the transfer of outcomes between research efforts addressing similar problems from different points of view—the typical example being the difficulties of technologists to make productive use of the outputs of socio-economic research.

The ecosystem approach has brought to the fore the deep ontological and epistemological differences between technological research borne out of the philosophical tradition aimed at designing and building "machines" operating in a well-defined, if reductive, objective reality, on the one hand; and social science research, which is more analytical and interpretative ("hermeneutic") in character and aims to account for the interaction between human action and socio-economic and technical structures and processes in the context of policy development, on the other hand. But the situation is even more complex since within social science itself sharply different philosophical positions have developed over the past several hundred years around most of the fundamental questions—that are then translated into difficult policy and political discussions.

In FP7 we should ensure that researchers from very different disciplines work together on the formulation of a common language and theoretical framework that can be mutually understood, on the analysis of the research problems, on the implementation of the technological solutions, and on the formulation of adoption methodologies for those technologies. *Multi*disciplinary research, i.e. the working side-by-side of different disciplines within the same project, should become more *inter*disciplinary, i.e. reliant on communication across disciplinary boundaries for a common definition of the problems and the methodologies of solution. Complexity science provides an example.

Complexity science grew out of the merging of biology, physics and mathematics, with a significant input from cognitive science, in the 1970s and 1980s.[25] In the late 80s it was applied to economics and, through chaos theory, to the dynamics of financial and stock markets. During the 1990s central tenets of complexity theory such as the concepts of emergence and self-organisation were appropriated by researchers in the fields of economics, sociology, policy and regulation, historical studies, and organisation and management studies. The results of these *trans*disciplinary explorations are not always regarded as useful by experts in the discipline being explored (i.e. social scientists do not generally regard as very useful the results and simulations obtained by natural scientists employing the techniques of complexity science to analyse socio-economic problems and systems). However, the value of new metaphors and conceptual frameworks for stimulating discussions across disciplines is generally recognised, especially when the focus is the development of new socio-technical systems.[26]

The role of social science in integrated projects

Since interdisciplinary debates are themselves part of social science and since our objective is to integrate ICTs productively into our social and economic systems, it seems appropriate to address the core of the issue by casting the problem in the language of social science. This paper can only skim the surface of such a deep and long-standing debate, but Fig. 2 may help as a frame of reference for the discussion in the rest of this paper. The table, an elaboration of a similar one proposed by Hollis,[27]

[24] The notable exception must be GSM and, more recently, text messaging although, to be fair, both arose before the Lisbon objectives were formulated. More on this below.

[25] www.santafe.edu

[26] Bullock, Seth, and Dave Cliff (2004). "Complexity and Emergent Behaviour in ICT Systems", last accessed 10/11/04 available at: http://comp.leeds.ac.uk/seth/DTi/report.pdf Hewlett-Packard.

[27] Hollis, M (1994). *The philosophy of social science: an introduction*, Cambridge.

summarises the main analytical traditions in social science over the past few centuries in addressing questions of socio-economic structure and human action. A few indicative and by no means exhaustive names are added to make the table easier to interpret. The left-hand column is generally associated with the rationalist, deterministic tradition, it is the older of the two, and grew out of naturalist philosophy. The right-hand column is more recent, it reflects a greater emphasis on the social world for defining our reality (ontology) and the construction of knowledge (epistemology). Although interpreting the two columns in terms of an objective-subjective dichotomy can only be a gross oversimplification, the thinkers in the left-hand column could be loosely grouped as sharing a belief in some form of "objective" reality, whereas a more "subjective" perspective permeates the ideas found in the right column. The different widths of the columns are meant to reflect the much greater constituency (and funding), within social science, that a critical tradition inspired by naturalist philosophy still commands.

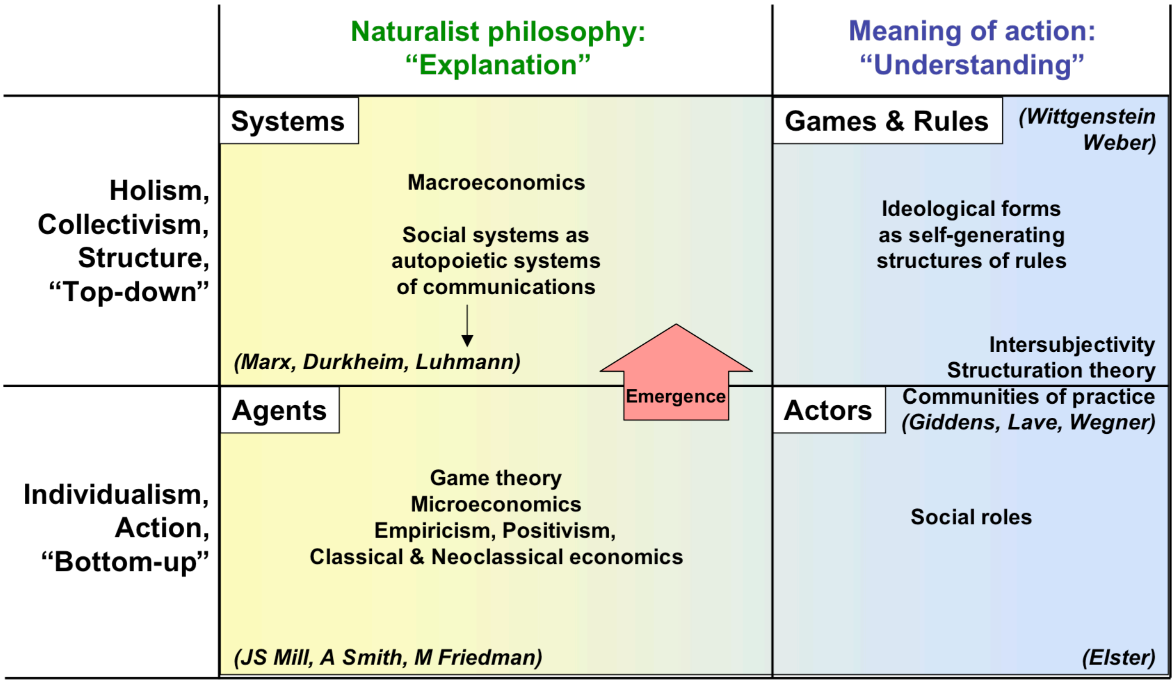

Fig. 2 A map of social science

The table can also be understood in terms of different accounts of social systems and therefore human action. The top row favours a view of society and the economy that biases the importance of structures and systems over individuals, whereas the bottom row represents the opposite view. This distinction correlates also to methodology, in the sense that theories in the top row tend to be deductive in deriving behaviour from general principles, whereas the bottom row is best associated with the long-standing and currently overriding tradition of empiricism and positivism, where general principles are derived from experience through an inductive process. The relatively new field of Complexity science is proposing new words for describing processes and phenomena that have long been studied in the social sciences, such as "emergence" to describe the not-so-well-understood relationship between local interactions and global behaviour. Part of the excitement felt by practitioners in this new field derives from the development of new conceptual, mathematical, and computational tools for modelling processes that had until recently been considered too difficult for the reductionist scientific approach—and had therefore been mainly studied in the social sciences. Digital ecosystems research is opportunistic with regard to Complexity science. Some insights are useful and illuminating, but a vigilant eye needs to be kept on the assumed ontological and epistemological basis when engaging in this particular type of interdisciplinary discussion in order to avoid falling back into the trap of "mono-rail" rationalistic thinking.

The implications for the role of ICT in the information society and the knowledge economy can be viewed from different positions within this table. A similar table was proposed in 1979 by Burrell and

Morgan.[28] Their book is more focused on sociological and organisational studies, and does not address economics. Thus, their table shares the "objective-subjective" dimension of Fig. 2 but in place of the "individualistic-holistic" dimension they utilise a "regulation-conflict" dimension. At this early stage in digital ecosystem research it is fair to say that the conceptual development has so far remained largely in the "regulation" part of Burrell and Morgan's table. This, however, does not in any way imply any underlying equilibrium, or equilibrium as an ultimate aim. The association of the organismic metaphor with regulation and equilibrium was made in organisational science several decades ago but does not apply in today's broader interdisciplinary debates. Such debates have benefited from more recent insights in the physics and mathematics of dynamical systems, which are beginning to shed light on the non-linear and non-equilibrium processes that characterise biological systems.

