IST Advisory Group

Software technologies, embedded systems and distributed systems

A European strategy towards an Ambient Intelligent environment

Report

June 2002

Information Society
Technologies

European Commission

IST programme

Report of the IST Advisory Group concerning

Software technologies, embedded systems and distributed systems

A European strategy towards an Ambient Intelligent environment

Information Society Technologies

http://www.cordis.lu/ist/istag.htm

A great deal of additional information on the European Union is available on the Internet.
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Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Official Publications of the European Communities, 2002

ISBN 92-894-3837-1

Printed in Luxembourg

PRINTED ON WHITE CHLORINE-FREE PAPER

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EXECUTIVE SUMMARY

ISTAG addresses the field of *Software technologies, Embedded systems and Distributed systems (the Domain)* as its title is given in the Specific Programme implementing the sixth Framework Programme for Community research. The objective is:

> *To develop a vision of the challenges and opportunities for European research and industry in the Domain with a view to enable the implementation of ISTAG's vision to "Start creating an ambient intelligence landscape (for seamless delivery of services and applications) in Europe".*

Ambient Intelligence (AmI) has been described([1]) as a vision of the Information Society where the emphasis is on greater user-friendliness, more efficient services support, user-empowerment, and support for human interactions. Where people are surrounded by intelligent intuitive interfaces embedded in the environment.

ISTAG has studied the challenges which the achievement of the AmI vision presents both to the technologies directly related to the production of software and services in general, and to some technologies closely related to this. The impact of AmI on the development of these technologies and their ability to support AmI have been assessed.

The current situation and the challenges faced by Europe in the field of software technologies, embedded systems and distributed systems have been analysed and presented in section 3.2 as Strengths, Weaknesses, Opportunities and Threats (SWOT). The recommendations made in this report build on this SWOT analysis.

AmI includes systems directly under human control and also systems which control the environment of human beings while not being directly under their control. AmI will involve large, complex, distributed systems and depend on seamless networking. The realisation of AmI will require massive development of application software, middleware and control software, as well as the infrastructure for efficient development and deployment of such software.

The success of AmI thus depends on our ability to effectively engineer and develop the increasingly complex software infrastructure with all the software needed for intelligent devices to provide the required functionality.

ISTAG recommends in section 8 a significant increase of support to research in the Domain.

Most importantly, large improvement in productivity and quality of software will be needed to support the marked increase in complexity which AmI will introduce. This requires the creation of *open development environments* providing intelligent support for software developers during the whole lifecycle from requirements assessment, via coding to software maintenance. It should provide methodologies, middleware and tools for the production of code, as well

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([1]) ISTAG report "Scenarios for ambient intelligence in 2010", February 2001.

as to support the development process (with agile methods). It should be based on open standards and provide interoperability to allow easy extension with sector specific elements. An important sector in Europe concerns *embedded software*.

Other important areas for research are generic concepts for *middleware technologies* and new *information management and database technologies*.

At the same time, sufficient attention must be given to *longer term foundational research* to create a sustainable basis for European software industry. This would relate to the foundation of software engineering as a engineering discipline, and also aim at abstractions in software technologies and complexity and autonomy in software engineering.

In order to build on European industrial strengths, support for these software technologies should promote *user-supplier collaborations* between secondary IT/Software industry users (i.a. telecom, automotive, aircraft, process industry) and software tool and component suppliers (often SMEs), supported by academic research.

Specific areas for such collaboration for developing software and service technologies and building software intensive systems are recommended for extra attention.

One is the telecommunications sector, making use of Europe's strength in mobile communication, recommending work related to *software for network management*, the *"Extended Home Environment"*, and *Value-added services creation*.

Other industrial sectors where the use of generic software technologies could have a strong multiplying effects for the industry and at the same time help building up a software supplier industry are: European automotive and aircraft industries, and business support (logistics, intelligent decision support).

The co-operation between domain-oriented disciplines and software, system and service technologies should be encouraged in the creation of Integrated Projects and Networks of Excellence. This includes priority areas given in the IST Programme domain "Applied IST research addressing major societal and economic challenges" which require a basis of generic software and service technologies for progress.

The provision of e-government services for the benefit of citizens should be promoted in particular with use of Open Source software. The use of Open Source software should also be encouraged where it could be useful for reasons of European industrial strategy (e.g. infrastructures, middleware, operating systems for devices) and in general for software produced in the IST Programme or indeed in FP6 as a whole.

Finally, attention is asked for stimulating direct exploitation of academic results by supporting spin-offs. In the software and service area, with low initial investment costs, this could create opportunities, especially also in the NAS countries.

1. INTRODUCTION

The IST Advisory Group (ISTAG) decided to establish a Working Group in the field described in the Specific Programme under the sub-bullet *Software technologies, Embedded systems and Distributed systems* (called further the Domain), with the objective:

> *To develop a vision of the challenges and opportunities for European research and industry in the Domain with a view to enable the implementation of ISTAG's vision to "Start creating an ambient intelligence landscape (for seamless delivery of services and applications) in Europe".*

In the Domain, areas of research and development that are critical to the implementation of ISTAG's vision should be identified, as well as European strengths and weaknesses in research potential and in potential for industrial exploitation in these areas. This should take account of application areas and enabling technologies which are major drivers of software technologies, for example: e-commerce, security, GRID's in computing sciences, networking and mobile communications. Strategies should be developed to exploit the strengths at full and to cope with or remove the weaknesses when appropriate. This should lead to recommendations for action to be implemented in the workprogramme for 2003 in FP6 — Priority IST, and in particular, but not exclusively, for the sub-bullet point describing the Domain, as well as to recommendations for actions in support of European research and industry as a whole.

In doing so, the group should take into account the report of the Programme Consultation Meeting of April 2001 for the area *Software Technologies, Services and Complex Systems,* the roadmap developed in the EUREKA-ITEA program, as well as ongoing activities of relevance in Member and Associate States. It should consider comparison between Europe and its main competitors and indicate Europe's strengths and weaknesses with respect to research, markets and competitive position. It should lead to a strategic plan aiming at ensuring a research and industry base in software, services and systems of sufficient strength to support the timely implementation of ISTAG's vision. This will include recommendations on required research themes and activities to be developed and implemented in the framework of the IST programme in FP6, and in particular its first workprogramme for 2003. The recommendations could also include possible co-operation with Eureka–ITEA.

ISTAG([2]) was supported by a core of external experts:

Gerard van den Broek	Philips	NL
Alfonso Fuggetta	Politecnico di Milano	I
Martin Gitsels	Siemens	D
Valerie Issarny	INRIA	F

([2]) See ISTAG membership at the end of the report.

Stefan Jaehnichen	GMD and TU Berlin	D
Wolfgang Klingenberg	Bosch	D
Tapio Tallgren	Nokia	FIN

In addition a group of external experts has been invited to provide input in two workshops and at the final draft report during June 2002. These experts were:

Gerard Briand	Thomson Multimedia	F
Eric Daclin	EUREKA/ITEA	F
Francisco Garijo Mazario	Telefonica	E
Peter Hinssen	EURASP	B
Torsten Leidig	SAP	D
Michael Luck	Univ. of Southampton	UK
Marek Makowski	IIASA	PL
Dominique Potier	THALES, RNTL	F
Juan Antonio de la Puente	Politec. Univ. Madrid	E
Antonio Rito Silva	INESC	P
Joseph Sifakis	Verimag	F
Norbert Streitz	GMD-IPSI	D

The group was supported by Unit E2 (Technologies and Engineering for Software, Systems and Services) of the IST Programme.

2. AMBIENT INTELLIGENCE

2.1. What is Ambient Intelligence?

Under Framework Programme 5, the IST Advisory Group (ISTAG) developed a vision for the further course of the IST Programme. This vision is coined with the term "Ambient Intelligence":

> *"The concept of Ambient Intelligence (AmI) provides a wide-ranging vision on how the Information Society will develop. The emphasis of AmI is on greater user-friendliness, more efficient services support, user empowerment and support for human interactions. People are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects. The Ambient Intelligent environment is capable of recognising and responding to the presence of different individuals. Ambient Intelligence works in a seamless, unobtrusive and often invisible way."*

The ISTAG vision proposed that we

> *"start creating an ambient intelligence landscape (for seamless delivery of services and applications) in Europe relying also upon test-beds and open source software, develop user-friendliness, and develop and converge the networking infrastructure in Europe to world-class".*

In this report when we use this concept of Ambient Intelligence, the terms imply:

- Ambient: surrounding, pervasive, being everywhere available
- Intelligence: The Turing test defined something to be 'intelligent' if a person communicating with it could not distinguish whether it was human or a machine. Based on ideas in the books by Byron Reeves and Clifford Nass: "The Media Equation" and "How People Treat Computers, Television, and New Media Like Real People and Places" (1999), we can define something to be 'intelligent' if people react and respond to it as they would to a human being.

Thus the concept of **Ambient Intelligence (AmI)** is used where intelligence pervasively exists in the surrounding environment. Such an environment is sensitive to the presence and activities of people in it; it "remembers and anticipates". It is the overall environment of which devices, applications, services and their interfaces may form part, as do the networks, sensor systems and other technologies that enable it.

The main features of an AmI enabled system with respect to its relation to the persons using it can be characterised by:

- *Non-obtrusive*: many often invisible distributed devices exist embedded in the environment, not intruding upon our consciousness, unless we need them
- *Personalised*: its behaviour can be tailored towards personal needs and can recognise the user

- *Adaptive*: its behaviour can change in response to a person's actions and environment

- *Anticipatory***:** it anticipates a person's desires and environment as far as possible without conscious mediation.

The ISTAG document "Scenarios for Ambient Intelligence in 2010" gives a more elaborate description of AmI, as being based on the convergence of three key technologies: *Ubiquitous/Pervasive Computing*, *Ubiquitous Communication*, and *Intelligent User Friendly Interfaces*.

Humans will be surrounded by intelligent interfaces supported by computing and networking technology which is everywhere, embedded in everyday objects such as furniture, clothes, vehicles, roads and smart materials, even particles of decorative substances like paint.

AmI implies a seamless environment of computing, advanced networking technology and specific interfaces. It is aware of the specific characteristics of human presence and personalities, takes care of needs and is capable of responding intelligently to spoken or gestured indications of desire, and can engage in intelligent dialogue.

AmI is non-obtrusive, often invisible: everywhere, and yet not intruding upon our consciousness unless we need it. Interaction should be relaxing and enjoyable for the citizen, and not involve a steep learning curve.

AmI is supportive to and controlled by people; it recognises persons, anticipates their actions and supports their activities on request, be it leisure or work. It can perform complex tasks that could involve communication and negotiation with other applications and/or persons, for example by agents acting on behalf of a person.

AmI will depend on seamless networking. There will need to be a large number and variety of devices, within spaces and as part of the electronic outfit, communicating with each other and with services. For this communication a variety of networks (xDSL, cable, WiFi, UMTS, satellite, Bluetooth …) will be used, which will need to operate seamlessly as one logical network for the applications and the users. Different devices would roam across multiple networks. The AmI environment will involve complex distributed systems. The development of methods and technologies for its control, maintenance and evolution will comprise essential strands in an R&D program for AmI.

Introduction of AmI will require a large number of complex application systems and it will lead to a marked increase of the complexity of the IT infrastructure. In a white paper published by IBM (Oct 2001) on **autonomic computing([3])** (it is stated that *'it's time to design and build computing systems capable of running themselves, adjusting to varying circumstances, and preparing their resources to handle most efficiently the workload we put on them. These autonomic systems*

(3) IBM Research. Autonomic Computing: IBM's perspective on the state of Information Technology. http://www.research.ibm.com/autonomic/overview/

must anticipate needs and allow users to concentrate on what they want to accomplish.' The paper describes as main concepts of an autonomic computing system:

1) It needs to "know itself" — its components must also possess a system identity.
2) It must configure and reconfigure itself under varying (and in the future, even unpredictable) conditions.
3) It never settles for the status quo — it always looks for ways to optimise its workings.
4) It must perform something akin to healing — it must be able to recover from routine and extraordinary events that might cause some of its parts to malfunction.
5) A virtual world is no less dangerous than the physical one, so it must be an expert in self-protection.
6) It must know its environment and the context surrounding its activity, and act accordingly. It will find and generate rules for how best to interact with neighbouring systems.
7) It cannot exist in a hermetic environment. While independent in its ability to manage itself, it must function in a heterogeneous world and implement open standards — in other words, an autonomic computing system cannot, by definition, be a proprietary solution.
8) It will anticipate the optimised resources needed while keeping its complexity hidden.

Successful realisation of AmI will require autonomic computing and the IT infrastructure to support it. The ideas and characteristics given above provide insight into the issues at stake on the long road to achieving it. This demonstrates the need for massive development of application, middleware and control software, as well as the infrastructure support for this development and for its efficient deployment with sufficient quality.

2.2. Scenarios

The ISTAG report "Scenarios for Ambient Intelligence in 2010"([4]) elaborates the above given vision published for the IST Programme under the fifth Framework Programme. It states:

> *"Ambient Intelligence (AmI) stems from the convergence of three key technologies: Ubiquitous Computing, Ubiquitous Communication, and Intelligent User Friendly Interfaces. According to the vision statement, on convergence humans will be surrounded by intelligent interfaces supported by computing and networking technology which is everywhere, embedded in everyday objects such as furniture, clothes, vehicles, roads and smart materials even particles of decorative substances like paint. AmI implies a seamless environment of computing, advanced networking technology and specific interfaces. It is aware of the specific characteristics of human*

([4]) The document is available on ftp://ftp.cordis.lu/pub/ist/docs/istagscenario2010.pdf *presence and personalities, takes care of needs and is capable of responding intelligently to spoken or gestured indications of desire, and even can engage in intelligent dialogue. 'Ambient Intelligence' should also be unobtrusive, often invisible: everywhere and yet in our consciousness — nowhere unless we need it. Interaction should be relaxing and enjoyable for the citizen, and not involve a steep learning curve."*

To assist the further understanding of the concept of AmI, ISTAG developed in its report, with support of IPTS([5]), four scenarios for ordinary people living in an AmI world in 2010.

(1) ***Maria*** — personal ambient communicator

(2) ***Dimitrios*** — connecting people and expressing identities

(3) ***Carmen*** — traffic optimisation

(4) ***Annette and Solomon*** — social learning by connecting people and creating a community memory.

These scenarios should not be read as end-objectives in themselves. They are rather ways of discerning the technological challenges and opportunities for research and industry on the road towards the introduction of AmI.

The scenarios developed by ISTAG focus on applications in direct support of persons at work, in leisure time and learning, as well as on the direct interfaces used by human beings to communicate with the network and the applications.

The group wants to broaden considerations to include in addition those systems that control the environment of human beings, but that are not directly under their control. We may think of commercial systems in the back-office to support electronic or mobile commerce and services, industrial manufacturing systems to produce commodity goods, control systems for a secure and safe environment (in the factory, the ecology, or in society for disaster avoidance and management, air traffic control, car control, etc.). In such systems communication can be mainly between subsystems, based on cognition and intelligent control behaviour.

For illustration another scenario is given.

(5) ***Amos*** — Ambient Intelligence in Office and Business.

We envisage mobile service engineer in an industrial plant. He wishes to be informed of problems on the site. AmI gives him the benefit of being able to move around and be quickly at the actual location of a problem. He stays informed by wireless communication (Bluetooth, WiFi …) to his PDA. Via his easy-to-use PDA he can quickly obtain situation-dependent information on the location where problems are happening, and run simulations of complex situations to help him decide on the action to be taken.

([5]) See also ftp://ftp.jrc.es/pub/EURdoc/eur19038en.pdf

Another service engineer needs to reconfigure a manufacturing line. To do so, he connects to the system to update software modules and the system then reallocates resources to reflect its new configuration. Once the process of self-configuration is stabilised, the result is communicated to the service engineer. Since a stable configuration might not be found, the service engineer might carry out parts of the configuration manually.

The business manager would be directly informed of serious problems handled by one or more of the engineers, giving him the possibility to intervene or take over responsibility. The effect of reconfiguring manufacturing lines would be reported to the plant manager. Its effects on quality and efficiency will be reported in real time. Together with sales information and market data, intelligent tools and models can be used to support him in designing an optimal planning for the manufacturing, with in-time delivery.

3. SOFTWARE AND SERVICE TECHNOLOGIES IN EUROPE

3.1. Some figures on ICT and software products markets in Europe

Before discussing in detail the technological aspects related to the above question, it is worthwhile considering some facts concerning the European ICT and software market and industry.

Table 3.1 shows some recent figures concerning the development of the ICT market. From these figures it is possible to observe that the European ICT market share remains stable proportionally as opposed to the US which is proportionally decreasing. This might be partly due to the still relatively lower share of ICT in the European economy. In a few years, while keeping the current growth rate the European market might therefore become the largest market world-wide.

