Technology Roadmap on Software Intensive Systems

The Vision of ITEA (SOFTEC Project)

Executive Summary

ITEA Office Association
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Preface

This Technology Roadmap for Software Intensive Systems has been worked out in the frame of the ITEA programme by means of a specific project, SOFTEC. The present report confirms and deepens the vision of the ITEA Programme on the future of these Software Intensive Systems already expressed in the ITEA Rainbow Book (1998). Scenarios have been used to show how they together might create opportunities for future products.

As a whole, it repesents a classification of the technologies that are essential for ITEA and outlines how we think they can develop in the years to come. As such it will be a frame of reference to discuss the future.

Constructive feedback from readers is most welcome.

Acknowledgements

During our workshops the ITEA Roadmapping core team experienced that meeting other persons on this subject has also been a valuable Rendezvous. We would like to thank all participants and persons who have reviewed and commented on working documents.

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1. See for members ‘Names and email addresses of contributors’ on page 11

Executive summary

A Roadmap by ITEA

From computers to home appliances, from smart cards to cars, from telecom to health care, from business to home, software is pervasively invading every aspect of everybody's everyday life. The ITEA Programme has been launched to strengthen European industries in front of this very fast (r)evolution.

The present change brings industries from (once) very different application domains (Telecom, “classical” Information Technology, Consumer Electronics, etc...) in the same *technological* area: *Software Intensive Systems* connected through a *Network* and processing content rich in *Multimedia* information. It also faces them with new challenges in time-to-market and cost of reliable development. ITEA aims to contribute to a new generation of *software engineering tools* (e.g. paradigms, methodologies, languages, development environments) and *middleware* (e.g. distributed infrastructures, real time embedded platforms, new protocols, standards) to meet these challenges. The path of these developments needs to be charted if one wants to develop or enhance the right technology at the right time. The need for a prospective view on the timely developments in software is shared by the Public Authorities who co-operate in the funding of the Programme.

In response to this need, the Programme decided to launch a specific project (SOFTEC) in order to produce a “Technology Roadmap” of the evolution of software for Software Intensive Systems. To explain what “roadmap” means and for which purpose ITEA went this way, we quote from Robert J. Galvin, Chairman and CEO of Motorola:

> *‘A roadmap is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field.’*[1]
>
> *‘Roadmaps communicate visions, attract resources from business and government, stimulate investigations and monitor progress. They become the inventory of possibilities for a particular field….*

This roadmapping activity was initiated as soon as ITEA received the Eureka label, and, from the start, some specific issues had to be tackled.

First, the demand was not usual. Companies are familiar with the development of *product* roadmaps. These are their industrial property. ITEA, on the other hand, demands a *technology* roadmap that takes no account of any specific product or market, but that presents an overview of developments and challenges for the core of the ITEA programme activity: *Software Intensive Systems*.

Secondly, the scope of the present roadmap document is about Software Intensive Systems. The scenarios do mention some characteristics of devices and infrastructures (e.g. displays, bandwidth) in a specific context. It is however not the intention to create full roadmaps on this kind of topics. The scenarios give

1. Galvin, Robert (1998), “Science Roadmaps,” Science, Vol. 280, May 8, p. 803

some view from an end user perspective but are only used to widen the view of the technologists: software development may depend on many other technologies.

Third, the continuous and fast evolution of the domain requires quick access to the results that could be discussed publicly. This led to the approach of a “rolling document” of which the first release (this document) is published within two years after the start of the project. As a first step, among the five major domains of interest for ITEA (Home, Enterprise, Mobile, Intermediation Services & Infrastructures and System Engineering), only the three first would be thoroughly worked out. Only a first pass over the other two would be outlined in that time frame in order to identify if other technologies were requested. If this first step was successful, then roadmapping activity would continue, based on the results obtained.

These challenges have led to the development of an innovative process to generate the first set of roadmaps. They have even led to interesting methodological concepts, (e.g. the rendez-vous). A description of the process and of initial results forms the content of this release of the Technology Roadmap on Software Intensive Systems.

The next chapter of this executive summary will outline the methodology for building this roadmap. The others highlight the main results and conclusions to be found in the full document.

The Roadmapping process

The methodology

The general approach is as follows[1]:

- The five ITEA *application domains* have been chosen as a base for the Roadmapping because:
  - They give an almost complete coverage of the ITEA domain
  - Most of the core technologies would be covered
  - Experts were readily available
- Develop *scenarios* of their probable evolution
- Use the application domains as drivers for the identification of necessary technologies and services
- List the *technologies* from each domain, integrate these partial lists in one single table of technologies
- Group them into key *categories* to create an overview and a structure.
- For simplicity of presentation, these categories have been clustered into *groups* that are used further on in the report as chapter headings.

