Future Internet Enterprise Systems (FInES)

Research Roadmap

FINAL REPORT

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An application research domain of the ICT RTD Programme of the European Union

The written contributions and comments received in relation to the previous and this version of the Research Roadmap have been summarised. That summary and the specific observations from the editors are provided in the Annexes to this version of the Roadmap.

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The recommendations and opinions expressed in this document are those of the Task Force and contributors, and do not necessarily represent those of the European Commission.
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2.0	Second version for distribution to the FInES Cluster, focusing on Introduction, Chapters 1 - 4	15-02-2010
3.0B	Full draft version including the Chapter 5 and 6, and revised previous chapters (Annexes to be added)	02-06-2010
3.0	Full draft version with revised bibliography	25-06-2010
4.0	Final Report	29-07-2010

All public versions of this document are available at

http://cordis.europa.eu/fp7/ict/enet/documents/task-forces/research-roadmap/fines-researchroadmap.pdf

Key References of FInES Cluster

FInES Cluster Projects
http://cordis.europa.eu/fp7/ict/enet/ei-projects_en.html

FInES Cluster Position Paper
http://cordis.europa.eu/fp7/ict/enet/fines-positionpaper_en.html

Enterprise Interoperability Research Roadmap
http://cordis.europa.eu/fp7/ict/enet/ei-research-roadmap_en.html

Value Proposition for Enterprise Interoperability Report
http://cordis.europa.eu/fp7/ict/enet/ei-isg_en.html

FP7 ICT Work Programme 2009-2010 (Objective 1.3)
ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/ict-wp-2009-10_en.pdf

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Acronyms

AI	**A**rtificial **I**ntelligence
ANTIPHISH	**Anti**cipatory learning for reliable **Phish**ing prevention
API	**A**pplication **P**rogramming **I**nterface
ASTAR	**A**dvanced **S**emantic **T**echnologies for **A**nnotating digital **R**esources
ATHENA	**A**dvanced **T**echnologies for interoperability of **H**eterogeneous **E**nterprise **N**etworks and their **A**pplications
BP	**B**usiness **P**rocess
BPAL	**B**usiness **P**rocess **A**bstract modeling **L**anguage
BRIDGE	**B**uilding **R**adio Frequency **Id**entification for the **G**lobal **E**nvironment
CAD	**C**omputer-**A**ided **D**esign
CAM	**C**omputer-**A**ided **M**anufacturing
CNR-IASI	**C**onsiglio **N**azionale delle **R**icerche – **I**stituto di **A**nalisi dei Sistemi ed **I**nformatica
COIN	Enterprise **Co**llaboration & **In**teroperability
COMMIUS	**Comm**unity-based **I**nteroperability **U**tility for **S**MEs
ConDec	**Con**straint modeling in **Dec**larative form
CPFR	**C**ollaborative **P**lanning, **F**orecasting, and **R**eplenishment
CPU	**C**entral **P**rocessing **U**nit
CRM	**C**ustomer **R**elationship **M**anagement
CSR	**C**orporate **S**ocial **R**esponsibility
DB	**D**ata**b**ase
DEN4DEK	**D**igital **E**cosystems **N**etwork of regions for (**4**) **D**iss**E**mination and **K**nowledge Deployment
DFKI	**D**eutsches **F**orschungszentrum für **K**ünstliche **I**ntelligenz
DNA	**D**eoxyribo**n**ucleic **A**cid
EFQM	**E**uropean **F**oundation for **Q**uality **M**anagement
EPC	**E**lectronic **P**roduct **C**ode
ERP	**E**nterprise **R**esource **P**lanning
ES	**E**nterprise **S**ystem
ESA	**E**nterprise **S**oftware **A**pplications
ESB	**E**nterprise **S**ervice **B**us
EU	**E**uropean **U**nion
FET	**F**uture and **E**merging **T**echnologies
FIAT	**F**abbrica **I**taliana **A**utomobili **T**orino
FInES	**F**uture /nternet **En**terprise **S**ystems

FOT	**F**ederated, **O**pen and **T**rusted platform
GDSN	**G**lobal **D**ata **S**ynchronization **N**etwork
GRC	**G**overnance, **R**isk Management, and **C**ompliance
HR	**H**uman **R**esources
HTTP	**H**yper**t**ext **T**ransfer **P**rotocol
HUMABIO	**Hu**man **M**onitoring and **A**uthentication using **B**iodynamic **I**ndicators and behavi**o**ral analysis
IaaS	**I**nfrastructure **a**s **a** **S**ervice
IBM	**I**nternational **B**usiness **M**achines
ICT	**I**nformation and **C**ommunication **T**echnologies
INTEL	**Int**egrated **El**ectronics
Interop-VLab	International **V**irtual **Lab**oratory for Enterprise **Interop**erability
IoK	**I**nternet **o**f **K**nowledge
IoT	**I**nternet **o**f **T**hings
IPR	**I**ntellectual **P**roperty **R**ights
IPv6	**I**nternet **P**rotocol **V**ersion **6**
IST	**I**nformation **S**ociety **T**echnologies
ISU	**I**nteroperability **S**ervice **U**tility
i-SURF	An **I**nteroperability **S**ervice **U**tility for Collaborative Supply Chain Planning across Multiple Domains Supported by **RF**ID Devices
IT	**I**nformation **T**echnology
KMS	**K**nowledge **M**anagement **S**ystem
K-NET	Services for Context Sensitive Enhancing of **K**nowledge in **Net**worked Enterprise
MnM	**M**ultimedia a**n**d **M**arkup semantic system
MWSAF	**M**ETEOR-S **W**eb **S**ervice **A**nnotation **F**ramework
NFC	**N**ear **F**ield **C**ommunication
OASIS	**O**rganization for the **A**dvancement of **S**tructured **I**nformation **S**tandards
OPAALS	**O**pen **P**hilosophies for **A**ssociative **A**utopoietic digita**l** ecosystem**s**
OPENTC	**Open t**rusted **c**omputing
PaaS	**P**latform **a**s **a** **S**ervice
PPP	**P**oint-to-**P**oint **P**rotocol
PRIME	**Pr**ivacy and **i**dentity **m**anagement for **E**urope
PSL	**P**roperty **S**pecification **L**anguage
QoB	**Q**uality **o**f **B**eing
RC	**R**esearch **C**hallenges
RFID	**R**adio **F**requency **I**dentification

RR	**R**esearch **R**oadmap
RTD	**R**esearch and **T**echnical **D**evelopment
S3MS	**S**ecurity of software services (**3**) of **m**obile **s**ystems
SaaS	**S**oftware **a**s **a** **S**ervice
SAML	**S**ecurity **A**ssertions **M**arkup **L**anguage
SCM	**S**upply-**C**hain-**M**anagement
SCOR	**S**upply-**C**hain **O**perations **R**eference-model
SECOQC	Development of a global network for **Se**cure **Co**mmunication based on **Q**uantum **C**ryptography
SMEs	**S**mall and **m**edium **e**nterprise**s**
SOA	**S**ervice-**o**riented **A**rchitecture
SOAP	**S**imple **O**bject **A**ccess **P**rotocol
SOC	**S**ervice-**o**riented **C**omputing
SPIKE	**S**ecure **P**rocess-oriented **I**ntegrative Service Infrastructure for Networ**k**ed **E**nterprises
SUDDEN	**S**MEs **U**ndertaking **D**esign of **D**ynamic **E**cosystem **N**etworks
TQM	**T**otal **Q**uality **M**anagement
UML	**U**nified **M**odeling **L**anguage
UPON	**U**nified **P**rocess for **On**tology building
URI	**U**niform **R**esource **I**dentifier
US	**U**nited **S**tates
W3C	**W**orld **W**ide **W**eb **C**onsortium
WS	**W**eb **S**ervice
WSMO	**W**eb **S**ervice **M**odeling **O**ntology
XACML	**X**ML **A**ccess **C**ontrol **M**arkup **L**anguage
XKMS	**X**ML **K**ey **M**anagement **S**pecification
XML	E**x**tensible **M**arkup **L**anguage

Foreword

Future Internet Enterprise Systems (FInES) is a relatively recent term that describes a field of activity with the aim to improving the manner in which enterprises, by means of Information and Communications Technologies (ICT), may confront the future with confidence and integrity. This research domain - which combines Enterprise Interoperability, Enterprise Collaboration and Digital Ecosystems supported by the Commission over a number of years - is one important element of the overall research field of the Future Internet, and has a specific research focus on ICT adoption and usage by enterprises.

In June 2009, a FInES "cluster" meeting took place in London. As the Seventh Research Framework Programme (FP7) was reaching its mid-term, this was a milestone event, where flagship EU projects representing a broad range of stakeholders of the research community in the enterprise networking area were invited to express their views on the state-of-the art and the **future perspectives**. As part of this “concertation” process, a new Research Roadmap Task Force was launched by the projects and participating community members, to address new challenges for businesses in Europe.

The present document is the result of the effort delivered by this Task Force, supported by a process of open consultation on the future of Future Internet Enterprise Systems research coordinated by the European Commission, over a period of almost one year. It is intended to represent the **shared view** of interested stakeholders contributing to the development of the Future Internet Enterprise Systems research field.

The Research Roadmap took a broad perspective that spans the full scope of FInES, as identified in the FInES Position Paper[1] presented at the London Cluster meeting. To promote a **new generation** of ICT-enabled enterprise systems and sustainable businesses, the document emphasises the need for a multidisciplinary research approach to support disruptive concepts. It calls for better and smarter innovation, where scientific breakthrough should come in balance with the stepwise engineering focus, enforced by a more business-oriented approach.

The FInES Research Roadmap is a collective effort of all interested stakeholders in the FInES domain, spearheaded by the FInES Research Task Force. It will certainly not cover all the issues that are relevant to the competitiveness of our industry and SMEs. It is rather an input to every community wanting to convert **value innovation** into a business routine. We hope it will bring closer together the research community and the policy makers in defining new directions to be taken today, to empower Europe and its enterprises.

[1] http://cordis.europa.eu/fp7/ict/enet/fines-positionpaper_en.html

0. Introduction

"You never change things by fighting the existing reality.
To change something build a new model that makes the existing one obsolete."
(Buckminster Fuller)

0.2. General Scope and Objective of the Document

The Future Internet Enterprise Systems (FInES) Research Roadmap aims at defining new research challenges, in the context of a general reference framework for European enterprises, for the FInES research domain. Such research challenges are motivated by a long-term, highly innovative vision, with 2020 as the time horizon[2].

The Roadmap builds upon the baseline established in existing key Cluster reference documents, in particular the FInES Cluster Position Paper that has expressed the first global vision and policy, and research recommendations following the re-orientation of the FInES Cluster. The latter has brought together constituencies of three major research streams: Enterprise Interoperability, Enterprise Collaboration, and Digital Ecosystems. This research roadmap intends to address ICT-based enterprise innovation with a futuristic, even provocative, perspective; leading potentially to incremental and emergent or radical and revolutionary changes in thinking, practices, products, processes, or organizations.

The FInES Research Roadmap is a collective effort of all interested stakeholders in the FInES Cluster, spearheaded by the FInES Research Task Force. This document is an input to the next FP7 ICT Work Programme 2011-12.

0.3. Scope of the FInES Domain

The Future Internet is expected to give rise to new opportunities of creativity and innovation, to enable new forms of participation and collaboration, to catalyse further the formation of networked enterprises and business ecosystems that span from the local to the global, thereby ushering in a new generation of enterprise systems. FInES describes a field of activity with the aim to enabling enterprises, including SMEs, by means of ICT, to exploit the full potential of the Future Internet. The Internet thus is seen as a universal business environment in which new values can be created by competing as well as collaborating enterprises, by incumbent as well as new, through innovation in a level playing field and with sustainable positive benefits for the economy, society and the environment. Individual enterprise systems of the future are likely to be leaner, more adaptive, flexible, innovative, and open. They need to enable value innovation at the business level. They also need to deliver value beyond economic value and drive innovation that meets a set of business objectives and sustainability concerns much broader than those of today, including societal and environmental objectives.

It is important that FInES builds on existing reality, analyses emerging economical behaviors and considers the current globalization trends and new markets (e.g. India, China, and the Middle East). It is imperative for us to assess the current effectiveness of and the potential improvement to classical enterprises models and common business practices.

[2] We believe that more short/medium-term studies are better performed in an industrial context (e.g., by consultancy agencies).

The FInES Cluster has already demonstrated its capacity to contribute to this elaboration, which involves: (1) a wealth of multiple disciplines, (2) inter- and intra-enterprise complexity, and (3) inter-dependencies among different business and socio-economic areas. We are aware that there are several open questions regarding the model of future enterprises and their characteristics, the ICT trends and the future solutions, the relevance of the latter for enterprises, as well as the costs and benefits associated with their adoption. And, as the final key question, what generation processes and types of values would the future enterprise be able to deliver to customers and the society at large? A key consideration of this ability is the extent to which the future enterprise would adopt a markedly innovative behaviour (with innovative organization and process models), with the support of deeply innovative ICT solutions.

0.4. Method of Work

The approach

One of the main concerns of the task force, at the beginning of the work, was to avoid a technology-driven approach, i.e., to start from the emerging (and foreseeable) technological innovations and then to figure out how best to use them in future enterprises. Instead, we have proceeded with an enterprise-oriented approach, i.e., to figure out what kind of enterprises we can envisage for the future, what will be their characteristics and requirements, and how future ICT solutions would be able to support the envisaged future enterprises. This approach led to a "top-down" organization of the work, with a layered structure of key questions, as provided in Table 1. This report will try to answer to these questions.

Societal ***Vision and Values***	What will be the socio-economic context in which future enterprises will operate?
Future Enterprises ***Grand Objectives***	What will be the desirable qualities that (hopefully) will characterise future enterprises?
FInES ***Research Challenges***	Having identified a set of desirable qualities, what are the research lines for developing *future enterprise systems* able to support those qualities?
Future Enabling Technologies	What are the relevant ICT solutions that allow FInES to be developed in order to support the achievement of the above Research Challenges?

Table 1 – The FInES Research Roadmap Stack

Task Force activities and organization

The report is based on the work of the FInES Research Roadmap Task Force and the contributions of the FInES Cluster members. The activity has been organised into four phases. Phase 1, starting in September 2009 with the launch of the Table of Content, asking for contributions from the FInES Cluster members, and focusing on Chapters 1 and 2. It was concluded at the end of November 2009 with the release of the first draft document that covered the first two chapters. Phase 2, starting in parallel with the conclusion of Phase 1, aimed at the consolidation of Chapters 1 and 2, and the development of Chapters 3 and 4. It led to the release of the FInES Research Roadmap V2.0

document. Again, the end of Phase 2 triggered the start of Phase 3 that produced a final draft, Version 3.0, merging and integrating the outcomes of the two previous phases, and adding Chapter 5 to cover the State-of-the-Art, and the Chapter 6 with the Conclusions. Finally, Phase 4 has concluded the process with an extensive consultation and refinement of work, leading to the release of the official Research Roadmap final report.

The drafting and the collection, integration, and organisation of the contributions has been performed by the FInES Research Roadmap Task Force. The task force comprises Michele Missikoff (Rapporteur), Samia Drissi, Raphael Giesecke, Antonio Grilo, Man-Sze Li (Cluster Co-Chair), Nikolay Mehandjiev, and Dirk Werth. The Task Force has been supported by a review panel composed by Sergio Gusmeroli, Stephen Pattenden, and Hans Schaffers. Furthermore, the work has been achieved with a wide support of the members of the Cluster, both at an individual and project level, and facilitated by the Head of the Cluster, Cristina Martinez, of the European Commission, and, in the concluding phase, her assistant Nikolas Provatas. The drafting and editing of this document has been in particular under the responsibility of Michele Missikoff (for Chapters 0, 2, 3, 6), Man-Sze Li (for Chapter 1), Dirk Werth (for Chapter 4), Samia Drissi and Nikolay Mehandjiev (Chapter 5).

0.5. Content of the Document

In order to achieve the aims of the Research Roadmap, the document is structured into six chapters, plus this introductory Chapter 0.

In Chapter 1, after this Introduction, the document starts by defining the Vision and Values in accordance with the scope and ambition of the FInES Cluster, aiming at anticipating the paradigms and concepts that will characterize the future European knowledge society. The socio-economic drivers, the role of ICT in value production, and the relationships among the different cultures and constituencies, will be considered. In this sense, this chapter aims at drawing the main contours of a possible future context in which European enterprises will operate.