	2001 Value	2000 %	2001 %	2002 %
Europe	673	29.1	29.4	29.1
US	783	35.5	34.2	33.7
Japan	284	12.3	12.4	12.5
4 Tigers	75	3.3	3.3	3.3
RoW	476	19.8	20.8	21.3
Total	2292	100.0	100.0	100.0

Table 3.1
Evolution of ICT markets (values in Billion €, source EITO 2002) (6)

When turning to the world-wide market for IT only (ICT without Telecommunications) by region depicted in Diagram 3.1, the situation appears the same for Europe whilst the share for the USA is obviously bigger.

(6) EITO. *European Information Technology Observatory 2002*. EITO, 2002 – 10th Edition. (The 4 Tigers being Hong Kong, South Korea, Singapore and Taiwan).

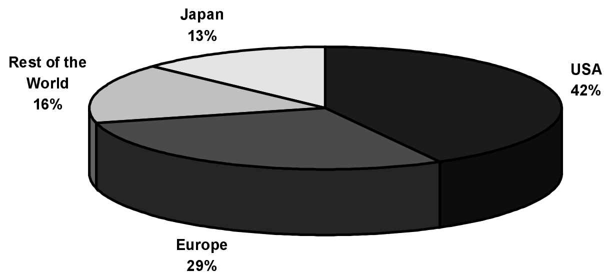

Diagram 3.1
World-wide IT Market by region in 2002 (source EITO 2002)

Looking now at the respective annual growths of the Western European IT and Telecommunications (TLC) markets as shown in Diagram 3.2, for the first time ever the traditional thrust of the telecom sector is starting to erode in contrast with a better IT outlook in 2003. Analysing the structure of the Western European ICT market in 2002, it can easily be seen in Diagram 3.3 that the IT services and Software products segments amount to nearly 1/3 of the total market in addition to the significant portion of the Carrier services where support for information is also prevailing in one form or another.

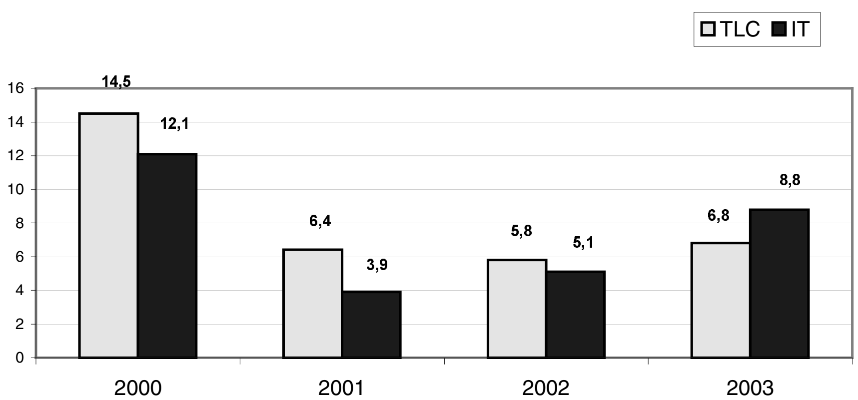

Diagram 3.2
Western European IT and Telecommunications markets annual growth in %, over 2000-2003 (source EITO 2002) (Total market value = 678 Billion €)

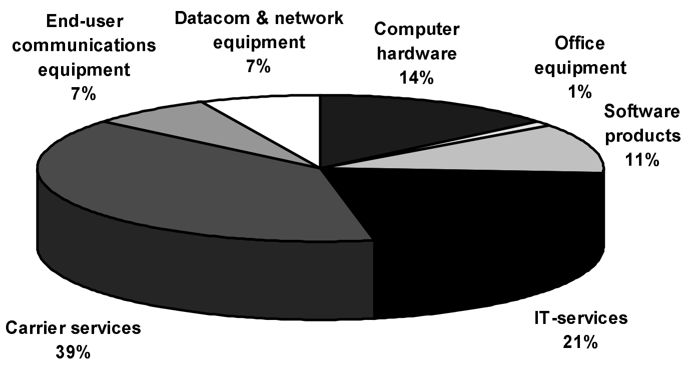

Diagram 3.3
Western European ICT market structure, 2002 (source EITO 2002)
(Total market value = 678 Billion €)

The most striking trend in the Western European ICT market is the differential annual growth rate by segments that are forecasted over the period 2001 to 2003. Here in Diagram 3.4, the Software Products and IT services segments exhibit the highest increase.

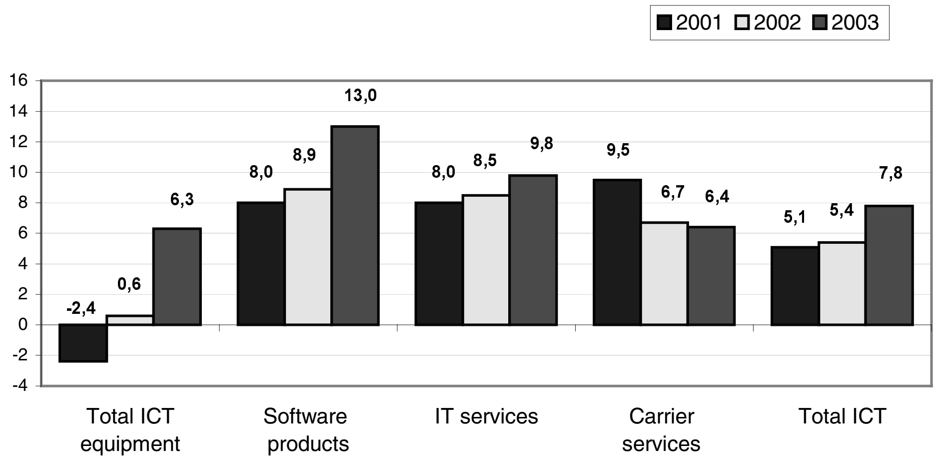

Diagram 3.4
Western European ICT market annual growth by segment in %,
over 2001-2003 (source EITO 2002) (Total market value = 678 Billion €)

Finally, Table 3.2 shows the European Union trade balance for ICT products and services. It is quite obvious that Europe's deficit in this area gives reason for concern. Even more, it appears that this deficit is increasing over the years, despite the significant efforts of the European Union and of Member States to increase the amount of European-made ICT products.

	In EU	Non-EU	US	Japan	4 Tigers	RoW	Total
EU Import	83,225	932	15,882	10,609	21,556	22,590	154,794
EU Export	85,590	4,787	7,893	2,399	2,342	13,850	116,861
EU Trade balance	2,365	3,854	-7,989	-8,210	-19,214	-8,740	-37,933

Table 3.2
EU Trade balance for ICT vis-à-vis the World
(values in Million €, source EITO 2002)

The European software market is clearly and significantly increasing as diagram 3.5 demonstrates. At the same time, the European ICT workforce is not growing enough.

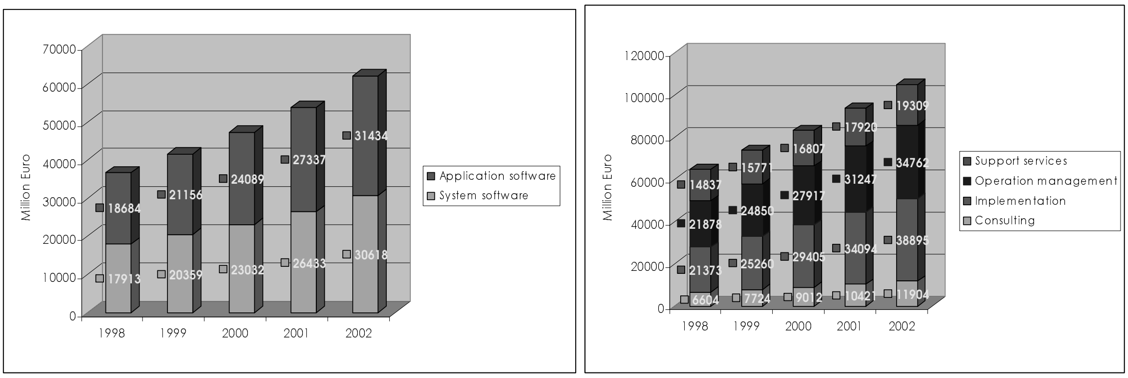

Diagram 3.5
Expenditures in software packages (left) and in software-related services (right)
in the European Union (EITO 2001) (7)

Finally we must note that the EU is experiencing an increasing shortage of ICT skills. The EITO 2001 edition provided an in-depth qualitative analysis of the situation in Europe. The 2001/2002 economical slowdown has eased the expectation for the skills shortage growth. However, as stated in EITO 2002, even if skill shortage seems not to be a critical issue today, if actions are not urgently taken, as the market recovers we will only exacerbate the problem, starting perhaps already in 2003. Shortages are expected to remain high in the leading edge, highly specialised areas, and will still be an issue in the core competency areas, whilst a decline may be seen in the most mature and low-technical areas. Hence there is an urgent need to rapidly devote enough resources to improving software engineering curricula and research at all levels.

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(7) EITO: *European Information Technology Observatory 2001*. EITO, 2001

		1999	2000	2001	2002	2003
ICT professionals	Demand	9450	10397	11170	12127	13030
	Supply	8612	9188	9815	10608	11344
	Shortage	837	1208	1355	1518	1686
	Shortage %	**9%**	**12%**	**12%**	**13%**	**13%**
E-business	Demand	1812	2800	3913	5084	6327
	Supply	1480	2254	3039	3760	4346
	Shortage	331	545	873	1323	1980
	Shortage %	**18%**	**19%**	**22%**	**26%**	**31%**
Call centre	Demand	1000	1300	1690	2112	2577
	Supply	900	1183	1546	1954	2396
	Shortage	100	117	143	158	180
	Shortage %	**10%**	**9%**	**9%**	**8%**	**7%**

Table 3.3
Skill shortage trends (In thousands; source EITO 2001)

3.2. Software and service development in industry and academia

EU's universities and non-industrial research organisations have significant strengths in parts of the field. Examples are formal methods and languages, real-time system design (RT-UML), dependability and embedded software.

The strength of European ITC academic research has also been demonstrated for example by the European origins of the Web and Linux. At the same time these examples show that Europe seems not to have the structure and players to profit from such research results.

We must conclude that the major software companies, in particular those which play a leading role in operating systems, interoperability and standardisation, development platforms and tools, and packaged office software are all established in the US. Some of these effectively play a global monopolistic role, in particular for servers and PC platforms and applications. It is essential for Europe's future to prevent such monopolies from overwhelming emerging markets in Internet and mobile services, and in embedded software, by using their market power and brands in current markets to penetrate neighbouring future markets.

In Germany, a study ([8]) showed that about 80 % of SW development takes place in secondary IT/Software sectors, combining IT software and application know-how but driven by product or service requirements (cars, mobile phones, banking, consumer electronics …). It is expected that overall in Europe this will be lower but still close to 70 %. Many thousands of embedded software developers work directly in aeronautics, automotive, mobile telephony and the consumer electronics industry.

The focus of Europe's software development is clearly not aimed primarily at an independent competitive software tools and service supplier industry, with some exceptions (e.g. SAP, Telelogic). This is opposite to the US, where for example

([8]) http://www.iid.de/aktionen/aktionsprogramm/fortschritt/english/a13-fort.pdf

Rational has a dominant position in the global software development platform market, and Microsoft, SUN, IBM, ORACLE and other genuine software companies provide developers with languages, development environments and kits to support their products and proprietary standards. They use their clout to dominate the standards and interoperability forums, which creates further weaknesses for European industry.

As indicated above, the European situation leads to non-optimal exploitation of the research done at universities and research establishments, results being too generic for secondary industry. Research results created in Europe — as well as the researchers educated here — too often lead to successful exploitation only in the US.

Below we summarise and complete the discussion above in a table on Strengths, Weaknesses, Opportunities and Threats (SWOT).

Table 3.4
Software and service technologies in Europe — a SWOT analysis

Strengths	**Weaknesses**
1. Very good educational basis which stimulates good theoretical research. This is apparent in parts of the software technologies field (e.g. logic, semantics, formal methods; agent-based computing; architectures and algorithms for the design of real-time and embedded SW, dependability) and enabling areas (systems theory, decision support) 2. Strong secondary IT/software industrial sectors: e.g. mobile communications, automotive industry, consumer electronics, aeronautics/space and process industry 3. Strong position in Embedded software 4. Strong in application systems 5. Strong players in niches: e.g. creative design capability, CAD, ERP, modelling/analysis tools for real-time and telecom, requirements management (DOORS), UML tools, tools for Automotive Control SW (ETAS) 6. Some strong SMEs for software tools, middleware and components for advanced business applications 7. Strong open source software development community 8. High variety in industrial structure (large and small) which demands flexibility and creativity of suppliers	1. Inadequate structure and weak culture for transferring and exploiting university research results. High quality education not optimally used. Inadequate capacity in IT base technologies (OS, HW). Fragmentation of academic efforts 2. Low budgets for defence IT research and no mechanisms for dual use exploitation of such research 3. Increasing shortage of IT skills 4. Lack of big software players such as tool vendors (this is related to the threats below) 5. Insufficient involvement in global discussions on Web service standards and interoperability 7. Insufficient awareness of and attention to security related issues

Opportunities	Threats
1. Emerging markets for Internet and mobile services call for Open Architecture and middleware (e.g., OMA)(9) for value-added services to stimulate innovative creation of seamless delivery of these services 2. To turn Ambient Intelligence into reality an increasingly complex software infrastructure is required calling for advanced development and execution environments, building upon academic strengths, the existing SME's in the field and the strong Open Source community, and providing a sound basis for sector specific tools 3. Europe's industrial structure contains strong secondary IT/Software industry (often large size) and a variety (but many SMEs) of primary software industry. This provides good opportunities to build strong user-supplier networks for a future with COTS and component based software systems 4. Rapidly increasing markets for embedded software, in particular in strong European industrial sectors, call for advances in networked control, fault tolerance, structured control, modelling and analysis of real-time systems, domain specific platforms for embedded systems 5. The strength in mobile communication, as well as in theoretical aspects of decision support and systems theory might create a chance to challenge the practical PC/server monopoly of Microsoft in office software, and to build a strong position in industrial application software 6. Export regulations of the US with respect to encryption technology challenges European industry which should be translated into system wide solutions 7. Next generation Internet and GRID technologies offer new opportunities in the infrastructure and services market. Europe could become a leader by early adoption of IPv6, broadband access and wireless access 8. EU candidate states have strong teaching focus in SW that can help to reduce the skills gap	1. US players dominate in operating systems, interoperability, development platforms and tools, as well as in related standardisation bodies such as OMG. Even ECMA is used by US companies to achieve fast track standardisation processes. This can easily create dependency and followers behaviour 2. PC platform and application software and server platform software is dominated by one specific technology company, leading to monopolistic and predatory behaviour in adjacent areas (e.g. multimedia, mobile services). This extensive platform creates large developer groups which use only this company's development tool kits, thus further strengthening its position 3. Developments in legislation in the US and the EU for Intellectual Property for content and software (copyright, patents) may create a playing field where the strongest will block the weaker, thus frustrating innovation. It may also hinder open source development where Europe is strong 4. DRM rules are heavily controlled by US content owners to the detriment of the consumer electronics industry and consumers

(9) See http://www.openmobilealliance.org/

This SWOT can help with formulating recommendations for changing the tide. The actions proposed must make use of the strengths of some European industrial sectors, e.g. the communications sector or the automotive sector. They should aim at building up a healthy user-supplier organisation in such sectors making also efficient use of academic results by effectively steering academic research towards industrial innovation. Such actions could help in building a software supplier industry in Europe and create a competitive edge globally.

More detailed recommendations could be thought of. For example, using the strengths of Open Source tools like Eclipse provides an opportunity to share an integration framework for an open development environment.

4. AMI AND SOFTWARE TECHNOLOGIES

4.1. Introduction

In section 2.1 we described the characteristics of AmI: non-obtrusive, personalised, adaptive and anticipatory. We also argued the need for an infrastructure of autonomic computing systems, which provides intelligence, self-configuration, self-healing, self-protection and self-management. We concluded that its realisation will require massive development of application software, middleware and control software, as well as the infrastructure for efficient development and deployment of such software.

Eventually, the success of the AmI program will depend on our ability to effectively engineer and develop the increasingly complex software infrastructure with all the software needed for intelligent devices to provide the required functionality. Hence we must overcome the inability of the European software industry to keep pace with competition and users' and customers' requests (see table 3.2). This requires a major and focused effort to improve the *effectiveness and productivity* in software engineering and development activities.

Achieving the AmI vision will require the development of a range of technologies such as new devices, sensors, and interfaces. Also, we will need a new generation of processors and communication infrastructures that will be used to distribute and interconnect "intelligent devices" (i.e. computerised systems) everywhere. Such "intelligence" is provided by software embedded in these devices. Any added value offered by a computerised system is eventually determined by some software. It is software that provides the "intelligence" in commodity products (cars, TVs, mobile phones, etc.) for its functionality, control and communication. Therefore, we need environments, methods and tools to develop *embedded software* taking account of the specificity of the products in which it is embedded (real-time control, restrictions on power, computing power and storage, etc.).

Consequently, the crucial question is: what are the engineering technologies and methods needed to build large complex software systems and systems consisting of embedded hardware and software.