Because the application of such a strong physical science perspective to socio-economic research is still very difficult and problematic, the rest of this paper places greater emphasis on the connections between social science and computer science, and relies on Fig. 2 as a reference disciplinary ontology. The next section presents a few representative "research case studies", all of which naturally grew out of the contact points that have been established between technological and social research in the DBE project.

6 – A few socio-economic research case studies

Markets and Hierarchies

As summarised in Table 1, the emphasis of New Institutional Economics on economic efficiency as the principal driver of organisational change explains the formation of corporate hierarchies in terms of lower transaction costs relative to what would be required by trading across a market interface.[29, 30] By the mid-Eighties a different account, associated with the new field of economic sociology and with Granovetter's work in particular, was taking shape.[31] Granovetter argued that Williamson's reliance on a Darwinian argument to explain the evolution of the firm oversimplifies the process of organisational change. This position is particularly interesting from the point of view of research in digital ecosystems because it clarifies that biological metaphors do not necessarily apply to the business ecosystem, where other dynamics may be more important. To Granovetter, the anonymous market of neo-classical economics is virtually non-existent in economic life and transactions of all kinds are rife with social connections, both inside the firm and in a market setting. He describes economic life as "embedded" in a network of social relations. Thus, Granovetter sees Williamson's notion of the market to explain economic action as "under-socialised" (very little embeddedness, or "atomised" agents), whereas his notion of the governance in the hierarchical firm appears "over-socialised" (too much embeddedness, actors constrained by social norms and roles).

An efficiency incentive is thus necessary but not sufficient for a hierarchically integrated firm to form. The work of the Digital Ecosystems cluster reinforces this view since an open-source service-oriented architecture of the information system supports the interactions between small firms and renders the efficiency argument for the formation of hierarchies less pressing. Granovetter concedes that he has looked only at proximate causes, i.e. his paper does not attempt to trace or connect the socio-structural characteristics observed to broad historical or macro-structural circumstances. The embeddedness approach is not meant to answer large-scale questions about the nature of modern society or the sources of economic and political change. However, it is seen as a necessary step to arrive at the ability to relate micro- to macro-level theories.

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[28] Burrel, G, and Morgan, G (1979). *Sociological Paradigms and Organisational Analysis*. Ashgate.
[29] Coase, R (1937). "The Nature of the Firm", *Economica*.
[30] Williamson, O (1975). *Markets and Hierarchies: Analysis and Antitrust Implications*, New York, Free Press.
[31] Granovetter, M (1985). "Economic Action and Social Structure: The Problem of Embeddedness", *American Journal of Sociology*.

Table 1. Summary of Williamson's markets vs hierarchies argument		
	Within hierarchical firm	*Across market interface*
Transaction properties	• Uncertain in outcome • Frequent recurrence	• Straightforward • Non-repetitive
Transaction-specific investments	• Bounded rationality: contingency handled by governance structure • Opportunism: mitigated and constrained by authority relations and better identification	Minimal

At the end of the paper, Granovetter points out that the importance of the embeddedness approach in explaining proximate causes of patterns of macro-level interest is demonstrated by the example of small firms. The persistence of small firms is usually explained by the need of large corporations to shift the risks of cyclical fluctuations in demand or of uncertain R&D activities. Granovetter instead holds that SMEs persist in a market setting because a dense network of social relations is overlaid on the business relations connecting such firms, and reduces pressures for integration into hierarchical structures. This view is further supported by the observation that often SMEs do not behave rationally. Their decisions often reflect what their owners want to do rather than what is economically most advantagious for the firm. Thus, efficiency arguments are not necessarily applicable in a straightforward manner. Fig. 3 shows where Granovetter's thinking fits in the map of social science.

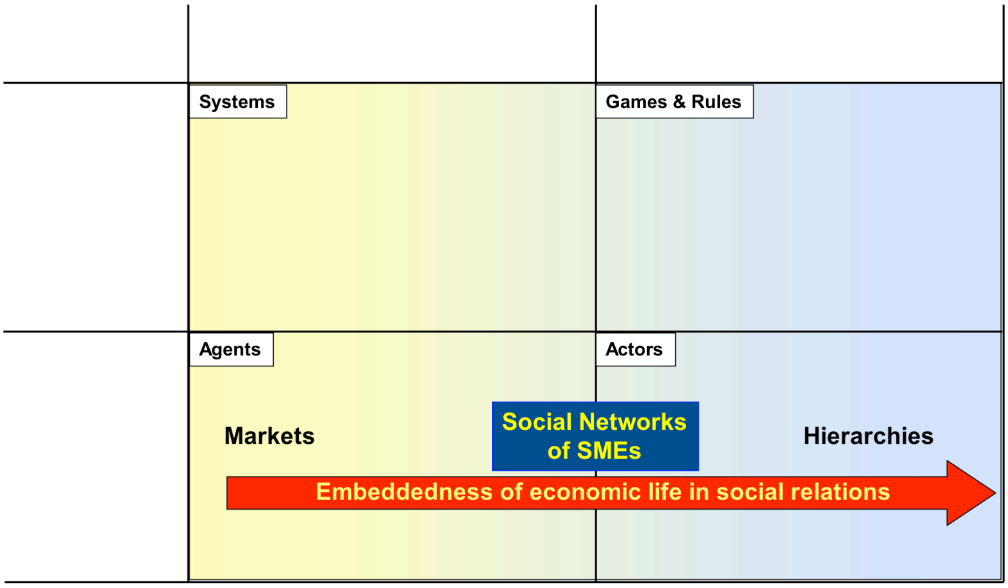

Fig 3. Positioniong Granovetter's embeddedness argument

Managing information infrastructures

Economic analysis of information infrastructures shows that large set-up costs, learning effects, coordination effects, and adaptive expectations lead to self-reinforcing processes which, in turn, cause path dependence, lock-in, and possible sub-optimal end-results.[32,33] In other words, while from a technical and managerial point of view the business is to design, build, align and control an infrastructure, the economic understanding of the dynamics of infrastructures points out that they behave like organisms with a life of their own. They are unwieldy and practically impossible to control in the idealised way envisioned by the traditional management agenda. Taking into account the human dimension of infrastructure leads to the conclusion that, rather than "managing" infrastructures,

[32] Ciborra, C, and Hanseth, O (1998). "From tool to *Gestell*: Agendas for managing the information infrastructure, *Information Technology & People*.

[33] See also the work of P A David: http://www-econ.stanford.edu/faculty/david.html

"cultivating" an installed base is a wiser and sounder strategy. Infrastructures should be built by establishing working local solutions supporting local practices which subsequently are linked together, rather than by defining universal standards and subsequently implementing them. This position is consistent with the digital ecosystems vision, which empowers regional players to define their own business ecosystem through the technical and language tools provided by and through the open-source infrastructure. Fig. 4 shows how this line of thinking fits in the map.

Interestingly, the first case study emphasises social networks over biologically-inspired efficiency arguments, whilst the second case study argues that an "organic" view of infrastructure is more effective at capturing its real character than a technocentric view. This shows how difficult it can be to generalise in either direction between the relevance or not of biological metaphors in the social sciences and in technology. The approach followed by the Digital Ecosystems research is to find the right blends of points of view, respecting the rigour of each discipline but being opportunistic about useful explanatory metaphors and models.