Chapter 2 identifies the Grand Objectives, represented by a number of desirable qualities (e.g., transparency, accountability, sustainability) that will characterize future enterprises. To organize the presentation better, each of the qualities is described and labeled as an ideal kind of enterprise. For example, a Green Enterprise is characterized by the respect of the environment. Each of the proposed labels intends to provide a high level description of a specific dimension of future enterprises, their role in society, and how they may operate and produce value in future. The description also indicates a number of objectives, the achievement of which will need high quality multidisciplinary research.

Chapter 3 addresses 8 Research Challenges that need to be tackled in the next decade, for the purpose of fostering a deep renewal of enterprises towards the Grand Objectives described in Chapter 2. In particular, the Research Challenges identify 8 research areas that are necessary to support the emergence of the next generation of enterprises, which are capable of achieving the Grand Objectives illustrated in the previous chapter. Here the key message is “continuous, open innovation”. This is to be achieved not only through technology, but also by leveraging the scientific bases and fighting the cultural and disciplinary fragmentation, in order to provide innovative, integrated “socio-technical” solutions. This chapter will also consider, with reference to the Research Challenges, the main barriers that prevent enterprises from adopting innovative solutions.

Chapter 4 addresses specific innovative ICT solutions, including methodologies, that will be needed to support the achievement of the Research Challenges. This chapter provides a comprehensive reference grid that includes those ICT solutions that, despite being considered strategic for future enterprises, are generally not sufficiently covered in the existing ICT innovation trends.

Chapter 5 aims to identify the most advanced ICT solutions available today, with particular attention to the key achievements of past projects, presented in the form of a state-of-the-art review. The objective is to promote the reuse of existing advanced solutions. We know there are cases where existing solutions can be either directly used or easily extended, thus avoiding new development from scratch. The outcome of this chapter can be contrasted with the outcome of the previous chapter, for deriving important indications of ICT research directions useful for future enterprises.

Chapter 6 provides overall conclusions and recommendations. Specifically, it will recap the main indications stemming from the Research Roadmap elaboration, focusing also on the results that may be achieved in implementing the recommendations in this Research Roadmap, as a starting point for guiding future research initiatives.

1. Vision and Values

"Dream of the future, learn from the past, but live in the present"
(Anonymous)

1.1. Context Change and Enterprise Transformation

After a decade in preparation, the Treaty of Lisbon came into force on 1 December 2009. This achievement is however tempered by major structural challenges confronting the EU, of which systemic weaknesses in financial regulatory frameworks and institutions exposed by the 2008/9 economic crisis constitute one pronounced example. In initiating work on the EU 2020 Strategy, the European Council noted that "The time has now come … above all, to look ahead". In view of the economic and social impact of the crisis, in view also of the challenges posed by ageing populations, increasing inequalities and climate change, a new approach is needed more than ever (European Council, 2009). Important issues, singled out by the Council in need of examination, include the benefits offered by a "greener" economy, the improvement of the business climate (especially for SMEs and the industrial base), and the enhancement of the knowledge base in the European economies, including research and innovation.

The recent financial crisis is taking a heavy toll on enterprises. However, critical times are opportunities for change. A time for deep transformation for Europe is also a time for deep transformation for enterprises based in Europe. As stated by the European Commission, the exit from the crisis should be the point of entry into a new sustainable social market economy (as already enshrined in the Lisbon Treaty)[3], which is moreover a smarter, green economy. The new drivers for prosperity and growth will come from innovation and from using resources better, where the key input will be knowledge (European Commission, 2009). In other words, the social-economic as well as policy context within which Europe's enterprises will operate in the coming years is rapidly changing. Future competitiveness will be driven by factors far beyond conventional economic dynamics. Instead, increasingly the focus is on conserving and making more effective use of energy, natural resources and raw materials; it is also on social cohesion, tackling unemployment and fostering social inclusion. European enterprises have the opportunity to thrive in this post-crisis landscape by means of environmentally and socially responsible business innovation and creativity. The time has come to re-consider value creation, business values and practices, thereby demonstrating European openness to the groundswell of citizen opinion and to the world, as well as openness to new ideas and solutions. This openness will be based on knowledge, powered by intellectual capital, and grounded in efficient, fair and transparent rules.

The scope of the FInES Cluster makes it particularly well-placed to advance European research that anticipates the qualities of future enterprises and equips them with ICT solutions to confront the future with confidence and integrity. The FInES Cluster Position Paper has already made a first sketch of the

[3] See Article 3(2) of the Treaty which sets out the economic constitution of Europe's single market. The term "social market economy" was coined by Ludwig Erhard and Alfred Müller-Armack in 1946. As noted by Erhard in his book "*Wohlstand für Alle" (Wealth for All)*, "An economic policy may only be called social where it makes sure that economic progress, higher performance and productivity growth in the end will benefit the consumer" (quoted by Viviane Reding in her speech on "Digital Europe – Europe's Fast Track to Economic Recovery", The Ludwig Erhard Lecture, Lisbon Council, Brussels, 9 July 2009). Social market economy combines private enterprises with government regulation to establish fair competition, social welfare and specific policy goals. As Erhard also observed, "the free market economy did not need to be made social but was social in its origin".

path towards sustainable value creation by enterprises, focusing particularly on new business models, business flexibility and business agility. Building on that foundation, this chapter sets out a number of key drivers for enterprise transformation, followed by a vision statement for future enterprises.

1.2. Key Drivers for Enterprise Transformation and Future Enterprise Environments

1.2.1. The Overall Context: Digitalisation, Individuals and Enterprises

Europe is set to become ever more digital in the years to come. There is already a new generation of "digital natives" applying technologies in novel ways in particularly the social sphere. Social networking, blogging, podcasting, twittering and "wikinomics" are beginning to make - or perhaps are already making - a mark in the way enterprises communicate with their (would be) customers, partners and employees (however concerns about the use of such technologies, e.g., over privacy threat or information leakage, should not be underestimated). The concept of "open innovation", for example, has become fashionable to describe external sourcing of ideas, capabilities and know-how via sharing and collaboration with interested parties "out there" (e.g. end users)[4]. A new "architecture of participation" is emerging for companies to do business (O'Reilly, The Architecture of Participation, 2004), (O'Reilly, What is Web 2.0, 2005). Several years ago, IBM published a report on the future of the enterprise, suggesting that a common set of interests, goals and values – called "the endeavour" – provides the necessary glue between individuals or entities, relegating the role of the organisation to the orchestration and facilitation of those endeavours (IBM, Global Information Outlook 2.0). These ideas contributed to the company's more recent Smart Planet initiative, based on the notion that digital savvy customers are driving corporations to re-imagine their business models (IBM, Smart Planet, Visions). The future outputs of enterprises will be integrated into our lives; they will work in more personal ways and adapt to our individual needs.

Enterprises therefore need to respond to and potentially help shape two related trends: increasingly flat social interactions and structures, and extreme customisation on a massive scale. The former implies new forms of ICT-enabled collaboration outside hierarchical structures and controlled media, of which "open innovation", "collective intelligence" and "agile organisations" are examples. The latter implies not only that future products and services will enable individuals to express their unique identities, but also technology as a facilitator will become firmly "human-centric", based on the (multiple) uniqueness of the individual as opposed to the collective of group patterns. Enterprise competitiveness will simultaneously need to address a more participative as well as collaborative social culture and processes, and extreme customisation (as in the target "market of one") along a potentially fully elastic "long tail" of the demand curve.

All the indications are that the service sector of the economy will acquire increasing importance. A key insight is that the service component of a transaction – arising from any mode of production – must provide added value as an innovative differentiator. This has important consequences for business strategies: how to deal with the exceptions of the market?[5] Future enterprises will not be able,

[4] In contrast with the strictly linear and "funnelling" approach to innovation practiced within the closed world of corporate confines. This has subsequently been generalised to "collective intelligence". See (Chesbrough, 2003)

[5] As such, it makes little sense to speak of a fixed value chain because value generation as a critical differentiator is required to be extremely dynamic, delivered on demand, and dealing continuously with the exceptions of the market of one. Concepts such as "value network" and "value ecosystem" have been proposed by scholars. Research within the FInES Cluster suggests that the more forward looking companies have found it increasingly difficult to apply the value chain concept with its assumptions of linear processes and stable, clearly delineated

by themselves, to provide let alone dictate the context of business activity. Instead, they will need to focus even more than before on their value proposition and delivery as shaped by their characteristics, activities and relationships (which may be called an "ecosystem").

Value lies at the centre of our consideration of the future of enterprises. There are three dimensions to this consideration: policy & governance, technology and business-economics. In the following subsections, we discuss, in turn, each of the key drivers as well as obstacles that may mitigate the effects of those drivers. The overall view is that the main obstacle is not the lack of technologies, but the lack of courage in advancing new ideas particularly beyond the existing economic context with its structural bottlenecks and imagination to find innovative solutions. Also, we should be reminded that the origin of business is social as much as economic. Economic growth does not arise just from adding more labour and more capital, but importantly from new and better ideas expressed as different types of progress, while at the same time without jeopardising the well being and choices for future generations. Possibilities do not add up. They multiply[6].

1.2.2. Policy & Governance: Knowledge, Ownership and Control

The EU has already put forward free movement of knowledge as a fifth freedom. Knowledge should be available to all, no matter where it is situated. The central role of knowledge in the digital economy is expected to be reinforced in the EU 2020 Strategy, which will advance the "European Knowledge Area", underpinned by a world-class knowledge infrastructure, from which all actors including enterprises will benefit[7]. The diffusion, acquisition and use of knowledge as intangible assets, or intellectual capital, will be critical for the success and indeed survival of future enterprises. Tapping into such assets will offer especially great opportunities for SMEs – the "mainspring of Europe's economic resurgence" (Reding, 2009).

For some time, the EU has sought to introduce a renewed strategy for intellectual property rights, which it links to measures for narrowing the digital divide. But we are faced with two opposite and apparently opposing phenomena: the search for new business models and customisation, versus the clinging to traditional (high value) rights notably copyrights and IPRs[8]. Intellectual capital includes not only the generally acknowledged human capital, but also the less studied and understood structural capital (how to bridge people inside with the people outside) and relational capital (the extended network or ecosystem). However, the latter two classes are expected to have a far greater role in the shaping of future business missions and models. Specifically, ownership of intellectual capital may not preclude others from having a share in the ownership of such capital[9].

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competitive forces. See, e.g., the Cluster's report on Value Proposition for Enterprise Interoperability, 2008 http://cordis.europa.eu/fp7/ict/enet/ei-isg_en.html

[6] This is adapted and expanded from Paul Romer's work on New Growth Theory. He wrote: "Economic growth occurs whenever people take resources and rearrange them in ways that are more valuable … Every generation has perceived the limits to growth that finite resources and undesirable side effects would pose if no new recipes or ideas were discovered. And every generation has underestimated the potential for finding new recipes and ideas. We consistently fail to grasp how many ideas remain to be discovered. Possibilities do not add up. They multiply." Source (Romer)

[7] European Commission *ibid.* As noted by the Commission, SMEs make up 99% of all enterprises and account for over 100 million jobs, and innovative start-ups can generate value added jobs right across Europe.

[8] Amartya Sen, the Nobel Laureate, has likened the "ignorance trap" relating to intellectual capital to the "poverty trap" where an individual's economic success is setting dependent. See the contribution of Leif Edvinsson to the present Roadmap, in which he reports the conversation with Professor Sen on the occasion of the Nobel Prize ceremony where Sen collected his prize.

[9] The analogy is that Linux users and developers do not mind that "their" ownership of the Linux Operating System on "their" machines does not preclude others in owning the same.

It has already been widely noted for a long time that from an economic perspective, information has peculiar characteristics compared to tangible goods – its consumption does not reduce its availability (non-rivalry) and its possession does not prevent others to possess it (non-excludability)[10]. Conventional economic models are not designed to take account of these features of information. But the digital economy, and the knowledge infrastructure supporting it, must embrace them. It is not so much that ownership and control are slipping away; indeed some current debates and measures of commercial actors suggest precisely the opposite. Rather, new notions of ownership and control of intangibles, and their exploitation as capital and revenue, are needed. Furthermore, there is a distinction between ownership and control over the means of information (the communication device and mechanism), the act of informing (the communication as an information flow), and the information itself (which may be capitalised and with which rights are associated), even if all three are often conflated into one contiguous and – consequently – confused debate.

The spill over of Web 2.0 into the enterprise environment is inevitable and will only rise[11]. With increased communications comes the pressure of openness and to open up. On the one hand, there are rising concerns about security and privacy. On the other hand, transparency is becoming a new "currency" that enterprises may deploy to their own strategic advantage. According to research, companies that are open perform better; in other words, the reason to be open is not a moral argument, it is a business argument (Tapscott & Ticoll, The Naked Corporation: How the Age of Transparency Will Revolutionize Business, 2003) (Tapscott & Ticoll, The Open Enterprise, 2009). However, transparent information does not necessarily become shared; transparent information also does not automatically become knowledge which adds value. More must be done to understand (a) the nature of intangibles, (b) the role and relationships of intangibles in respect of enterprises, (c) the approach to handling intangibles by enterprises, (d) the relationship between openness, information and knowledge, and (e) the kind of knowledge infrastructures that may be required to support enterprises. Promising technologies, such as those envisioned for the Future Internet, will not by themselves provide answers to these core questions.

1.2.3. Technology: Infrastructure Models

ICT is set to become ever more all-pervasive, with major implications for doing business. The latest articulation of this vision in European Research is the federating theme of the Future Internet. For enterprises, the major issue is not more sophisticated technologies per se, but technologies that will increase the value of their offering. To do so, technologies must enable enterprises to continuously innovate as a business routine. That innovation includes not only products, services and processes, but also value innovation (see next sub-section).

In the future, a potentially unlimited array of high value-added capabilities, fine-tuned to the precise needs of the end-user, will be enabled by software-based services, delivered on-line, on-demand and in

[10] See, for example (DeLong, 2000) and (Mansell, 2009). As formulated by Mansell, one can give information to someone else and still possess it (non-rivalrous) and information cannot be taken back once it has been given and receivers can pass it on without giving it up (non-excludable). Note that these characteristics of information is a key basis for the definition of the Interoperability Service Utility (ISU) – the first Grand Challenge of the Enterprise Interoperability Research Roadmap developed by the predecessor of the FInES Cluster, and initially published by the European Commission in 2006. See ftp://ftp.cordis.europa.eu/pub/ist/docs/directorate_d/ebusiness/ei-roadmap-final_en.pdf

[11] Thanks to the ubiquity of the Internet and the pervasiveness of the Web, citizens of the information society at the end of the 20th Century discovered that they could interact with their social groups in new ways. The ability to shape and extend one's digital environment at home and at work was supported by highly effective and affordable - even free - search and related tools. The drive to codify and organise knowledge was harnessed by community projects like Wikipedia.

real-time. Those services will be simple to use, adaptable to dynamic needs, affordable to small budget holders, as well as having the required technical attributes of accessibility, reliability and interoperability. This would lead to an explosion of ICT adoption by particularly SMEs, according to research performed within the FInES Cluster. It has been suggested that a whole new level of commerce which is active in a grey area between enterprises, consumers, and consumers with consumers would become possible. Equally, it has been argued that this could enable those in developing countries to find and build their own way of development [17].

For this to happen, the software-based services markets must be fully open and competitive; existing barriers to entry need to be lowered and eliminated so that newcomers are not unduly disadvantaged relative to the incumbents. One major proposal from the research field is the availability of a universal ICT infrastructure model that all could exploit, including at the level of software-based services which are the building blocks for enterprise applications.

Over the years, many infrastructural models and associated architectures have been advanced in the research environment, including client-server, distributed, P2P, Grids and so on; many have failed to deliver impact beyond research. The latest trend is so-called Cloud Computing, which combines notions such as infrastructure-as-a-service, platform-as-a-service, and software-as-a-service. Alongside the technical discussions are business discussions as regards notably the business models for clouds, policy discussions as regards governance of clouds (which might lead to lock-in), as well as European strategy debates on the importance of clouds for the digital economy (such as the call for European clouds by Viviane Reding for ensuring benefits to European SMEs (Reding, 2009)).

In summary, there is a move away from the current Internet that is dominated by intelligence in the form of personal computers linked to a shared server at the end of a relatively dumb network (Zittrain, 2008). Google, Amazon and other global service providers have clearly demonstrated how technological innovations allied with novel business models could transform society's activities, habits and cultures on unprecedented scales with unprecedented speed. The achievements of such technologies are presently challenging the structure of the ICT industry. They are also signposting how the Future Internet might develop, including the control of critical resources enabled by particular infrastructure models. The eventual impact on enterprises will be substantial, in terms of not only how and where enterprises would run their businesses, but also the way in which enterprises build business relationships and markets, and the extent to which ICT supports business level innovation.