To understand the status of software engineering as a discipline we need to go back to the time of its inception. The term Software Engineering was introduced over 30 years ago, with the intention of presenting software development as an engineering discipline as opposed to a craft. The latter is characterised by the use of a set of prescriptive and descriptive rules of thumb. On the contrary, engineering entails the systematic reuse of already engineered artefacts by means of well-established methods for constructing systems fit for purpose. Additionally, an engineering process is supported by formal mathematical representations of the objects, rules and guidelines involved to it.

Twenty-five years after the introduction of the term, little engineering discipline was really in place in software development. This was largely due to a lack of communication between the communities of theoretical computer scientists and software practitioners. Theoreticians' work was based on the belief that reliable software should be developed through formal specification, program development by refinement and mathematical verification. However, application of their results was limited to small, artificially complicated example problems and therefore their influence to the software development practice has been minimal.

In the more recent years, the gap between theory and practice in software development appears to have decreased. More recent work on Formal Methods for instance, enables the use of sound methods in the construction of components and in their composition. Formal tools such as model checkers, theorem proving environments, specification formalisms and theoretical refinement methods are now available for component construction complemented by theoretical approaches to compositionality and software synthesis. On the software practitioner's side, the emergence of Java or XML-based development environments seamlessly imposed component technology and integration mechanisms, while UML, a de facto standard, represents an amalgam of various approaches to OO design.

The state of software engineering nowadays is nevertheless still worrying. Quality, dependability, security, and other non-functional requirements are too often sacrificed for time to market and productivity. The pervasive use of software in an AmI world makes it all the more necessary to address all aspects equally and in a well-designed way, allowing for full traceability.

4.2. Fundamental abstractions underlying AmI

Many reviews of different technologies that may be relevant to the AmI vision have concentrated either on characteristics or properties necessary for ambient intelligence applications, or on a more general assessment of the state-of-the-art and current issues in specific areas of software technologies. In order to develop a coherent and integrated view of how AmI *impacts* various technologies, and how these technologies may *support* AmI, it may be useful to consider what kinds of abstractions could underlie this vision. The features and abstractions below are not exhaustive, but merely indicative of the kind of understanding needed.

Artefacts

The AmI vision describes an environment of potentially thousands of embedded and mobile devices (or software artefacts) interacting to support user-centred goals and activities. This suggests a component-oriented view of the world in which the artefacts are independent and distributed. Most relevant documents consider autonomy, distribution, adaptation, responsiveness, etc., to be key characterising features of these Ambient Intelligent artefacts, and in this sense they share the same characteristics as agents.

Interactions

In particular, these AmI artefacts are likely to be function-specific (though possibly configurable to tasks) and will, of necessity, need to interact with numerous other AmI artefacts in the environment around them in order to achieve their goals. Interactions will take place between pairs of artefacts (in one-to-one co-operation or competition), between groups (or systems) of artefacts (in reaching consensus decisions), and between artefacts and the infrastructure resources that comprise their environments (such as large-scale information repositories, or other supporting resources, possibly through legacy code encapsulation). In the Web based world interactions with services are mainly oriented to human beings. In the AmI world the dynamic (re-)configuration of loosely coupled artefacts together offering services will require interactions between programmed artefacts. This puts several new requirements on the artefacts, the middleware and frameworks. One example of a new architectural approach is open resource coalition as described in "Open Resource Coalitions"([10]). Interactions like these enable the establishment of *electronic institutions* or *virtual communities (VC)*, in which groups of artefacts or agents come together to form coherent groups able to achieve some overarching goals.

Semantics

Importantly, interactions will also occur between artefacts and users, potentially requiring greater sophistication in interface issues, and in user understanding (and modelling). This will be a huge challenge as users don't perceive the physical world as a collection of computing environments, but as a collection of places with rich functional, administrative and cultural contents and meanings (actually semantics). Kindberg and Fox ([11]) call this the *Semantic Rubicon* of ubiquitous systems. Current software techniques are insufficient to meet this challenge and therefore in the short term, designers should make choices about what system software will not do, but humans will. These choices would need to be reflected in intelligent user interfaces driven by shared logical or formal representations of explicit and conceptualised knowledge, i.e. *ontologies*, capable of helping to infer machine processable definitions and symbolic rules from natural languages or human concepts. These ontologies will inevitably be built for specific and often local purpose in a first stage. They will depend on the context of use, the particular usage and also of the environment (particularly of services) in which the above artefacts — user interactions will take place.

Environment

Though largely included in the previous paragraphs, the environment provides the infrastructure that enables AmI scenarios to be realised. On the one hand, artefacts offering particular services can be distinguished from issues concerning facilitating services such as the physical infrastructure needed to support effective interaction through sensors and actuators, and the physical connectivity for supporting quick and efficient interactions, for example. On the other, they can be also be distinguished from issues relating to the virtual infrastructure needed to support resource discovery, large-scale distributed and robust information repositories (as mentioned above), and the logical connectivity needed to enable effective interactions between large numbers of distributed artefacts and services, for example.

([10]) Mary Shaw, http://www-2.cs.cmu.edu/afs/cs.cmu.edu/project/vit/www/paper_abstracts/iwssd10-in.html

([11]) Tim Kindberg and Armando Fox, Systems Software for Ubiquitous Computing. Pervasive Computing IEEE, Jan-Mar 2002, p. 70-81.

An additional aspect of the environment concerns *organisation,* which takes into account the capability of groups of artefacts to co-operate to achieve a common goal. It would include the encapsulating capacity forming a single unit or organisation consisting of artefacts accepting common rules. Such organisations may communicate with each other and reconfigure for purpose.

Two particularly important points to note in relation to the pervasiveness of artefacts or organisations in the environment relate to *scalability,* or the need to ensure that large numbers of artefacts and services are accommodated. There is a need to ensure that the heterogeneity of artefacts and services is facilitated. The provision of appropriate ontologies could assist in effective interactions, in particular between systems and humans, thus crossing the semantic Rubicon as mentioned above.

The relation to computing and software technologies

In relation to the above key building blocks, the questions to be asked of separate sub-areas of computing and software technologies are as follows.

- How can they help to support the abstractions identified above?

For example, how may traditional software engineering techniques be used to support the development of *large-scale agent-oriented information systems* in which the key primitive is qualitatively different from conventional objects, in the sense that it enjoys more autonomy and initiative? How can virtual communities be reflected as first-class software modules?

- What issues need to be addressed to enable existing technologies to be applied in support of these abstractions?

For example, *negotiation* is likely to be a key technique underlying the interactions between AmI artefacts. Is this something that can easily be “bolted-on” to standard software components and developed with existing technologies or are novel methods needed? In more general terms: is interaction between components intrinsically realised by each component or should *patterns/schemas of interaction* be supported independently?

To what extent are *interoperability standards* (including such aspects as agent communication languages) needed to enable large-scale interactions between large numbers of heterogeneous AmI artefacts?

- What impact might these abstractions have on the current state of software technologies – what problems will arise?

In any large, open and dynamic system, questions of *security and dependability* become especially important. What is the extent of the security issues that arise in the context of the scale of Ambient Intelligence, and is it simply a matter of applying existing techniques more broadly? Can security and other system properties be transparently superimposed on existing components? Are there fundamentally new issues raised?

For example, questions of trust in particular artefacts or services arise. What models and mechanisms will be needed, and how can they be integrated into the infrastructure?

4.3. Structuring the field

For the following discussion we will use a structuring of the field that tries to picture the basic software technologies in its relation to other technologies that are needed for the realisation of AmI. We will distinguish: (1) the technologies for engineering software systems, (2) the foundations on which these technologies are built to make software development an engineering discipline, (3) the additional enabling technologies required to build software intensive application systems, and (4) the building of the application systems itself. The software engineering technologies concern the development and operation environments, the middleware and network-enabled technologies, and the information management that supports the developer during all phases of the development process: requirements engineering, design, implementation and testing, deployment and operation (see Figure 4.1).

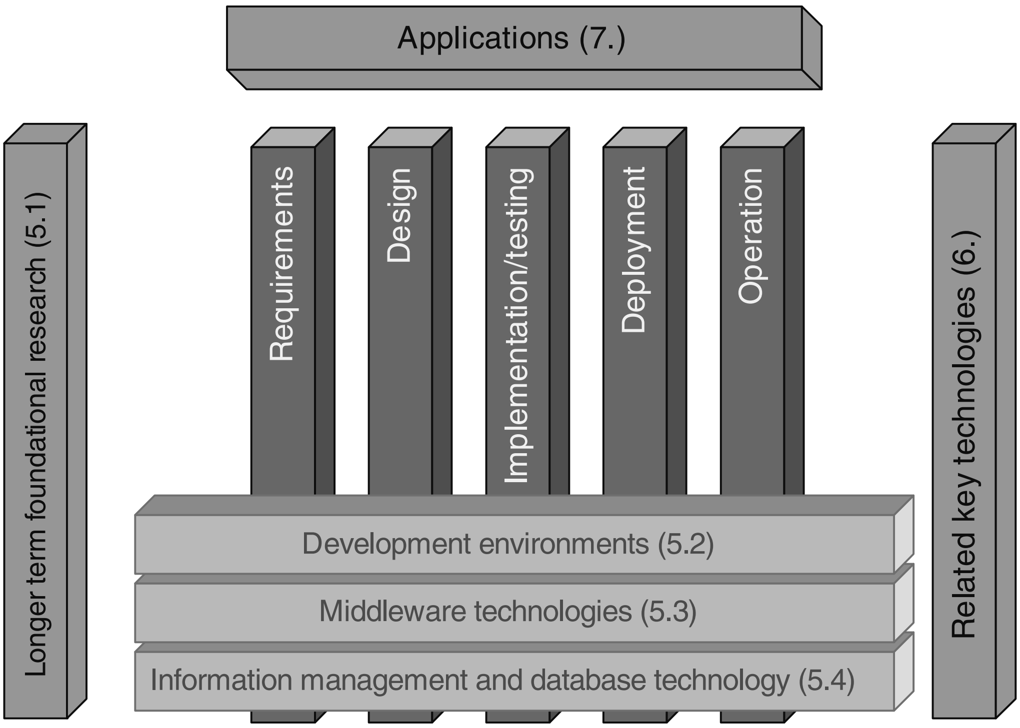

Figure 4.1
Development phases and software technologies

5. SOFTWARE AND SERVICE TECHNOLOGIES

5.1. Longer term foundational research

Longer-term foundational research is generally a necessity to ensure progress and innovation in the field at longer term. For that reason strict limitations are not desirable and indeed, the European university research system generally provides such infrastructure for longer term research.

In view of the objectives of the IST Programme and the arguments developed above in relation to the creation of an AmI environment however, we may consider giving particular priority to three subject areas for longer term foundational research in software technologies:

1. *Foundation of software engineering as an engineering discipline:* Despite the recent progress in bridging the gap between theory and practice, it is widely admitted that there is still a long way to go before one could speak about a true software engineering discipline.

   The primary objective would be to bring together important problems in software development practice with the current theoretical advances that promise solutions. This activity would lead to the identification of gaps in the theoretical foundations and therefore lead to new items on the research agenda. Additionally, the above investigation would identify available theory, which is promising but needs to be packaged for becoming applicable in practice. Research issues could include:

   - Fundamental design concepts: Behaviour representation and analysis (e.g. concurrency and duration of activities) for supporting the design process. Representation of non-functional properties and their use in design. Evaluation of these properties of systems constructed by combining components with defined properties. Organisation of design knowledge (e.g. standardised architectures and problem frames). Generalisation of these concepts to application domains.

   - Specifications: Systematisation of domain knowledge for different application areas and generic properties in such approaches. Definition of specification and refinement patterns to encapsulate design choices.

   - Theoretical tools: Languages with strong modularity properties. Study of behavioural principles (concurrency, distribution, timing, etc.). Improved analysis tools (model checking, etc.). More systematic testing (e.g. through animation and simulation).

   - Quantitative data: Use of quantitative analysis to establish usefulness of various architectures, patterns and testing schemes. Principles of measurement in data gathering.

2. *AmI related abstractions in software technology:* In section 4.2 a number of issues are mentioned which are directly related to the fundamental abstractions underlying AmI (independent and distributed artefacts —

software or hardware, interactions between (groups of) artefacts, semantic issues related to interaction, pervasiveness of artefacts in the environment). The questions in particular relevant to software technologies are:

- How can computing and software technologies help support these abstractions; e.g. in developing large-scale agent-oriented information systems.

- What issues must be addressed to enable existing technologies to be applied in support interactions between artefacts; e.g. negotiation between artefacts.

- To what extent are interoperability standards (incl. agent languages) needed before large-scale interaction can take place between large numbers of artefacts.

- What would be the impact of these abstractions on the state of software technologies.

3. *Complexity and Autonomy in Software Engineering:* The breakdown of modern software engineering techniques frequently happens when the perceived complexity of software seems to prohibit the application of disciplined and rigorous methods. Modularity of software — including all development artefacts and their interrelationships — is often not satisfactory, because current software technology provides insufficient support for managing complex real world software in its many aspects and dimensions simultaneously and sustainably over periods of evolution.

   The IBM article referred to in section 2.1 also sees complexity as a major challenge. It gives particular attention to the infrastructure containing the host of services and functionality that a software system expects to be available in its context. However, with the increasing level of integration between information systems and the ongoing merging of tele- and data-communications, this infrastructure is evolving towards unmanageable complexity levels.

   The solution that is proposed is analogous to the autonomic nervous system in the human body. Many of the functions in our body, including breathing, heartbeat, blood sugar levels and digestion, operate without any involvement of our consciousness. It is claimed that IT infrastructure functionality should behave in the same fashion, i.e. adapt to changes in workload, break down of system parts, hacker attacks, etc. without the involvement of system administrators or system users. I.e. the infrastructure should act autonomously (or autonomic like the nervous system).

   The notion of autonomic computing can be viewed as indicative of a general trend in software engineering. With increasing variability, the amount of exposed complexity becomes unmanageable and the solution is to extend the component itself with functionality to manage itself, i.e. to make it more autonomous. For example, most component models allow components to identify the interface of other components at run-time. This facilitates dynamic (re-)configuration of component-based systems. Also, clustering techniques are used in, among others, telecom systems to increase availability by run-time fail-over solutions.

The problem of complexity and autonomy in software is broader than just the infrastructure. It affects all software components and systems and is directly relevant to the development environment and tools. It is already addressed in research, e.g. many types of functionality, including configuration and testing, are performed at later and later stages in the software lifecycle and ultimately at run-time. It needs however further research in a more coherent and focused manner, including more fundamental interdisciplinary research. Dynamic configurability is a necessity for self-managing software systems and dependability is crucial considering the economic interests that many complex software systems represent.

It should be noted that the Committee on Networked Systems of Embedded Computers of the US National Research Council ([12]) recommends for the field of networked embedded systems the stimulation of research on three key areas for research (self-configuration and adaptive co-ordination, trustworthiness, and computational models) also including the intersecting themes: predictability and manageability, adaptive self-configuration, and monitoring and system health.

5.2. Software technology: increasing productivity and quality

It was argued in section 4.1 that a major and focused effort is required to improve the effectiveness and productivity in software engineering and development activities. This aims at methods and tools to support the development process at a generic level as well as at the level of specific sectors, including those with the main focus on embedded software/systems, where specific requirements may need specialised tools. For instance aspects like real-time control, restrictions on power or computing and storage resources create specific requirements in embedded software. Similarly, security, dependability, scalability, etc. might lead to different requirements and therefore also different architectures and design methodologies.

In order to satisfy software development needs at the scale and complexity level required to realise the AmI vision we need *a quantum leap in software productivity and quality*, by providing major improvements in the development and operation environments, addressing middleware, tools and methodologies.

This is not new. In the past, there has been significant research in software engineering environments. Still, nowadays the practice is based on quite traditional tools. Only some of the CASE technologies proposed in the past have really been successful. Therefore, why do we need to invest in these topics again, and how can we be successful given the (at least partial) lack of satisfactory results from past efforts? Why should this time be different?

([12]) Embedded, Everywhere — A Research agenda for networked systems of embedded computers: http://books.nap.edu/html/embedded_everywhere/notice.html [04/01/2002].

It might be interesting to consider some examples. Typical successful software development tools are compilers, debuggers, and configuration management environments. They are successful because no software developer would ever be able to develop any significant software without them. How can one manage all the software artefacts in a complex project without a version and change control system? These technologies are successful also because they directly contribute to the creation and management of the software code, i.e. the final outcome of a software development activity. By using them, developers have the clear perception that they will be able to produce code, and to produce it faster. Indeed, practice demonstrates that this is true.

Conversely, most software engineering tools and environments do not exhibit this kind of behaviour. For example, typical UML tools are used to create UML diagrams that describe the requirements and/or the design of the system to be developed. Typically, these diagrams cannot be used to generate the real code of the system. In practice, most developers simply do not use these diagrams and jump directly into coding. Others quickly forget the UML diagrams they initially created, especially once the code has been developed and changed. UML descriptions tend to become inconsistent with the state of the code. In general, the underlying problem is that most UML tools are used "off-line" with respect to "hard" software development activities: they are not perceived as able to directly contribute to software creation, i.e., the final 'product' on which a developer and a software company is eventually evaluated by customers. An additional example of this issue is testing tools. They are often used "off-line" with respect to programming environments. However, to be effective they must become strongly integrated with programming environments, similarly to debuggers and code optimisers.