This process is summarised by Fig. 1: ‘Roadmapping process’ on page 3.

1. As explained in the first chapter, this approach has been limited to three domains, the study of the other two starting just in 2000

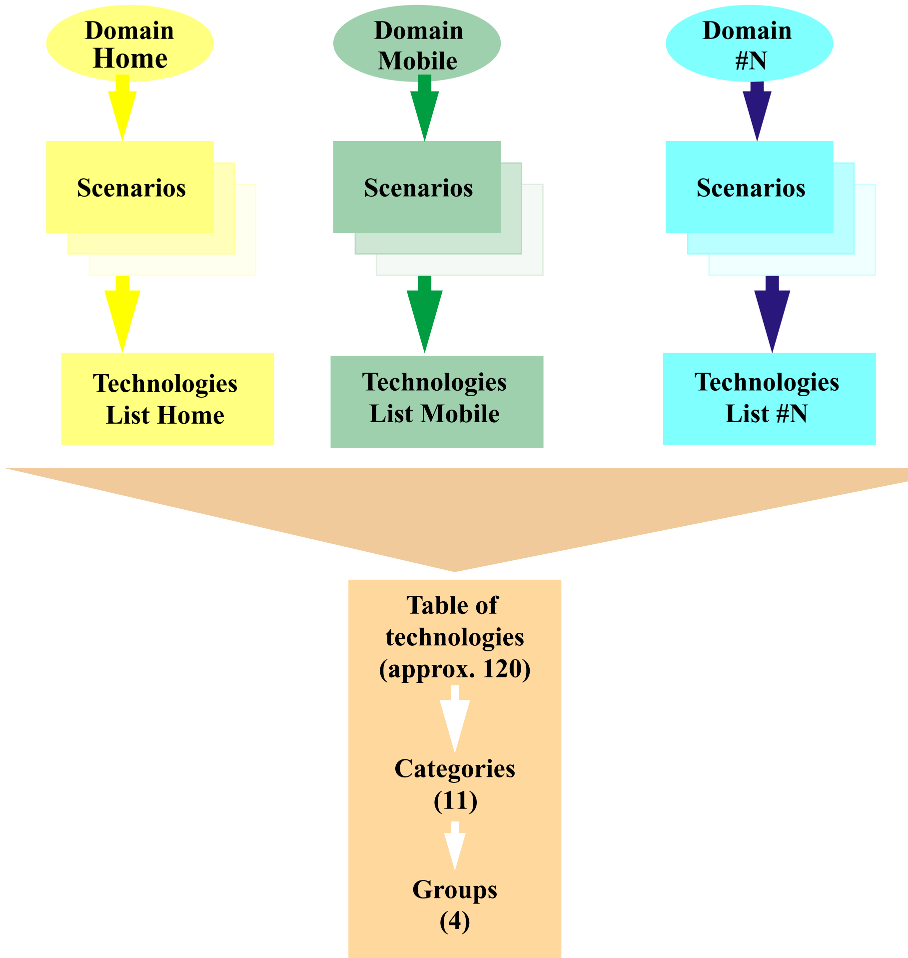

Figure 1: Roadmapping process

The organisation

The organisation put in place had to focus upon three objectives:

- Develop a technology roadmap, which is neither an application roadmap, nor a product roadmap;
- Check that the scope of the Roadmap corresponds with the six Core Competencies defined in the ITEA Rainbow Book.
- Make sure that the work keeps pace with the fast continuing evolution of the software field and of the outside technological world.

A core team of on average six experts (the Core Team) operates as the motor for the generation of the roadmaps. They have group meetings and communicate intensively by electronic mail. Their mission consists of producing discussion papers and presenting them to two-day technical workshops (four were held in 1999, three in 2000). The members of the *ITEA Steering Group*[1] participate in the workshops to generate information and to review, improve and validate core team results. The Steering Group has been assisted by other experts according to the type of work to be done.

1. The ITEA Steering Group is in charge of the technical content of the Programme.

Other actions have been made to enrich the roadmap. Intermediate results were presented and discussed during the ITEA Symposium held in September 2000. An ITEA workshop has been conducted in December 2000 with external experts from Academia and Research. Comments and suggestions from these meetings have been incorporated as far as possible.
All these activities are co-ordinated by the Project Leader of the ITEA SOFTEC Project and supported by a professional facilitator.