1.2.4. Business & Economics: Towards a New Value System

The recent global financial and economic turmoil has left few enterprises untouched. New business narratives are necessary to identify where businesses should go. The introductory remarks to this section indicate that there are three lenses through which business objectives could be viewed: at the economic level, at the environmental level, and at the social level. While business competitiveness has traditionally focused on the first, all the indications are that the second and the third will play an increasing role in determining the contributions of enterprises and ultimately the valuation of a "business" in future markets. In short, how the "success" of enterprises is to be perceived, measured and rewarded. Evidence includes:

- The limitations and indeed unreliability of conventional business accounting and market capitalisation practices are the more visible in light of recent global turmoil, with the financial markets subject to reform and greater regulation across the world
- Traditional economic models have been put under stress and into question in their failure to guide policy making; additionally they fail to deal with information as a resource unrestricted by the scarcity principle which undermines those models

- The accounting of economic performance is not sufficiently reflecting the transition of especially the developed world from a production-oriented economy to a service-oriented economy and to the more recent knowledge-oriented economy
- The ascendancy of Internet-based markets where the creation of economic surplus is based not solely on the exchange of goods and services, but "soft" factors such as reputation, trust, other forms of goodwill, even "community spirit"; money is not the only currency of those markets and the network effects generate new dynamics alien to the traditional production paradigms
- Internet-enabled phenomena such as pro-sumption, co-creation, the open source model of "production" and related open innovation, as well as the trend towards fusion between the physical and the virtual world, are raising issues regarding the nature of assets and their means and modes of "production"
- New markets (including modes of exchange) for natural resources are emerging, including different forms of alternative energy, carbon emission and trading, smart grids, etc.
- Perhaps most important of all, society at large is no longer satisfied with attributing pure economic improvements as the dominant - or even *the* - driver of social progress, and with economic measurement as an infallible yardstick for society's "well being".

The "Stiglitz Report" (Stiglitz, Sen, & Fitoussi, 2009)[12] , commissioned by the French President Sarkozy , is a clear signal of the global concerns about the shortcoming of present tools of economic and social performance measurement, mismatch between market prices and things (or qualities) that society (i.e. people) value, and the nature of societal goals. As the report puts it: "what we measure shapes what we collectively strive to pursue - and what we pursue determines what we measure".

Looking ahead, we believe our present system of business values is no longer adequate in supporting the full range of business goals that future enterprises would consider as relevant and important. Enterprises in formal terms as legal entities vested with rights and obligations will undoubtedly have new obligations due to regulatory as well as social pressures. Conversely, we argue that enterprises should be given new rights to capabilities that would help them to innovate in a changing world, of which ICT should be a key enabler. These would include, for example, access to and exploitation of knowledge (section 1.2.2), value-added capabilities and the underpinning ICT infrastructure model (section 1.2.3); the right not to be locked into specific ICT systems; and the opportunity of meaningful choices of ICT solutions.

A tentative listing of business values for future enterprises may include, but not limited to:

- Revenue and profit
- Reputation
- Efficient use (and conservation) of physical resources, natural resources and raw materials
- Environmental footprint
- Employee relationships
- Business partner relationships
- Customer relationships
- Exploitation and use of knowledge, especially in its tacit and implicit forms (Mäki, 2008)
- Business transparency and corporate governance
- Social responsibility.

The above are interdependent. They also place a greater emphasis on the demand side to drive business value. Whilst it may be conventional wisdom to believe that the pursuit of profit is inconsistent with any or all of the others, the issue is that current economic valuation and "standard measures" (and pricing) do not adequately account for all the costs incurred. The valuation and

[12] For background and context, see also (Stiglitz J. , 2006) and (Sen, 1993).

measures would change especially when sustainability is taken into consideration, where the cost is computed not by short term techniques such as net present value, but by more meaningful attribution of externalities, opportunity costs, and realistic assumptions and choices about the future.

A new system of business values logically leads to new business models and the need to innovate. In light of recent market failures and the greater role that has been expected from and indeed played by government, business arrangements other than pure commercial enterprises are more regular features in the new business climate. In many sectors including ICT, in Europe and elsewhere, public-private partnerships are being formed as part of the economic recovery package. It may be the case that different kinds of business arrangement would be needed for different sectors as well as different geographic regions at different points of the economic cycle. The social market economy, allied with the drive for a smarter and greener economy, and leveraging the capability of the Internet, is expected to provide greater freedom for business model and business arrangement experimentation.

1.3. Vision Statement: Future Internet based Enterprise Systems 2025

By 2020, the Internet will become a universal business environment on which new values can be created by competing as well as collaborating enterprises through innovation in a level playing field. Within this environment, FInES will become a transparent and invisible part of the business operation, available and affordable to all enterprises as required. It will make optimal use of the capabilities provided by a universal service infrastructure based on the concept of the Interoperability Service Utility (ISU)[13]. It will support and enable the full range of enterprise qualities as described in Chapter 2 of this Research Roadmap.

[13] The first Grand Challenge of the Enterprise Interoperability Research Roadmap [European Commission, 2006 and 2008].

2. Grand Objectives of FInES

"The visionaries are the true realistic people"
(Federico Fellini)

2.1. Introduction

This chapter focuses on enterprises and their anticipated distinct features in the year 2020. It highlights enterprise characteristics that are likely to become relevant to the next generation of Enterprise Software Applications based on the Future Internet (referred to as FInES). Some of these characteristics are visible already (e.g., environmental orientation), others may emerge only later and will evolve by 2020. Note that the Grand Objectives are not intended to suggest that enterprises must adopt new organizational structures or business models. Instead, they are intended to anticipate a number of qualities and capabilities (e.g., transparency, innovation aptitude, and knowledge-oriented keenness that successful enterprises may exhibit in the future. Such qualities are not depicted as precise targets to be reached; rather, they represent directions along which an enterprise can proceed, progressively improving over time. In this respect, a Grand Objective can be seen primarily as an "intention", as a commitment to proceed in the indicated directions. From this perspective, pursuing the long term Grand Objectives will bring visible benefits in the short term.

We anticipate that reaching a Grand Objective will not be just another linear process. Effective innovation strategies will be necessary, capable of removing (or, at least, reducing) the roadblocks that are to be found along the pathway. Thus, the following Chapters 3, on the Research Challenges, focus on innovative ICT systems with which to support enterprises in their progressive evolution towards the Grand Objectives. We are also aware that technology per se is not sufficient and this evolution needs to take place in a comprehensive socio-technical perspective, according to the main lines identified in the previous chapters.

2.2. The Grand Objectives as enterprise qualities

We view the Grand Objectives as being connected to a set of complex processes that will take place both inside and outside (in business ecosystems and the society at large) an enterprise, progressively introducing deep changes in its nature and behaviour. To describe such changes, we introduce a wider notion of quality than is used today.

The European Framework for Quality Management (EFQM) has already successfully expanded the philosophy and practice of Total Quality Management (TQM). The EFQM approach has been extensively disseminated and is widely accepted in Europe and beyond. We suggest further extending the current notion of enterprise quality, including other issues, such as environmental impacts and ethical issues. We therefore introduce the notion of the enterprise Quality of Being. This will be the approach adopted for this chapter.

Concretely, we address different dimensions referring to distinct features that characterize the Quality of Being (QoB) of an enterprise. We believe that the QoB deeply influences not only the way an enterprise operates, the management style, the relationships with employees and staff, with clients and partners, the marketing strategies and practices; but also the carbon footprint, the level of social responsibility; and finally, the enterprise's contribution to the overall development of society at large.

In essence, the FInES Grand Objectives will be a kaleidoscope of qualities likely to be pursued by enterprises over the next decade. In this chapter we do not intend to elaborate on how such qualities

can be acquired by an enterprise, what such an enterprise should do, what organization model it should assume, and, more specifically, what technological solutions it should adopt. The former themes are left to the entrepreneur's initiative; the last one will be addressed in the next Chapters 3 and 4.

Below, a brief description of proposed QoBs for future enterprises is presented. To make the presentation less abstract, the QoBs are illustrated in the form of a number of exemplary enterprises.

2.3. The Grand Objectives as exemplary enterprises

In this central section we illustrate a number of enterprise qualities. Please note that they are not independent of each other and we expect that a future enterprise will exhibit a certain blend of the different exemplar enterprise qualities described below.

2.3.1. Inventive Enterprise

This is the primary dimension of the successful enterprise of the future. It refers to the essential traits of a very innovative enterprise, impacting a large number of aspects, primarily the organization, the processes, and the products. It requires continuous (even disruptive) changes for improvement, while ensuring its operations run profitability and deliver value. Its main distinctive features are an inventive vision, flexibility and continuous change. It is active, grows and improves like a complex living entity, displaying non-linear behaviour[14]. Tight organization and control may reduce flexibility, therefore *Inventive Enterprises* may be characterised by partially organized structures, where several components are endowed with great autonomy[15] and are not subject to tight central control. In an enterprise context this means a strong delegation from the top to the lower operational levels, allowing the development and production units large margins of autonomy of means and strategies, while intermittently coordinating for common business goals. Control over an *Inventive Enterprise* will involve different approaches capable of defining and managing incomplete models. These "partial" methods and models can be coupled to feedback mechanisms[16] and embedded controls that, even in case of unpredicted critical situations, will be able to minimise the negative impact of such events.

The other primary traits concern the innovation on products and the capacity of a continuous repositioning on the market. The previous FInES publication "Value Proposition for Enterprise Interoperability" (Cordis.lu, 2009), references the strategic positioning of an enterprise according to two different competition scenarios, referred to as "blue ocean strategy" and "red ocean strategy". The two scenarios are connected to the capability of an enterprise to innovate. The blue ocean scenario reads: *Companies competing on blue ocean strategies simultaneously pursue differentiation and low cost. Their aim is not to out-perform the competition in the existing industry, but to create new market space or a "blue ocean", thereby making the competition irrelevant. They achieve this through value innovation, i.e. introducing radical innovations in the products, services, processes, etc. that are genuinely valued by customers.*

This *QoB* is highly synergic with the two following ones: the *Cloud Enterprise*, characterised by loose production connections, and the *Cognizant Enterprise*, since a great quantity of knowledge needs to be continuously exchanged among its parts, and with the outside world, typically across fuzzy boundaries.

[14] These are characteristics typical of complex systems and FEDS (Far from Equilibrium Dissipative Structures), defined by (Prigogine & Nicolis, 1977) in (FIAT, 2010).
[15] See, for instance, Autopoietic Systems, as proposed by Maturana and Varela (1980, 1987) cited in (Maula, 2006).
[16] This is sometimes referred to as a Cybernetic Model of an enterprise. (Stafford Beer, 1965) in (Rettig, 2007).

2.3.2. Cloud Enterprise

This dimension refers to an enterprise whose boundaries cannot be definitively defined, i.e. what is *in* and what is *out*, the "external" and the "internal" sections of the value network. We strongly believe that this is an already known and used (e.g., through cloud computing and crowd sourcing) paradigm that will continue to develop in the future. More specifically, this *QoB* implies the capability of relying on a flexible, potentially unrestricted set of value production units, operating in places and according to processes largely outside the control of the main organization, sometimes even unknown. Intermediate (raw) products are typically fabricated (elsewhere) with a low level of coordination, but with clearly defined agreements on time and quality of the produced goods and services. Additionally, in the supply level agreement, the prime partner will be qualified to introduce production conditions such as low energy consumption, low carbon footprint, aiming at short supply chains (primarily moving ideas instead of things), and the respect of human rights.

This paradigm applies both to the production of tangible goods in the manufacturing world, to the production of services, and to the composition and mash-up of digital intangible goods, like the web services in the software world. In particular, a Cloud Enterprise, owing to the inherent non-hierarchical nature of its networked structure, is often playing simultaneously the role of consumer and provider of goods and services, including IT services.

Examples of *Cloud Enterprises* are the majority of Open Source Software production, but also *App Store, Amazon Mechanical Turk, Netflix Prize, BellKor Pragmatics Chaos*, and in a traditional sector, such as automotive, the FIATMIO initiative (FIAT, 2010); furthermore, in a less commercial context, we need to recall *Wikipedia*. As a client-side counterpart there are new ways for customers to be organized and accumulating better negotiation power, see, e.g., *CarrotMob.org*.

2.3.3. Cognizant Enterprise

This dimension concerns the enterprises capable of reaching beyond knowledge management, opening the possibility of fully acquiring not only specific knowledge, but also the way to use it, the context and the expected effects of its adoption, risks and alternatives, etc.

Currently, enterprises are adopting advanced ICT solutions for gathering, storing, organising, and accessing enterprise knowledge easily. Going beyond that requires that people make extensive and flexible use of explicit enterprise knowledge; relevant knowledge should be identified and delivered to the right person at the right time in the right manner (often proactively). Today a Knowledge Management System (KMS) is capable of managing documented (i.e., explicit) knowledge, typically sector- and application-based (i.e., applicative knowledge). We believe that the development of a knowledge-based economy requires a significant enhancement in knowledge management, primarily by extending the current notion of enterprise knowledge. An important step forward will be when the enterprise will be able to go beyond concrete applicative knowledge, adding higher forms of knowledge (on semantic and "meta" levels), such as the rationale, motivations, and information about the operational context. Essentially, a *Cognizant Enterprise* will be able to better use specific (technical, applicative) knowledge in conjunction with all the other knowledge assets, capable of guaranteeing an effective behaviour. Another aspect is the proactive attitude in knowledge delivery, with a sensible KMS capable of "sensing" specific situations and forwarding useful information, plus context and background, to the actors involved.

Another important feature of the Cognizant Enterprise is the capacity of managing and using knowledge to mull over itself, exhibiting *learning capabilities*. The knowledge will be used to rethink its own organization (see also the *Inventive Enterprise*), restructuring its processes, production, logistics, marketing, finances, and HR management, according to the newly acquired knowledge. To this end, it uses methods and tools aimed at observing and keeping traces of the activities, recording

the effects of actions, i.e. practical experiences leading to successes or failures, which will be systematically elaborated and stored for future reuse. Traces of enterprise operations, and therefore material for enterprise learning, will be also extracted from things (supported by the emerging *Internet of Things*), equipped not only with sensors, but also with computing and storage facilities, and capable of notifying their states and evolutions (see the notion of a FInER in the next chapter).

This new way of managing knowledge, also at the basis of open innovation, is related to the idea of *Cloud Knowledge*. It means that the knowledge assets of a *Cognizant Enterprise* will not be limited to the resources stored locally, but its scope will span over the full Internet, having the possibility of accessing knowledge resources at a global level (supported by the emerging *Internet of Knowledge*). In a systematic way, internal and external knowledge will be related and complemented. Ultimately human capital, organizational capital, and relational capital will be developed into knowledge assets.

2.3.4. Community-oriented Enterprise

This is a rich and articulated *QoB* with many facets that impact both the internal way of organising the business and the positioning of the enterprise in the socio-economic context. An important trait concerns the transparency and accountability. It is alleged that the economic downturn is largely due to the absence of adequate levels of transparency and traceability of specific financial products (e.g. mortgage-backed securities in the subprime crisis), but probably this episode highlights a more general problem of transparency, accountability, and social responsibility. The last one, in particular, has a wider impact when referred to as CSR: corporate social responsibility. In fact, CSR has an extensive significance, as explained in the following description[17]: "*CSR policy would function as a built-in, self-regulating mechanism whereby business would monitor and ensure its adherence to law, ethical standards, and international norms. Business would embrace responsibility for the impact of their activities on the environment, consumers, employees, communities, stakeholders and all other members of the public sphere.*"

The features of a *Community-oriented Enterprise* pertain in principle to the NGOs and many (former) public owned enterprises that operate with a marked social orientation. But here we intend to go beyond the category of non-profit organizations, aiming at a more general quality that will progressively permeate future successful enterprises. We expect by 2020 the emergence of trends towards non-monetary profits: value profits. These profits will be measured by other means than monetary currency, following the logic of the recent "Stiglitz report"[18]. The primary target of a *Community-oriented Enterprise* is the attention to people, managing services – both *from* and *towards* people and their internet representations (e.g., avatars). An early, successful instantiation of these services has been crowd sourcing. Our fantasy as of today does not yet enable us to imagine the complete gamut of possibilities of maximising such human-oriented values. Tentatively, we predict that areas of medical care, well-being, supporting the helpless as well as further humanitarian and human basic needs will be mostly attractive. Also we forecast that the ownership of such enterprises will move towards defined communities, either by topic or (geographical) area. These communities may exist anywhere within the private-public-NGO triangle. Last but not least, we assert that *Community-oriented Enterprise* is a quality that will be a requisite attribute for traditional industrial sectors, as a general attitude and with renewed focus on socially orientated values not least because of the increased transparency and openness delivered by the future internet where almost any corporate action may become visible and judged by its peers and customers.