Hence it is critical to make software engineering environments more successful by creating tools that directly, visibly, and effectively contribute to developing code. Developers must perceive all their efforts as related to "the software" that is being developed, which continuously grows and improves as they work in different views of a complex model, which in turn is simply a view of the software system being produced.

Another important aspect of software development concerns process methodology: i.e. imposing a disciplined process upon software development with the aim of making the result more predictable and more efficiently produced. The most frequent criticism of methodologies up to date is that they are bureaucratic. There's so much "stuff" to do to follow the methodology that the whole pace of development slows down. As a reaction a new group of methodologies have appeared in the last few years. One could call these *light methodologies* (the term *agile methods* is also used). Examples are Adaptive Software Development, Extreme Programming, SCRUM and Crystal Clear. Light methodologies are less document-oriented, more code-oriented, adaptive rather than prescriptive, and people-oriented rather than process-oriented. Open Source development can also be seen as belonging to this general trend.

Workflow concerns active support for planning, performance and co-ordination of work based on a (more or less complete) explicit process model. Traditional approaches generally separate process definition from process enactment. These activities are supported by different tool components, and performed by different actors or roles. The traditional separation between dynamic/adaptive and static/production workflow refers to whether changes to the definition of a workflow type can affect running workflow instances.

Adaptive Workflow then extends the scope by including support for more forms of co-ordination, less structured process models, and by integrating process definition, or planning, as part of the process. Particularly for distributed or other forms of co-operative software development, adaptive workflow can be essential. To provide the dynamic aspects of adaptive workflow, dynamic object models approaches([13]) have been proposed for adaptive workflow systems([14]).

Major issues to address for next generation integral development environments are:

- *Powerful methods and tools integrated at higher level* to provide consistency and traceability across all development phases of the lifecycle. Attention must be given to early phases of the life cycle relative to their primary role in determining the functional and non-functional requirements of a system and how it translates into *architecture and design*. Specific attention must be given to architectures, methods and tools for (networked systems of) embedded systems.

- *Model alignment* Improvement of concepts for structuring system design and implementation with the goal of addressing complexity and autonomy as abstractions at the model level. An example is the use of agents and/or agent-oriented software engineering.

- *Close integration:* The various tools need to co-operate in a way that allows frequent switching between tools and views. Development steps need to be communicated between tools in order for developers to intuitively experience the interrelationships between different views and techniques.

- Exploit *component-based and COTS-based development* techniques to increase the ability to effectively develop software applications using high-level concepts and not just programming languages features. Notions such as components and features (which are extremely popular and used in software development practice) should permeate tools and environments.

- *Adjustable levels of formality* suiting different cost/quality tradeoffs. Formal methods could allow for more automatic tool support. It will require a varying level of formality and completeness depending on the needs while remaining in the same framework (e.g. UML with different levels of semantics) (see also 5.1.1).

- *Light methodologies and adaptive workflow* providing a dynamic and adaptive environment, suitable for co-operative and distributed development work and supporting high quality and traceability.

([13]) http://www.adaptiveobjectmodel.com/ICSR7/

([14]) http://micro-workflow.com/PDF/domaw.pdf.

- *Flexibility and openness* providing mechanisms for plugging in new tools, especially experimental ones coming from research are essential here. Open source development of the basis layer of the environment can facilitate the rapid adoption and evolution of such tools.

- *Use of intelligence and decision support* where appropriate in the middleware and tools of the development environment.

- *End-user programming can* provide the environment and high level and intuitive tools for professional users and consumers, to help them building applications in a reliable way, adapted to their requirements.

It should be noted that most of the above is equally applicable for the development of value-added services. We need *environments for the creation of value-added services*, which includes as the main element a software development infrastructure for easy creation and deployment of new types of services.

5.3. Middleware technology

Middleware is a distributed software layer which abstracts the complexity and heterogeneity of the underlying network technologies, computer architectures, operating systems and programming languages to ease programming and managing distributed applications. There is a clear relation between the software technologies discussed in section 5.2 and middleware. First, since design methods and tools must take into account the implementation platform, middleware is considered the "means" to implement distributed architectures. Secondly, many software engineering environments are built using middleware as one of the implementation means. Some of the most important research issues in this area are of direct relevance to building AmI.

- *Standardisation of languages and protocols:* A particularly important example concerns value-added end-user services (see also section 7.3). Here functionality must be provided through different and heterogeneous networking infrastructures, computing platforms, devices and interaction modalities. It strongly calls for the creation and standardisation of abstraction and interoperability layers and technologies, something which is actually already ongoing. It can be seen in many fields covering for example formats for data (XML), messaging (SOAP), web based services (WSDL), architectures for service discovery and deployment like JINI, UDDI or UPnP, platform independent programming languages like Java, middleware platforms like Sun ONE, J2EE, .NET, OMA, or DotGNU, or initiatives and architectures for service delivery over heterogeneous networking and communication environments like Parlay, VHE, OSA, the JAIN community or OSGI.
  Another example concerns agent communication languages, such as FIPA ACL, and negotiation protocols.

- *Distribution:* Middleware is a layer on top of operating systems. This layer can and must be distributed especially to achieve scalability and autonomy. Traditional middleware systems had a monolithic approach. Advances in middleware show an increasing effort in developing distributed middleware architectures. For instance, TIBCO, which is a popular event-based middleware for financial trading systems, is based on a tree of autonomous and distributed event dispatchers. The issue of distributed event-based middleware is vital for ambient intelligence. Other issues concern distributed resource management, e.g. in Grids or Peer-to-Peer networks.

- *Fault tolerance:* Middleware must guarantee interoperability among a number of distributed components. Often it is necessary to create fault-tolerant systems where a fault occurring in a middleware component can be recovered. In the example above of a distributed event-based system for financial (on-line and often quasi real-time) trading, the need for continuous operation is obvious.

- *Reflection (reconfigurability and adaptability):* Middleware systems can be built according to different architectures, policies, and algorithms. Several algorithms might be applicable in the same situation, but with different performances, depending on the specific situation. Hence selection and adoption of any of them would depend on the operation profiles exhibited by the application at run-time. Such behaviour is typical in large-scale, distributed and multimedia applications such as those developed for ambient intelligence.

- *Quality of service (including real-time properties):* Most of the discussion on quality of service is moving up from network technology to middleware and from connectivity to functionality. Indeed you want to be able to control at the application level the QoS you need for a specific application or service.

Integration and interoperability among different middleware paradigms: CORBA is basically synchronous and unicast. JMS is mainly event-based. Javaspace uses a tuple-based approach. These are completely different middleware paradigms and each of them works well in specific areas/settings. Ideally all of them are needed. Therefore, some effective and efficient ways to integrate all of these different paradigms and technologies are needed.

5.4. Information management and database technology

Information management and database technologies have always been an integral part of software technologies, raising many problems at architectural level and requiring software development environments and tools. To realise an AmI environment we can distinguish a number of urgent RTD issues, many of which have direct relations with software and service technologies.

- *Downscaling of the software infrastructure* to the level of PDAs, and further to embedded processors. Although some existing products are already available, the real distinction will come from better differentiation of the store-recall functionality of the DBMS in relation to the applications. You see currently a tendency in AmI-like (and agent) applications to either ignore the database management issues, (and lessons) or to re-invent technology.

- *Software renovation*: The complete infrastructure of commercial DBMS is still based on 80ties hardware infrastructure. With the changes in hardware there is now a need for a large renovation of the software. The current dominant suppliers do not invest strongly, which provides an opening for EU industry, provided they are able to package generic technology early in the process as a solution. Technically, the introduction of object-spaces (tuple-spaces, java-spaces) combined with experience from the database field could be used to leapfrog ahead.

- *Evolutionary database management*: Database applications are mostly built around a single schema with associated data container. However, one should expect that the functionality, content, and interpretation (integrity constraints) in the AmI components will change over time. This requires the DBMS to adjust automatically without the need to 'start from scratch'.

- The data involved in AmI systems or environments will most likely not be managed by a single database system but as a *federation of repositories*, including data warehouses as well as smaller databases. Some of these might be strongly coupled to the physical environment by sensors collecting life data.

- *Petabyte databases in your pocket:* A vision in the database field is that within some decades you will have instant access to all the knowledge you have experienced in your life (emails, photo collections ...) as well as efficient and instantaneous access to any information world-wide. How to manage those petabytes (in your 'pocket') is a big challenge, especially if some of these storage devices are regularly disconnected and need occasional synchronisation. An important aspect in this situation is the Digital Rights Management of content.

- *Proximity based query processing:* The DBMS should greatly improve its technology to support answering 'incomplete' queries. This could be based on the (learned) user profile, the accessibility of resources, as well as the cost involved.

- *Open-ended querying and active database management technology:* Currently DBMS are mainly activated upon an explicit request, and there is a clear point in time it has finished its task. In the context of AmI, DBMS systems will be confronted with never ending tasks, e.g. continuously monitoring a (multiple) event stream entering the database. This calls for a complete overhaul of the query optimisers and data-access layers.

- *Data mining, knowledge extraction, and reasoning:* The learning and reasoning components of an AmI require inclusion and scaling of the techniques developed in AI. Alternatively, the DBMS could be better equipped in supporting those algorithms with the appropriate summaries and quick response on queries to make learning tractable within the time constraints of the applications. Furthermore, representation and extraction of knowledge using analytical models should be given attention.

A number of the above issues will require co-operative work including knowledge technologies (semantic queries, knowledge modelling, AI techniques, etc.).

6. RELATED KEY TECHNOLOGIES FOR SOFTWARE-INTENSIVE SYSTEMS

In section 5 we discussed the software and service technologies which directly aim at supporting the production and creation of software and services, related in particular to the systems design (requirements handling, architectures, programming tools, environments and methods to support the development process and ensure quality, traceability, scalability, etc.). There are, however, other key technologies, which on one side are needed to support the development of the technologies mentioned in section 5, and on the other side are required on its own to successfully build the software-intensive systems required for businesses, industry and consumers in a future AmI environment.

It is clear that hardware devices, including sensors, actuators, systems on a chip, but also mechanical constructs, form also an integral part of many software-intensive systems, embedding such devices in for example commodity systems. We will however not consider the enabling technologies required to develop and produce such hardware, but restrict ourselves in this report to the 'soft' technologies. We will discuss below those technologies which we consider most relevant to the software and services field.

6.1. Intelligent components and decision support

In section 4.2, we identify function-specific hardware and software artefacts as the key units of implementation of ambient intelligence, and these artefacts are described as independent, autonomous components. Through their interaction with human users, and with other artefacts, they can support human activities. In this section, we briefly touch upon enabling technologies that can be used to build such function-specific components, in particular in view of seamlessly supporting complex human activities such as control, decision, discovery and search, analysis, etc.

In looking at intelligent support of human action, we can take different views. We must also realise that this subject is inherently inter-disciplinary, bringing together software, hardware, design, psycho-sociological and marketing viewpoints.

In the *device-centred view* we start with the relation of humans to objects identifiable as separate entities, which is deeply rooted in anthropology (actually some anthropologists consider that making tools and mastering language are inseparable, their conjunction defining mankind). An important form of intelligence needed in devices is therefore awareness of the environment: knowing where they are, what they can sensibly do there, what resources are available for use, and how to present information in a usable way in such an environment. This requires:

- Models of usage environments in association with sensors/actuators (from location to physical parameters)

- Resource discovery in the wide sense: what other devices are available, what information, what computing ability, what connectivity services. Including history

- Autonomous components (agents without the mobile code aspect) doing some intelligent tasks, like permanent housekeeping: keeping track of something, organising and presenting stuff, and sending things home.

In an *activity-centred view* intelligent components would aim at supporting an activity. For instance the "recording ideas and thoughts" activity. Whether you are a teenage girl writing a diary or a creative designer or thinker, the problem is that ideas and thoughts come in very diverse situations (from getting bored in a meeting or a classroom to riding a train, from discussing in a restaurant to walking in the street). People use all types of devices to support this activity, from notebooks to voice recorders, but there is a clear lack of integration or reusability, i.e. of manageability in the resulting storage. This would require the ability to collect, to merge and organise things, and to make them searchable. It would need:

- Scaleable and searchable information representation (all media) and information space models

- Artificial intelligence techniques (that prove much more efficient when applied within well described tasks and contexts), including intelligent decision support techniques.

In the *information-centred view* we require the ability to create, manage and produce in a personal information world linked with the global world of information. Current support is ad hoc, location dependent, not moving with the user and badly integrated. Can we bring together separate (in location, in devices, in form) pieces of our personal information world and have a consistent relation with the full set? Can we communicate with other personal information spaces? Aspects of relevance are:

- Personal profile and data management

- Self-tuning protocols that make best efforts at some systemic property (Internet Protocol model).

For the *knowledge-centred view* in the knowledge-based economy of the future, we will have to address various representations of knowledge in any type of models. One example could be representations based on logical patterns. Hence, relevant aspects for research are:

- Knowledge discovery in large data bases and federations of large and small databases

- Knowledge representation by analytical mathematical models applied in diverse fields, such as various areas of engineering, management, environmental studies, decision support.

6.2. Network infrastructure

A worldwide communication network infrastructure needs to be established, combining the principles of the contemporary internet and fixed and mobile phone systems and consisting of seamless interconnection of various forms of wired (telephone, cable, glass) and wireless (3G, Bluetooth, 802.11b …) nets, with guaranteed service levels. The "Book of Visions 2001"([15]) from the Wireless World Research Forum and the document "A vision on systems beyond 3G"([16]) present a vision and research issues on this future network. Within this net, connections can be kept up even if a mobile device moves from one local ambient system to another. Moreover, services are available independent of the type of personal device used. Local systems consist of mobile and stationary devices forming collaborative regions connected by wire as well as wireless. Multiple communication protocols for low-power point-to-point, community-wide, and world-wide communication will be available.

This communication infrastructure should meet certain requirements. It should support full interoperability and plug-ability, which refers to a situation in which devices are easy to add, replace, or remove. It should seamlessly support active networks, virtual dynamic networks and ad-hoc networks. Network management should include ruled-based monitoring. In particular it should be neutral in supporting various existing and future distributed systems technologies (e.g. GRID, P2P). Research networking is part of an integrated network infrastructure on which research GRIDs can be provided.

Moreover, since we can't expect the user to have even a basic knowledge of network administration, these operations need to be as simple as switching lights on and off. Also the capacity of an in-home network should be sufficiently large, with respect to both the number of devices that can be connected to it, and the communication bandwidth.

It is clear that current network technologies do not meet all of these requirements at the same time. A world-wide network infrastructure (protocols, standards) needs to be developed which is based on IPv6 to allow sufficient flexibility to include the enormous amount of devices used. Beside communication schemas, this network system should include a middleware framework for ambient devices, based on decentralised concepts of loosely connected software subsystems. It will need safe and secure execution of mobile code. Agent technologies may play a major role here as well as the replacement of control, pre-programming and centralisation by concepts such as autonomy, emergence and distributed functioning. Redundancy, self-organisation, as well as self-repair will help to cope with the growing complexity of such distributed systems. They will also help to make these systems flexible, robust and able to adapt quickly to changing environments. Many of these (often software based) techniques and concepts are not well understood now, and require theoretical investigation and foundation.

([15]) http://www.wireless-world-research.org/Bookofvisions/Bov.html

([16]) http://www.cordis.lu/ist/ka4/mobile/beyond3g.htm

The network infrastructure together with the standards and interoperability layers, and the management layer to provide such seamless and high Quality-of-Service connection, will form the basis on which the interoperability layer must be built for a service creation environment (see section 5.4). Such an environment id a pre-requisite to stimulate the creation of sufficient innovative services to make the introduction of 3G a success, whilst at the same time beneficial business models must be developed and agreed for connecting providers as well as service providers and end-users in an AmI world.

The area will need the results on architectures, development tools, autonomy in systems, agent technologies and middleware being researched in Software Technologies.

6.3. Semantics and ontologies

As mentioned in above section 4.2 semantic research and ontologies as well as supporting technologies (such as languages or inference engines) will be required to cope with the heterogeneity of users, artefacts or distributed systems of artefacts. The interactions between artefacts in different contexts and environments require mechanisms for understanding these contexts/environments and translating their characteristics into machine understandable language. *Ontologies* provide a basis for such mechanisms. They provide the means for artefacts to store and to present to the outside world the description of their behaviours and potential interactions in semantic terms, which can then be logically inferred and symbolically interpreted by other artefacts or systems of agents or the service infrastructure (e.g. the Semantic Web services) in their dealings with them. In the long term, real reasoning services could be offered to or built into artefacts for driving their interactions.

It is clear that research as indicated above will be essential to develop sufficiently generic agent based software/system architectures that support mobile software (agents) moving from one environment into another providing the services needed in an AmI environment.