From scenarios to categories: the first building blocks

Scenarios

The detailed *scenarios* that correspond to the three domains worked out in priority are to be found in the main report. At the level of this executive summary, they are not so important, *per se*. What is important to catch is the underlying assumption that has been chosen for all of them: *our technological environment will become, step by step, more and more networked, more and more autonomous and self-organising*. In the Home, the appliances and the domestic network will adapt to each other from the first interconnection and exchange information, if necessary. In the Enterprise, a technological environment will facilitate decentralised, distributed development of applications in highly pro-active collaboration rooms. Mobility will be encouraged by seamless integration of applications in vehicle and cyber space as well as by seamless roaming between different networks.

From now to this long term vision, generally two stages may be foreseen, even if there are slight differences between the domains: the *self-configurability* and *interoperability* of the terminal devices and the *integration* of the different networks.

Technologies, categories, groups

To achieve these results the software technology must progress in a lot of fields. For example, in these three domains, reaching the final stage will require advances in active networks as well as in mobile agent technologies. In the report are listed more than fifty basic technologies and detailed opinions about their development are given. To make things easier for the readers of this summary, we will explain the most significant results by taking a different view: clustering the technologies by *categories* and grouping them under four headings as they appear on the table of 'Overview of technology categories' on page 5.

NOTE: The study of Complex System Engineering and Intermediation Services & Infrastructures has started by mid year 2000. This has led to two new first draft domain papers and resulted in the following *preliminary* conclusions:

- Intermediation Services & Infrastructures: a few new technologies have been introduced. This is not a surprising result: Services and Infrastructures being the “connector” of the three first domains, a lot of related technologies are shared with them.
- Complex System Engineering: important additional technologies have been identified. They are included in the table of technologies and grouped in the relevant three categories.

Content	
Content capture, creation & authoring	Technologies needed to capture and create digital content (data, images, software, graphics, voice, video etc.)
Content representation	Technologies to represent digital content and make efficient use of resources
Data & content management	Technologies that allow efficient storage and retrieval of data
Infrastructure and basic services	
Network transport and protocols	Technologies to carry digital data from one place to another.
Network and distributed management	Technologies for managing the dynamically changing network or distributed infrastructure for roaming users and mobile services. Transmission, communications, network and distribution technologies
Resource management	Implementation technologies that take into account resource constraints (physical, computing, time, spatial, Herzian)
Security	Technologies to provide safe access to data, user identification, etc.
HSI	
Human system interaction	Technologies that deal with interaction with the end-user.
Engineering	
System engineering	Techniques, methodologies and tools to design and construct systems under constraints (time to market, technological, legal, economical and patrimonial)
Software engineering	Techniques, methodologies and tools to design and construct architectures and effective technologies for implementation, deployment, execution, exploitation and maintenance of software systems
Engineering process support	Methodologies, techniques and tools to support an (distributed) engineering process

Figure 2: Overview of technology categories

Observations and conclusions

Key drivers

An important characteristics of the digital revolution is that state-of-the-art equipment will more and more go directly to professionals and the general public, while, until now, the most advanced technology was usually reserved for mostly technically minded people. This has some consequences, which can be considered as key drivers for the development and wide acceptation of the new applications. Let's consider some of them before we enter in more technical subjects.

- From the user's point of view, “ease of use”, “stay in control” and “sense of safety” are vital. The two first characteristics depend on the functionality of the system and of the architecture (safe and reliable systems) of its software, but are for a large extent also reflected by the user interface. The last one is related both to security and safety. From a technology point of view, the categories *Security, System engineering* and *Human Machine Interface* are in charge of progresses in these areas.

- "Privacy" is a most important feature expected by the users (be they individuals or businesses). In an interconnected world, achieving it depends very much on the categories *Network transport and protocols, Network and distributed management, Security and System engineering*.
- Not only will the industry have to bring to the market systems/products/services that have these qualities, but also they will have to make it "right from the first time" and under severe "time-to-market" pressure. This may ring the toll for the correction of bugs by means of successive software versions. Enormous progress is expected from *Software engineering*.
- Finally, the utmost *diversity* of the networks themselves (copper wired, glass fibre wired, wireless...) and of their terminal nodes (from health sensors to smart cards, from large size high resolution displays to the screens of handheld devices...) brings the problem of the handling of the huge *amount* of heterogeneous multimedia data. The technologies of the three categories related to Content (*Content capture, creation & authoring, Content representation, and Data & Content management*) must provide solutions.

About CONTENT

Content capture, creation and authoring

Having more and more data and information in a digital format allows for storage, manipulation, analysis and (automated) reaction. This creates opportunities for new applications and services, especially if this is combined with the progress in network technology. Most of the basic necessary technologies (except for composing) exist but must progress (Table 1 on page 19)[1].