[17] http://en.wikipedia.org/wiki/Corporate_social_responsibility
[18] (Stiglitz, 2009)

2.3.5. Green Enterprise

This *QoB* is tightly connected to the recognition that enterprise profit should not be obtained by offloading part of the costs onto the society at large, and onto future generations[19]. The concern about the environment should not be simply considered as compliance with the existing laws and regulation, it should be integrated into the "DNA" of the enterprise: into its organisation, processes, products, after-sales relationships, till to its advertising and marketing styles.

In selecting the enabling technologies, in deciding how to proceed along innovative programmes, in all the enterprise activities there are wide possibilities of adopting a "green attitude." Formerly, a green attitude has been perceived as giving rise to additional costs for the enterprise. But the opposite is becoming more widely accepted. The first movers in this direction (see for instance the hybrid car manufacturers) are enjoying a competitive advantage. This will surely continue in the future, and the Green Economy is generally considered, particularly during this difficult economic situation, one of the sectors with the most promising prospect for growth.

2.3.6. Glocal Enterprise

With the advent of globalization, enterprises have been pushed to operate at an international level in terms of sourcing, production and markets, as well as finance and technologies. This process has promoted a number of improvements for the economy of the planet, allowing for new business scenarios, with new players entering the scene. But at the same time, especially where the enterprises do not show transparency and social quality (see above), globalization is producing hardship and difficulties for part of the populations in both advanced and developing countries. Globalization is with us, and it will remain. Thus rather than fighting against it, a number of corrections to limit its downsides must be introduced. One of the most significant is the possibility of conjugating two apparently contradicting dimensions, i.e., local and global, merging them into a virtuous blend referred to as "*glocal*".

A *Glocal Enterprise* will be able to understand and think at a global level, while being aware of the local levels in which it operates, acting in harmony with its geo-social surroundings. To achieve this, it is necessary to show a specific kind of flexibility, necessary for instance to adapt products and production processes to the culture and needs of a given geographic area. This includes, for instance, adopting different marketing strategies depending on the regional characteristics, the locally available technology, the financial conditions, the availability and costs of natural resources, as well as cultural and religious diversity.

If we switch from the spatial to the temporal perspective, this quality is reinterpreted along a timeline, referring to the capacity of the enterprise to be active and aligned with the present time while at the same time looking far ahead to be ready for future challenges. A *foresight enterprise* shall be looking ahead not only in terms of innovation, but also (see the *Cognisant* and *Green Enterprises*) being capable of "trading" an immediate advantage for a better future improvement or a reduced future detriment, to itself and to the society as a whole.

2.4. Conclusion

In this chapter we presented a set of Grand Objectives for future enterprises, by using a method that illustrates such Grand Objectives through an exemplary set of enterprises, and their *Qualities of Being*. These are labelled as:

[19] In economic terms, this means that externalities should be priced and factored into the cost of a firm in producing goods or services.

- *Inventive Enterprise*
- *Cloud Enterprise*
- *Cognizant Enterprise*
- *Community-oriented Enterprise*
- *Green Enterprise*
- *Glocal Enterprise*

We expect that the future enterprises will use the Future Internet and, in general, the innovative ICT solutions to achieve a virtuous blend of the above qualities. However, we believe that such virtuous evolution will not happen spontaneously as a result of the technological innovation taking place within a universal trend of growth and progress. On the contrary, the achievement of the above qualities needs careful and dedicated studies, capable of following a roadmap for the evolution of socio-economic systems, and tenacious endeavours to proceed along indicated pathways. It is evident that the mere existence of such a roadmap may help, but will not be sufficient to achieve the outlined objectives. There is a strong need for two main drivers: (i) a constant and determined governance of the organisational development and innovation processes; (ii) the systematic identification of barriers (such as the defence of the "status quo") and their removal. Such barriers are the real opponents to innovation and change; their systematic monitoring and the deployment of counter-strategies to eliminate them are essential elements of achieving the Grand Objectives.

3. The FInES Research Challenges

"In the first decade of this century we built the means to understand, in this decade we need to build the means to change" (Anonymous)

An enterprise that intends to pursue the objectives indicated in the previous chapter, while retaining its competitive edge, needs to adopt innovation as its driving force. For this reason, FInES research challenges will have innovation as their key trait. Innovation is primarily a business attitude, independent of the business sector (aerospace, furniture, banking, etc.) or the enterprise department (marketing, production, human resource, etc.). Accordingly, the Research Challenges described in this chapter will be sufficiently general to impact on a FInES, irrespective of the type of enterprise or enterprise department.

A continuous innovation in the enterprise and its business requires special characteristics (e.g., agility, evolvability) for the supporting ICT systems. To this end, we believe that a FInES should be highly modular, based on a federation of "smart", interoperable components that we will refer to individually as Future Internet Enterprise Resource (FinER). A FInER will represent the digital image of some entity (tangible or intangible, simple or complex) in the real world, provided with four key features: public identity, computing, storage, and networking capability. A FInES will be implemented (and will evolve) by gathering and interconnecting different FInERs, characterised by different functions and granularity, located in (possibly) different places (typically, in the "cloud"), provided by (possibly) different suppliers.

In essence, we expect that the future research activities aimed at FInES will consider the following points:

1. The driving force of a FInES is its orientation to continuous business innovation.
2. A FInES will be capable of smoothly evolving while operational, i.e., while supporting ("in vivo") the enterprise in doing business (guaranteeing the daily work of enterprise resource management).
3. FInES functions and capabilities will be directly defined and shaped by business experts, without the intermediation of ICT experts or going through any form of software production cycle.
4. FInES will be based on the Cloud Computing paradigm and will consist of a cloud of cooperating FinER components.

According to the above points, we define for FInES six operational Research Challenges (RC) plus two strategic Research Challenges:

RC1 – FInES federated open application platform

RC2 – FInES awareness and intelligence platform, for monitoring a running FInES, and the context, to discover innovation needs and opportunities

RC3 – FInES re-design for innovation

RC4 – Innovative FInES implementation recasting

RC5 – FInES meta-knowledge infrastructure

RC6 – FInES interoperability & cooperation infrastructure

Then, we have the two strategic Research Challenges:

RC7 – FinER: the FInES constituent

RC8 – FInES Science Base: the foundational scientific methods

In this chapter, the above RCs will be expanded and better specified, aiming at providing some concrete indications for the future research activities in this area.

3.1. Introduction

A possibility for this chapter was to start from the primary industrial departments and functions (Finance and Controlling, Human Resources, Marketing, Production, Logistics, R&D, etc.) of an enterprise, trying to identify the possible evolutions and research challenges for the corresponding enterprise software applications. Another possibility was to start from the list of Grand Objectives illustrated in the previous chapter, identifying the research lines for the ICT solutions needed to achieve them. Either option risks being too analytic, failing to seize the essence of the paradigm shift that (hopefully) we will witness in the next 10 to 15 years. Such a paradigm shift is represented by the progressive drifting of the focus of Enterprise Systems, both for a single enterprise and, moreover, for networked collaborative enterprises, from enterprise resource management (that will undergo a progressive commoditization process) to enterprise innovation management.

Enterprise software applications were introduced almost half a century ago, aiming at automating three key areas of the enterprise: accounting, payroll, and resources & inventory management (Rettig, 2007). Since then, ICT has tremendously evolved: computers, communications, software methods and tools, interfaces; as have, in parallel, the markets, enterprise competition and production systems. However, the large majority of enterprise software applications (ESA) are still mainly dedicated to the management of enterprise resources.

We believe that there is an increasing need for changing the above picture, primarily because current ESA are too rigid and can hardly support continuous enterprise innovation. We expect that future research on FInES will provide the solutions to fill the gap between the (continuously changing) business needs and the ICT systems serving those needs (gap in terms of functionalities, but also in terms of delays in developing / re-engineering the required new functionalities). Finally, FInES research should be capable of changing the technological nature of the offered ICT solutions, by systematically introducing a number of non-functional features, such as interoperability, scalability, and evolvability, by design, i.e., as inherent characteristics and not as additional features.

3.2. Shifting from Enterprise Resource Management to Enterprise Innovation Systems

The shift from management-centric to innovation-centric enterprise systems will represent a major discontinuity in current ICT solutions and will pose key research problems. This research will be successful only if, in parallel, Future Internet, and the supporting technologies (from Internet of Things to Software as a Service, from Social Networking to Semantic Knowledge Management) will be consolidated and openly available. In particular, the paradigm of the Cloud Technologies appears able to provide the necessary flexibility and agility that today's enterprise systems are far from exhibiting.

Enterprise resource management is a complex discipline that (in general) is well understood and encoded in enterprise software applications, like, e.g., ERP systems. Such ESA, that represent today the key technology for an enterprise, exhibit a high degree of complexity and, when deployed in an enterprise, often require a long and expensive customization/development process, not compatible

with the agility and flexibility required by future enterprises (Umblea, Haftb, Ronald, & Umble, 2003). In fact, enterprises entering into a dimension of continuous and fast paced innovation call for a completely new way of conceiving and implementing enterprise systems. Another important aspect is the progressive adoption of networked collaborative enterprises and cloud enterprises, for which we need to rethink the boundaries, and their ICT systems need to span beyond the traditional enterprise borders (that, according to the mentioned Grand Objectives, will progressively fade way). Therefore ESA will be one of the first targets of the research.

Open enterprise innovation (Chesbrough, Vanhaverbeke, & West, 2006) is the key driver. Innovation can hardly take place within one single enterprise: it needs open boundaries and a continuous knowledge exchange. Such an exchange takes place downstream (from the research cloud, according to the Figure 3.1), promoted by research organizations and universities, but also upstream, driven by new markets and products.

Effective and consistent innovation can be achieved only if the three key fields: research, production, and market are tightly connected and there is a knowledge infrastructure that guarantees the continuous and smooth flow of information, experiences, scientific results, including production and market feedbacks. Figure 3.1 is a sketch of this idea, with a circular knowledge infrastructure that seamlessly connects all the playing fields with the central innovation field.

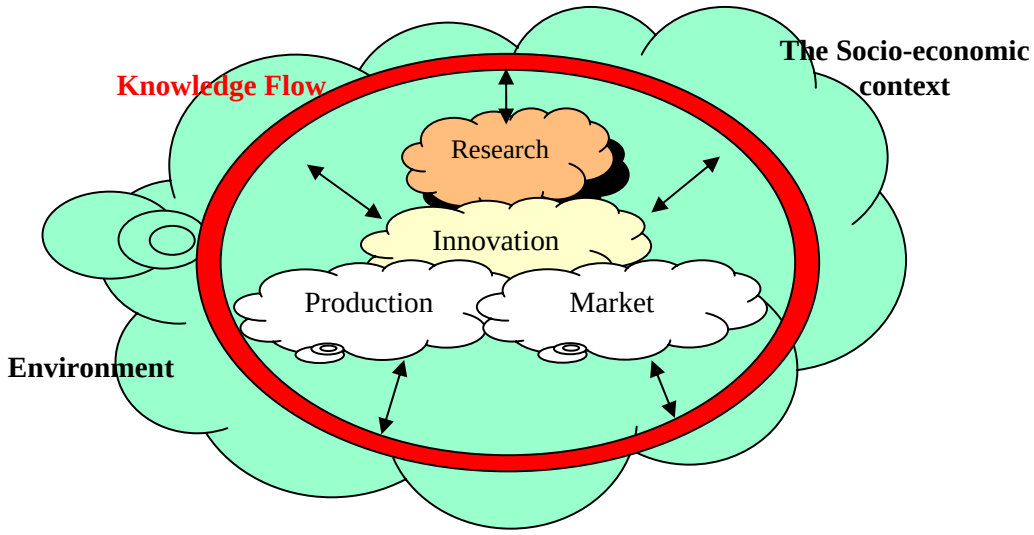

Fig. 3.1 – The circular knowledge

In Figure 3.1 each cloud represents, simultaneously, a set of characterizing activities and a number of different players, e.g., academia, industry, financial institutions, government, etc. The players are not rigidly positioned in one specific cloud, but may play different roles acting in different fields. For instance, an advanced enterprise can be positioned in all four clouds, while a university is mainly on the first cloud, but can be active also in the others (e.g., providing training courses for a commercial market or promoting academic spin-off).

3.3. The FInES Research Challenges

This is the central section that focuses on the 8 FInES Research Challenges. They intend to represent (again, as already done with the enterprise qualities in Chapter 2) more research directions than precise scientific objectives. According to our vision, the proposed research challenges will be (supposedly) pursued to variable extents; nevertheless we believe that even partial results will bring benefits to the enterprise world.

3.3.1. RC1 – FInES federated open application platform

This research challenge focuses on the identification of the guidelines for a service platform devoted to business operations and enterprise resources management, i.e., all the value-producing activities of an enterprise, in a continuous innovation perspective. In such a perspective, the business activities may be constantly subject to changes that may impact on a single area of the enterprise or cut across several of them. But the day-by-day activities cannot be stopped when introducing enterprise innovations and, accordingly, upgrading the ICT systems. The changes to the running systems will continuously happen. Depending on the nature of changes, in certain cases there can be a parallel running of new and old versions of the system.

Another objective of this RC is the extensive adoption of Cloud technologies. We expect that FInES computations will be achieved by services offered by FInERs, running "somewhere outside" in the digital sky. The same is true for the enterprise data, largely dispersed in some smart components (again FinERs), having autonomous processing, networking, and storage capabilities. This research challenge will identify new plarforms and architectures, open, federated, and trusted, aimed at optimally managing highly componentised architectures, where the business logic will be defined by business process models, enriched with business rules. Among the key enabling services there will be advanced search and dynamic composition of business services and resources, with effective orchestration and seamless interoperation, for the daily, value-producing business operations. In this kind of open, federated platforms, we expect that consistent research activities will aim at improving also non-functional aspects, such as trust and security.

3.3.2. RC2 – FInES awareness and intelligence platform

This research challenge addresses the problem related to the capacity of an enterprise to look at its own operations, understanding how it is doing, identifying innovation needs and opportunities, but also shortcoming and problems to be corrected. Here the research activities will aim at improving and integrating extensive monitoring, assessment, and forecasting capabilities into the FInES application platform envisaged in RC1. During the FInES operations (doing business) the constant observation of the enterprise reality, activities, performances, outcomes, quality, etc. is highly necessary. But equally necessary is the observation of the operating context: competitors as well as international markets, costs of resources, financial markets, and new technologies. Research achievements are expected, capable of capturing and representing the above observations, to be then carefully analysed and assessed in short to medium time perspectives, by business experts. The monitoring and gathered knowledge will feed activities able to identify the needs and opportunities for innovation. Such knowledge will be encoded in a rigorous form, ready to be used by advanced intelligence and analysis tools, and the outcome will be made available for the software environments that will emerge from the next RC3.

3.3.3. RC3 – FInES innovation-oriented continuous (re)design environment

This research challenge concerns methods and tools conceived for business people, to allow them to specify, and contextualize in the enterprise, the innovation needs and opportunities discovered inside

and outside the enterprise world (thanks to the outcomes of *RC2*). Business specification methods and tools, simulation, *what-if* methods will be available to support business experts' work. The emergent enterprise engineering methods, business process modelling tools, enterprise ontologies, represent some of the research directions that will contribute to RC3. Here modelling methods, tools, and notations (that may be formal or informal, diagrammatic or textual) will be particularly relevant. We expect that important scientific results will come also from research on Controlled Natural Language (Kuhn, 2007). The objective is to allow business experts to specify, in a precise and unambiguous ways, the innovations to be introduced at a business level, identifying where to intervene and how. Innovation and Change (I&C) specifications will be business-oriented, therefore avoiding any reference to the ICT dimension and the re-engineering of the underlying ICT systems. But the business specifications will eventually be precise and unambiguous, therefore making possible the mapping to the technical world and, ultimately, a rigorous selection of the new system components. With this approach, the responsibility of FInES development is markedly in the hands of business people. (In this perspective, the current problem of Business/IT Alignment (Luftman, Papp, & Brier, 1999) will simply disappear, since FinER components will directly implement business entities, and changes in the enterprise models will be fully mirrored by the new FInES specifications and therefore the FInER-based platform.)