The research results in this area could also be of great value in the automatic creation of sector specific software development tools, where the system requirements will depend on the semantic description of the application environment. In particular, the description of software components and COTS will need a certain level of formal semantics in order to enable efficient support to software developers and automatic composition tools for component-based or COTS-based programming.

6.4. Interaction and collaboration technologies

Citing the Book of vision of WWRF, page 25 (see [15]): *It is very likely that the introduction of new interaction techniques will be the trigger of major disruptive leaps in the use of new technology. Recent advances in wearable computing and intelligent fabrics hint at future directions of ways to realise truly ubiquitous computing.*

Speech, handwriting, touch screens and vision, rather than keyboards and mice, may provide the main modes of interaction of humans with machines (or more general: artefacts) in truly ambient intelligence systems. Multi-modal integration increases the effectiveness of these perceptual technologies, for example, by using vision to augment speech understanding with recognition of facial expressions, lip movement, and gaze. Perceptual technologies will be an essential part of ambient systems. Speech interaction does need, however, serious progress to bridge the problem of different semantics.

New ways of interaction will be sought, surrounding people with intelligent intuitive interfaces that are embedded in all kinds of objects. It will make use of augmented reality, e.g. using a semi-transparent visor or head up display, to enhance the users' perception of the reality, and unobtrusive conversational interaction. Moreover, humans will be able to use sensors and actuators for monitoring and shaping their physical surroundings.

In a further future we might extend the use of the human senses for interaction with the AmI environment, using direct brain — computer interfaces or technologies that would add "senses" to those human have now.

The main objective will be full integration for interaction in a laid back fashion, that will also be essential for user acceptance and full e-inclusion.

Another form of interaction is between the real world and systems. Capturing data from the real world (not only time, date, temperature, and humidity but also geographic and semantic location and situation) and combining this data with other information such as personal profiles and preferences or theoretical models is the basis for a large number of services and intelligent support applications. E.g. location parameters are essential elements to build all kind of location or situation aware services. Stock market data can be used with economic models to provide intelligent advice to portfolio owners. Environmental data can help humans to avoid health risks at specific locations. Such services can be local e.g. in the home, car or building or more global (depending on how a person wants to be contacted in a specific situation) or related to e-commerce (push personalised information).

Interaction between artefacts in distributed systems could lead to fully intelligent automated business and services work flows or manufacturing process systems. Product lifecycle management, and supply chain management are example areas for *collaborative workflow* techniques. These techniques could create powerful evolutionary environments for highly process oriented service component creation at design phase and composition at run-time. Current workflow technologies will have to be enhanced in order to accommodate dynamic process configuration, sequencing and orchestration depending on constantly varying situations and circumstances.

A last aspect of interaction concerns collaboration between people. Collaboration technologies could for example enable the formation of spontaneous collaborative regions that accommodate the collaboration between highly mobile people and between general artefacts (or both). Collaboration between humans requires i.e. support for recording and archiving speech and video fragments from meetings, and for linking these fragments to issues, summaries, keywords, and annotations. It could include tools for sketching support, memory support, joint design and brain storming in virtual groups or groups of people working with on electronic whiteboards or design tables. Examples in the professional environment are given by Norbert Streitz ([17]).

6.5. Security

Security has received particular attention in the last year. The specific political attention since 11 Sep 2001 relates mainly to *civil security* or 'homeland' security. This focuses on intelligence, disaster containment, preserving secure communication, etc.

We have however also seen special attention from politicians and large software companies alike, recognising that security must be a main priority in general software system design and development. Protection of governmental, business and personal systems against hacking and virus attacks becomes more and more important, given the increasing dependence on ITC systems in our society.

The latter includes the security of the *personal info-sphere*, covering the notion of securing personal info-assets and credentials and relates to access based on personal profiles to personal area networks composed of personal devices, including devices implanted in the human body. These devices can all be interconnected and may store and manage individually or jointly considerable amounts of information.

Privacy aspects related to anonymity, pseudonymity, linkability and observability must be considered in the design phase of such networks.

A general issue is the security of *virtual communities,* covering aspects related to establishing and managing trust relations in such communities, concerning social as well as business or even military relations. Within this context there is a need for flexible and configurable security policies that also cover different levels of authentication and authorisation of the actors in transactions whilst safeguarding anonymity requirements for certain categories of actors. Trusted infrastructures are needed to implement these policies. This challenge is getting even harder because of the growing intelligence, functionality and responsiveness being placed in the infrastructure, which itself is increasingly becoming dynamic.

The security of the IT Infrastructure underpins the economy and society of the European Union. Technological developments and the needs of law enforcement provide increased opportunities for surveillance in cyberspace. Better managing and strengthening of our infrastructure would make it more efficient and resilient without the need for unnecessary surveillance. A societal debate that strikes an acceptable balance between surveillance and the rights of the individual is needed.

Given the above we can consider several aspects for research:

([17]) http://www.roomware.de

- *Privacy and secure access* is an essential security concern that should be considered in any R&D activity aiming to sustain and promote the development of large-scale networks and information infrastructures. General Internet and mobile services would be based on personal profiles and personal data (e.g. about health, investments, etc.) and have almost universal location potential. The use of such services will only be accepted if users can trust that the privacy of such data is guaranteed and that location and identification can be switched off when desired. Research aiming at building an open service creation environment (see section 5.4) will necessarily need to give strong attention to privacy protection.

  This will require attention at the level of the architecture, defining protocols and standards, guaranteeing usability and functionality based on the user's choice. It might be in particular advisable to stimulate or demand the use of Open Source software for interoperability and middleware in this field, to ensure complete transparency on the means used.

  A high priority for massive deployment of services (wireline and wireless) is the development of an infrastructure for efficient use of personal profiles, to allow access and personalization of services.

  In such infrastructure we need *privacy preserving schemes*, possibly based on pseudonyms and capable of empowering the user to control anonymity and observability, as well as *authorisation schemes* adapted to different kinds of applications on one side and the need for strong authentication on the other.

- *Risk management and intelligence gathering* are important elements in civil security. This includes intelligent support as described in section 6.1; dependability of distributed systems of embedded systems which should be based on improved software engineering as described in section 5; storage management (see also section 5.3), knowledge discovery techniques and semantic technologies (see section 6.3), and general system control technologies. Other disciplines like social and psychological behaviour, sociology, etc., will be relevant for general improvement of civil safety and its perception. Europe can use its methodological strength but need to catch up with developments in the US.

- *Trustworthy ("trusted") components* should become more easily available to users to support user confidence and security. The further development of composability of software and end-user development tools in distributed and networked environments could give users the possibility to choose (as appropriate) components that they trust for the support of storage of personal information and credentials on the network.

  To give users confidence and trust in their choices of components for their environment, we need evaluation and assessment of security levels and features of components, systems, services, etc. Since the security of a system depends on the interworking and interoperability of different systems and processes, schemes for evaluation and assessment should support the same dynamics (in time and space) and lifecycle as the technologies they are assessing. There is also a need for fundamental research, to improve techniques for assessing and verifying security properties, and to ensure that alternative approaches are available in the event of unexpected successes, for example in breaking factoring-based cryptography or in developing quantum computing.

- *Information infrastructures* are critical for the functioning of society. They are vulnerable because of new types of threats and of complex interdependencies, both of which need to be better understood. The new topics for research in this field (see section 5.3) need to take account of the security issues that are crucial for the future development of information systems and services.

7. SOFTWARE INTENSIVE APPLICATION SYSTEMS

The eventual objective of advancing the technologies described in sections 5 and 6 is to build the software intensive systems which are needed to realise the AmI environment envisaged in the vision laid out by the ISTAG (see section 1 and 2). Such systems need a broad scale of technologies. The IST Programme addresses under the sixth Framework Programme (FP6) a number of priority application areas (e.g. communication, business and work, health, mobility, environment, cultural heritage, e-learning, content development). Software development is in fact important in all other priority research areas of FP6.

EUREKA-ITEA is another European initiative addressing research for the development of software intensive systems. The EUREKA/ITEA office published in 2001 elaborate RTD roadmaps for software intensive systems([18]). These roadmaps provide a rich source for policy development, based on input of major European enterprises and were developed in five application domains: (1) Intelligent home, (2) Cyber enterprise, (3) Mobility (the nomadic end-user), (4) Intermediate services or value-added services, and (5) Complex systems engineering; and four technology clusters:

(1) *Content*: content capture, creation and authoring; content representation and data and content management

(2) *Infrastructure and basic services*: Network transport and protocols, networks and distributed management; resource management; security

(3) *Human system interaction*: dealing with interaction with the end-user

(4) *Engineering*: system engineering, software engineering and engineering process support.

Clearly the scope of the ITEA report, which addresses all 'soft' technologies needed for the development of software intensive systems, is much wider than the subject of this report. It has however played an important role, as appears also from a number of common topics; e.g. focus on architectures and non-functional requirement, composability, mobile software, embedded software, reconfigurability and self-adaptability, formal methods, complexity, etc.

Another roadmapping exercise taken into account is the US report giving a research agenda for networked systems of embedded systems([19]).

Finally, the “Book of Visions 2001”([20]) from the Wireless World Research Forum presenting a vision and research issues related to services in a "Wireless World" has given input to this report.

([18]) Technology Roadmap on Software Intensive Systems — The vision of ITEA (SOFTEC Project), March 2001 http://www.itea-office.org/newsroom/publications/roadmap_only_download.htm

([19]) Embedded, Everywhere — A Research agenda for networked systems of embedded computers: http://books.nap.edu/html/embedded_everywhere/notice.html [04/01/2002].

([20]) http://www.wireless-world-research.org/Bookofvisions/Bov.html

In this section we discuss some specific software intensive application areas, which we consider particularly relevant from the perspective of software technologies. We have chosen these due to the high relevance for application and demonstration of innovative software technologies as described in section 5. These areas are relevant for the proposed roadmaps given in the ITEA report, the US report and the report of the WWRF, but are more specific and aim at relatively short-term advances in the fields without explicitly defining the longer-term goals.

7.1. AmI and software technologies in telecommunications

Telecommunication is at the basis of any implementation of AmI and at the same time it is one of the most software intensive sectors.

There is an important effort in the telecom sector for providing advanced telecommunication services incorporating most of the features required for AmI. This requires improved Network Management (NM) and connection services on 3G networks integrating natural language processing (text and speech communication), graphical capabilities, localisation capabilities and specific application content. Such connection services aim to enhance communication and information presentation to the user, based on factors such as location and direction of view, user situation/context awareness (time of the day, business holidays, etc), user preferences (i.e. preference in terms of content and interests), and terminal and network capabilities. They incorporate aspects such as: new kinds of devices (more powerful, more intelligent, multi-mode, reconfigurable, etc.); new application areas (electronic and mobile business; communities and entertainment; etc.), and the increased mobility of users, devices, and software.

The NM therefore must take into account new aspects such as: numerous service providers, always connected users, automatic service adaptation, context awareness and new IP devices. Dynamic service discovery and service provisioning (for users) in unknown environments and personalised service usage should also be considered.

For that Network Management Systems (NMS) require a common unified conceptual model of the network supporting:

- Heterogeneous hardware devices: user terminals, switching, transmission, storage devices, etc.

- Interconnection of different network models (LAN, WAN, POT, IN, ISDN, Cable, IP, ATM, GSM, GPRS, UMTS, Wi-Fi) and seamless provision of connection services.

- Multi-modal communications: voice, data, graphical information, video, etc.

- Full interoperability and plug-ability.

The effort to produce such a new Network Management model should include the following directions:

(1) **Standardisation of network elements**. This includes interfaces, computational properties and management properties. Network elements should evolve into autonomic entities, which will have awareness of their own state and might take decisions according to their state, such as self-protection, reconfiguration and communication.

(2) **New models for fault management**. This covers fault detection, isolation and correction of improper behaviour of network resources. It should take advantage of the local capabilities for self-monitoring, self-testing and self-diagnosis of network elements incorporating preventive actions that anticipate possible faults. Robust models for distributed fault detection and correction will also be necessary.

(3) **Business model for connection and account management**. New connection management models — set up, maintain and release connections — should include capabilities for managing quality of service, adaptation, negotiation, and personalization according to different customer needs and circumstances. Accounting management should also facilitate the recollection of resource usage information and to apply the adequate charges for that usage.

(4) **Integration of NMS into more complex systems**. One NMS should behave as an autonomic entity able to co-operate with another NMS and perform self-management activities such as reconfiguration, local optimisation, "self-healing" after malfunctioning of parts, self protection and interaction with the environment. Agent technology seems most suitable to deal with these issues. This requirement establishes the need to integrate existing TMN models and standards such as CMIS and CMIP with agent based architectures and communication models such as FIPA, ACL, KQML, KIF and ontology definition formalisms.

In addition, NMS should contain logical and computational models to inter-operate with other computational entities (e.g. other NMS or service management systems). An issue that concerns NMS as well as telecom regulating agencies, is monitoring of quality and pricing of networks and services. For the future heterogeneous but seamlessly integrated networks, with no visibility to users of the providers used, this will require special attention.

Special software for the above will likely need agents, knowledge extraction and model-based intelligent decision support.

7.2. The extended home environment

Realisation of the AmI vision as expressed in Section 2 would need the extended home environment where people will not only be provided with enhanced in-home facilities but will in particular be able to use the same facilities when away, in the most intuitive fashion possible through voice and gestures, while preserving privacy. Essential here is that one has the same personal information and service environment wherever he/she is and whatever device he/she is using, whilst the networking is fully transparent.

Various facilities are envisioned in such context but many others are yet to be devised. The development of such facilities or value-added services are the subject of the next section 7.3.

The current situation is that persons at home or mobile, have various electronic devices of different origin, which are only loosely connected and not interoperable, with services working only on one device and not on the other. The ultimate future is a world consisting not only of a number of stationary interoperable devices in the home or office but includes collaboration with all kind of wearable personal devices such as mobile phones, personal mobile gateways, portable players and personal storage devices, which provides the same personal "extended home environment" wherever one is, or whatever device one uses.

The extended home environment will be based on the network management level providing the connection services as described in 7.1 above. But it will in particular need seamless co-operation among the various electronic devices at home and mobile. Moreover it will require the right end-to-end systems that will in a secure way allow for transparent roaming and ubiquitous availability of services, and for easy provision of services.

The following objectives can be identified:

- A new device/platform architecture that provides computing invisibility, seamless access from various platforms and sufficient processing power and data storage capacity. Improvement of the interfaces making use of speech and vision.

- Managing the users' information and service space (including his profile data, contextual information and the world-wide information base available over the Internet).

- Making services, including information services, available at the right time and place, based on situation sensitive knowledge of the user, taking account of quality of service and security and privacy. All aspects of availability, connectivity, security etc. must be transparent and invisible to the user.

- Middleware for (small) devices and for the infrastructures to effectively enable their interoperability at network level and at the service provision level.

- Tools for assisting the development of the base infrastructures and the applications built upon them.

Meeting the objectives requires enhancements in a number of areas, including:

- *Adaptive operation* with respect to the requested services and available resources to allow for the adaptation of the system behaviour to the (dynamically) changing service delivery parameters and device characteristics.

- *Reconfigurability,* supporting the hosting of a variety of services with their specific needs to execute algorithms in a dedicated manner.

- *Software and middleware development*, supporting the development of robust infrastructures and applications, which should be adaptive and might be dynamically composed out of third-party services and components.

- *Seamless operation of services*, independent of communication channels, device characteristics and service delivery, to allow the user to consume services independent of these physical characteristics.

- *Interoperable operation* of services, delivery channels and end-user terminals in order to allow for horizontal service delivery in an open market and for composite services, based on existing services and service components.

- *Extensibility,* that is the enabling of future proof service delivery and end-user terminal operation as well as the provision for updating and upgrading for enhancement and/or repair.

- *Situation sensitivity*, that is the ability to provide services adaptive to user needs with respect to location, need and importance, incorporating the dependence on the available services, environment, user perspective and device characteristics.

- *Multimodal user interfaces* to bring the user interface closer to the natural way human beings communicate but also to allow the optimal combination of user interface technology for the given situation.

- *Security and trustworthiness* at a level that allows acceptance, but remains easy to use, for the end user, and the service provider.

- *High-performance* computing platform operating, when necessary, on constrained power sources to support the high processing demands of the foreseen applications that are required for the success of consumer ambient intelligence applications.

7.3. Value added services — Platform and provision

In section 7.1 we discussed the telecom network management and connection layer required for the provision of services in an AmI world. We gave attention to the requirements for interoperability at the hardware and communication layers to ensure seamless network management. In section 7.2 we developed this further towards the functional requirements of users in an extended home environment, related to interoperability of device platforms and the availability of a user "extended home environment" and profile to deliver the information and services to him wherever he is or whatever device he is using. An important part of all this work relates to standards and middleware for interoperability at various levels.

Openness and interoperability should in particular be applicable to the layer of value added services or functional services provided to industry, business and consumers during their work or leisure activities. Rapid development, personalization and a long list of non-functional requirements such as adaptability, reliability, security, reusability, etc. should be considered. Research and engineering effort must be focused on these related levels.