Content representation

Even though resources as bandwidth, storage and processing are expected to grow in capacity (as physical and power limitations are getting less stringent in portable and mobile devices), there is still a need for new compression algorithms:

- Supporting more voluminous content (e.g. video)
- Handling real-time and symmetric compression issues.

Most of the basic technologies exist but must progress. MPEG4 is an important subject (Table 2 on page 19).

Data & Content management

To enable effective storage, management and access to content, we need to manage a lot of other (meta)data as well. Some examples are:

- Indices and catalogues
- Personal information like preferences and profiles
- Content information related to places

1. Unless otherwise stated, the references called in this chapter refer to the complete report.

- Device characteristics and status
- Meta information on content, ownership, access conditions, localisation, etc...

For this meta data, it is not sufficient to handle the structuring of data, but semantical processing is needed too. An important issue in this context is the unique identification of all kinds of objects in the real world, to correlate information to these objects and make this available in a digital world. Solutions in specific domains are available or in development but an overall unifying approach is missing. Basic research is probably mandatory in this category (Table 3 on page 20).

General observations about categories related to "Content"

More and more information and knowledge becomes available in digital format, asking for storage, manipulation, analysis, and automated reaction. Although available resources are increasing (e.g. bandwidth), the growth in content seems to be such that available bandwidth will lag behind what is required. Therefore, new compression algorithms are needed for every type of content, but especially for large volume content. And, simply to be readily usable, the large amount of such digital information requires standardisation of metadata to allow semantical processing.

As in a lot of other situations there are several ways to achieve the goal. (e.g. trade-off between bandwidth and compression technology). Together, these improvements might produce new opportunities for competition to the current broadcasting models (this is of course also impacted by legislation and regulations).

About INFRASTRUCTURE & BASIC SERVICES

Network transport & protocols

There is a fast evolution in network technology. Many competing approaches exist and the winner (if there is one) is not clear. Special attention is needed to interoperability and bridging. A reasonable effort must be done on all protocols (Table 4 on page 21).

Network management

We will have more and more networks where consumers will connect in an *ad hoc* way. From a point of view of ease of use and reduction of failures, auto configuration and zero administration will be needed. These important aspects are not yet supported by specific technologies (Table 5 on page 21).

Resource management

Constrained resources such as memory, bandwidth, display size, time, power should be managed in such a way that an appliance, device or system is able to function in a proper way. Technologies associated to real time and resource allocation have to be developed (Table 6 on page 21).

Security

Security plays an important role at places within future services and appliances and for several purposes. Important aspect include:

- Access to information and/or systems should be granted under the constraints of access rights, which might depend on the actual role of the user or on specific access keys.
- Information should be transported in a secure way.
- Persons should be able to interact with systems while staying anonymous or using pseudonyms. This might require a trusted third party to act as intermediary.
- It should be possible for transactions to be performed anonymously.
- It should be possible to screen actors in a transaction to check whether they are trustworthy.
- Contents should be protected against illegal use and copying.

To achieve this it should be possible to identify persons and contents, to authenticate persons, contents and services, to transport data in a secure way and to control access by assuring certain constraints are met. Cryptography and steganography (tattooing or watermarking and covert or subliminal channels with cryptographic protocols) are the two basic technologies to solve these requirements (confidentiality, integrity and availability). Another problem is the multitude of passwords and pin codes each individual is confronted with. Biometrical parameters (voice, keystrokes, fingerprints, etc...) will be introduced to authenticate individuals. Most basic technologies exist but require further progress to answer the expectancies of the users (Table 7 on page 22). Encryption implies a lot of legal issues and, regarding encryption technology, US export law may forbid their use outside the USA.

General conclusions about "Infrastructures & basic services"

For reasons depending upon technical constraints and consumer needs, the technologies of this category will undergo dramatic changes during the next years. To cope with the technical constraints, new protocols and basic algorithms are required (e.g. for resource allocation, downloading of applications, real time virtual machine). To face the consumer requirements for *much more* security and trust, new progresses must be done. This concerns tools (e.g. use of biometrics) as well as possibly the architecture (e.g. trusted third party).