Here, an important research area will address the problems that an enterprise faces in maintaining a unity of vision and action in a multiplicity of situations and conditions. Here once more we expect an important change of paradigm, diverging from the current approaches where we tend to design everything, to keep everything under control. We believe that in the future a FInES will interact with components provided with a large autonomy[20], in an open and federated approach, and the interactions will take place on a service base, disregarding inner details.

3.3.4. RC4 – FInES implementation recasting platform

Here the research objectives will be the identification of methods and tools aimed at transforming the I&C specifications into technical specifications and then a renewed running FInES. Since we expect that a FInES will be totally based on “intelligent” components (FinERs), the FInES Recast will be driven by the I&C specs and will be performed by: (i) search and retrieval of the new candidate FInERs; (ii) selection of the best fit FinERs; (iii) getting them together and (iv) integrating them in the running systems. The research in RC4 will identify solutions capable of supporting continuous innovation taking place “in vivo”, i.e., the upgrade and evolution of the FInES without stopping the ongoing business operations. Therefore a FInES will be able to always keep on its operational and running state. In this perspective, changes will be continuously applied and there will not be major releases as in today’s software systems. This RC concludes the four main sections of what will be a FInES ICT business environment. The two following RC represent two key infrastructures necessary to support the FInES philosophy.

3.3.5. RC5 – Meta-knowledge infrastructure

All the solutions stemming from the research activities proposed in the previous sections, RC1 to RC4, will be based on a constant flowing of business and technical knowledge. Here the research challenge proposes again a paradigm shift: from knowledge repository to knowledge flux. This RC5 addresses new methods and ICT solutions necessary to go beyond the existing knowledge management tools, fully deploying the idea of Internet of Knowledge (IoK). In fact, FInES knowledge will not be stored using the knowledge repository solutions we use today, that will survive only for specific cases. New solutions are needed to manage highly dispersed collections of knowledge fragments, directly positioned at the sources (typically, the FInER components), where they are generated and maintained.

[20] Autonomic computing and Multi-Agent Systems represent areas that will significantly contribute along this line.

For instance, a drilling machine will be an intelligent component of the IoK, capable of knowing not only its duties and capability, but also of storing its characteristics and the memory of its past activities. Such a memory will be (selectively) made available to other FInERs that may need to retrieve it.

The research will identify solutions for knowledge repositories that will exist at a "meta" level, in the form of ontologies and semantic directories, necessary for the indexing of all the resources over the Net. Among the offered services, based on such a meta-knowledge infrastructure, we expect effective solutions for the semantic search and retrieval of FInERs, for the semantic routing of information (i.e., information delivered not on the bases of a network address, but on the bases of the explicit or implicit information needs), for extensive ontology-based semantic annotation.

3.3.6. RC6 – FInES interoperability & cooperation infrastructure

This research challenge addresses one of the key problems that the emerging FInES approach raises: the fact that a FInES architecture will be highly federated, and therefore inherently "fragmented." A FInES will not exist as a defined system, e.g., as a fixed collection of software components, the large majority of the computations will be performed by intelligent interconnected "entities", i.e., the FInER material and immaterial components. The research activities in this RC will provide the ICT solutions to "glue" (in a digital way) together the different components and make them cooperate in a seamless way. To this end, the Interoperability Service Utility (ISU)[21] will be fully developed and widely available.

But since a FInES is inherently a socio-technical system, the human FInERs (more precisely, their digital image) will play here a central role. In this case, we expect the emergence of research solutions capable of managing interactions based on different paradigms, offering services that represent an evolution of, e.g., today social networking, cooperative decision making, and the ICT solutions for social and business transactions. Seamless cooperation between people, things, and computers will be fully deployed.

Since the basis of the FInES implementation is represented by the notion of a FinER, the next research challenge will be fully dedicated to this essential element of the FInES strategy.

3.3.7. RC7 – FinER: the FInES constituent

This RC foresees a progressive implementation of a rich, complex, articulated digital world where elements, referred to as FinER (Future Internet Enterprise Resources), will largely reflect what exists in the real (analogical) world. We expect that the FInER world will include all possible objects, creatures, entities, both simple and complex, animated and inanimate, tangible and intangible, that can be found in the real world. But that world will include also entities that we cannot find any more (e.g., since they existed once upon a time, but then ceased to exist), that we cannot yet find today, but we may find in the future (such as a simulated artefact before its implementation), and finally that never existed in the past nor will exist in the future (such as the Unicorn, Sherlock Holmes, or an aborted project).

We expect that such FInER entities will have a unique identity (e.g., according to IPv6, URI[22], or ENS[23]) and will be constantly connected (transparently, in a wired or wireless mode) to the Internet, reachable anytime, anywhere, by any other FInER. Depending on its real world nature and capabilities, a FInER will be able to perform from very simple operations, such as providing its

[21] The first Grand Challenge of the Enterprise Interoperability Research Roadmap developed by the predecessor of the FInES Cluster.
[22] Universal Resource Identifier, see Berners-Lee et al., 2005: http://gbiv.com/protocols/uri/rfc/rfc3986.html
[23] ENS: Entity Name System, proposed by the OKKAM project (www.okkam.org)

identity and state (e.g., in terms of its current property values), to complex operations. For instance, a FInER training course will be able to provide, when queried, the names of teachers and attendees, the room where it takes place, the teaching material, etc. A FInER business process (BP) will be able to evolve in time, proceeding along its steps, looking for other FInERs (e.g., web services, material resources, people, etc.) necessary to achieve its duties.

An enterprise will be a rather complex FinER; its components can be produced by the enterprise itself, like a business strategy (an example of an intangible FInER) or by someone elsewhere (e.g., a service forecasting the BRENT cost). We expect that advanced research will soon be capable of defining how to produce their correct description, specification, and composition starting from simpler FInERs[24]. The creation of a FInES (i.e., a FInER enterprise) will be largely based on the availability of a rich digital world from where the FInER components of the enterprise will be acquired, very similar to what exists in the analogical world. FInER elements will move in and out of the enterprise cloud (e.g., when hiring a new employee, dropping a project, activating a new partnership).

FinERs can be organised into 5 categories connected as a pentagon, where the enterprise is defined in terms of, and operates in cooperation with, FinERs representing: people (Per), public institutions (Gov), tangible (Tan) and intangible (Int) objects. This is illustrated in Figure 3.2.

In the figure, the FInES Pentagon, where the nodes correspond to the 5 FInERs categories, represents a totally connected pattern, since in principle each FInER can communicate with any other one. Furthermore, there are loopy links that represent the cooperation among FInERs of the same category. For instance, an enterprise can be connected and interact with other partner enterprises, or access to (the public information about) competitor enterprises. Let us see each node in more detail.

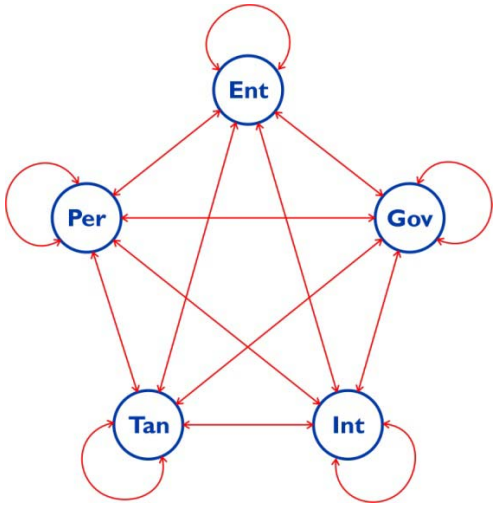

Fig. 3.2 – The FInES Pentagon

Tan – Tangible entity. This is a FInER that will be made available by the research of future Internet of Things (IoT). We expect that, depending on the complexity and the role of a Tan, the corresponding FInER will have computational, behavioural, networking, and memory with more or less advanced capabilities. RFID and nano-computing will play here a central role. In terms of capabilities, they will go from a minimum of presenting itself, when queried (or "hit" by a wireless request, in case of the simplest FInERs without a power autonomy) to a maximum of complex functionalities of an engineering artefact (such as an aircraft, aware of

[24] Here we will expect to see an acceleration in the Enterprise Engineering discipline

its characteristics, components, etc.), where the computing capabilities of the whole (e.g., self-diagnosis) will include also the sum of its components' capabilities. (But, obviously, will have emergent features not derivable by the sum of its components.)

Int – Intangible entity. This is a FInER that represents, as anticipated, any possible immaterial object, method, artefact. Similarly to a Tan, also in this case they may go from simple to very complex. But the main difference is that they exist only in a digital form (e.g., as a knowledge base entry, as a web service) even if some parts can be Tan (e.g., the room of a training course). Therefore, an Int, as a whole, is a social or conceptual entity (e.g., a virtual organization, a marketing strategy, a soccer game) and, being immaterial, it exists with its identity and the associated capabilities somewhere in a computing cloud.

Per – People. This kind of resources tightly corresponds to natural persons in the real world. Indeed this is a complex FInER, since a person may have different roles (employee, father/mother, tennis player, etc.) and different kinds of records (e.g., medical, fiscal, legal, etc.). Furthermore, we need to consider also the diachronic dimension, since the Per will be also aware of his/her past experiences and events. How all this will be represented is a challenging research question, but we are confident that within a decade, concrete results will be practically available.

Gov – Public Administration. Here we will have the FInERs representing the organizations, offices, and functions of the Public Sector (Government). In our perspective, we do not consider the Gov at large, but only the specific aspects that concern the interaction with enterprises (this limited perspective can be easily extended, if needed, e.g., in a PPP context). A single public office will appear as a complex FinER, offering services and exhibiting behaviour, composed by other FInERs and, as illustrated in the Pentagon, interacting with all the other FInERs needed to accomplish its duties.

Ent – Enterprise. An enterprise is a complex, articulated entity. A FInES will be a coalition of FInERs components, working together to implement the corresponding real world enterprise. Such FinERs will be selected and composed according to the specifications produced in RC3 and implemented according to the methods identified in RC4. The main FInER components will be organized according to enterprise functions and departments: from production to marketing, from human resources to technological infrastructures, from research and development to finance and control. Today, ESA in enterprises (such as SCM or CRM, CAD/CAM or ERP) are at the same time highly specialized, pervasive, and still not fully interoperable. Such a situation is further aggravated when we address global companies, that operate in different markets and produce in different regions of the planet. We expect that, thanks to FInER and ISU solutions, the mentioned difficulties will progressively fade away.

3.3.8. RC8 – FInES Science Base

This is a foundational research challenge that will cut across all the other RCs. The objective here is to provide sound scientific foundations to the FInES research activities, avoiding researches that often tend to be too technology-driven. FInES is emerging as a complex research domain, where different scientific disciplines converge, together with empirical practices, engineering techniques, and technological solutions. Technology represent the bricks and mortar of FInES, but when it starts to be the driving force of a research, it is easier to get concrete results in a short term, but at the same time such results will be dependent on the selected technologies. Technologies evolve at a very fast pace, and technological waves follow one another; past experiences show that solutions tightly connected to a specific technology are difficult to be updated when the latter is outperformed by a new, more convenient technology. We expect that research activities founded on solid scientific and mathematical basis will have a longer life. Furthermore, the produced solutions will have clearly

defined properties and foreseeable behaviour, often supported by suitable metrics and measurement techniques.

3.4. Conclusions

In this chapter we described 8 major research challenges related to a new generation of enterprise systems referred to as FInES. The illustrated RCs are primarily motivated by the need for an open innovation paradigm, to be structurally embedded in future enterprise systems. This is the major challenge that calls for a substantial research effort at European level, since the presented objectives are hardly reachable by a fragmented research community. Furthermore, the outlined research activities need to gather a number of different disciplines together, since once again the richness and complexity of the needed socio-technical solutions cannot be obtained by a single disciplinary scientific community. In essence, FInES represents a research domain where successful initiatives need an interdisciplinary approach, gathering competences that go from telecommunication to knowledge engineering and linguistics, from enterprise engineering to business modeling and sociology, from economics to mathematical logic and graph theory.

As anticipated, the RCs illustrated in this chapter intend to draw a number of research directions rather than precise scientific objectives. The extent to which the indicated directions will be covered will depend on many factors, among which of paramount importance will be the availability of supporting technologies. The next chapter will address this fundamental part of the FInES Research Roadmap.

4. Future Internet Enterprise Systems – Emerging and Supporting Technologies

"Technology is neither good nor bad; nor is it neutral."
(Melvin Kranzberg)

4.1. Introduction

Enterprise Innovation is often regarded as business-driven. However, history demonstrates that it is often the case that a new technology stream enables new innovations in general and new Enterprise Systems in particular. Therefore, we follow a two way approach: On the one hand, we base our roadmapping analysis in the research challenges that are presented in chapter 3 by performing a top down objective-driven process from the conceptual research challenges into the technological sector. On the other hand, we investigate the current technology situation from the bottom up. This reveals new technological trends that are currently emerging which will affect enterprise systems in the future. Consequently, in order to analyse emerging technologies and to evaluate their effect on the research in Enterprise Systems, we follow this methodological approach:

- We start by identifying technologies that have arisen in the last few years and have gained a certain momentum. From these technologies, we determine the behaviour of the current major technological streams and extrapolate them into future time periods. On this base, we analyse the potential impact and show the consequences for the research challenges. But this analysis is mainly based on extrapolating the current technological situation.
- In order to identify upcoming technologies, we screen for current technological developments that although immature are likely to be successful. We examine this portfolio and select promising initiatives that have the potential to influence the business domain and enterprise systems most.

Following this methodology, we cover a wide range of individual development initiatives in order to reduce the risk of overlooking significant technologies. Moreover, in addition to identifying and describing the technologies, we correlate them with the research objectives identified in chapter 3. By these means, we provide a comprehensive and coherent view on supporting technologies and on their contexts.

4.2. Research Challenges and Emerging Technologies and Approaches

Chapter 3 of this Roadmap has identified the following 8 Research Challenges:

RC1 – FInES Innovation-oriented open application platform

RC2 – FInES Awareness. i.e., monitoring a running FInES, assessing its operations and outcomes, and the context to discover innovation needs and options

RC3 – FInES re-design for innovation

RC4 – Innovative FInES recasting

RC5 – FInES meta-knowledge management

RC6 – FInES interoperability and cooperation support

RC7 – FInER: the foundational element of the FInES approach

RC8 – FInES Science Base: the foundational scientific methods

Among these, the last two are strategic research challenges and the first six are operational ones. The operational challenges are related as shown on the left of Figure 4.1: The **Operations** are a short name for RC1: FInES Innovation-oriented open **application** platform, which is established as a result of RC4: Innovative FInES **Recasting** and RC3: FInES **Re-design** for innovation. RC2 – FInES Awareness (**Monitoring and Analysis**) collects information and metrics to be used for the Re-Design from the sensors established in the "Operations" level.

The Open Platform and Operations challenge is supported by RC6: **Interoperability and Cooperation** support, which in turn depends on RC5 – FInES **Meta-Knowledge Management**.