7.3.1. Communication service architecture

This concerns the definition of the service architecture for different categories of services in terms of building blocks for communication functionality that appear as computational entities with various levels of granularity and functionality. Examples are user interface sessions, communication sessions, resource adapters, proxies, communication drivers, protocol interpreters, monitoring entities, notification systems, persistence resources, e-mail drivers, etc. Existing paradigms for distributed processing concepts, such as architectural components, architectural frameworks, agents, and autonomic systems might be integrated to provide useful abstractions to engineer new categories of services. It is essential to cover all phases of the service life cycle: provisioning, usage, management and operation.

7.3.2. Components

Composability and technologies for component-based development are crucial for efficiency and time to market and their importance was already mentioned in section 5.2. In particular for the creation of services we need specific attention to semantic descriptions of the structural and functional aspects. While UML is a de facto standard for describing structural characteristics, the behavioural/semantic aspects need more elaboration. Formal techniques, integrated with graphical and textual description, might be useful. Collaboration with standards bodies and related organisations such as OMG will be essential.

The following aspects should be considered for software components in general, but also for services as a component in a system in particular:

(1) Component composition: definition of composition properties and constraints.

(2) Component categorisation: definition of component libraries. An important effort has been made to create specific categories of components such as graphical user interfaces, industrial simulations, business components and so on. However, more sophisticated component libraries are needed, such as natural language dialogue, gesture interpretation, hand-writing interpretation, network resources, management resources, the various categories of agents — reactive, cognitive, hybrid —, agent organisations and some others.

(3) Component use or definition of the component life cycle: definition, localisation, instantiation, implementation, adaptation, composition, execution, testing/debugging, management and deployment.

7.3.3. *Service execution platforms*

Existing and emerging middleware such as J2EE, COM/DCOM, CORBA, .NET and OMA provide a collection of facilities for deployment, localisation, activation/invocation, use, persistence, transaction and security. Several standards address already aspects of interoperability, such as web service description languages (WSDL), Simple Object Access Protocols (SOAP), Dynamic Discovery (UDDI), XML and transactions (BTP). Further work need to be done to let these platforms evolve to incorporate more sophisticated entities such as agents and/or autonomic entities, new communication models between entities such as speech acts, peer to peer, multimodal user interfaces and new management services such as quality control, fault management, dynamic configuration and so on. In the medium to long term the SEP would evolve to behave as an autonomic entity providing the functionality needed to optimise the process of quick installation and deployment of services. This includes simplifying service deployment and supervising the process of service execution to guarantee its optimal functioning.

7.3.4. *Creation environments for value-added service*

Service architecture, service components, and service platforms will, together with development tools, form a creation environment for the development of value added services. It should provide interoperability between services and allow the building of new services by direct use of existing ones, as well as from available software/service components. It will require new functionality in future tools:

- To create and maintain libraries of components and services, usable as components of new services. This includes definition, categorisation, classification, storing and retrieval of components and existing value-added services

- To support the process of COTS and component-based development, helping the engineer in selection, implementation, adaptation, communication, composition, execution, testing, and management

- To validate and test the whole service

- To dynamically update/enhance existing services

- To deal with service management aspects such as: customer profiles, CRM, delegation of management functions, service level agreement (SLA) and dynamic workflow aspects relevant for building services from existing ones

- Management of the relationships with other stakeholders such as application service providers, service brokers, content providers and network operators.

AmI sets up new challenges for new methodologies and technologies for service and application development. Fundamental abstraction defined in section 4.2, based on the characterisation of artefacts (e.g. agents), interactions, environments and organisations, might facilitate the definition of the processes, methods and components.

From an engineering perspective, building organisation-based applications would provide the level of abstraction needed to deal with complex applications, reducing the time to market without diminishing the quality.

7.3.5. Metrics and benchmarks

A final issue to be considered is the need for metrics and benchmarks to assess the progress in both techniques and standards. Benchmarks should allow practical demonstration that improvements have been achieved in methods, techniques and tools in aspects such as productivity, quality, efficiency and cost.

7.3.6. Provision of value-added services; experiments and examples

Europe aims to gain from its strengths in mobile communication and to make its huge investment in 3G profitable. This could be realised by stimulating quick, widespread and profitable value added services delivered via the network infrastructure that allows seamless use of many types of, often mobile, devices as described above.

The Internet experience has demonstrated that providing an open end-to-end communication infrastructure with low entry cost can lead to unprecedented growth, by stimulating large and small entrepreneurs trying their luck in a market which barely existed and where success was based on creativity and not on control.

To achieve the same for value added e-services, a key issue to be examined is the viability of an open technology at the higher level without some control over the underlying platform.

The Open Mobile Alliance (www.openmobilealliance.org) is a coalition of companies pursuing such a platform. It has a strong European representation, as the major mobile terminal manufacturers, network equipment manufacturers, and operators are represented. The platform, which will be independent of the underlying network technology and handset operating system, will provide services for multimedia messaging, presence, and location. Thus, it presents a platform on top of which domain-specific middleware and applications can be built.

Whatever will come out of this effort, it is essential that an open end-to-end infrastructure be obtained with low entry or opportunity costs for building end user services accessible through mobile networks as well as broadband Internet networks.On the short and medium term, mobile phones can play an important role as an already ubiquitous device in such an infrastructure. They are carried everywhere, trusted by their users, have reasonable user interfaces, enable short-range connectivity (Infrared, Bluetooth), and excel in long range connections (GSM, GPRS, UMTS). The network topology makes it easy to implement services on a server, even if the goal is to put them on the phone itself. Mobile telephony is also enhanced by open platforms and architectures, like the Symbian platform and Java. Finally, the introduction of the 3G networks in Europe, where the speeds are an order of magnitude greater than at present, make new applications possible that could not be done with slow connectivity.

The future role of mobile phones in a seamless wireline/wireless broadband network is difficult to predict. It will obviously change in a network — using IPv6 — where users are connected seamlessly with portables, PDA's, mobiles and other devices, to a network that uses DSL, cable, optical fibre, 3G, WiFi, Bluetooth, infrared in a way which is transparent to the user.

To stimulate research and development towards future services and their acceptability, it would be advisable to implement *real-life experiments* with new services and concepts. Presumably, these will fall into a number of areas with similar requirements for connectivity, middleware, and other services. The report the "Book of Visions 2001"([21]) from the Wireless World Research Forum presents a vision and research issues on this topic. Especially the sections on "The Human Perspective of the Wireless World" and "The Service Architectures for the Wireless World" discuss a number of topics related to AmI. A project to create these would speed progress and prevent unnecessary reinvention.

The topics for experiments and the benefits to European citizens of the projects would depend on the application areas. The following are possibilities that could in particular benefit from the strong position of the mobile phone in Europe:

- *Services for the elderly and disabled:* these would integrate the mobile phone with intelligent sensors that monitor the vital signs. The phone would register any anomalous findings with a centralised server that could decide on further actions. There could also be easy-to-use services to facilitate everyday life.

- *Short-range peer-to-peer services:* The proliferation of Bluetooth phones, e-mail clients, cameras, and recording devices and schedules on phones will mean that people will store more personal information in their phones that they want to share with their friends. Moreover, such information requires synchronisation with similar information at other devices (e.g. PC's, photo storage devices and viewers, incl., TV). There could be a middleware platform to allow exchange, synchronisation, viewing or copying of the information. Businessmen in a meeting could see each other's schedule for the next week during the meeting, independent of the device used. Integration with 802.11 should be considered.

- *Personal information storage services:* People do not always want to give out details of their lives, such as where they are, when they turn on their mobile phones, and if they are currently reading their electronic mail. Still, there are useful services that could use this information: it could be nice to get a notification when a friend is nearby; it would be convenient to send a mail to a person who is currently reading e-mails; and it could be reassuring to know when a person who has been sailing a long distance is nearing a shore. The key to these services would be a framework that allows people to choose

([21]) http://www.wireless-world-research.org/BoV1.0/BoV/BoV2001v1.1B.pdf what information they are willing to give out, to whom, and what they expect in exchange. Experiments with services based on profiling of users on the network could give insight in what users would embrace and what not.

Common to these experiments is that they may not be useful services as such, but would allow insight into future requirements and developments, as well as basic building blocks that could be used in a future infrastructure.

A mobile phone or some successor as a "personal mobile gateway" supporting integrated wireless/wireline access networks could be one means by which people access ambient intelligent services. All these services should be aware of the user and adaptive to her needs, situation, and location, and to network and device characteristics.

Services for the elderly could lead to innovations in sensor technology and to new methods to analyse the data gathered.

Short-range peer-to-peer services are new in a dynamic environment. Implementing the platform could require new protocols. Innovative user interface designs are required so that the user stays in control of the applications.

Personal information storage services require a new paradigm for the design of services. Access to information is simply not allowed or denied, but it is allowed exactly when the user gets something in return.

Other examples of services could be thought of, which are of a more general nature:

- *Contributing to healthy food consumption:* as barcode scanners track almost every consumer product purchased anywhere in the world, the smart in-home kitchen barcode scanners monitor the quality of food, and in case of detected production errors, dangerous products may easily be tracked and buyers warned.

- *Easy access to the medical world:* health records are easily accessed by doctors, and specialised hospitals all over the world can be contacted by saying: *"please contact a doctor for these symptoms"*, allowing quick response times for emergency teams. Electronic health services might drastically reduce waiting times and promote efficient use of hospitals by in-home diagnosis.

- *Improved working conditions:* one source of improvement relates to safety, as an intelligent surrounding can detect problems, respond to verbal commands and to emergency situations in much less time than, e.g., having to look up the necessary procedures in a manual or handling it by improvisation.

- *Improved education:* Easy access from home to one of the 100,000 libraries and museums in Europe stimulates the absorption of knowledge and the performance of professionals. The enhancement of knowledge will ultimately contribute to an increased competitiveness of Europe in the world. Ambient intelligent systems will be low-barrier access points for knowledge.

- *Easier interaction between business and consumers:* So far, business-to-business e-commerce has had a great start and continues to grow fast. However, business-to-consumer e-commerce has suffered from the need for people to access a computer, or the still low percentage of households owning a computer. This will change drastically once ambient intelligent homes become reality for everyone. Connecting mobile personal assistants to the smart home systems will contribute to a fast start of mobile e-commerce. Ambient intelligent systems will also encourage the emergence of new businesses.

- *Improved traffic management*: Congestion on the roads is very acute in urban areas and transport corridors, with the consequent negative environmental effects. By enabling telework, the extended home environment contributes to reducing traffic, relieving many currently congested urban roads. In general, traffic can be improved by reducing structural inefficiencies in how people travel. Traffic information systems should be integrated in the in-home environment, where, e.g., intelligent appointment systems can stimulate car-pooling, and route-planners become more easily accessible.

7.4. AmI in business

Today business software consists of a number of more or less isolated systems dealing with a certain subset of every day functions in a corporate user's life (Customer Relationship Management, Human Capital Management, Finance, Supply Chain Management, Product Lifecycle Management ...). If there is any integration, then the integration is either on the very backend side of the business software and relies on a common database scheme or on the front-end side using web-based portals, which provide a single point of access to otherwise disconnected applications. Also we don't do all things with business application software systems. We also use desktop applications (like word processors and spreadsheet calculators), phone, fax, mailing systems, dictaphones and even paper and pencil. All of these things are usually outside of the application system, nevertheless an integral part of our working life. Further, activities in business are not carried out by single persons; they heavily rely on teamwork. The following example applications will show the need for ambient intelligence in business life.

7.4.1. Ambient Intelligent business support

Business managers require regular data on the status of their sales orders, the market forecasts, actions of competitors, the supply stock, resources and capacity of their manufacturing line, etc. They might need intelligent support for the interpretation of the data and on actions that can be taken. Today, such support requires various data sources, reworking by staff into other views and matching with stock, resources and manufacturing data. Although not all of this can be done automatically, a number of data manipulations can be based on standard models and alternative scenarios proposed automatically. Such services for the manager can have a high added value and make use of strong expertise available in Europe in the field of intelligent decision support, system theory and manufacturing.

Simpler services could already be foreseen in support of workers for travel planning. Suppose I want to make a business trip, the travel destination should always be clear from analysing my current activities and working plan (calendar). It is also clear how to handle the travel claims later on, because the customer and the cost centre are directly related. In fact, the actual fresh information really needed to be entered to the system for a trip is surprisingly small. However, today I have to use at least three different systems (travel planning, time planning, cost planning, travel claim, and maybe I also have to negotiate with the travel agency).

Applications need to be aware of the context and situation of a user, which contain semantic information about last activities in a certain timeframe according processes or work flows. But context also means what other relevant things are happening in the workers environment regarding to activities of others, what others are doing in the same overall environment related to the business tasks which are supported by my application system. Taking context into account can make the user interface of business software much easier, because a lot of things are already obviously deducible from my context (roles, activities, contacts, and so on) situation.

Technology research includes ubiquitous user interfaces, device-independence, standardised semantic descriptions of documents and processes, context-aware applications, distributed knowledge databases and diverse decision support techniques.

7.4.2. Ambient mobile office

Working behaviour of employees has changed a lot over the last few years due to technological advances in the field of mobile computing. For instance, people who traditionally worked at a fixed desk at the company's base change working location and environment quite frequently, and might even not need a personal desk anymore. Working places for sales and technical staff are more and more at the customer's site, at airport lounges or in a train compartment. In this context, the term *nomadic user* is often used. Suppose you are visiting a subsidiary of your company for a while. You certainly want to have access to local infrastructure services such as printers, file servers and Internet mail. However, you would like to access these services using your personal device, without running into the hassle of connecting and configuring the device.

An AmI enabled mobile office gives a user access to a local infrastructure through a wireless link without user dependent configuration. Context information about the current situation of the user is analysed to personalise services in a way that, for instance, on printing a document the printer closest to the user is selected. Access to services and devices might take place spontaneously in a way that visitors at a meeting may instantaneously exchange electronic documents among each other.

Technology research focuses on plug&play technologies, context modelling, standardised service interfaces, tracking techniques for location detection, discovery and composition of services.

7.4.3. Ambient learning companion

On the other hand most of the complexity of business software today does not come from the immature implementation by software developers. It rather comes from the complexity of the business process itself. Although Ambient Intelligence can make user interfaces for complex business applications much easier, it is still necessary to understand the processes and learn the required skills. However, Ambient Intelligence also can help the employee. Through its context-aware and anticipatory nature it can help to assist the worker in providing learning material and services as needed with an appropriate level of detail and with respect to the pre-knowledge of the worker. It should also make use of different learning appliances such as ordinary PC, and ubiquitous mobile learning devices such as smart pads, smart whiteboards and enhanced mobile phones.

7.4.4. Ambient Intelligent product lifecycle management

A challenging field is the support of collaborative evolution of bodies of knowledge over large amounts of time and space (in distributed teams), such as knowledge intensive design, review and support processes typical of Product Lifecycle Management or Software Engineering. The combination of ubiquitous computing devices, multimedia input capabilities and wireless networking together with advances in storage systems, multimedia indexing and search engine capabilities can provide support for groups of people working jointly on knowledge intensive tasks for prolonged amounts of time. Ubiquitous computing offers unobtrusive user interfaces for everyday meeting situations, allowing capturing context such as time, place and people as well as interactions. Research topics include privacy issues, multimedia indexing and retrieval, ubiquitous user interfaces and synchronisation for distributed capture and storage.

7.5. Holistic health services

7.5.1. The vision

Imagine a holistic health care where all required data services reaching from prevention over therapy to secondary treatment are integrated into one system. Every time and everywhere you would be able to access personalised and specific data no matter whether you are a doctor or a patient. These provides the basis for a steadily increasing quality-of-life. More and more, these services are based on information processing devices, e.g. for control, diagnostics, and treatment. For an optimal support of the citizens all health care services have to be co-ordinated. They have to guarantee the optimal quality as well as the efficient utilisation of expensive and rare resources. They have to allow for a secure, personalised and task-relevant data access. They have to interact with each other to meet the individual needs of the citizens on a resource-efficient level. Our visions are open evolutionary health systems, that are highly self-organised and self-adaptive. In such systems new devices and services will integrate themselves, offering their functionality to others and sharing relevant data with all others on a secure level. Furthermore, in such systems the complex interaction of diagnosis, treatment, and monitoring will be achieved by distributed automatic self-configuring task planners and schedulers. One example is the collaboration of highly specialised surgeons distributed all over the world during a complicated surgery. Another example is the personalised preparation and online scheduling of all necessary rescue steps during an emergency treatment based on personalised data and interactive planning and scheduling tools.

7.5.2. The current state

An inventory of the current health services shows that in the medical area a lot of devices for diagnosing, controlling and monitoring the human health status exist. Those devices also provide specialised services which are often based on sophisticated information processing. However, powerful standards for data exchange, collaboration and negotiation protocols, or for self-organised task elaboration helping to achieve integrated or holistic services are very rare. Apart from some rudimentary interface and data standards we are often confronted with isolated applications that have to be integrated manually.