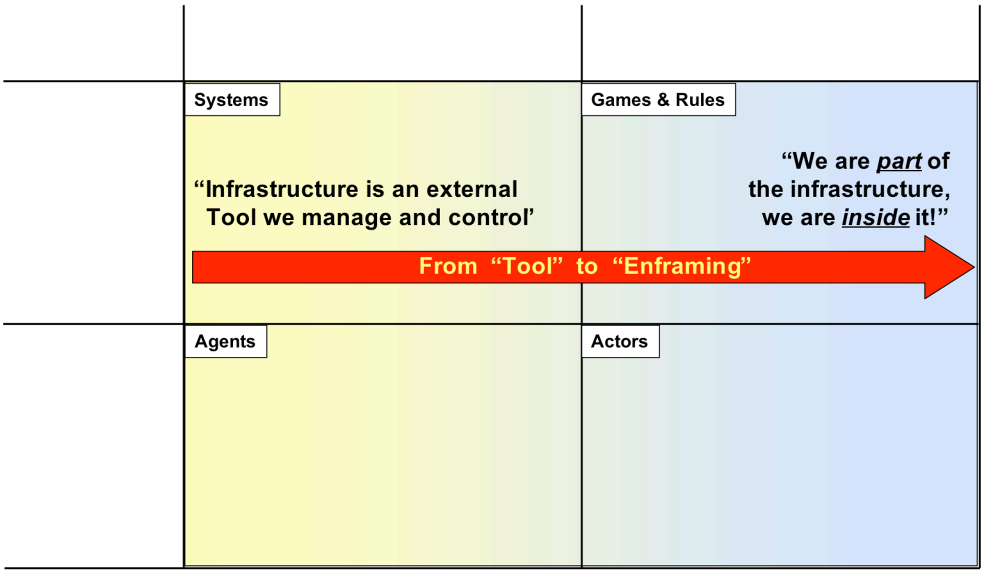

Fig. 4 Expanding the machine

The role and innovative business model of Open Source

Although Benkler's argument mentioned in the Introduction is appealing, given the significant involvement of capital, in one form or the other, in mature open-source communities it would be hard to maintain that production is entirely self-reinforcing. The idea that Free/Open Source can produce valuable commodities out of thin air is faulty. Just because people are not paid to do something does not mean that development is costless. Just because there are low transaction costs measured in the traditional sense does not mean that there are not other costs involved elsewhere.[34] Just because the source code is open and could be reused and modified does not mean that it cannot be based on alternative revenue models. At the same time, production does not stop to be self-reinforcing the minute companies get involved. So the issue is far from clear-cut and many individuals and companies around the world are looking for ways to make Open Source work in a sustainable way.

It is encouraging to note, however, that over the last 15 years we have learned several lessons from the Open Source experience. The Open Source paradigm has showed that community software projects, initially relying predominantly on networked volunteer labour motivated and organised through the value of reciprocity (the gift economy), could become sustainable and could be based on a variety of innovative revenue models. Some of these communities have evolved into new kinds of commercial

[34] Steven Weber (2000). "The Political Economy of Open Source Software," UCAIS Berkeley Roundtable on the International Economy, Working Paper Series 1011, UC Berkeley.

actors, cultivating relationships with companies and therefore becoming more intensively part of the exchange economy.[35] At the same time large and small companies are benefiting from the work of these communities and developing business models suited to the open source model. A typical example is a commercial company donating its developers' time to the GStreamer open-source toolkit and at the same time developing a proprietary streaming server based on that same toolkit. Open source software is also increasingly adopted at the regional level to boost ICT adoption and development (the case of Extremadura, Spain, and its LinEx distribution[36]). These considerations are another example of the intertwining of economic and sociological aspects of ICTs, which appears to apply well beyond the debate of Open Source vs. IPR. A challenge for FP7 research can therefore be phrased as follows: "Can we develop a socio-technical infrastructure and a policy framework that integrates the interests and models of organisation of all these different actors in a more cohesive way than is currently being done?"

Digital Ecosystems as the new industrial districts: Globalisation, delocalisation, and diversity

Industrial districts of 50-100 years ago brought together similar and complementary industries and became the engines of regional economic growth. Tacit and explicit knowledge was embedded in the firms and in the business and social networks, leading to self-reinforcing network effects. ICTs promise to provide a similar repository of knowledge that supports economic growth and social development, but they must be able to capture, formalise and retain knowledge so that it can remain a public good at the sectoral and regional level, promoting a public common infrastructure. Open-source digital ecosystems provide such a public good in the form of an adaptive environment that retains and redistributes the knowledge formalised by its users, a form of public accumulation of human capital embedded in the digital ecosystem.

This formalisation process is far from straightforward due to the difficulties entailed in capturing tacit knowledge.[37] Digital ecosystems address this challenging issue at both a technical and a human level. Their adaptive and evolutionary nature will, for example, enable the formation of clusters of shared business models, while their status of "digital commons" will add to the incentive to rely on the technology and make it work for them. Because the formalised knowledge is accumulated within the ecosystem and, due to the structure of cooperating SME networks, the tacit knowledge and the human capital are dispersed among the SMEs of a region, digital business ecosystems cannot be moved or shut down the same way as a manufacturing plant can simply because another part of the world offers lower labour costs. Their distributed architecture makes them resilient and scalable, so they will grow with the regional and sectoral economies they support.

The issue of delocalisation touches on a range of concerns associated with the "Fortress Europe" question. There are two sides of the debate. One says that we should resist the forces of globalisation even if it means losing competitive edge; the other is consistent with a market philosophy of facilitating flexibility through applying fewer constraints. On this point, the issue of delocalisation is seen in terms of "can't stem the tide". An approach that digital ecosystems could utilise is to find something that regions can put on the world stage, a regional focus, attached to natural resources, born of situation. Thus, rather than relying on regulation and tariffs to control globalisation, it is wiser to create the structural conditions to support production in the regions, acknowledging the key role of the knowledge embedded in the regions and integrating SME business concepts with ICT solutions. The key is diversity. Standards can travel round the world, but if something can be explicitly rooted at the regional level—for example, food, art, the natural environment—it will tie economic development to the region.

[35] O'Mahony, Clare Siobhan (2002). "The Emergence of a New Commercial Actor: Community Managed Software Projects." Doctorate Thesis, Stanford University,

[36] http://www.linex.org/linex2/linex/ingles/index_ing.html

[37] Steinmueller, E W (2000). 'Will New Information and Communication Technologies Improve the 'Codification' of Knowledge?' *Industrial and Corporate Change* 9 (2): 361-376.

Ultimately the digital ecosystem community is charged with the task of drawing together research questions and outputs relating to each of the issues outlined in this paper. Whilst it is important to keep sight of open questions and realise that some research questions can never be fully answered, in the final analysis, outputs have to be operationalised. It is not only scientific and technical outputs that have been operationalised, social science outputs have been instrumental in carrying out the digital ecosystem engagement strategy, formulating the knowledge platform and constructing a knowledge base of the regulatory framework. With respect to contributions originating from natural science, the following section describes a core breakthrough that represents a key research outcome as well as an operational success that draws a common thread through a variety of subject disciplines and finds its expression in the technical architecture of the ecosystem itself.

7 – Formalisation of knowledge: a practical bridge between the disciplines?

The role of biology

The pervasiveness of biological metaphors present in digital ecosystems discussions gives us pause. It is not clear to what extent biological metaphors apply to the envisioned behaviour of software, and to what extent they might apply to the "business ecosystem". This opens two areas of interdisciplinary research that should be further investigated:

1- the interface between socio-economic systems and ICTs, as already stated
2- the interface between computer science and biology

The implication that is beginning to take shape is that whereas it may be possible to find some direct correspondences between the structure and dynamics of biological systems and information systems, the relevance of biology to socio-economic systems may best be left at the level of metaphor for the time being. Fig. 5 shows how we can shift our focus from disciplinary to interdisciplinary research questions.