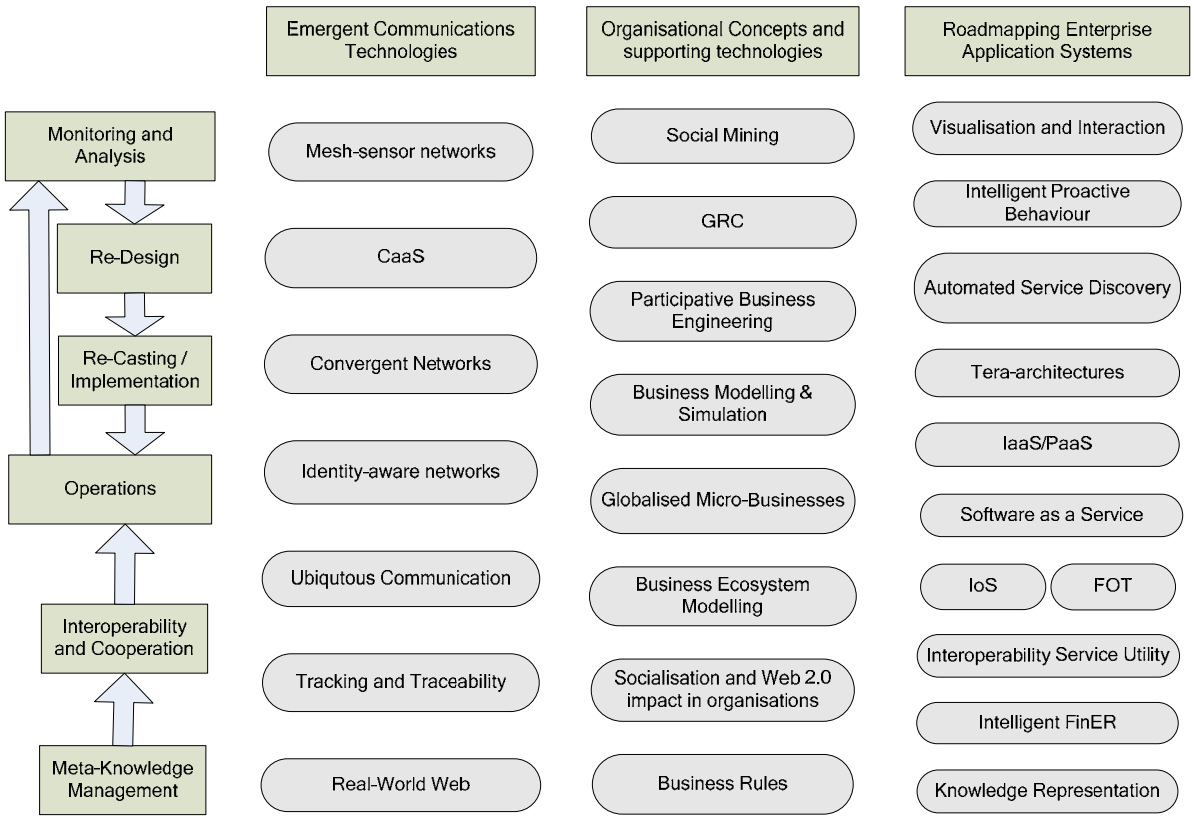

Fig. 4.1 Emergent Technologies and Approaches in Relation to the FINES Research Challenges

These dependencies between the different research challenges give us the levels at which we can seek support from innovative emerging technologies and approaches. These can be classified into three groups, represented as columns in Figure 4.1 – Emergent Communications Technologies; Organisational Concepts and their supporting technologies; and Roadmapping[25] Enterprise Applications Systems. Each of these groups will be reviewed in a separate section below, after a general introduction to Enterprise System Technologies demonstrating their linkage.

[25] In essence, here the research lines specifically aimed at the development of enterprise applications are reported.

4.3. Understanding Enterprise System Technologies

An Enterprise System (ES) is a complex socio-technical system. In order to understand and analyse this system better, we will proceed to decompose the ES structurally. Mainly, enterprise systems can be differentiated into a social and a technical part. The social part describes how people work in an enterprise or ecosystem. It is related to the organisational structure. Therefore we call this part the organisation system. The other part is related to all kinds of technical systems, which we will further decompose. In respect to information, we can differentiate three kinds of operations with information: (i) systems that mainly process information, i.e., application systems; (ii) systems that mainly transfer information, i.e., communication systems that transport information from one entity to another; and (iii) non-ICT technical systems, i.e., systems whose core function does not deal with information (e.g., manufacturing robots, automated inventories). Consequently, technical enterprise systems can be divided into the above four categories of systems. Each of these systems can either have an intra- or an inter-organisational focus.

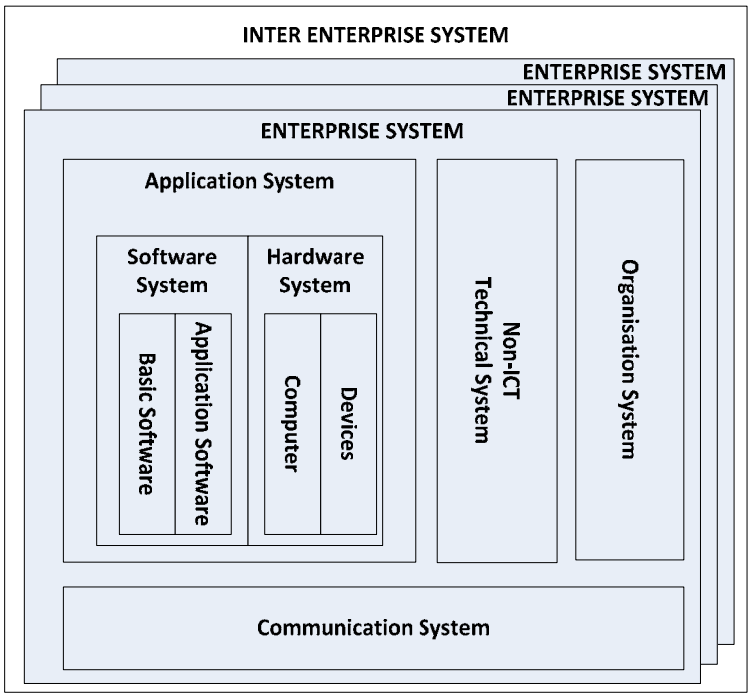

Fig. 4.2 Categories of an Enterprise System

In our analysis, we will mainly focus on the aspects of business (the organization system) and of ICT (application and communication systems).

4.4. General trends

The guiding current trends in technologies are decentralisation and socialisation. The first is ranging from enterprise organisation concepts, e.g. dynamic business ecosystems, via software architectures, e.g. Software-as-a-Service paradigms, to hardware technologies, e.g. mobile devices and RFID/NFC (Near Field Communication). Both logical and physical centralistic structures are being dissolved towards structures where the components have their own resources and the autonomy to control them. Socialisation is the other major trend. It also affects both the business domain, e.g., by mass

customisation and viral marketing, and the technical domain, e.g., by Web 2.0 software. Following this line of evolvement, we will come up with an environment that is fully decentralised and social-oriented. Small and highly specialised enterprises whose core competence relies on their human resources are densely interconnected both by ICT itself and by ICT supported social relationships. In these dynamic ecosystems the computational power is provided by the devices that are tagged to things and humans and that are highly networked.

4.5. Emerging Communication Technologies

The main driver in communications is **convergence**. This trend affects all major areas, in particular:

Convergent networks: Different kinds of networks (wireless or wired, P2P or meshed, ...) for different purposes (voice, video, data, control, …) are being homogenised and share protocols and formats. But convergence is more than a simple basic technology trend, as more and more features are included in the networks. This development started with the quality-of-service aspects that are needed to be addressed in all transportation layers and components. Newer developments incorporate more application-side aspects in the communication. One example is **identity-aware networks**. In those, the communication infrastructure authenticates user and uses this user data, and the associated user profile, for on-instance-customisation of the communication (e.g. the routing). Another example is **context-aware networks**, where the state of the context is used by the network to direct user requests to the right application service. In this respect, the border between applications and communications is increasingly blurring.

Wireless Communication is another steady trend. On the one hand, this means that communication devices are connected via radio-frequency channels. More and more communication scenarios are influenced by mobile technology. Starting with regular voice technology, continuing via data communications on the mobile, and then to Wi-Fi last mile connectivity, wireless increasingly substitutes the wired connection. This is expanding to all kind of 'smart' things, connected by RFID and NFC.

Real World Web: Due to the fact that sensors and small devices are penetrating daily life in all respects and that the correlating communication channels are spread mesh-like over the different domains, the real world communication is no longer distinct from the technical communication. This leads to wide-spanning and all-to-all-connecting networks, e.g., discussed as the Real World Web.

Ubiquitous Communication: Following this line of development, there will be no differentiation between real communications – in speech, script or gesture – and its correspondence in the digital world. Ultimately, it drives towards ubiquitous communication.

Smart-Product Infrastructures: Targeting the real-time identification and tracking of products associated with RFID tags, these technologies for example will facilitate and speedup the information visibility in supply chains.

Mesh-Sensor Networks: Wireless architectures are mainly centralised. In regards to wireless communications, the technological direction points towards a decentralised architecture at the side of the "front store devices" (mobiles, terminals, etc.) and a centralised architecture at the side of the backend infrastructure. At the front store, terminals and devices will be structured like Mesh-Sensor Networks. This means that they build up wireless ad-hoc networks based on mobile devices where in a peer-2-peer manner available routing resources are used in the most efficient way.

Communication as a Service: At backend, the communication infrastructure will further be consolidated, standardised and partially virtualised. By this, the technical infrastructure will be organised as Communication as a Service.

4.6. Emergent organisational concepts and supporting technologies

The way people work in an enterprise already is and increasingly will be influenced by the possibilities offered by participative, social software and intelligent components that can proactively work in decentralised, loosely coupled structures. Thus, going beyond static models of organisational systems and corresponding ways of IT development, emerging technologies for adaptive business process modelling, participative software development, and flexible yet stronger automated interconnections between players in the value chain (e.g. customisation) will allow the development of optimised, dynamic business ecosystems. To enable such systems, the following emerging and supporting technologies can be expected to play a major role:

Collaborative Enterprise Networks - Interconnection of enterprises is one of the most important trends in the information age. As a consequence, there emerge different concepts on networked enterprise practices. E.g., they strive for a loose coupling of organisational systems that requires only minor changes of internal systems but still enables the automation of cross-organisational processes. The emphasis is more on collaboration processes that form the baseline for flexible business networks. In special cases, these networks are created ad-hoc on a spontaneous business opportunity and they will dissolve after the opportunity is closed.

Participative Business Engineering - The fast and correct integration of (business) requirements is a traditional goal of software development. In this context, methods for Participative Business Engineering should be developed, that support the incremental development of organisational systems by making use of the collective intelligence of multiple stakeholders, as well taking into account other contextual factors.

Social Mining Techniques - To analyse requirements for generic products as well as organisational IT systems expressed in user communities, Social Mining Techniques need to be developed. Such techniques derive information from the mainly unstructured data that people place in IT systems (e.g. email or communities) and from the contents of the communication between them.

Business Ecosystem Modelling - The participative approach should also be used for Business Ecosystem Modelling, representing a number of interlinked enterprises (either large or small enterprises, including for example Globalised Micro Businesses), which collaborate and compete within a given marketplace segment. This field enhances the traditional discipline of enterprise modelling and enlarges its scope.

Business Modelling - In a similar vein, methods and tools for Business Modelling should be developed that depict the overall business model of an organisation (e.g. “the essence of a business”) in order to support the automatic analysis of its business performance and to provide for (automated) adaptations of the business model.

Comprehensive Business Simulations – Based on Business Ecosystem Modelling data and Business Model specifications, economic systems can be simulated. Such simulation models based on ecosystem principles can be used by both analytical and predictive tools. For example, the model can replicate existing systems in order to discover patterns in the way inter-company relationships react to change. In the predictive mode, changes in the norms governing the business ecosystem can be experimented with, and "what if" scenarios played out. In order to

obtain a continuous alignment and system optimisation, (real-time) analysis and predictive methods should be combined.

Business Rules - For the sake of optimisation, flexible, fast adapting business models and organisational systems are wanted. However, these need to follow **Marketplace norms and rules**. To describe these norms and validate enterprises that follow them, approaches for formalising the organisational and legal norms governing a certain marketplace or a business ecosystem have to be developed. Building on such formal representations as well as representations of the tasks to be achieved by components, the behaviour of organisations can be guided and analysed according to the rules specific to their context. In order to comprehensively analyse and predict the behaviour of organisational systems, inter-disciplinary technologies need to be developed that integrate multiple aspects of decision making, as done for example in **Behavioural Economics.**

GRC - Further, technologies for **Governance, Risk Management, and Compliance (GRC)** need to be enhanced, paying attention to more complex environments and large amounts of data to be processed. Technologies for modeling rules, adapting them flexibly and analysing intelligently the underlying systems, have to be created.

Security, Privacy and Trust - Organisations running FInES have to open their firewalls and networks for external users of collaborating companies. As well, the power of individuals by e.g. Web 2.0 techniques, raises additional security and privacy risks for such distributed environments. Hence, those trends (decentralisation and socialisation) change existing concepts fundamentally and evolve computing to the next stage. However successful, efficient and in particular secure operation of such environments requires an immense degree of further research in the fields of computer security, privacy-enhancing technologies and trust mechanisms for organisations, FInES, and individuals.

4.7. Roadmapping Enterprise Application Systems

The main technological paradigms of decentralisation and socialisation foster an apparently clear picture of future internet enterprise systems. However, examining technological trends that are still too immature to get wide attention but that incorporate high innovation potential, the picture could change.

Tera-architectures are one example. The foundation is the trend that all kinds of systems capture, collect and report more and more data about its environment. Examples are temperature-measuring-RFID-tags or geotagging mobile applications. In future, probably everything electrical will potentially communicate its status, what it is doing, where it is, and what the environment is doing in its vicinity. The amount of information collected by these devices will grow rapidly, resulting in system environments that have to deal with multiple terabyte of data – mainly in real-time (see FInER in previous chapter). The achievement of such decentralised, network-connected structures is one of the technological challenge of the future.

Applications with proactive behaviour are another example. The main paradigm of the current technological streams is to record and to process transactions (in the wider sense). There, ICT has a passive or at most a reactive behaviour. In order to best support humans and organisations, systems have to foresee the upcoming activities and provide assistance for things that even haven't started yet. Systems should initiate changes rather than reacting on events, in terms of investigating several information sources, performing an internal forecast, and updating accordingly the related processes. This is similar to a prefetching activity within a CPU: Things are anticipated risking that the activity might be useless. But

in fact this contradicts to the initiative of Green IT, aiming at reducing energy consumption and eliminating useless or effect less activities. On the other hand, proactive forecasting can predict the non usage of resources and shut down energy using devices if it is foreseen they will not be necessary.

IaaS or PaaS: On the one hand, future software systems have to fulfil the requirements of changing organisational settings, e.g., support flexible yet controllable business ecosystems. On the other hand, developments in software systems trigger organisational development by expand the way these can work. Recent trends observable in emerging and supporting technologies in the field of basic software and infrastructure include for example software related to cloud computing like IaaS or PaaS (Infrastructure/Platform as a Service). However, existing solutions for cloud technology focus on the solutions offered by specific vendors (e.g. Amazon) or on clouds inside organisations. To make the market for resources in the cloud larger and more transparent, developments are needed that enable the usage of resources also beyond such limited areas; therefore, methods to specify the searched resources and to ensure the correct (trustworthy, reliable) delivery of the resources are needed.

Interoperability as a Service: Due to the increasing permeation of networks and the increasing number of heterogeneous components comprised in them, future infrastructures need to offer advanced interoperability technologies. Here recent trends like the **Interoperability Service Utility (ISU)**, aiming to establish "out of the box" services that provide interoperability, will be elaborated. These trends envision interoperability support as a utility, like capabilities that needs to be supported by an enabling system of services, for delivering basic interoperability to enterprises, independent of particular IT deployment. The ISU is specifically envisaged to provide interoperability as a technical, commoditised functionality, delivered as a service.

Knowledge Representation and Semantic Modeling: However, to allow such services to work, they need underlying concepts for matching syntactically heterogeneous concepts to each other, i.e. advanced, scalable technologies to obtain Semantic Interoperability. Knowledge Representation and Semantic Modeling techniques are needed for the reconciliation of different eBusiness documents for collaborative planning, further covering the semantic mediation of available services, by providing information to express meaning of the data and of the vocabulary referenced by the interface. Formal automated reasoning needs precise representation of knowledge, in such a manner as to facilitate human knowledge inferencing.

Federated, Open and Trusted Platforms (FOT): In summary, the mentioned above technologies should support Federated, Open and Trusted Platforms (FOT) in which the smart applications of the future internet can run.

Internet of Services (IoS): This is also expressed in the idea of the Internet of Services concept, where services of all areas of life can easily be found, composed and executed over networks. To realise this aim, the merging of technologies known from SOA, semantic web and Web 2.0 is necessary.

Software as a Service (SaaS): Complementary to the trends described above, emerging and supporting technologies in the field of application software will elaborate the Software as a Service (SaaS) concept. Here again, concepts for discovering, executing and composing trustworthy services need to be improved.

Automated Service Discovery and Configuration: Also, technologies that automatically deduce characteristics of the searched service need to be enhanced, for example context-dependent technologies like **Mobile Search**. In this context, intelligent **Matchmaking and Negotiation Mechanisms** need to be developed, enabling both the discovery of resources with certain attributes and the automated agreement on monetary or other conditions of service execution. See section on the FInER in the previous chapter.

Intelligent and smart components: These are instantiations of FInER. They could be realised by agents, or, more generically, by software components that incorporate some intelligence. Therefore, knowledge-representation and other AI techniques need to be combined to create components which are proactive in pursuit of set goals and can be used to both represent and support items at different levels of abstraction - from information repositories and people to interacting enterprises. Such components can use standard high-level languages to exchange information, negotiate a sale or another contract, and even to argue with each other about what would be the best course of action. They can then serve as a building block for relation approaches such as business ecosystem modelling.