7.5.3. The aim

The aim is the development of enabling software technologies that help to realise our vision: the provision of highly qualified and efficient, holistic health services. Therefore, well-defined, open communication protocols and service architectures will be developed. These system architectures will be based on intelligent components, self-configuring software agents, integrating adaptive and evolving algorithms that allow collaboration, self-adaptation, data mining, reasoning, planning and thus self-organisation. For an intelligent interaction with the environment standards for embedding sensors, actors, and multi-media technologies will be defined and realised. Personalised services and data access will be achieved by profiling. Data security will be guaranteed by the use of authentication and encryption. Different data views will be used to focus on relevant information.

One technical realisation containing all these aspects are holistic workflow management and monitoring systems for hospitals where the usefulness and proper interrelation of the developed concepts are provable.

7.5.4. Ambient emergency rescue

The rescue of people after a heavy accident or disaster is a time-critical operation in terms of the need for quick diagnosis, closest available hospital and good traffic conditions. Studies have shown that the duration of a rescue operation substantially determines survival chances and follow-up costs for rehabilitation of a patient.

During an AmI enabled rescue operations, the patient is authenticated by a wireless connected finger-print sensor to get access to his/her basic patient profile from a remote database. Dependent on indicators such as blood-pressure and the health history of the patient, a first diagnosis will be compiled, using automated decision support systems. Electronic logistics support gives information about the next available and suitable hospital, initiates staff assembly and emergency room preparation, and provides an on-the-fly patient check-in.

7.5.5. Ambient patient management

Efforts for health improving activities currently take quite a share from people's salary, at least in industrial countries. Novel business models have recently been defined by health insurance companies to implement cost cutting measures at hospitals. That is, the patient's stay time will basically be reduced by optimal multi-resource planning of space, infrastructure and equipment. In addition, internal processes such as the visit of a doctor will be optimised.

In an AmI enabled hospital, doctors get ad-hoc access to patient data during the visit. This mobile patient file improves efficiency of the visit in terms of quick access to data required and easy initiation of further treatment. For instance, support for localisation and scheduling of equipment helps to improve the efficient use of resources. Preventive diagnostics will be supported in a way that mobile patients are monitored and localised.

For both scenarios, technology research focuses on aspects of security and privacy, forecasting techniques for resource demand, information retrieval and reasoning, simulation and forecasting of health status, adaptive resource scheduling and optimisation, discovery and composition of services, and constraint programming.

Tool integration, component technologies, open frameworks and appropriate standards for key areas such as communication and service composition are considered as enabling technologies.

7.6. E-government and ambient intelligence

7.6.1. Technologies for e-government

The creation of a common European environment for citizens and enterprises demands deep innovation from public administrations and bodies. In particular, there are two kinds of problems that must be addressed in the next few years:

- *E-government services*: The operations of each administration or body should be radically rethought and reengineered in order to take advantage of ICT products and services. Citizens must be able to obtain all the services they need through the Internet, GSM phones, and, in the near future, new generations of devices such as UMTS. This will make it possible to improve the efficiency of public administrations and bodies, and to bring them closer to the real needs of citizens and enterprises.

- *Union-wide e-government services*: The creation of a "real" union of all the member states will require the creation of Union-wide, cross-country e-government applications, able to take advantage of the services offered by each individual country and to add value through their integration and combination. Incrementally, the diffusion of such applications will make it possible to create a single and uniform working and living "ambient" for European citizens and enterprises, thus contributing to a deeper consolidation of the Union.

In order to make this scenario feasible, from the software technology perspective, the Union and its member states have to invest and make progress in several directions:

(1) The development of innovative services exploiting new mobile information and communication technologies made available to citizen and enterprises will demand for advanced middleware layers able to integrate and interoperate distribute applications running on such a variety and number of devices.

(2) The creation of new services will greatly benefit from the availability of application frameworks tailored to e-government problems and issues. Specifically, this will reduce the time and cost needed to develop solutions through standardisation and reuse of solutions and best practices.

(3) The integration of different media and interfaces will require new *development environments* able to simplify the creation of services and to provide a complete support to software developers through the entire software lifecycle.

This kind of initiatives is consistent with the general objectives and goals of the Ambient Intelligence program.

7.6.2. The role of open source

In the light of the analysis given in section 3 with respect to the software industry in Europe, proposing and supporting the idea of new investments in software technology, requires identification of strategies and enabling factors that can make these efforts successful. The main reason for the lack of significant diffusion of European software technology is the weakness of the European software industry and its inability to counterbalance the dominance of American products. As a consequence, European users of software technology are often more inclined to trust and use American tools and products, rather than investing in competing European alternatives.

In the past decade, open source software has emerged as an factor able to change the scenario of the software technology market. Certainly, some of the major claims associated with open source software can be equally applied to proprietary and closed software ([22]). However, it is equally true that open source has a number of positive aspects and original features:

- Open Source is a powerful means to disseminate innovation.
- Open Source is a commercial strategy that can be used to establish a community of users and form an infrastructure for user-supplier networks.
- Open Source is useful to reduce cost and to exploit synergies among users of the same technology.

For these reasons, exploiting the open source approach for strategic competition reasons and as a means to facilitate the diffusion of the results of the Framework Programme, should be stimulated broadly. As argued above it is particularly interesting for e-government applications and services. Actually, the European Union may require that all the e-government software developed through funds provided to public institutions must be open to any other European Institution or body, who would be free to adapt and reuse it for its own purpose. This could be a driving and enabling factor that will facilitate the dissemination of European technology across the Union.

7.7. The AmI car

7.7.1. The vision

The goal of safer transport is given by the EU White Paper "European transport policy for 2010: time to decide" ([23]):

> *"In 2000, road accidents killed over 40 000 people in the European Union and injured more than 1.7 million. ... One person in three will be injured in an accident at some point in their lives. The directly measurable cost of road accidents is of the order € of 5 billion. Indirect costs (including physical and psychological damage suffered by the victims and their families) are three to four times higher. The annual figure is put at € 160 billions, equivalent to 2 % of the EU's GNP([24])."*

and:

> *"The European Union must, over the next 10 years, pursue the ambitious goal of reducing the number of deaths on the road by half; this by way of integrated action taking account of human and technical factors and designed to make the trans-European road network a safer network."*

([22]) A. Fuggetta. Open source software: an evaluation. To appear on Journal of Systems and Software. Draft available at: http://web.cefriel.it/~alfonso/documents/Papers/opensource.pdf

([23]) Commission of the European Communities; Brussels, 12/09/2001; COM(2001) 370.

([24]) Report by Ewa Hedkvist Petersen on the Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions on "Priorities in EU road safety - Progress report and ranking of actions" (COM(2000)125 - C5-0248/2000 - 2000/2136(COS)), adopted by Parliament on 18 January 2001.

Measures with AmI relevance in the White Paper are:

- safe new vehicles with active safety systems including systems for distance control, for collision prevention and for monitoring driver alertness.
- intelligent transport systems.

The "intelligence" of the car has to be improved by dynamic interpretation of the traffic situation through acquisition of vehicle surroundings. Necessary is an extensive use of sensors using different physical effects: short range ultrasonic (e.g. for black spot detection), front obstacle radar, visible camera for lane and front area recognition, navigation as long range sensor. A medium/high class vehicle today already contains more than 60 software controlled electronic units (ECUs). The units perform a large variety of tasks from comfort (e.g. seat position adaptation to different drivers) through engine control (motor management) to safety functions (like Airbags, ABS, and ESP). This will increase dramatically in the future. Today every vehicle manufacturer (OEM) together with its suppliers develops its own integration framework for software interfaces, communication interfaces, and the tool environment with the corresponding rules. The next technology step is to integrate the different hierarchical levels of software from the lowest level, closely related to hardware, actuators and sensors, through less and less hardware but more function related layers to the uppermost level where the overall vehicle control and handling level is situated.

The interaction Road User/Vehicle/Road Infrastructure will play an increasing role in the future. A "Systems View" (combining and integrating currently independent solutions) will replace individual developments in assistance, passive and active safety systems. In combination with this, traffic will be seen as a co-ordinated process, which implies communication between all players: User — Vehicle, Vehicle — Infrastructure and Road Operator, but also Vehicle — Vehicle. It is expected that a multi-sensor-platform in a vehicle can provide information not only to control the vehicle's functions but can also provide information about the traffic situation to be used by other participants (travel speed, road and weather conditions ...). Different communication scenarios are expected: Vehicle — Vehicle communication will use short range ad-hoc networks within narrow communication areas. Vehicle — Road Side — Vehicle communication will use microwave short range communication. Two way communication between cars and centralised traffic control centres will use hybrid networks with cellular data up-link and digital data broadcast down-link. The Internet will enter cars, therefore "Internet on Wheels" and a unique "IP-Address for every Car" today are discussed not only in scientific journals but also in popular newspapers and are demonstrated in concept cars. These concepts are very much favoured by the car manufacturers to build customer-supplier partnerships and to enhance their business platforms through AmI-services (e.g. remote diagnostics, traffic information services like dynamic route guidance, etc.). While on the move drivers and passengers are also interested in general information and even entertainment (Audio, TV, interactive games, etc.).

All these services play an important role for Ambient Intelligence.

7.7.2. *Automotive systems engineering*

The focus in automotive systems engineering will be on mastering the complexity of the vehicle itself. A function oriented design process will replace the current ECU-based design process. This means the use of a standardised Architecture Description Language (ADL) and development of components with clear interfaces as the basis for the ADL.

Variant management will therefore be based on composition methodology, integrating software-components by the vehicle manufacturer which are acquired separately from software components and 'naked'-ECU suppliers. It will use system level behaviour descriptions for the control algorithms fitting the component concepts and automatic code generation of ECU-code out of the components algorithmic descriptions, with software components mapped to ECUs.

Suppliers in automotive user-supplier networks will have to use the middleware common among vehicle manufacturers. Communication between vehicle manufacturers will be customised to the communication medium "vehicle area network" (VAN). Automatic configuration of ECU-middleware and communication code with respect to the distribution of software components to ECUs within a vehicle project will be required. In such user supplier networks Intellectual Property protection for the suppliers is needed during software integration.

Finally, simulation and validation methods (virtual integration, Rate Monotonic Analysis) need to be enhanced, enabling virtual tests of the Vehicle Control System.

Research has to advance with the integration of complex environmental models, i.e. using systems engineering methods which can seamlessly focus between a macroscopic view (hundreds of vehicles in a town or on a motorway) and a microscopic view (the vehicle's behaviour itself). To find the right abstraction levels and appropriate simulation methods with feasible turn-around times from an engineering point of view might be the biggest automotive system engineering research challenge in the next ten years.

7.7.3. *Automotive software architecture*

Research on the automotive software architecture will focus on:

(a) Common standards of interfaces for interoperability of systems (plug & play, integration of customer software, competitor software, customer specific encapsulation of proprietary core competencies)

(b) Structuring of vehicle functions via domain analysis and requirement engineering

(c) Architectural platforms for diagnosis, test, and remote download of software and parameters

(d) Scalability, reuse and approvals for software designs (especially needed for safety applications)

(e) Integration of non-functional requirements (cost, safety, reliability, redundancy, reusability ...) in function oriented architectures (timing, functionality, resource distribution, operating systems)

(f) Independence of functionality from HW/SW realisations (management of platforms and variants by object oriented design and abstraction layers/middleware).

7.7.4. Automotive networking architecture

Also in the field of automotive networking architecture, progress is required to achieve the goals. These relate to event-triggered and time-triggered network systems, low end/low cost networks in certain HW/SW realisations, high data rate networks for infotainment, gateways and firewalls, and communication interface standards, allowing Internet connections, car-to-car communication, ad hoc networking of cars and remote access for diagnosis and software download.

7.8. AmI in industry

From the industrial perspective, a less human- and more system-centred definition of AmI is considered. Typically, distributed systems generate some result and communicate this to a human engineer, who is interactively supervising the behaviour of the system.

Regarding new technologies, industries typically follow a rather conservative approach. That is, take technologies that are well understood and established in other areas and adapt them to industrial needs. For instance, component technologies are started to be applied to the industrial field. The dominating factor for this behaviour is the fact that restrictive system qualities such as real-time, reliability and miniaturisation must be maintained at industrial strength. Pure software solutions also typically take a backseat. Nevertheless, the following two scenarios can be considered as realistic for AmI in industries.

For both scenarios, technology research focuses on embedded software deployment on a large scale, self-configuration of component based embedded systems, description techniques for system properties and reliable eventing and communication, if carried out at a large scale.

7.8.1. Mobile service engineer

We envisage a mobile service engineer in an industrial plant. The engineer wishes to be informed of any problems at the site. AmI gives him the benefit of being able to move around and be at the actual location of a problem. He stays informed by wireless communication, for instance over Bluetooth, to his PDA. Via his easy-to-use PDA he can quickly obtain information on the location where problems occur, simulations of complex situations and intelligent decision support to help him decide on the action to be taken. Presentation of information will be situation-dependent and dedicated to the control situation at hand.

7.8.2. Configuration-free manufacturing lines

If goods and machines were aware of the environment they are in, and also aware of other goods or containers and machines nearby, one could envisage that these goods and machines could start collaborations and configure the manufacturing line without the need for central control. Re-configuration of manufacturing lines is in practice however, a tedious, time-consuming and error-prone task, especially if carried out by human service engineers.

From the software perspective, some portions of the task can already be automated in a sense, that after modification of software parts the system re-configures itself and establishes required system qualities on its own. Hence, the service engineer connects to the system, updates software modules and the system reallocates resources according to its previous configuration. Once the process of self-configuration has stabilised, the result is communicated to the service engineer. Since a stable configuration might not be found, the service engineer might carry out parts of the configuration manually. From a technical point of view, a modular systems architecture, precise description of system qualities, configurable scheduling of resources and standardised interfaces are required.

Future research could work towards more self-configuration, taking account of the production requirements, the production environment and the supplies and resources available. This would greatly enhance productivity and could also increase safety. (For example, if pallets with fireworks — or even the fireworks themselves — could sense what other fireworks are close by, they could raise an alarm whenever too much explosive material is stored too close together or stored in the wrong conditions.)

Research topics include safety and security to make sure that the processes work as expected and cannot be tampered with (“malicious goods”), frameworks for communication and co-ordination, supply chain management models, discovery of goods and their functions and capabilities, wireless communication protocols, context and context-awareness, and intelligent user interfaces for the involved or affected humans.

8. RECOMMENDATIONS AND CONCLUSIONS

In section 3 we discussed the challenges Europe faces in the field of software technologies, embedded systems and distributed systems. We gave an analysis of strengths, weaknesses, opportunities and threats in the field. Moreover, in section 4 we discussed topic fields that are considered of high relevance in the area under discussion. This has been extended in section 6 by discussion of fields which are closely related, considering that many of the software intensive application systems that eventually have to be produced will need close co-operation between a number of technology fields in order to realise the ambition of the AmI environment. Finally we have described in section 7 a number of software intensive application fields that could be considered for priority research in the IST Programme. These applications are in the centre of the AmI vision and could have significant stimulating effects on the development of technologies in the field of software technologies, embedded systems and distributed systems.

The recommendations in this section are based on the discussions in the former sections. The focus is on the area of software technologies, embedded systems and distributed systems, but placed in the context of European industrial priorities and with a view to realising the AmI vision. These topics are recommended whilst being aware that technologies and tools are being developed with the aim to support the software and service production in Europe. These technologies are not goals in themselves. Finally, the work that is already undertaken in EU Member State programmes should also take into account when possible, in order to stimulate co-operation between existing programmes and avoid overlap.

Research and development in software technologies is necessary for Europe to create, maintain and extend its position in software development in general, and its leadership in certain specific areas like business software, embedded software and Internet (mobile) services in particular.

<u>Recommendation 1</u>: **The IST Programme should give substantial support to RTD in software technologies, especially in the sub-domains:**

(1) *Longer term foundational research* (5.1), using academic strengths in particular parts of the field and ensuring a sound basis for the future. The main issues are:

- Foundations of software engineering (fundamental design concepts, specifications, theoretical tools, quantitative methods)
- Abstractions in software technology (independent and distributed artefacts and their interactions)
- Complexity and autonomy in software engineering.

(2) *Productivity and quality in software development* (5.2), which is a pre-requisite for any significant development of systems needed in an AmI environment. The strengths of niche players in the field of tools and environments should be used, as well as the specific expertise in large

secondary IT/software industry (incl. mobile telecom, automotive, consumer electronics, aircraft and process industry). The main research issues are:

- Next-Generation Open Development Environments: providing consistency and traceability across all development phases of the lifecycle, architecture-based development, exploiting composability, use of intelligent and formal tools, open to extension with sector and user dedicated tools. Particular attention must be given to development environments for Embedded software

- Light methodologies (agile methods), adaptive workflow and Open Source development methods to improve the software production process and the quality of the results. Approaches for better involvement of users in systems definition and evolution.