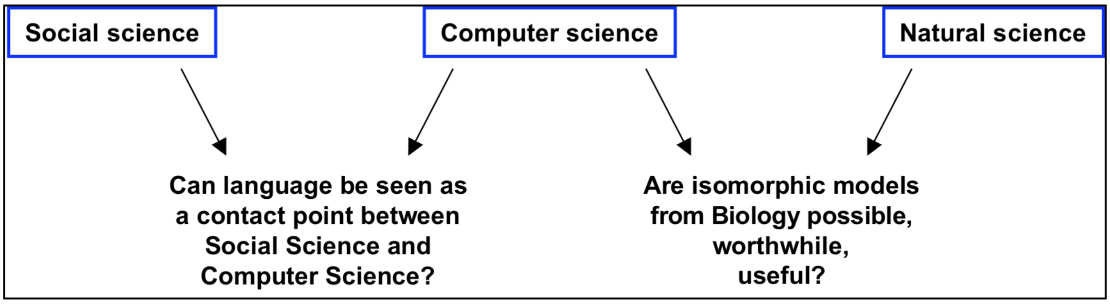

Fig. 5 Interdisciplinary research questions

The fundamental dichotomy of digital ecosystems

An important aspect of interdisciplinary dialogues within the digital ecosystem community has been accepting that no single theory, philosophy, language or model is capable of drawing together all of the elements required by an ecosystem. Accepting this, there is nonetheless an opportunity to formulate a theory of digital ecosystem that is capable of drawing together and operationalising key ecosystem characteristics without remaining tied to typical institutional or disciplinary topics or theoretical boundaries. Emerging are some important lines of enquiry that aim both to express and operationalise key characteristics of a digital business ecosystem.

The bottom-up story: Behaviour
On the one hand, digital ecosystems are dynamic and adaptive. Their infrastructural components and the software services they support embody memory mechanisms[38] that translate into an ability to learn and self-organise in a P2P environment. The scale-free nature of P2P networks makes search and discovery of services by broadcasts possible over the Internet, which is not a broadcast medium. The dynamic topology and finite memory of the network layer has enabled the definition of a distributed evolutionary environment that supports the formation of niches according to business domains, industry sectors, and value spaces. The adaptive combination and aggregation of services to respond or even anticipate user requests is therefore an active area of research in FP6 but it is likely to benefit from additional research activities under FP7.

The top-down story: Symbols
On the other hand, the matching of a service request with a service offering, the evaluation of the fitness of a service or a service chain and, most importantly, the definition and creation of software services all require the description of these "digital species" by some kind of formal language. Whereas the run-time behaviour of a digital ecosystem is well served by dynamic, bottom-up architectural principles, the *population* of the ecosystem itself necessitates a symbolic interface to the human users that enables the formalisation of business knowledge and the expression of business requests. The DBE project, which is building a first rudimental implementation of the digital ecosystem infrastructure, has adopted the Object Management Group's Model Driven Architecture framework to rationalise the development of business modelling and service description languages as the first step in the creation and implementation of services.[39]

The top-down creation of services and their bottom-up optimisation represent two opposing perspectives on the development of software technology as long as we remain within a rationalist frame of mind, as shown in Table 2. To see how these two accounts can be reconciled we must step out of the box, as we now set out to do.

Table 2. The fundamental dichotomy of digital ecosystems[40]

	Evolutionary Biology	*Cognitive Science*
Symbols	NEO-DARWINISM GENETIC DETERMINISM[41]	COGNITIVISM
Behaviour	AUTOPOIESIS	CONNECTIONISM EMERGENT SYSTEMS

The power of communication

Computers are abstract machines that function at the boundary between the world of objects and the world of people. They can, accordingly, be understood from both points of view. By far the overriding interpretation since their invention 60 years ago has been as computing machines. Similarly, the default position relative to the optimisation of a company or a business process is to treat them as

[38] A simple example of such a mechanism is the proxy-based service architecture first pioneerd by Sun Microsystems in its development of Jini (http://www.sun.com/software/jini/). Under FP5 funding this approach was extended to the Internet with the development of FADA (http://fada.jini.org/). The DBE Project has built its non-persistent storage layer on top of FADA. The fact that everything is based on a variable lease time (time-to-live) means that the run-time environment continually adapts to the users, on a range of time scales.
[39] www.omg.org/mda
[40] This table is adapted from: Varela, F, Thomson, E, and Rosch, E, (1991). *The Embodied Mind: Cognitive Science and Human Experience*, MIT Press, Cambridge, Massachussetts.
[41] Discussed in Dawkins, R (1989). *The Selfish Gene*, 2nd Ed, Oxford.

machines and as processes carried out by machines, respectively. In 1987 Winograd and Flores[42] opened up the other half of what computers are about: from the point of view of the users computers are about communication, not computation. This realisation has by now become commonplace and in fact provided the initial motivation for CRM, SRM and ERP systems. If, however, we focus on communications as *data*, we fall back into the problems of managing information infrastructures discussed above. When looking at the world from within a rationalist frame of mind, we must make a conscious effort to include the users of the technology as part of the "organism"—i.e. meaning a more complex form of "system". From the point of view of the users, on the other hand, communications are primarily about the coordination of commitments to act.[43] The human perspective of information technology thus highlighted their connection to the philosophy of language, and in particular to the constitutive power of language to mediate the construction of reality understood through an intersubjective social process.

Once we realise that organisations can be understood also as networks of commitments, it becomes easier to see how ICTs can catalyse the formation of social structures. But if social structures to a large extent define our world and ourselves, then language can be seen to carry a subtle but far-reaching power or self-determination for social groups. Digital ecosystems research is also about connecting communities of users to this constructive power. Shared and open knowledge, of which Open Source is a subset, encourages the creation of the instruments of expression, formalisation of knowledge, and communication of commitments because it enables their ownership by the users as a public good. The fact that this pivotal role of knowledge sharing is just starting to be regarded as a form of local accumulation of human capital leading to growth[44] justifies a significant research effort in FP7 to investigate new business and economic models based on Open Source and knowledge sharing.

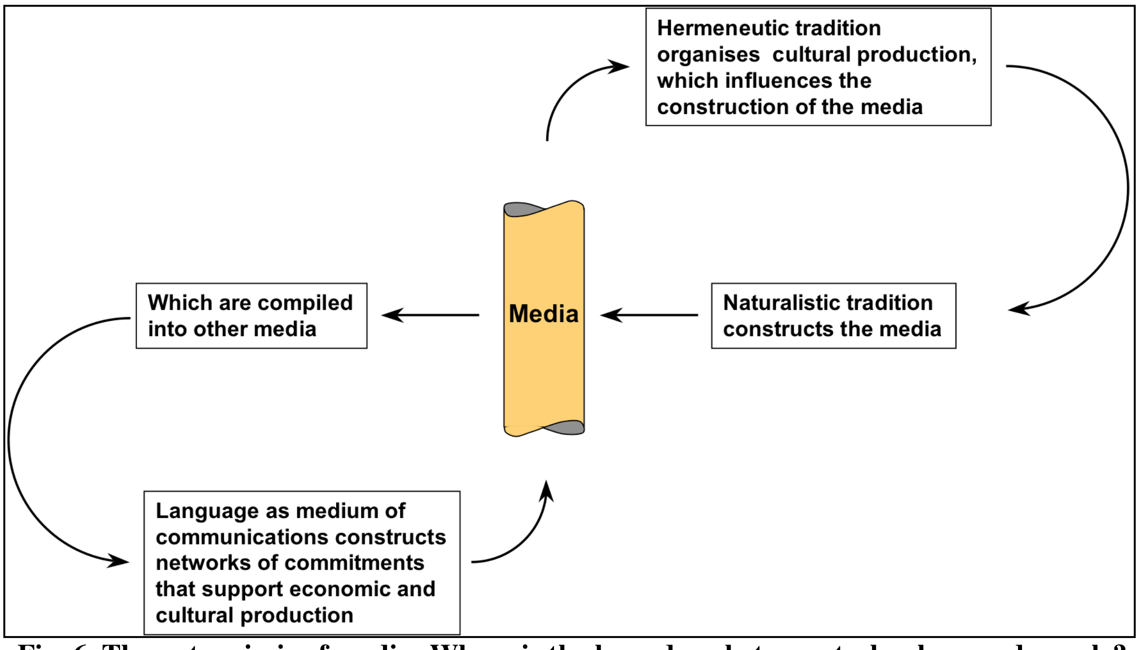

Fig. 6 The autopoiesis of media: Where is the boundary between technology and people?