About HUMAN SYSTEM INTERACTION

Human System Interaction will need to (further) become uniform and flexible, self-explaining and simple, context dependent and self-learning. The most important issues to be solved are:

- Multi modal user interfaces are required, covering as many senses as useful. Including all kind of sensors and actuators in the environment or on the body.
- The Human System Interface should interpret the action and extract the meaning (e.g. natural language interpretation).
- General recognition patterns (like gesture recognition) could lead to data reduction in transmission (e.g. do not transmit a nod by video but by an *ad hoc* digital message).
- The Human System Interface should become interactive (e.g. preventing you from falling asleep in your car).
- Means for validation and measurement of satisfaction are requested in connection with requirements for and specification of Human Machine Interface.

Friendly, reliable and forgiving interfacing between people and systems is mandatory for the real development of the digital world. Only very few technologies exist, which need serious progress, while many need to be developed (Table 8 on page 22).

About ENGINEERING

System engineering

Requirements on quality, flexibility, adaptability, extendibility and evolution requires new approaches to construct (systems and) services. Advanced services will be built by dynamically composing them from existing, more elementary services (e.g. different payment systems or presentation formats). Present technologies should be extended with a special stress on formal verification methods (Table 9 on page 23).

Software engineering

Software engineering must respond to the growing complexity of systems and the requirement for high quality, bug-free and fast implementation upon a wide variety of platforms. This in turn requires:

- The ability to compose systems from available components, both in-house and components off the shelf (COTS).
- The independence of component life cycles from the system life cycles.
- More flexible product configuration possibilities.
- Powerful and automated code generation and verification.

Huge progresses need to be done in these directions either by progressing from existing methods or tools or by launching new developments (e.g. formal verification methods, downloadable certified software, etc...: Table 10 on page 23).

Engineering process support

Systems that allow tracking of requirements or changes through all representations of a system are needed. Advanced process support systems that use workflow based technology to support the collaboration of distributed teams are highly needed. Most of the corresponding technology needs to be developed (Table 11 on page 24).

General conclusions about “engineering”

The engineering process will require new methodologies, models and implementation techniques to support the efficient development of future software intensive systems and end-to-end services.

Engineering will require:

- Technology to master complexity and capture end-to-end specification of a distributed system.
- Implementation tools that support short time to market and that guarantee a cost efficient, resource limited implementation on a wide variety of platforms.
- A design flow that supports the development process in a multi-disciplinary team.

NOTE: the move to component-based systems (e.g. to increase re-use) will lead to new opportunities for business models. They might vary from “free software”, “open source” models, licensing components, to “pay per use”.

Overall conclusion and perspectives

The digital world looks like a land full of promises. This Technology Roadmap for Software Intensive Systems shows that, for these promises to be kept, a lot has to be achieved. By looking at scenarios and showing the associated technologies, then by clustering them in categories, this work helps to measure where and how much progress must be made. But the landscape of software for Software Intensive Systems is a quickly moving one, which depends as much from technology as from society. This Technology Roadmap, therefore, is not a perfect, definitive document. It is a timely contribution to the evolution of our technologies. ITEA will continue enriching it, with all willing contributors.

Appendix 1.Names and email addresses of contributors

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Appendix 2.Background information

Many references have been mentioned in the Glossary in the form of URLs to (technology) web sites.

1. ITEA Rainbow book, see www.itea-office.org
2. EDAA (European Design and Automation Association) roadmap. http://www.iae.nl/users/ldje/edaa.html
3. Information Technology Research: Investing in our future. Presidential Information Technology Advisory Committee (PITAC)
4. Anthony Finkelstein & Jeff Kramer, 'Software Engineering: A Roadmap' http://www.softwaresystems.org'
5. MEDEA Design Automation Roadmap
6. Rapidly changing field of computing; weekly column on Internet: http://www.compaq.com/refoc
7. A description of user needs for the professional being mobile in a vehicle can be found in the article 'Fast-lane Browsers Put the Web on Wheels' , Lewis and Fuller, IEEE Computer Jan. 1999 page 144.
8. 'Roadmapping' by Gerrit Mulder, http://www.extra.research.philips.com/natlab/sysarch/roadmappingPaper.pdf
9. For a more extensive discussion of roadmapping see the article 'Roadmapping integrates business and technology' by P. Groenveld, published in Research-Technology Management, Sept./Oct. 1997
10. Geoffrey A. Moore, 'Crossing the Chasm; Marketing and Selling High-Tech Products to Mainstream Customers', HarperBusiness, New York, 1999
11. Abraham H. Maslow, 'Motivation and Personality', Harper & Row, New York 1970'
12. Fourth edition of Organizational Psychology, David A. Kolb at all, page 27, 1984