(3) *Middleware technologies* (5.3), providing the distributed software layer abstracting underlying network and system technologies, which is essential for AmI introduction. Main issues are:

- *Standardisation of languages and protocols,* with particular attention to the field of value-added services

- *Distribution, fault tolerance and reflection,* to ensure trustworthy and flexible working in large distributed environments

- *Quality of service*, in particular of the network infrastructure and communication services

- *Integration and interoperability between middleware systems,* proving an open and flexible environment with freedom of choosing the best system for a given situation.

(4) *Information management and database technology* (5.4), necessary to provide the information services required to stimulate massive use of value added services in a seamless broadband based network infrastructure. The main research issues are:

- Downscaling of information infrastructure to the level of PDA's and embedded processors, and up-scaling towards large numbers of federated databases and repositories

- Querying methodologies (proximity based, semantically based, open-ended), data mining and knowledge extraction and decision support techniques

- Evolutionary database management.

A large investment in software technologies is necessary but not sufficient to address the dominant position of US players in large parts of the software market and to create a successful and innovative software industry in Europe. For that to have a chance we need to build on the strong existing industries in Europe that have a clear need for high quality and high productivity in software development in order to maintain their own global competitive position in their market sectors. This concerns in the first place the telecommunication industry (devices, networks and carriers). But more classical industrial sectors in Europe are also under the best performing world wide. E.g. automotive, aircraft, consumer electronics, process industry. These industries make very significant efforts themselves in embedded software and software components, and they use components, COTS and services from suppliers, all to produce their primary products in a competitive way.

A European RTD strategy should therefore aim in particular to:

- engage large IT/Software secondary industry in Europe in an effort to build up, jointly with primary software industry (often SME's) and where needed with academia, strong software user-supplier relations in their sectors
- development of open environments, platforms and frameworks allowing for interoperability and extensions tailored to the specific needs of sectors, and stimulating optimal innovation in development of intelligent tools and services
- ensure sufficient long-term research to guarantee long-term viability and innovation in the software and service sector.

<u>Recommendation 2</u>: Support of RTD actions in the software technologies suggested in Rec. 1 should in particular focus on topics with highest chances to lead to successful user-supplier collaborations with user partners in strong secondary IT/Software sectors and existing and emerging software industry as suppliers, together with technological support of academic research. Effective co-operation between the IST Programme and EUREKA-ITEA is suggested.

It is argued in the above sections that the research mentioned in Rec. 1 aims in particular at the requirements to develop software intensive application systems. Particular software intensive applications have been described in section 7 and most of these also include related technologies as described in section 6. From the viewpoint of European industrial strengths and opportunities, the software intensive systems aiming at telecom, mobile services and added-value services in general can bring great advantages for European competitiveness, are pre-requisite for an AmI environment, and at the same time can boost the development of software technologies in Europe. Hence work in these areas is especially recommended:

<u>Recommendation 3</u>: It is strongly recommended to support significant work in the software technologies suggested in Rec. 1 with direct applications in the domains described in sections 7.1, 7.2 and 7.3:

(1) Telecommunications, with focus on standardisation, network management, middleware and complexity

(2) Extended Home environment, aiming at seamless access, at any time, anywhere and with any device, requiring software architectural research, middleware, resource management, adaptivity and reconfigurability, etc.

(3) **Value-added services, with RTD focussing on service creation environments, incl. service architectures, composability and composition, middleware, metrics and benchmarking.**

These technologies need experimentation and demonstration in real-life to ensure acceptation and usefulness. Specific support to such take-up activities must be foreseen.

A second sector that could give particular benefit to software and system development and at the same time strengthen its own global position is automotive and aircraft industry, or generally vehicles. Automotive and aircraft industry are extremely important for the economy and employment in Europe and have a strong position globally. Hence, the use of generic software technologies and applying and extending them specifically in this sector could have a strong multiplying effect. Although this sector will also be given strong attention from the viewpoint of "Major Societal challenges" in the IST Programme, addressing safety and mobility in particular, the angle of system engineering and embedded software and architectures should be equally addressed.

Recommendation 4: It is recommended to specifically encourage RTD for *System engineering and software architecture in vehicles (7.7)*, addressing architectures and development environments and tools for embedded systems and software in cars, aircraft, etc. This industrial area is of utmost importance to Europe and support could ensure leadership of this industry for the future.

In the FP6 - IST Programme, particularly in the domain of "Applied IST research addressing major societal and economic challenges", a number of priority areas are described including: trust and security, health, mobility, environment, leisure, tourism, cultural heritage, e-business, e-government, e/m commerce, e-learning, complex problem solving in science, engineering, business and for society. Software and service technologies will be needed for progress in these areas.

Recommendation 5: It should be encouraged to set up vertical Integrated projects and Networks of Excellence in application oriented areas as described under the heading "Major Societal Challenges" of the IST Programme. Such actions should show strong co-operation between application domain oriented disciplines and software, service and system technologies and should contain significant RTD components in these core technology fields. Particular examples are AmI in business, Holistic Health services and AmI in industry as given in sections 7.4, 7.5 and 7.8.

Also in the public sector however special advantages could be gained from achievements in software development processes and technologies. This concerns in particular the advantages of exploitation of Open Source software in e-government. The second concerns the attention to be given to systems engineering and software architecture in vehicles.

Recommendation 6: It is recommended to specifically encourage RTD for: *Technologies for e-government (7.6)*, on one side focussing on governmental services and therefore related to Rec. 3 and 5, on the other side making use of

Open Source Software and creating a joint open environment for public services to use to the benefit of the citizens.

The above recommendations are mainly technology specific. We also want to request attention for some general issues, which are sometimes addressed in specific ways in the above recommendations, but which need general highlighting.

The first relates to support of SME's. Many companies in software and services in Europe are SME's. Following recommendation 1, we stressed that an important strategic objective should be to build up user-supplier relations between large IT/Software secondary industry and usually SME primary software industry. Also, following recommendation 2, providing an open service environment and supporting experiments with services would strongly stimulate SME's to emerge or be strengthened for bringing innovative services to the market. It is believed that SME support should in particular aim at such specific actions.

The second point to mention is the stimulation of Open Source software in general. As was argued in 7.6.2, Open Source can be a factor in changing the situation in the software technology market, away from large, almost monopolistic companies, giving chances to competitors and innovative start-ups.

<u>Recommendation 7</u>: **The use of Open Source licensing should be stimulated for software generated in the IST Programme, and indeed in all parts of the sixth Framework Programme. This holds in particular for software/middleware infrastructure and standards, for e-government (see Rec. 6) and in other situations where it could lead to strategic advantages for European industry.**

With respect to Newly Associated Countries, it is felt that the development of a software and service industry might be of particular relevance. The relative low level of investment needed for this industry can be particularly attractive in these countries. Moreover, academic training levels are generally high in disciplines related to software, systems and services. Activities aiming at stimulating spin-offs in this fields from university research could be particularly rewarding.

<u>Recommendation 8</u>: **The IST Programme should stimulate research and development as well as education and training, in particular in NAS countries, aiming at reducing the skills shortage and at direct exploitation in university spin-off companies in the field of software, services and intelligent decision support tools.**

To conclude, it is the strong conviction of the Working Group that there are concrete and realistic opportunities to bring European software industry up to a level where it can be a strong global player in significant parts of the market for software technologies, embedded systems and distributed systems. It needs however a clear choice for prioritisation of this field in European research, at member state level, as well as in FP6 and other European research programmes like EUREKA-ITEA. The above recommendations give guidance to such priorities.

ANNEX — RELATED LINKS

IBM Research. Autonomic Computing — IBM's perspective on the state of IT.
http://www.research.ibm.com/autonomic/overview/

OMA — Open Mobile Alliance
http://www.openmobilealliance.org/

ISTAG — The IST Advisory Group
http://www.cordis.lu/ist/istag.htm

"ISTAG Scenarios for Ambient Intelligence in 2010"
ftp://ftp.cordis.lu/pub/ist/docs/istagscenarios2010.pdf

"An Approach to Preserving Sufficient Correctness in Open Resource Coalitions", by O. Raz and M. Shaw
http://www-2.cs.cmu.edu/afs/cs.cmu.edu/project/vit/www/paper_abstracts/iwssd10-fin.html

"Embedded, Everywhere — A research agenda for networked systems of embedded computers"
http://books.nap.edu/html/embedded_everywhere/notice.html

Workshop on Software Reuse and Agile Approaches, ICSR7
http://www.adaptiveobjectmodel.com/ICSR7/

"Dynamic Object Model and Adaptive Workflow", by D. Manolescu and R. Johnson
http://micro-workflow.com/PDF/domaw.pdf

WSI — Wireless Strategic Initiative
http://www.ist-wsi.org/

WWRF — Wireless World Research Forum
http://www.wireless-world-research.org/

WWRF "Book of visions 2001"
http://www.wireless-world-research.org/BoV1.0/BoV/BoV2001v1.1B.pdf

IST Cluster on Systems beyond 3 G
http://www.cordis.lu/ist/ka4/mobile/beyond3g.htm

"A vision on systems beyond 3G"
ftp://ftp.cordis.lu/pub/ist/docs/ka4/mb_sb3g-vision2001.zip

Roomware
http://www.roomware.de

"Technology Roadmap on Software Intensive Systems — The vision of ITEA"
http://www.itea-office.org/newsroom/publications/roadmap_only_download.htm

"Open source software: an evaluation", by A. Fuggetta. To appear on *Journal of Systems and Software*. Draft available at
http://web.cefriel.it/~alfonso/documents/Papers/opensource.pdf

Philips Research — "Ambient Intelligence : A new user Experience"
http://www.research.philips.com/generalinfo/special/ambintel/sheets/

The IPTS Futures Project Conference. — M. Schuurmans' presentation on AmI
http://futures.jrc.es/FuturesConference/slides/1schuurmansuturesconf_ambintell/sld001.htm

Smart Connections at Philips Design
http://www.design.philips.com/smartconnections/

Eureka project Ambience
http://www.extra.research.philips.com/euprojects/ambience/

The MIT Project Oxygen
http://oxygen.lcs.mit.edu/

"Wireless Village" — The mobile IMPS initiative
http://www.wireless-village.org/

"The disappearing computer" — An IST initiative in FET
http://www.disappearing-computer.net/index.html

"Ambiente — Workspaces of future"
http://www.darmstadt.gmd.de/ambiente/

Ubiquitous computing
http://www.ubiq.com/hypertext/weiser/UbiHome.html

Hitachi — Wearable Internet Appliances
http://www.hitachi.co.jp/Prod/vims/wia/eng/main.html

Information Society Germany — "Innovation and Jobs in the Information Society of the 21st Century"
http://www.iid.de/aktionen/aktionsprogramm/fortschritt/english/a13-fort.pdf

GLOSSARY

.NET	A web services platform from Microsoft. http://www.microsoft.com/net/
3G	Third generation, the next generation of mobile communications which aims to provide enhanced user services and high speed mobile connectivity.
4 Tigers	Hong Kong, South Korea, Singapore and Taiwan
802.11b	A family of specifications from the IEEE for wireless, Ethernet local area networks in 2.4 gigahertz bandwidth space.
ABS	Antilock Braking System
ACL	Agent Communication Language
ADL	Architecture Description Language
AmI	Ambient Intelligence
ATM	Asynchronous Transfer Mode
Bluetooth	A standard for low power, local wireless connectivity. http://www.bluetooth.com
BTP	Business Transaction Protocol An XML based protocol for managing complex business to business transactions over the internet. http://www.oasis-open.org/committees/business-transactions/
CAD	Computer Aided Design
CASE	Computer aided software engineering
CMIP	Common Management Information Protocol A network management protocol.
CMIS	Common Management Information Services A standard for network management information services
COM/DCOM	Component Object Model/Distributed Component Object Model. Local and distributed middleware standards from Microsoft.

CORBA	Common Object Request Broker Architecture A middleware standard from the Object Management Group. http://www.omg.org/
COTS	Commercial off-the-shelf
CRM	Customer Relationship Management
DBMS	Database Management System
DOORS	Dynamic Object-Oriented Requirements System A requirements management tool. http://www.telelogic.com/products/doorsers/doors/index.cfm
DotGNU	A Free Software project to create a platform for webservices that can be written in a variety of different programming languages including Java and C#. http://www.dotgnu.org
DRM	Digital Rights Management
DSL	Digital Subscriber Line
ECMA	European Computer Manufactures Association An international industry association dedicated to the standardization of information and communication systems. http://www.ecma.ch/
ECU	Electronic Control Unit
EITO	European Information Technology Observatory http://www.eito.org/
ERP	Enterprise Resource Planning
ESP	Electronic Stability Program
EUREKA	EUREKA is a pan-European network for market-oriented, industrial R&D. http://www.eureka.be
FIPA	Foundation for Intelligent Physical Agents A non-profit organisation aimed at producing standards for the interoperation of heterogeneous software agents. http://www.fipa.org

FP6	Sixth Framework Programme The European Community research, technological development and demonstration activities programme for the period 2002–2006. http://www.cordis.lu/rtd2002/fp-debate/cec.htm
GNP	Gross National Product
GPRS	General Packet Radio Service A technology allowing faster data transfer over GSM networks.
GRID	GRID computing aims to provide a distributed computing infrastructure enabling coordinated resource sharing between dynamic collections of individuals, organizations and resources.
GSM	Global System for Mobile communications
HW	Hardware
ICT	Information and Communications technology
IP	Internet protocol
IPv6	Internet Protocol version six An updated version of the internet protocol offering larger address space, support for mobile devices and built-in security. http://www.ietf.org/html.charters/ipv6-charter.html
ISDN	International Switched Digital Network A digital telecommunications protocol allowing high speed data transfer over existing copper telephone lines.
IST	Information Society Technologies Programme A single, integrated research programme within the European Union's Fifth RTD Framework Programme, the IST Programme builds on the convergence of information processing, communications and media technologies. http://www.cordis.lu/ist/overview.htm
ISTAG	IST Advisory Group http://www.cordis.lu/ist/istag.htm
IT	Information Technology

ITEA	Information Technology for European Advancement A European programme for advanced pre-competitive research and development in embedded and distributed software. http://www.itea-office.org
J2EE	Java 2, Enterprise Edition http://java.sun.com/j2ee/overview.html
JAIN	A set of Java APIs which enable the rapid development of next generation telecom products and services on the Java platform. http://java.sun.com/products/jain/
JINI	A Java-based connection technology which allows Jini-compatible devices such as printers to connect transparently to a network and to interact. http://wwws.sun.com/software/jini/
JMS	Java Message Service A Java API for enterprise messaging.
KIF	Knowledge Interchange Format A language designed for use in the interchange of knowledge among disparate computer systems. http://logic.stanford.edu/kif/dpans.html
KQML	Knowledge Query and Manipulation Language A language and protocol for exchanging information and knowledge. http://www.cs.umbc.edu/kqml/
LAN	Local Area Network
NM	Network Management
NMS	Network Management System
OEM	Original Equipment Manufacturer
OMA	Open Mobile Alliance http://www.openmobilealliance.org/
OMG	Object Management Group A consortium that produces and maintains computer industry specifications for interoperable enterprise applications. http://www.omg.org

OO	Object-Oriented
OS	Operating System
OSA	Open Services Architecture
OSGi	Open Services Gateway Initiative http://www.osgi.org/
P2P	Peer to Peer
PC	Personal Computer
PDA	Personal Digital Assistant
POTS	Plain Old Telephone Service
QoS	Quality of Service
R&D	Research and Development
RTD	Research, Technological Development and demonstratio
RT-UML	Realtime extensions to UML
SCRUM	A lightweight development process. http://www.controlchaos.com/
SLA	Service Level Agreement
SME	Small and Medium Enterprise
SOAP	Simple Object Access Protocol An XML language for exchanging structured, typed information between peers in a decentralized, distributed environment. http://www.w3.org/2000/xp/Group/
Sun ONE	Sun Open Net Environment Web services architecture and platform from Sun Microsystems. http://wwws.sun.com/software/sunone/index.html
SW	Software
SWOT	Strengths, Weaknesses, Opportunities and Threats
TLC	Telecommunications
TMN	Telecommunications Management Network

UDDI	Universal Description, Discovery and Integration A “meta service” for locating web services by enabling robust queries against rich metadata. http://www.udi.org/
UML	Unified Modelling Language http://www.uml.org/
UMTS	Universal Mobile Telecommunications System A third generation standard for cellular communications.
UPnP	Universal Plug and Play
VAN	Vehicle Area Network
VC	Virtual Communities
VHE	Virtual Home Environment http://www.vhe-middleware.org/vhe_set.html
WAN	Wide Area Network
Wi-Fi	See 802.11b
WSDL	Web Services Description Language An XML languague used to describe web services and how to access them. http://www.w3.org/TR/wsdl
WWRF	Wireless World Research Forum http://www.wireless-world-research.org/
xDSL	Digital Subscriber Line A family of digital telecommunications protocols designed to allow high speed data communication over existing copper telephone lines.
XML	eXstensible Markup Language http://www.w3.org/XML/

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IST Advisory Group — Software technologies, embedded systems and distributed systems: A European strategy towards an Ambient Intelligent environment

Luxembourg: Office for Official Publications of the European Communities

2002 — 77 pp. — 21 x 29.7 cm

ISBN 92-894-3837-1

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