As hinted in Fig. 6, there is a huge amount of work to be done to understand how these socio-economic processes work, the role of technology (is it value-neutral?[45]), the formation of identity, the dynamics of regional development, and the conditions for sustainability. As long as we can communicate across disciplinary boundaries we can construct new areas of collaborative research that

[42] Winograd, T, and Flores, F (1987). *Understanding Computers and Cognition*, Addison-Wesley.

[43] Flores, F (1998). "Information technology and the institution of identity", *Information Technology and People*, Vol 11, No 4, pp 351-372.

[44] Sen Amartya (2005) "La retorica dello sviluppo lacrime e sangue" *Lettera Internazionale,* June.

[45] Feenberg, A (1991). *Critical Theory of Technology*, Oxford.

are closely coupled to technology that people will use. From this perspective, the model-driven software engineering development process, generally referred to as top-down when focusing on the technology, can begin to look like the source of the bottom-up formation of the knowledge economy.

Cooperation and competition in open-source digital ecosystems

As long as we accept that the interaction between ICTs and society is circular and iterative we can begin building something with an open mind. Research efforts in FP7 should focus on supporting a framework that can advance Europe toward the Lisbon objectives. Thus, we need to empower SMEs to construct *their own* knowledge economy. We must give them *their own* language tools as one important component of the resources needed to achieve this. We must enable them to use *their own* problem solutions and *their own* networks to build trust. A framework that has been advanced by the OMG's Business Enterprise Integration Domain Task Force seems appropriate as an explanatory case study and as a starting point for the formalisation of knowledge based on language. It consists of the definition of a framework for the generation of models and meta-models, under the heading of Semantics of Business Vocabularies and Business Rules, or SBVR.[46] An attractive feature of this approach is that it intrinsically supports the transposition of models between different human languages, since the business concepts and rules are defined at a meta-level that can be instantiated into any human language for which an SBVR vocabulary has been constructed. Fig. 7 shows how such a framework could be usefully harnessed by the digital ecosystems approach. The most important aspect of this figure is that it shows how cooperation, at the bottom of the figure, gradually turns into competition at the top in a manner that is economically sustainable for the SMEs. A pressing question that is receiving a lot of attention and that warrants further research activities in FP7 is how to make the Open Source block at the bottom economically sustainable.

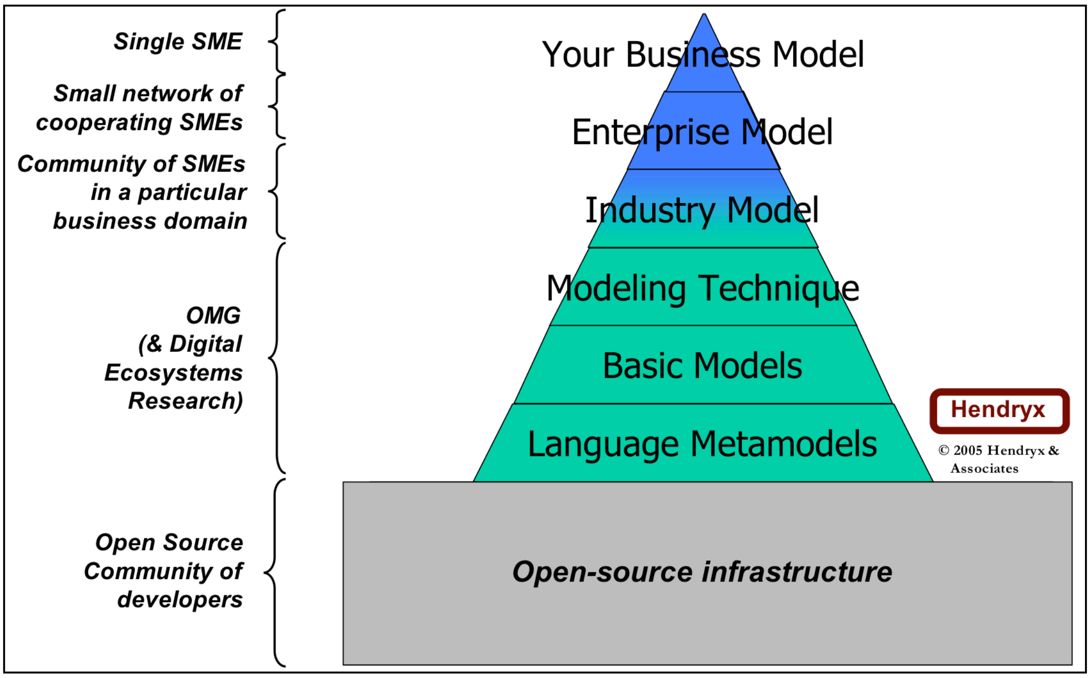

Fig. 7 Balancing cooperation and competition

The following points should be mentioned about the pyramid approach to semantic integration:

- Existence of basic, industry, and enterprise models will enable individual SME models to be independently and asynchronously developed and still have good prospects for interoperability with other models developed earlier or later.

[46] http://www.omg.org/docs/br/03-11-01.pdf

- Existence of basic, industry, and enterprise models will significantly reduce the cost of creating an SME model, since many concepts in a typical SME model are expected to be adopted from models lower down in the pyramid.
- Semantic integration is a social issue first, then a technical issue. Semantic integration is about aligning people's minds on the concepts they need to share for effective communication to happen. Representing the shared concepts in a technical formalism enables such communication to occur at a distance, over a telecommunication network and with the involvement of information systems.
- Models lower in the pyramid are expected to be more stable. Models higher in the pyramid are expected to be more volatile. The more widely shared and stable a model, the more necessary and appropriate is government support of its development. Necessary because individual SMEs do not, in general, have the ability or interest to create them and promulgate them. Appropriate because they are widely used by the public for the public good.
- An architecture of models is needed to inform orderly development and integration of all of the models in the pyramid. The Architecture of Business Modeling paper cited above is a start toward this end, but much more work is needed. This should be a priority research topic in FP7.

Semantic integration of SME models is critical to the success of the digital ecosystem approach. FP7 support is needed for more than just the Open-source infrastructure. It is needed also for most of the items below the Single SME level. Existence of robust Basic Models is essential to effective semantic integration of SME models at the Enterprise, Industry, or global level. Pursuant to this, a recommended FP7 activity is creation of Basic Models, which can be shared and reused by many domains and individual SME business models. Some work on Basic Models is being done by the OMG, but not all; FP7 support is needed to complete the work. FP7 activities also need to support creation of certain Industry Models and Enterprise Models. Source material is available for much of this vocabulary work at the industry level; it does not need to start from scratch, but should build on standardization work of industry associations. What is needed is to capture and formalize these vocabularies in SBVR, so they can be reused in SME models

8 – The digital ecosystem infrastructure

Digital ecosystems rely on a technological infrastructure to mediate the formalisation of knowledge in SME networks, the creation of software services, and the B2B interactions between the SMEs. The DBE project has begun to define and develop the first rudimental instance of this infrastructure. Much remains to be done to make it gradually evolve towards a more intelligent digital ecosystem. At the natural science end of the spectrum of theoretical understandings of digital ecosystems, this infrastructure should enable digital business ecosystems to exhibit the behaviour of autopoietic systems by 2010.

Fig. 8 highlights the modularisation and composability of the software, which can be understood as a structural requirement to enable the software environment to "track" the changes in business models driven by the market and by the SMEs while remaining compatible with the legacy systems. The vision of service composition shown in this figure can only be realised through a sophisticated infrastructure for the construction, operation, and optimisation of the digital ecosystem. These functions are provided by the Service Factory (SF), the Execution Environment (ExE), and the Evolutionary Environment (EvE), respectively. The best economic model is not as straightforward to identify, as discussed in previous sections, and may vary between regions or industry sectors. The starting point of the philosophy of digital ecosystems, however, is to make the SMEs the owners of the tools with which they will build, operate, and optimise their ecosystems. This is why the infrastructure must be open-source. The services that run on top may then be open-source or may follow more traditional licensing models.