Appendix 3.Glossary of terms and acronyms

Term or Acronym	Description
access points	Boundary between the network and the access nodes
ACD	Automatic call distribution
ADSL	Asymmetrical Digital Subscriber Line, http://www.adsl.com
AMIC	Automotive Multimedia Interface Collaboration
API	Application Programming Interface
ASP	Active Server Pages (®Microsoft)
ASP	Application Service Provider
ATM	Automated Teller Machine
ATM	Asynchronous Transfer Mode
A/V	Audio/Video
B-2-B	Business To Business
Bluetooth	http://www.bluetooth.com
CAD	Computer Aided Design
CODEC	Coder-decoder
CORBA	Common Object Request Broker Architecture, http://www.corba.org
CSCW	Computer Supported Co-operative Work
CSE	Complex Systems Engineering, one of the core competencies of ITEA
CT	Core Team that prepares and digests ITEA roadmap information
CTI	Computer Telephony Integration
DAB	Digital Audio Broadcast, http://www.worlddab.org
data	data-information-knowledge
DCOM	Distributed Common Object Model
DECT	Digital Enhanced Cordless Telecommunications, http://www.etsi.org/dect/dect.htm
DNS	Domain Name Services
DILKY	Double Income, Little Kids. Description of a special group of end users
directory (X509)	(Standard for)
DVB	Digital Video Broadcast, http://www.dvb.org
EDAA	European Design and Automation Association, http://www.iae.nl/users/ldje/edaa.html
EDIFACT	Electronic Data Interchange For Administration, Commerce and Transport, http://www.adminet.com/weeb

Term or Acronym	Description
EDM	Electronic Data management
EMC	Electro-Magnetic Compatibility
Eureka	http://www.eureka.be
GEN	EC funded project "Global Engineering Network"
GEO satellite	geo-stationary earth orbit, at approximately 36000 km height
GPRS	General Packet Radio Service, http://www.mobilegprs.com
GPS	Global Positioning System, http://www.mobilepositioning.com
GSM	Global System for Mobile telecommunications, http://www.gsm.org
HAVI	Home Audio Video Integration http://www.havi.org
HiperLAN	Wireless communications standard, http://www.hiperlan.com
HomeCast	Standard for wireless communication between devices in the home domain
HomeRF	Standard for wireless communication between devices in the home domain, http://www.homerf.org
HRM	Human Resource management
IEEE 1394	High speed in-house network e.g. 'Fire-wire™' or "i-link™'
IETF	Internet Engineering Task Force, http://www.ietf.org
IIOP	Internet Inter Operability Protocol
IP	Internet Protocol
IPv6	Latest version of Internet Protocol, solving a.o. namespace & security issues
IP	Intellectual Property
IPNG	Internet Protocol Next Generation ((IPv6), http://www.ipv6forum.com
IPMP	Intellectual Property Management & Protection
IP radio	Internet Protocol radio
IPSEC	IP security
IrDA	Infra red
ISG	ITEA Support Group
ISP	Internet Service Provider
ITEA	Information Technology for European Advance, http://www.itea-office.org
ITEA SOFTEC	ITEA roadmapping project
JAVA	Programming language, object-oriented, platform independent, internet enabled

Term or Acronym	Description
J2EE	Java 2 Enterprise Edition
JINI™	JINI™: connection technology for ad hoc connection of devices to a computer / home network (™Sun), http://www.sun.com/jini
JPEG	Joint Photographic Experts Group, standard for picture compression http://www.jpeg.org
KBE	Knowledge Based Engineering
LAN	Local Area Network
LDAP	Lightweight Directory Access Protocol
LEO satellite	Low Earth Orbit
MEO satellite	Medium Earth Orbit
MIME	Multipurpose Internet Mail Extension, Standard for coding (multimedia) in (originally) electronic mail
MM	Multimedia
MP-3	Audio compression to MPEG-1 standard
MPEG	Motion Pictures Experts Group (versions 2,4,7), http://drogo.cselt.stet.it/mpeg
MUD	Multi User Dungeon (& Dragons), network role playing game
multi cast	Efficient one-to-many transportation of data
NLP	Natural Language Processing
ORB	Object Request Broker
PA	Public Authorities
PDA	Personal Digital Assistant
PDM	Product Data Management
PDMS	Product Data Management System
PGP	Pretty Good Privacy™, program supporting public key cryptography
PKI	Public Key Infrastructure, http://csrc.nist.gov/pki
PKIX	Public Key Information Exchange, http://www.ietf.org
POTS	Plain Old Telephony Service
push (wake up)	Inverts search role vs pull: information looks for interested users
QoS	Quality of Service
RMI	Remote Method Invocation
RT	Real Time
RTIP	Real Time Internet Protocol
RTOS	Real Time Operating System