Visualisation and Interaction technologies: Moreover, building on current trends from the convergence of real and virtual worlds (e.g. augmented reality), suitable Visualisation and Interaction means need to be developed to help creating, modifying and analysing complex business systems.

5. Assessment of Key Achievements of Past Projects and Beyond

"We are dwarfs standing on shoulders of giants"
(Bernard de Chartres)

5.1. Introduction

This Chapter uses the research challenges identified in Chapter 3 to report on the main areas of existing technology and research work and the extent to which they cover the emerging technologies and research issues identified in Chapter 4. The analysis is informed by existing projects within and beyond the FInES cluster, e.g. COIN, CuteLoop, iSURF, K-NET and many others. It covers projects contributing to the interoperability, RFID and digital ecosystems dimensions of the cluster. In this it utilizes the vision that by 2020 enterprise collaboration and interoperability services should become an **invisible**, **pervasive** and **self-adaptive knowledge** and **business utility** at disposal of the European networked enterprises from any industrial sector and domain in order to rapidly set-up, efficiently manage and effectively operate different forms of business collaborations, from the most traditionally supply chains to the most **advanced** and **dynamic business ecosystems**.

Chapter 4 focused on three main aspects of emergent technology and research challenges: Emergent Communication Technologies, Organisational Concepts and Supporting Technologies, and Enterprise Application Systems. It itemised a number of emergent technology and research challenges, and aligned them under each the three areas and against one or more of the research challenges identified in Chapter 3 (see Figure 4.1.) Figure 5.1 complements this and illustrates how these items are covered by the eight main areas of research and technology state-of-art reviewed in this chapter. Inevitably, there are some gaps, mainly because some of the emergent technology and research challenges are still at very early stages of their lifecycle and there is no significant body of research.

The eight main areas of research and technology state-of-art reviewed in this chapter are as follows: **Smart Products** and **Security and Policies** under the *Emergent Communications Technologies* column, **Socialisation** and **Digital Business Ecosystems** under the *Organisational Concepts* column, and **Intelligent Software**, **Operational Infrastructure**, **Software Services** and **Enterprise Interoperabilit**y under the *Enterprise Application Systems* column. These will be reviewed in turn.

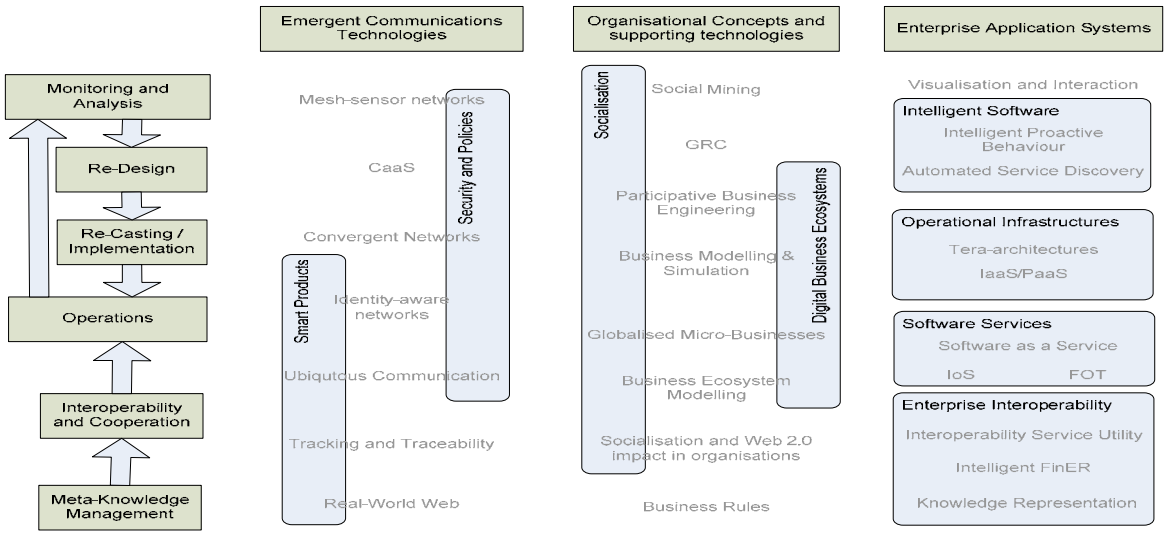

Fig. 5.1 - Coverage of R&D themes by the eight main areas of SoTA discussed in this Chapter.

5.2. State-of-the-Art

Below the FInES State-of-the-Art analysis is reported according to the mentioned three main technological categories.

5.2.1. Emergent Communication Technologies

Smart Products

Within a matter of several years, an entire industry has been built around **Smart products** and **networked devices,** as revolutionary intelligent products. This session introduces the state-of-the-art on top of the RFID standards, which are the core smart-enabling technology. Currently EPC (Electronic Product Code) has been established as a global standard in this area, initiated by the collaboration of GS1 and Auto-ID Center after the emergence of RFID technology.

As the new applications require new standards when dealing with the increased data communication, a further standardization initiative called EPCGlobal Network has been launched by EPCGlobal, a joint venture between GS1 and GS1 US, addressing the changing requirements in the field. The aim of the EPCGlobal is to effectively create an "Internet of Things" that establishes the connection between software and real objects. The Electronic Product Code (EPC) Network allows immediate, automatic, and accurate identification of any item in the supply chain of any company, in any industry, anywhere in the world, as well as the tracking, tracing, monitoring and triggering of events. With the global adaptation of EPCGlobal, it is expected that the supply chain visibility will be enhanced.

GS1 GDSN™ (Global Data Synchronisation Network) supports that by offering an automated, standards-based global environment that enables secure and continuous data synchronisation, allowing all partners to have consistent item data in their systems at the same time. The Global Data Synchronisation Network (GDSN) connects retailers and suppliers, via their selected data pools, to the GS1 Global Registry™. The GDSN vision is being realized today by thousands of retailers and manufacturers worldwide who are reaping the benefits of live implementations. Global Registry membership covers multiple sectors across North America, Latin America, Europe and Asia Pacific.

Being an active research area, in this respect several EU-projects have been launched at the example of BRIDGE, CuteLoop and iSURF.

Security and Policies

Trust and Security remain the most critical issues, raising awareness when designing and launching new technologies. Therefore many European projects have focused on security topics, which aim at bringing to light new concepts related to risk analysis, privacy and dependability. In this respect the Journal of Computer Security (European Commission C. , 2009)[26] has launched a special issue highlighting the results of six projects funded under the 'Information society technologies' (IST) Thematic area of the EU's Sixth Framework Programme (FP6): ANTIPHISH[27], S3MS[28], SECOQC[29], OPENTC[30], PRIME[31] and HUMABIO[32].

[27] ANTIPHISH ('Anticipatory learning for reliable phishing prevention')
[28] S3MS ('Security of software services of mobile systems')
[29] SECOQC ('Development of a global network for secure communication based on quantum cryptography')
[30] OPENTC ('Open trusted computing')

From a technological perspective that relies on service-oriented-architecture as latest state-of the-art, several standards bodies have been developing standards and specifications to provide comprehensive security schemes for web services; such as the World Wide Web Consortium (W3C), the Organization for the Advancement of Structured Information Standards (OASIS), and Liberty Alliance. The prominent standards and specifications include XML Signature, XML Encryption, XML Key Management Specification (XKMS), Security Assertions Markup Language (SAML), XML Access Control Markup Language (XACML), and WS-Security.

5.2.2. Organisational Concepts

The terms of **virtual organization and virtual clouds** refer actually to the trends in the theory of socio-economical transformation of the classical organisational structures. In the virtual organization companies come together for a common purpose and present themselves as a single (virtual) entity whilst retaining their independence. Many organisational concepts contribute to this vision; here we focus on socialisation and digital business ecosystems.

Socialisation

From the technological perspective "Web 2.0" has been the revolutionary technological paradigm, which contributed in facilitating interactive information sharing over web applications, as well as interoperability, user-centric design and collaboration on the World Wide Web. Currently Web 2.0 includes web-based communities, hosted services, web applications, social-networking sites, video-sharing sites, wikis, and blogs.

Building on that, new emerging approaches are being explored in the perspective of the Knowledge Society and enterprise context for enhancing a better involvement of customers in the product life-cycle. Hence the term Enterprise 2.0 becomes currently more and more applicable, referring to the introduction and implementation of Web 2.0 technologies in the enterprise business and commercial contexts, by including rich Internet applications, providing software as a service, and using the web as a general platform. Additional information about the customer context for the enterprise products can be provided by the social network analysis (Newman, 2003) (Jamali & Abolhhassani, 2006) (Mika, 2007)

In this space, the FP7 EU-project K-NET[33] is exploring how to enhance knowledge management for a company by using services which manage social interactions in a networked enterprise.

Digital Business Ecosystems

In the network era competitiveness of companies is reduced when decision making is inconsistent due to incomplete understanding of the impact of decision on the organization. This requires collaborative, open and transparent, self-organizing and always evolving systems, known as Digital Business Ecosystems, which refers to a business community of organizations and interacting individuals in an environment of networked organizations. Enabling this vision requires supporting cooperation and collaboration, knowledge-sharing, open and adaptive technologies, as well as evolutionary and scalable business models. Beyond Second Life and Facebook, Digital Ecosystems are becoming currently an active research area, for example the OpenGrid-Wide Marketplaces and Social Geo Tagging Systems.

The FP6 EU-project OPAALS[34] is in this respect a multi-disciplinary network of research excellence which aims at building a sustainable interdisciplinary research community in the emerging area of

[31] PRIME ('Privacy and identity management for Europe')
[32] ('Human monitoring and authentication using biodynamic indicators and behavioural analysis')
[33] http://www.k-net-fp7.eu/k-net/index.jsp

Digital Ecosystems and to develop an integrated theoretical foundation for Digital Ecosystems research, which spans three widely different disciplinary domains: social science, computer science, and natural science.

In the enterprise context many standardization efforts on different enabling disciplines have been realized, such as on the knowledge-sharing establishing a **Supply-Chain Operations Reference-model (SCOR)** or formalizing the processes between the trading partners through **Collaborative Planning, Forecasting, and Replenishment (CPFR),** which helps partners to agree upon a joint plan and forecast, monitor success through replenishment, and recognize and respond to any exceptions.

5.2.3. Enterprise Application Systems

Intelligent Software

The current developments in ubiquitous embedded devices, RFID and sensor networks make it imperative to move beyond traditional experts systems view toward interactive and proactive computing behaviour. Systems of the future should act proactively to human behaviour, monitoring and responding without constant human supervision, using devices that can configure, adapt and maintain themselves and decide what actions should be taken given a certain situation. These devices are conceptualized as agents and multi-agent systems, which can manifest self-organization and complex autonomous behaviours. The challenge for the research community is to explore and investigate the implications and issues related to having hundreds or thousands of networked computers and devices per person, and to overcome the significant challenges on the road to realizing the vision of proactive computing. Being a multidisciplinary research area, Proactive System architectures are building on artificial intelligence technologies in terms of dealing with uncertainty and ability to anticipate human needs and acting on them; wireless technologies, as a requirement for deep networking; and Macro-Processing technologies to provide a fluid mechanism for computations to move from one node to another; further focusing in the future on the socialization paradigm on making computing personal.

Industry has been interested in this research topic for many years. In 2001, INTEL opened a lab to develop proactive computing technologies; working toward environments in which networked computers proactively anticipate our needs and, sometimes, take actions on our behalf[35]; focusing on technologies that could be commercialized in the 2005 to 2010 time frame. Also on national level, the Board of the Academy of Finland in cooperation with the French Ministry for Research and New Technologies has been decided on November 2001 to launch a three year Research Programme on Proactive Computing (PROACT). The programme was carried out during 2002–2005. At the European commission many initiatives have been launched in FP6, to be enhanced during FP7. For example, the ICT-FP7-workprogramme 2009-2010 has been including several FET Proactive Initiatives, as the example of “Self-Awareness in Autonomic Systems”, which aim at investigating the concepts and implications of self-awareness, as being a key enabler to autonomic behaviour, and the challenges in modeling, engineering and building self-aware autonomic systems.

In this respect the FP7 EU-project SAPERE[36], which has been funded under Call-5, FET proactive, Goal 8.5: Self-Awareness in Autonomic Systems; is aiming at developing a highly-innovative theoretical and practical framework for the decentralized deployment and execution of self-aware and adaptive services for future and emerging pervasive network scenarios.

Operational Infrastructures

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[34] http://www.opaals.eu/
[35] http://www.eetimes.com/news/semi/showArticle.jhtml?articleID=10810097
[36] http://www.pervasive.jku.at/

The operational infrastructures reviewed here offer the support needed for the organisational concepts of virtual organisation and digital business ecosystems. The next generation of **cloud computing** technology, for example, is being adopted for applications related to supporting extended collaboration among global supply chain processes. Since cloud computing is providing the capability of flexibly outsourcing the supply chain collaboration software and infrastructure needs in a much more efficient manner. Rather than paying and maintaining for peak use, this technology offers the flexibility to add on the fly, based on overall business process and supply chain network model.

Software-as-a-Service (SaaS)

SaaS is one of the fastest growing segments of the of the software industry, because it enables enterprises to meet their business objectives in a more cost-effective way than traditional packaged applications. SaaS relies on the **Service-Oriented Computing** paradigm (SOC) which includes **Service-oriented Architecture (SOA),** and both are based on the concept of a service, aiming to bring the benefits of loose coupling and encapsulation to integration at an enterprise level.

An Enterprise Service Bus (ESB) is a message-based, distributed, integration solution based on open standards that provides routing, invocation, and mediation services to facilitate the interactions of disparate distributed information technology resources (applications, services, information, platforms) in a reliable manner. In relation to SOA the ESB is mostly a physical piece of software ("the infrastructure") while the SOA itself is the encompassing guideline ("the architecture"). Many vendors nowadays offer ESB products or products to set up or implement an ESB.

Web Services are building blocks for creating open distributed systems, and allow companies and individuals to make their digital assets available worldwide. Web Services support re-usability of software as well as dynamic access to remote software services or components. IBM defines Web Services as: *"Web Services are self-contained, self-describing, modular applications that can be published, located, and invoked across the Web."* The following characteristics of Web Services will form the heart of the next generation, distributed Internet systems:

- Interoperability: any Web Service can interact with any other Web Service, because of new standard protocols as SOAP supported by all of the major vendors.
- Ubiquity: Web Services communicate using HTTP and XML. Therefore, any device that supports these technologies can both host and access Web Services.
- Low barrier to entry: the concepts behind Web Services are easy to understand and free toolkits from vendors like IBM and Microsoft allow developers to quickly create and deploy Web Services.
- Wide industry support: all of the major vendors are supporting the surrounding Web Services technology, e.g. Microsoft .NET platform, or IBM Visual Age.
- The core Web Services standards were jointly developed and submitted to the W3C.

Semantic Web Services use the vision of the *Semantic Web:* enriching "traditional" syntactically oriented web pages and services with semantics, giving a formally expressed meaning for the information presented on the web pages and the functionality provided by the web service, using:

- a knowledge representation structure;
- a language for encoding the meaning;
- tools for semantic modeling and semantic annotation.

The SaaS paradigm in turn fits well fit the ISU concepts and can be seen as a software application delivery model where a software vendor develops Web-native software services and hosts and operates them for use by its customers over the Internet. Customers do not pay for owning the software itself any longer but rather for using it on-demand. They use it through an API accessible over the Web and often written using Web services.