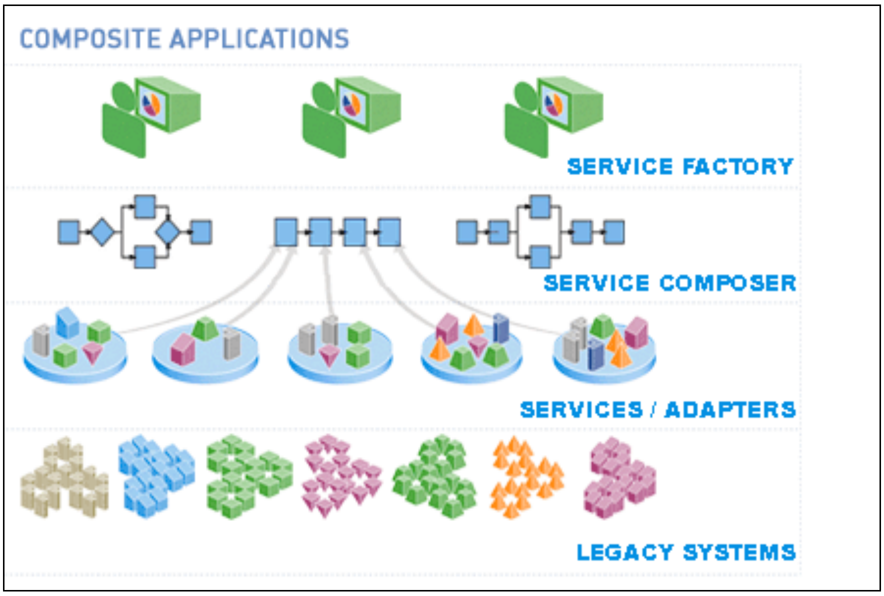

Fig. 8 Digital ecosystems as an environment for dynamic service composition

The Service Factory

The Service Factory (SF) groups several functional components such as the DBE Studio, the distributed Model Repository, the Service Composer, and the Testing Environment. Fig. 9 shows a high-level view of the software creation process starting from business and service models expressed in languages such as SBVR. Research areas that have just begun to be addressed in the Service Factory and that need further work are:

Business networking tools: active editing tools for supporting business interactions and the formation of business networks. The user must perceive an immediate benefit in their utilisation. The main purpose of such tools is to capture quickly the business networks pertinent to a provider or a consumer. Much attention will need to be paid to privacy and sensitive data. Besides the networking tools the SMEs will continue to ask for "the human interface" so coaching them into using networking technologies is essential.[47] Such tools must be based on a formal modelling platform that supports:

- Search for partners, clients, providers
- Management of provider-consumer contracts and business agreements
- Publication of business offer, search and identification of competitors
- Web publication of searchable content
- Definition and management of business processes

Business modelling tools: tools that enable the definition and description of business and service models at a more detailed level than above, in a manner that is semantically rich and does not require knowledge and skills extraneous to the business users. The description of a business offer must be expressible in natural language but must also be computable. It must support the search for customers and business partners but must also be searchable in order to support intelligent discovery. In short:

- Modelling languages for analysis and monitoring queries
- Business language meta-models
- Natural language editor

Decentralised persistence mechanisms. A distributed, decentralised, and P2P knowledge base architecture needs to be developed to allow the storage and retrieval of models through mechanisms that are owned by everyone and cannot be controlled by any one actor. Knowledge must be shared and accessible by all. Distributed tuple-spaces are encouraging examples of the

[47] UEAPME

technologies that are likely to be required, supported by a redundant P2P network and associative memory mechanisms to enable content searching.

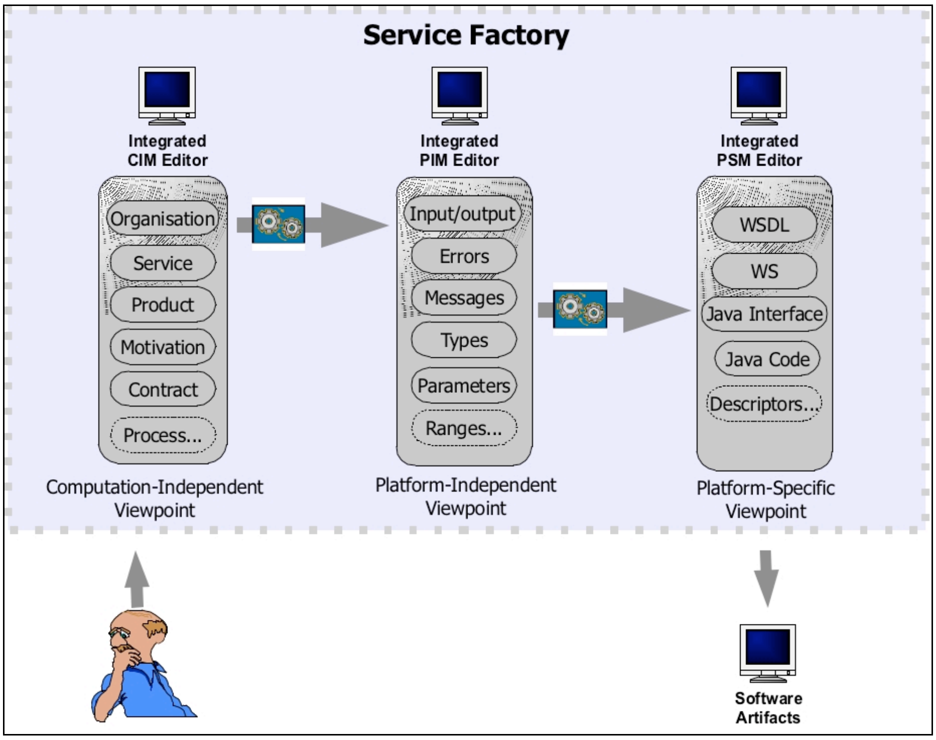

Fig. 9 Schematic of Service Factory generation process

Monitoring and visualisation tools. It is very important to be able to assess and visualise the business environment according to different criteria such as industry sectors, geographical reach, number of partners, turnover, capitalisation, etc. Much of this information is already public but not easily accessible by small players who cannot afford to pay for expensive market analyses. Other uses of such graphical maps[48] are for real-time monitoring of business activity ("taking the pulse of the ecosystem"). Such research efforts will need to coordinate closely with issues of privacy and with the security architecture.

The Service Manifest as formalised knowledge

The link between the SF and the ExE is provided by the Service Manifest (SM), a searchable container of the "DNA" of a service. The Service Manifest holds the CIM and PIM models of a service, the data that identifies the service provider, the usage history of the service, a reference to the proxy type (which can then access the remote implementation of the service), and a deployment descriptor. Since it contains business models that are readable both by humans and by computers it represents the "hinge" that formalises the knowledge created in the ecosystem and connects its human to its technical parts. While the CIM and PIM models are held in the distributed Model Repository, once they become associated with an implementation and a provider in the SM they are held in the distributed Semantic Registry. Together, the Model Repository and the Semantic Registry represent the long-term memory of the ecosystem, one of the learning and adaptation mechanism through which the ecosystem as a whole evolves to fit the needs of its users.

FP7 research should be used to develop further the concept of the Service Manifest to incorporate the fundamental principles of digital ecosystems. For example, the information contained in the SM should be open, public and royalty-free. It should be compatible with the governance and regulatory aspects of the ecosystems, for example references to appropriate decentralised Certification Authorities, elements of the contract appropriate for the consumption of the service it represents,

[48] See for example http://mappa.mundi.net

security signature, license, etc. A more ambitious and longer-term vision might be to incorporate a PKI-like data structure that can be recognised by a distributed security framework inspired to the immune system, complete with antigens.

The Execution Environment

The Execution Environment (ExE) is a P2P platform that allows the sharing of services and data between companies, in the same way that popular P2P platforms allow the sharing of files between people. In this way we are opening the digital door to the SMEs and facilitating the realisation of the Digital Ecosystem metaphor. The ExE makes distributed computing easily accessible to the SMEs through a Client/Server approach that makes the users believe that all the DBE Services are deployed locally in their own systems. In addition, the complexity of distributed computing is hidden in the ExE, which is in charge of all the complex issues such as Remote Programming, Remote Data Access, Communication, and Security.