Term or Acronym	Description
RTP	Real Time transport Protocol
Satcom	Satellite communications
servlets	Applets running at a server
S-mail	Surface mail (vs. e-mail)/ secure mail
SGML	Standard General Mark-up Language
SIP	Session Initiation Protocol
SME	Small Medium Enterprise
SMIL	Synchronised Multimedia Integration Language
S/MIME	Secure MIME, http://csrc.nist.gov/pki/smime
SNMP	Simple Network Management Protocol
SP	Service Provider
SPKI	Simple Public Key Infrastructure, http://www.ietf.org
TBD	To Be Determined
TCP	Transport Control Protocol, http://www.ietf.org
TMN	Telecom Management Network
UML	Unified Modelling Language, http://www.omg.org/uml
UMTS	Universal Mobile Telephone System, http://www.umts-forum.org
unified messaging	integration of the diverse media someone receives messages
Universal Plug and Play™	Microsoft alternative for JINI™ ((UPnP)
USB	Universal Serial Bus, http://www.usb.org
VAR	Value Added Reseller
VASP	Value Added Service Provider
VRML	Virtual Reality Modelling Language
W3C	The World Wide web Consortium, http://www.w3.org
WAP	Wireless Application Protocol, http://www.wapforum.org
WAV	Audio file format
Web TV	http://webtv.net
wireless 1394	see IEEE 1394
WLAN	Wireless Local Area Network
WML	Wireless MarkUp Language
xDSL	Digital Subscriber Line
XML	eXtendable Mark-up Language

Appendix 4. Technologies for Software Intensive Systems

Technologies

This appendix collates tables that summarise the needs for the evolution of some specific technologies in each of the categories of the Roadmap. These tables are not exhaustive. For a complete understanding of this complex matter, the interested reader should refer to the complete Roadmap report (chapter 3 to 7).

The dot in the tables indicates the start of deployment of the technologies. When more than one dot is shown, this indicates different generations of the technology.

Content capture, creation & authoring	NOW	ST	MT	LT
Synchronised streams of data				
- SMIL	•	•		
- HTML-time	•	•		
Location positioning				
- GPS	•	•		
- GNSS (Global Navigation Satellite System)			•	•
- Cellular phone base station based		•		
Describe structure and relations				
- HTML	•	•	•	
- XML	•	•	•	
- WML		•	•	
Content reuse				
- SGML	•	•	•	
Dynamic filtering and transformation				
- VRML	•	•		
Authoring				
- Acquisition	•	•		
- Digitising	•	•		
- Editing	•	•	•	
- Composing		•	•	
Sensor				
- personal sensor (medical appl.)	•	•	•	•
- environmental sensor (home/building/car)	•	•	•	•
- intelligent sensor	•	•	•	•

Table 1: Technologies for content capture, creation and authoring

Content representation	NOW	ST	MT	LT
Compression				
- MPEG2	•			
- MPEG4		•		
- MP3	•	•	•	
H.32X[1]	•	•	•	
SIP	•	•	•	

1. A series of standards for video conferencing

Table 2: Technologies for content representation

Data & content management	NOW	ST	MT	LT
Hyperdocument		•		
Digital library		•	•	
Unique identification				
- -Persons				
- Places				
- Things (audio, video, devices)				
Distributed file systems		•	•	•
Multi Media data bases			•	•
Indexing (MM)		•		
- MPEG7			•	
Portals (personal, organisation, community)				
Data mining	•	•	•	•
Querying (MM)		•		
Browsing	•			
Retrieval (MM)		•		
Transcoding		•		
Usage				
- Streaming	•			
- Interactivity		•	•	
- Viewing	•			
LDAP	•	•		

Table 3: Technologies for data and content management

Network transport & protocols	NOW	ST	MT	LT
Transport of data				
- download	•	•	•	
- streaming	•	•	•	
- reliable streaming		•	•	•
Efficient 1->n transport				
- multicast		•	•	
Wired				
- USB	•	•		
- xDSL	•	•	•	
- IEEE/1394	•	•	•	
- HomePNA	•	•		
- Powerline	•	•	•	
Cordless				
- DECT	•			
- HiperLAN		•		
- Bluetooth	•	•		
- HomeRF		•		
- HomeCast		•		
- IrDA	•			
Wireless connections				
- GSM	•			
- UMTS			•	
- 4G (4th generation mobile phone)				•
- GSM/GPRS	•	•		
Digital broadcasting				
- DAB	•	•		