Enterprise Interoperability

Relying on SAAS the EU FP7 IST IP Project COIN[37] has refined the paradigm of Enterprise Interoperability through the identification of the a set of Service Categories towards Enterprise Interoperability assessment , aiming at improving interoperability, mainly for SMEs, by reducing the costs of data reconciliation, systems integration and business processes synchronization and harmonization:

- **Model-driven Interoperability Services** support enterprises to formalise, exchange and align models that are relevant to set up collaborations. They refer to Meta-Modeling, Language Engineering, Model Mapping and Transformation, as well as Method Engineering.
- **Enterprise Modeling Interoperability Services** support enterprises to factually cooperate with other, external organizations in spite of e.g., different working practices, legislations, cultures and commercial approaches. They include Enterprise Modeling, Enterprise Models Interchange, Enterprise Models Deployment, and Enterprise Interoperability Maturity Assessment.
- **Business Process Interoperability Services** support enterprises to make proper external views of enterprise internal processes synchronized by a collaborative inter-enterprise business process. They address Cross-Organizational Business Process Modelling, Semantic Business Process Modelling, Business Processes Management, Business Process Monitoring, and Business Process Analysis. Semantic business processes propose a paradigm shift in business process modeling from the behavioural to the declarative approach. Among the emerging proposals there are ConDec (Pesic & van der Aalst, 2006), PSL (Conrad & Gruninger, 2005), and BPAL (De Nicola, Missikoff, & Tininini, March, 2008.).
- **Semantic Mediation Interoperability Services** support enterprises to apply ontology-based techniques for semantic mediation such as semantic reconciliation of business documents in order to support interoperability among heterogeneous software applications. They are presented through the *Ontology Building, Semantic Annotation, Semantic Reconciliation and Semantic Search and Retrieval*. These are expanded in separate paragraphs below.
    - **Ontology Building** is a complex process established by (Gruber, 1993), (Gruninger & Fox, 1995), and (Uschold, King, Moralee, & Zorgios, 1998). A complete ontology development process, METHONTOLOGY, is proposed by (Fernández, Gómez-Pérez, & Juristo, 1997). (Sure, Staab, & Studer, 2004) proposes OnTo-Knowledge, an ontology development process consisting of six main phases. Finally, UPON (Unified Process for ONtology building) (De Nicola A., 2009) is an incremental and use-case driven methodology for ontology building that is based on the Software Development Unified Process and uses UML.
    - **Semantic Annotation** or semantic enrichment helps to tag information elements and services with ontological expressions. Tools and methods exist for annotation of structured documents, like web service descriptions, business documents schemas, mainly support data mediation and reconciliation, (e.g., ASTAR (ATHENA IP, 2006), MWSAF (Patil, Oundhakar, Sheth, & Verma, 2004), WSMO Studio (Kerrigan, 2006). Other methods and tools focus on annotation of unstructured resources, mainly text document, audios, videos (e.g., Cohse (Bechhofer & Goble, 2001), MnM (Vargas-Vera, Motta, Domingue, Lanzoni, Stutt, & Ciravegna, 2002), OntoMat Annotizer (Handschuh, Staab, & R., 2003) and mainly support search and retrieval issues.

[37] http://www.coin-ip.eu/

- **Semantic Reconciliation** aims at seamless interoperability of software applications that were not initially developed for this purpose by using ontology-based techniques. The vision is of seamless information interoperability enabling process interoperability. Information interoperability has received much attention both in AI and DB community, where several approaches have been proposed for both Data Integration (Lenzerini, 2002) (Calvanese, et al., 2008), and Data (Kolaitis, 2005) (Haas, 2005).
- **Semantic Search and Retrieval** is enabled by semantic annotations of resources. Search requests are also formulated as ontology expressions. This allows the computation of the degree of similarity between the request and the resources, using classic information retrieval metrics (e.g., cosine similarity etc.), or metrics specialised to the topology of an "is-a" taxonomy (Lin, 296-304), (Kim & Candan, 2006), (Li, Bandar, & McLean, 2003.)

- **Data Interoperability Services** support enterprises to exchange and share business documents among organizations, by filling interoperability gaps related to the payload (format and content) and to the messages and/or structures to be exchanged. They refer to Data Mapping, Data Infrastructure Framework, Business Document Modelling, Business Document Interchange, and Business Document Process Integration.

6. Conclusions and final remarks

"An enterprise is a complex artifact, a (partially) organized entity that is primarily made of people, by people" (Anonymous)

"The members of an organization are not passive instruments, but are themselves designers who use the organization to further their own goals" (H. Simon)

6.1. FInES Research Roadmap as a practical instrument

The FInES Research Roadmap (RR) is the result of an intense and wide work carried out in the context of the FInES Cluster. It contains a number of indications, considerations, elaborations, and guidelines that (hopefully) will be useful to the FInES community: to Cluster members (and, may be, beyond it) in the definition of future research activities and project proposal and to other stakeholders in their offices. But it would be beneficial if this document could be used also as a practical instrument during the projects preparation and, later, the projects deployment and carrying out; to this end the FInES RR can be used for a benchmarking of the research directions that projects follow through. Using the FInES RR as a benchmark may yield positive outcomes for both the projects and the RR itself. To this end, we propose the idea of complementing the FInES Research Roadmap with a set of assessment maps that a project may use to position its research activities (see Annex I). In so doing we may have the following advantages:

- Provide a clear indication of where a given project is contributing in the global research strategy of the Cluster.
- Identify possible research topics that were not included in the FInES RR but that appear relevant for the strategies of the Cluster (in fact, the maps are open structures).
- Provide an assessment of the FInES RR in terms of its validity, i.e., its capacity of representing the research topics of the Cluster projects.
- Contribute to a systematic evolution of this document, including new research topics and identifying the topics that appear obsolete or out of scope, with the concrete help of the projects.

The assessment maps proposed in Annex I are derived from the content of the RR on the three key areas: technology, enterprise systems, and enterprise qualities. Below we revisit the main issues addressed in this report, drawing a 'fil rouge' that traverses the different chapters. We do this by inverting the sequence of the presentation: in essence, here we switch from the top-down approach of the previous chapters to a bottom-up approach, i.e., starting from the technological issues.

6.2. FInES research: the technological view

The technological support to a FInES is a crucial issue. The possibility of achieving the FInES envisaged in this report mainly depends on the availability of innovative ICT solutions. Some of them are already available and some are expected to be released in the next decade.

Chapter 5 can be seen as a starting point of our bottom-up analysis, it is essentially a State-of-the-Art and its organization mirrors that of Chapter 4, reporting the foreseeable technology requirements for FInES. Both chapters are organized according to 3 main categories: (i) Communication Technologies, (ii) Organizational Issues and Technologies, (iii) Enterprise Application Systems. Specifically, it focuses on 8 key technological areas that emerge for their relevance to the FInES. In particular, we

have the technologies for Smart Products and Security and Policy, in the networking area; technologies for Socialization and Digital Business Ecosystems, in the Organizational domain; then, in the Enterprise Application Systems: Intelligent Software, Operational Infrastructures, Software Services, and Enterprise Interoperability. In this chapter there is an illuminating figure that shows the links between these 8 technological areas and the rich map of future technologies reported in Chapter 4. In the latter chapter, the same 3 technological categories are elaborated in depth, showing also what the respective positionings are in the achievement of a FInES. Chapter 4 organises the matter in 26 technological areas that, starting from what exists today, are likely to emerge in the future. The general trends identified concern technologies aimed at achieving systematic *decentralization* and *socialization* objectives in future enterprises; strategic characteristics for FInES that are complex socio-technical systems.

In conclusion, the rich catalogue of emerging ICT solutions shows that future FInES research will have a wide base of suitable technologies; we can say that technology will not be the limiting factor, potential problems will come from the capability of enterprises in adopting them effectively.

6.3. Future Enterprise Systems and their supporting technologies

Here we shift the focus, positioning FInES in the center, showing that the Research Challenges reported in the Chapter 3 will be concretely supported by the technologies presented in Chapter 4.

The key idea of a FInES, described in the Research Challenges of Chapter 3, concerns the development of a new breed of enterprise systems orientated to enterprise innovation, rather than to the traditional value-making business operations. In this evolution, we foresee that enterprise systems will undergo a double transformation, in the underlying philosophy and the overall architecture. For what concerns the latter, a FInES architecture will be highly componentised, made of FInERs residing in and outside of the enterprises, offering the required services. The evolution is towards a progressive commoditisation of the traditional business operations, opening therefore a large perspective to the service economy (with FInERs and their commoditised digital services easily found on a large, global market). The other transformation will be towards the blurring of the presence of the technology in our everyday lives, it will become *invisible* because of a massive process of embedding in increasingly intelligent business entities that will appear to the end-users in their familiar (analogical) forms, positioned in their usual working and living contexts. Here the underlying idea is that computational components and the computing systems will be the representatives of real business entities (i.e., the FInERs).

The technological support to FInES is clearly depicted in the matrix of Figure 4.1, where the first column on the left reports the 6 operational Research Challenges (out of the 8 Research Challenges, being the last two of a strategic nature) of FInES.

Getting to the 6 operational Research Challenges, they are represented as the headers of the rows in the mentioned matrix. Such a matrix represents the interlinking of the future technologies with the FInES Research Challenges. The Figure 4.1 provides a global picture conveying a positive expectation on the support of technology for the achievement of the FInES Research Challenges. In fact, as anticipated, we can reasonably argue that the indicated technologies will be developed to a good level of maturity in the next decade.

Chapter 3 indicates that the signature of a FInES will be enterprise innovation. Innovation requires continuous change, e.g., in the technological systems, in the enterprise organization, assets, value proposition, business model, alliances and partnerships, financial and marketing strategies. The 8 Research Challenges propose a philosophy and an architectural paradigm that aim at fostering not simply a behavioral attitude towards an effective dynamism, but also the exploration of innovation

opportunities and ideas. The proposed FInES architecture will be able to foster enterprise innovation, but its actual achievement depends on people and their mental attitude.

6.4. The socio-economic context in which enterprises will operate

Another key part of this report is represented by the 6 Grand Objectives to be sought by the enterprises in the next decade (i.e., their qualities of being). We are aware that some of these objectives may appear far from the existing socio-economic culture. But there is a growing awareness that the latter is progressively leaving the scene to post-industrial socio-economic development models. The current 'modern' socio-economic development models are scarcely compatible with the planet resources, but also with the industrial globalized, hi-tech scenario. As usual, there will be forces that resist these socio-economic trends and, in the short term, they may be wining in term of monetary profit. But, in the midterm, those enterprises that take the risks to push forward a deep change, in the direction of the Grand Challenges, at the end of the decade will be positioned in the forefront of the new socio-economic development process. It is expected that this paradigm shift will not proceed rapidly nor in an uniform way. As usual, different forms, different models, different values will coexist for some times, and the achievement of the Grand Challenges will progress intermittently. But we need to bear in mind that these considerations are mainly valid for the western industrialized countries, while the emergent economies still need a more traditional (more 'modern') development model. It is expected that there will be a long term global convergence.

The Grand Objectives will not materialise spontaneously, they require a continuous endeavour to be achieved, and then maintained (since History does not proceed linearly). Adopting continuous innovation, open knowledge, a community-oriented paradigm, or a green attitude requires for an enterprise a dynamic stability (according to complexity theory) in the context of turbulent scenarios. For this reason, the research challenges of FInES are fundamental to achieve and maintain the Grand Objectives of future enterprises that, in turn, will guarantee the vision of Chapter 1.

6.5. Concluding remarks

According to many analysts, Europe (and the Western countries in general) is facing a long period of economic turmoil, caused by a number of converging factors. Such factors are both internal and external to such economies. Among the internal factors, the analysts indicate the current trends of the financial markets that are progressively honing their strategy, in a loosely regulated arena; a second factor is represented by the pressure of the emerging Future Internet to change the fundamentals of the traditional business models: from open innovation to pro-sumption, from co-opetition to crowd-sourcing, the business horizon is witnessing a number of opportunities that are challenging enterprises, but at the same time offer them unprecedented chances.

The external factors (sketchily labelled under the term 'globalisation') are mainly induced by the emerging economies, primarily of the Far East, both on the demand side, with their increasing need for natural resources, energy, raw material, and on the supply side, with their massive low cost production potential. Both sides are altering the business logic on which European socio-economic models has been structuring its development in the last century.

These are the main reasons why European enterprises cannot continue doing business as usual: new business models and, more in general, new life style will be soon a necessity. The economic trends of the last decade, with economic bubbles followed by sudden downturns, revealed the high instability of Western economies, with rapid change of directions, from economic expansions to swift downturns. It is a form of alternating 'fast economy' that produces social instability. Many experts would trade this

fast, but troublesome economy with a more stable ‘slow economy’, where we will accept a more limited growth (if not a steady, soft economic downshift) accompanied by a better governance over the socio-economic phenomena. Therefore, when talking about innovation, it is necessary to agree in what direction it should be deployed, avoiding the illusion of a future long-lasting sustained economic growth.

The globalization is pushing Europe to change, to innovate deeply, to reconsider the positioning of the different players in increasingly complex socio-economic scenarios. The players, who are numerous, manifold, and increasingly interconnected, include enterprises, with partners and competitors, business and civil society, citizens and customers, government and social organizations, operating at national and international levels. They face a constant recombination and repositioning of relative interactions, with old forms of separation and new opportunities of cooperation and integration.

The theory tells us that the complexity cannot be easily mastered; at the same time it tells us that there are different dimensions: social, political, financial, economic, and technological, that tend to evolve with different logics and rationales. We know that the technological dimension plays a double role. It is a pervasive, enabling reality that provides solutions necessary to the other dimensions to develop and achieve their objectives. But at the same time, technology has its own objectives and evolves along ‘independent’ trajectories, endogenously defined. This double nature of the technology makes the objectives of this report particularly difficult to realise. And, for this reason, in our work we tried to avoid a ‘closed’ approach, a self-referential method centered on a technological perspective. Conversely, there is a growing need for a comprehensive vision capable to yield a strategic governance of such complex scenario. This is why the report opens with the first two chapters that have a focus largely independent from the technology. Chapter 3 can be considered the hinge between the socio-economic dimension and the technological dimension. And, at the same time, the part of the report that describes the actual research challenges of FInES.

In conclusion, we believe that this report should be considered a starting point rather than a concluding word. It presents a number of issues and some research lines that may be useful as reference points, not as a final truth. Reference points are important, especially when sailing in troubled waters, no matter if we are travelling towards them or we are leaving them behind us. We hope that this effort will be useful for some and will contribute to the future achievements of our FInES Community.

“The End”

(so far…)

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Annex I - FInES Research Assessment

Here we propose a method to position the research activities of a FInES project within the Research Roadmap of the Cluster. To this end, we organized the different topics proposed in the chapters 2, 3, and 4 in three research maps, shaped in the form of tables. The idea is that a project will position itself on the maps, indicating its focus and interests in terms of research objectives. This exercise has different objectives:

- The mapping activity will clarify the positioning of the project within the FInES Research Roadmap.
- The union of all projects positioning will reveal the degree of coverage of projects in the Cluster with respect to the FInES RR, showing if there are densely populated areas and if there are areas that, for some reasons, are not covered.
- In parallel, this exercise allows an assessment of the FInES RR itself, questioning the suitability of topics that are not covered by any project, triggering the debate on the suitability of keeping such topics in the RR.
- At the same time, it is possible to extend the list of topics, giving the possibility to projects to add further items. In so doing the RR has the opportunity to constantly evolve renewing the set of research topics.

In assessing the positioning of the projects on the maps, it is suggested to indicate a score as follows:

> ***Score*** *– **A**: topic centrally addressed, main resources are concentrated here; **B**: topic/objective relevant but outside the core; **C**: topic/objective somehow addressed.*
>
> *Empty cells indicate: n/a or marginal.*

I.1 FInES Research assessment: technology topics

The maps are reported in a bottom-up order, i.e., starting from technological topics. In the technology area, the assessment map can be articulated in three sub-tables, one for each technological category reported in the Figure 4.1.

Communication Technologies	Score	Organizational Technologies	Score	Application Technologies	Score
Mesh-sensor networks		Social Mining		Visualisation and Interaction	
CaaS		GRC		Intelligent Proactive Behaviour	
Convergent Networks		Participative Business Engineering		Automated Service Discovery	
Identity-aware networks		Business Modelling &		Tera-architectures	

		Simulation			
Context-aware networks		Globalised Micro-Businesses		IaaS/PaaS	
Ubiqutous Communication		Business Ecosystem Modelling		Software as a Service	
Tracking and Traceability		Socialisation and Web 2.0 impact in organisations		IoS / FOT Platfroms	
Real-World Web		Business Rules		Interoperability Service Utility	
Others:……		Others:……		Intelligent FinER	
				Knowledge Representation	
				Others:……	

Assessment Map 1 – Technology

I.2 FInES Research assessment: Software architectures and Enterprises

This section reports the two maps conceived to assess the research programs and the projects' achievements over the two research areas illustrated in Chapter 2 and 3.

FInES Software Architectures	Score		FInES Enterprise Qualities	Score
Innovation-oriented open platform			*Inventive Enterprise*	
Innovation Awareness platform			*Cloud Enterprise*	
FinES re-design for innovation			*Cognizant Enterprise*	
Innovative FinES recasting			*Community-oriented Enterprise*	
FinES meta-knowledge management			*Green Enterprise*	
FinES interoperability and cooperation support			*Glocal Enterprise*	
Socio-business Alignment			*Inventive Enterprise*	
FinER: the foundational element of the FInES approach			Others:	
FinES Science Base: the foundational scientific methods				
Others:				

Assessment Map 2 **Assessment Map 3**