The ExE is a decentralised and modularised run-time environment whose main initial actors in the first rudimental digital ecosystem infrastructure are:

- the SERVENT (SERVer + cliENT) "DBE virtual machine" deployed on an SME's computer that enables the consumption of services by acting either as local client or as remote server
- the distributed Semantic Registry, which holds the Service Manifests and is accessed by the Recommender and by the Evolutionary Environment to respond to user requests.
- a scale-free network of proxy servers based on FADA,[49] an open-source and free implementation of Jini for the Internet that was developed under the FP5 project FETISH.

The lease-based architecture of Jini, which was extended and applied to every aspect of the DBE, renders the infrastructure intrinsically adaptable to changes in the environment, and the services more reliable, since only the services that are actually available will be visible. Fig. 10 shows a high-level view of the ExE.

This new vision of computing as an ecosystem, instead of just a system, poses new research challenges for FP7, in particular in the following areas:

Data Management beyond the centralised system approach: Research in the area of data sharing and the use of advanced caching technologies to enable a user-centric vision, where the data are related to the user and automatically adapt their distribution to user habits and devices. The information is not in the components of the network, but in the network itself. In other words, the information contained in the nodes is negligible, what is relevant is how the network is connected because it contains information regarding usage, and the ontology associated to such usage. Change the computing paradigm from a classical approach in which the information arises at the edge of the network, is processed and stored in the centre of the network, and is then sent back to the edge for its consumption, to a model in which the information is generated, processed, and consumed at the edge of the network (although it is still universally accessible).[50]

Loosely coupled trust and security mechanisms are crucial for enabling the dynamic cooperation among SMEs and should be provided as infrastructural components. In the initial implementations of the ecosystem, they are based on reputation and reinforced learning. Looking for real-world models based on dynamic interactions and the history of the actors.

Robustness vs Completeness: Research on robust algorithms that can deal with incomplete data, as in the real world where decisions are taken always based on incomplete information. In other words, research on the implications of having access to an incomplete network (95%) but with high availability and very good look-up time. In this area there is a need of research in network

[49] www.sourceforge.net/projects/fada
[50] Lessig, L (1999). *Code and Other Laws of Cyberspace*, Basic Books, New York.

topologies, specially in scale-free networks and their unique characteristics in terms of scalability and resilience.

Fractal Software model: The software development model has reached its limits in its ability to manage complexity. The effort needed to deploy complex systems is growing exponentially, and the cost of ownership of such systems leaves out of the game most SMEs. To cope with the increasing complexity of software and keep it manageable a new approach in the design of distributed software systems is needed, which could be dubbed "fractal" since the properties of the components must remain invariant with the growth of the software in size and complexity. This approach is based on principles of re-organization and self-organization of the components beyond the original idea of the designer, similarly to how genetic algorithms can generate new information and new solutions.

Network Complexity & Reusability: Research in the area of distributed computing and network complexity and in the scalability of new networking approaches under the new paradigms based on looking at the internal structure of the network as a scale-free network and the data distributed in the nodes of such network. Identify simple behavioural rules (the real software rules) based on which all complexity emerges.

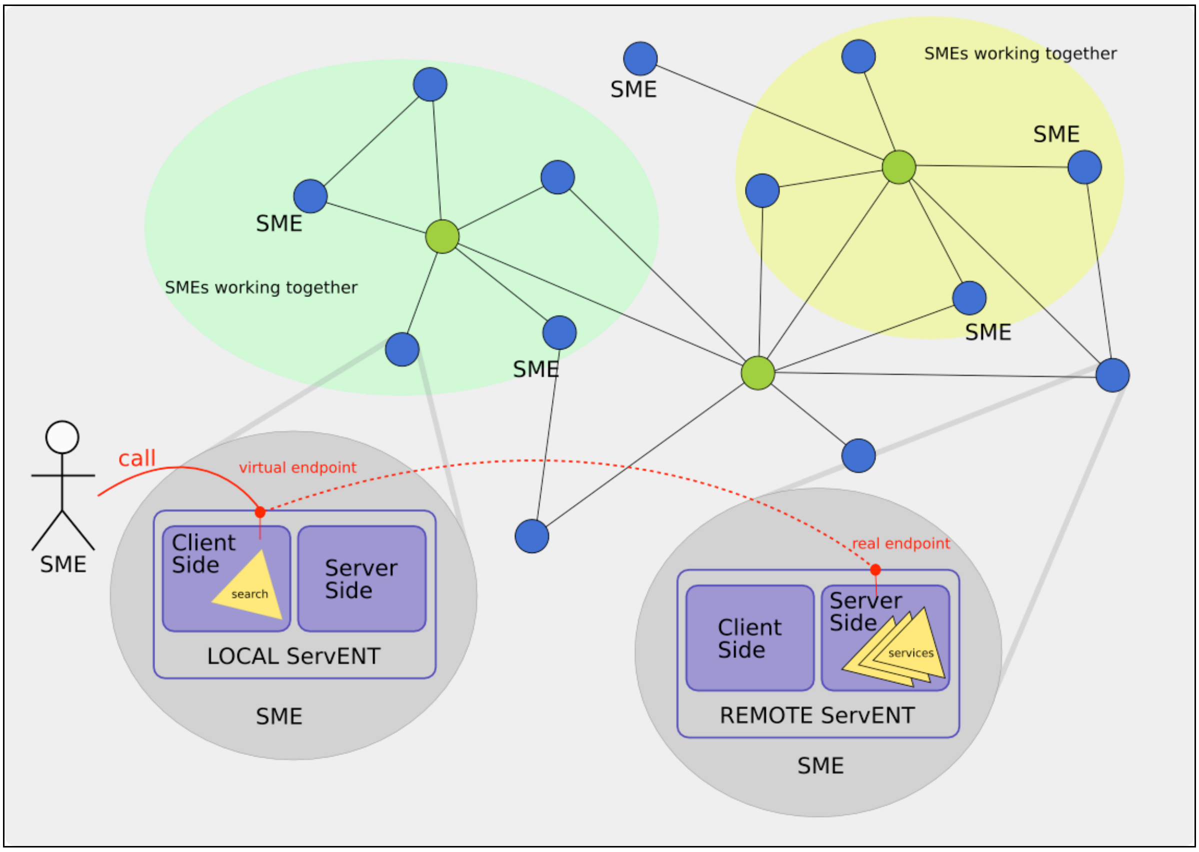

Fig. 10 Schematic of the ExE (SERVENT = SERVer + cliENT)

<u>The Evolutionary Environment</u>

The distributed digital ecosystem Evolutionary Environment (EvE) relies on the dynamic memory mechanisms of the ExE to support service migration, cluster formation according to business domains and industry sectors, the search and discovery of optimal services in response to user requests, and the optimisation of service chains. The EvE relies on genetic algorithms and on a flexible and very general fitness function framework to evaluate the "fitness" of the services relative to user profiles and user requests. This enables the long-time self-organisation and self-optimisation of digital ecosystems around the needs of their users, enabling them to respond more quickly to changing market conditions and implicitly providing market and business intelligence.