Network transport & protocols	NOW	ST	MT	LT
- DVB		•	•	
Satellite	•	•	•	
Protocols				
- WAP	•	•		
- IPv6		•	•	•
- IIOP		•	•	•
- DNS	•			
- HTTP	•			

Table 4: Technologies for network transport and protocols

Network management	NOW	ST	MT	LT
Safe and secure execution of mobile code				
- applets	•			
- servlets	•	•		
- agents			•	
Active network			•	
Rule based monitoring			•	
Virtual dynamic (personal) network			•	
- adaption to network characteristics			•	•
- adaption to device characteristics		•	•	•
- adaption to (personal) profile		•	•	•
Software radio		•	•	
Ad hoc network connections				
- HAVI	•	•	•	•
- JINI	•	•	•	
- Universal plug and play	•	•	•	
Quality of Service management			•	
Java VM	•			
Interoperability between networks	•	•	•	•
Auto configuration	•			
Zero administration		•		

Table 5: Technologies for network and distributed management

Resource management	NOW	ST	MT	LT
Intelligent power management			•	•
Bandwidth usage control			•	•
Memory management	•	•	•	•
Timing constraints	•	•	•	•
Real time virtual machines		•	•	•
Dynamic resource allocation		•	•	•
Contract based resource allocation		•	•	•
Real-time software components		•	•	•

Table 6: Technologies for resource management

Security	NOW	ST	MT	LT
Authentication				
- PIN	•	•	•	
Digital signatures	•	•	•	•
Bio-authentication				
- fingerprint	•	•	•	
- voice	•	•	•	
- iris		•	•	
- face		•	•	
- DNA profile			•	•
Watermarking	•	•		
Labelling	•			
Authentication & profile devices				
- Smartcard	•	•		
- JavaCard	•			
IPSEC	•	•		
HTTP-S	•			
Cryptographic algorithms	•	•	•	•
SSL (Secure Socket Layer)	•			
S-MIME (secure MIME)	•			
Public key management				
- PKI	•			
- PKIX (Extended Public Key Infrastructure)		•		
- PKCS#11	•			
Secure transactions				
- Encryption	•			
- Decryption	•			
Intrusion detection	•	•	•	•

Table 7: Technologies for security

Human System Interaction	NOW	ST	MT	LT
Multi modal user interface				
- voice command	•	•	•	
- speech to text		•	•	•
- natural language speech recognition			•	•
- text to speech	•	•	•	•
- gestures		•	•	•
- eye movement			•	•
Multi user interfaces				
- 2-D presentation		•	•	•
- 3-D symbolic presentation		•	•	•
- 3-D real presentation			•	•
Adaptable user interface				
- user profile		•	•	•
- learning user interfaces			•	•

Table 8: Technologies for human system interaction

System Engineering	NOW	ST	MT	LT
Systems architecture				
- real time	•	•	•	
- fault tolerant	•	•	•	
- secure	•	•	•	•
- safe	•	•	*	•
- recongifurable architecture		•	•	•
Specification (real time, dynamic distributed)				
- languages	•	•	•	•
- methods	•	•	•	•
- tools	•	•	•	•
Verification				
- formal methods		•	•	•
- security	•	•	•	
- safety	•	•	•	
Product family architectures		•	•	•
Automated testing	•	•	•	•
Simulation	•	•	•	•
- design space exploration	•	•	•	•

Table 9: Technologies for system engineering

Software Engineering	NOW	ST	MT	LT
Architecture Description languages		•	•	•
Integration frameworks for				
- asynchronous applications	•	•	•	
- interactive applications	•	•	•	•
- synchronous applications		•	•	•
- COTS components			•	•
Downloadable software		•	•	
Dynamic extendable and upgradable SW			•	•
Upgradable software		•	•	
Formal verification technology for				
- distributed systems			•	•
- components (also certification)		•	•	•
- agents			•	•
- automated software testing	•	•	•	
Domain specific languages		•	•	•
Product family/line architectures		•	•	•
Mobile code (agents)	•			
- J2EE	•	•		
Distributed applications integration				
- CORBA	•			
- Java RMI	•			
Software process				
- Component Based Development	•	•	•	•
- Personal Software Process	•			
- Extreme programming		•		
- Design patterns	•	•	•	

Table 10: Technologies for software engineering

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Engineering process support	NOW	ST	MT	LT
Requirements management	•	•	•	•
Requirements tracking		•	•	•
Change management		•	•	
Executable Process definitions		•	•	•
Concurrent engineering		•	•	•
Hw/Sw co-design			•	•
Distributed engineering		•	•	•
Workflow		•	•	

Table 11: Technologies for engineering process support