Fig. 11 shows how a digital ecosystem can be visualised as a network of “habitats” where each habitat is a local environment running on an SME’s computer (essentially inside the SERVENT) and optimising the match between that SME’s business requests and the service offerings available in the ecosystem. Short and long-term memory mechanisms allow the formation of clusters of SMEs that have similar or complementary needs, thereby accelerating the evolution of optimum service compositions

The long-time scale adaptation and short-time scale response of the system to user needs will continue to pose research challenges in FP7, in particular in the following areas:

Semantic matching of service offers with requests and in the composition of complex services from atomic services

Integration of distributed intelligence and learning behaviour with the evolutionary algorithms to speed up the optimisation processes (“set-cover problem”)

Application of evolutionary algorithms to the evolution of the languages and vocabularies that underpin business rules, business models, and the regulatory framework

Extension of automata theory and xUML toward context-sensitive formal languages, DNA, and non-linear dynamical systems to achieve context-sensitive code generation from models

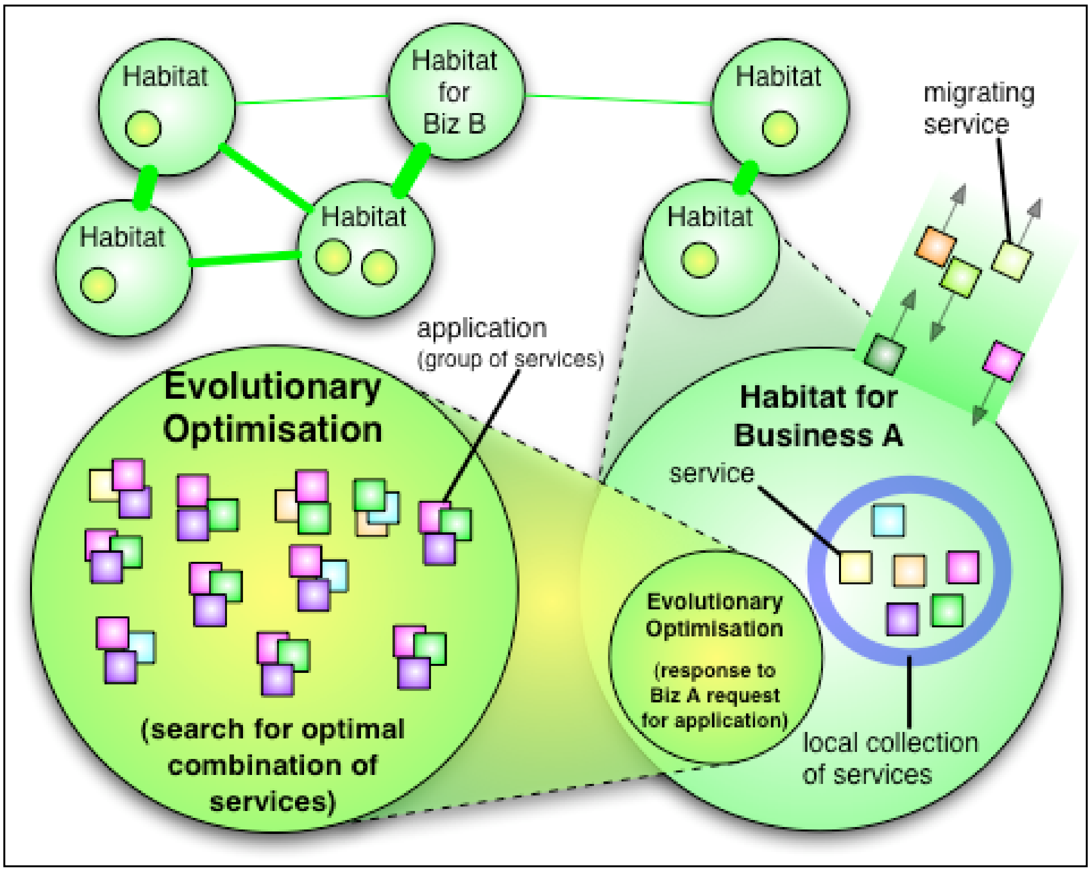

Fig. 11 The Evolutionary Environment as a network of Habitats

9 – Conclusion

This paper has discussed the EC policy background and objectives in the context of the overriding presence of SMEs in the European economy, has reviewed past attempts at reaching these objectives through Framework Programme research, and has highlighted the gains to be accreud by following a more aggressive research policy of interdisciplinarity between sciences and between science and business. The paper then acknowledged the profound cultural, methodological, and philosophical obstacles that need to be overcome for technologists and social scientists to work together in a manner that is both mutually compatible and productive in advancing Europe toward the Lisbon objectives, and indicated how the FP6 Integrated Projects are an encouraging first step in the right direction. Some of the outputs of recent workshops and of currently funded projects in the Digital Ecosystems Cluster of the ICT for Enterprise Networking Unit were then leveraged to argue that the digital ecosystem vision offers a very promising approach for empowering SMEs to construct their own sustainable regional business ecosystems. The role of language was emphasised and, in particular, new business modelling tools based on natural language such as SBVR promise to provide SMEs with the ability to formalise their regional business knowledge, to discover business partners, and to conduct transactions entirely within an electronic virtual environment of e-Business that they will have the instruments to construct in both a technical and a social sense. The role of Open Source in building a digital ecosystem infrastructure supporting this process is absolutely fundamental because it lowers the activation threshold of a virtuous circle of self-determination. This highlights the need for further research to understand better the opportunities for constructive interaction between the gift economy and the exchange economy. In this sense the digital ecosystem initiative, with its focus on SMEs and regional development, is parallel to and complements the Software/GRID ETP initiatives.

Out of this vision are emerging the key research areas, as shown in Fig. 12, needed for building a digital ecosystem infrastructure for the European knowledge economy of 2010 and beyond. An important finding of current digital ecosystem research is that the same business models and regulatory framework can play a dual role as the semantics of the software services, to facilitate the use of ICTs by human users, and as the "syntax" of socio-economic behaviour at the regional scale. In this manner the formalisation of knowledge will serve as a hinge between information technology and the knowledge economy.

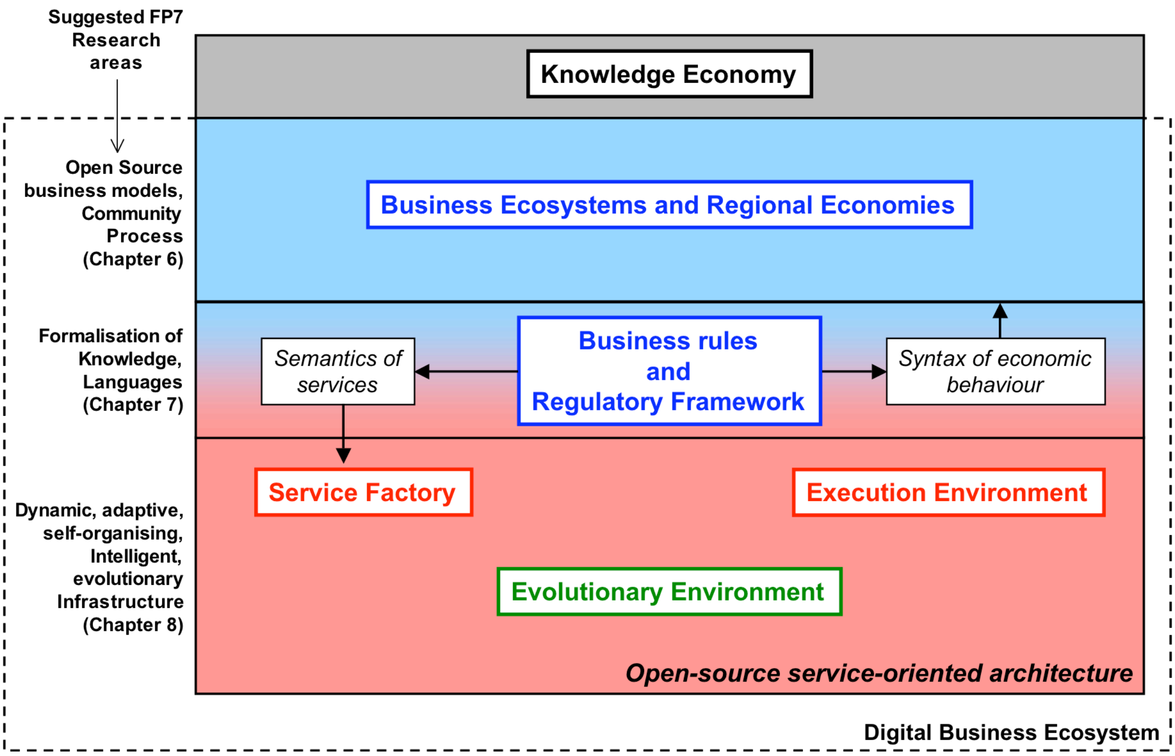

Fig. 12 An architecture for the Knowledge Economy

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