ISTAG in FP6: Working Group 1
IST Research Content

Final Report

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Contents

Executive Summary

WG1: Scope and Methodology

Working Group 1 was set up at an ISTAG plenary meeting on 21 January 2003 to enable ISTAG to carry out an in-depth analysis that would allow it to advise and support the Commission in the definition of the strategic orientations for the *Research Content for IST in Europe*. Three other WGs were established at the same time to examine and report on: "Human resources and infrastructures for IST research", "Exploitation of IST research results" and "Funding mechanisms and partnership for IST research".

Working from March to September 2003, WG1 began its analysis by refining and updating the current "Ambient Intelligence" (AmI) vision and by identifying the key socio-economic challenges and opportunities for AmI in Europe together with those areas where AmI can already be seen to be supporting EU policy objectives. A number of almost mandatory research domains or components were then identified in which significant progress must be made in order to further develop and realise the AmI vision. Here WG1 attempted to move beyond the analysis provided in the ISTAG paper on *Strategic orientations and priorities for IST in FP6* by developing a model where the main structuring differentials between the research domains are:

- a 'systems'/'environment'/'background' view (~ 'the ambient') versus a 'user'/'person'/'foreground' view (~ 'the intelligence')

- a 'components' view versus an 'integration' view

Having identified key research challenges in each of the domains or components, WG1 focused on the extent to which new mechanisms can be found to ensure the successful integration of components and their convergence into AmI systems. Finally, WG1 proposed seven recommendations related to new mechanisms and processes that will help speed this integration process by removing some of the stumbling blocks that are impeding the realisation of the AmI vision.

Chapter 1: Revisiting the Ambient Intelligence Vision

Insofar that it sees AmI as "a condition of an environment that we are in the process of creating", ISTAG does not think it necessary to more tightly define the term Ambient Intelligence, although it may help to explain what is the nature of the 'intelligence' being alluded to in the AmI vision. ISTAG suggests it is important to communicate that AmI remains "an emerging property" and that future scenario building and iterations of the vision will benefit from treating Ami as "an imagined concept" that may be particularly visible at the boundaries of where discrete research disciplines impact.

AmI should not be promoted as a universal panacea for social problems, but it must also be recognized that it represents a new paradigm for how people can work and live together and provides radically new opportunities for both individual fulfillment and social discourse. In Europe we may generally be more sceptical towards the concept of intelligent technology, regarding it as inherently suspect and inferior to human and social intelligence; in order to win public acceptance, it remains extremely important that "AmI should be controllable by ordinary people.

The focus on AmI as a 'people first' vision should continue, but the future development of the vision needs to combine the focus on the citizen and the individual person with more scenarios related to how the vision can be applied at the enterprise level in both large companies and SMEs as well as in public sector and non-profit organizations.

Assessment of the early impact of the AmI vision is difficult to quantify although there are initial indications that the vision has succeeded in bringing forward a number of best practice projects and initiatives and that Europe is already actively engaged in trying to realise the concepts behind AmI. There is evidence that the AmI vision has influenced national research programmes but is

more implicitly than explicitly reflected in national foresight exercises and exchange visions on the future of Information Society Technologies in an Enlarged Europe.

Articulating the dynamic, social aspect of the AmI vision presents serious challenges and will require innovative approaches to scenario building, requirements engineering and prototyping. ISTAG is convinced that the key focus must remain on the potential of AmI to meet the needs of Europe's citizens and workers and that a military or defense agenda (such as that in the U.S.) should not become a key driver for European AmI research.

Further development of the AmI vision in Europe needs to progress beyond a discussion of the user - user interface - AmI system environment towards a more holistic understanding of AmI and how it can be applied within a social context.

Chapter 2: Challenges and Opportunities for AmI in Europe

While they do not represent a universal panacea for the set of complex socio-economic issues confronting the European Union, information and communication technologies have the potential to enhance virtually every aspect of people's lives. As such, AmI is seen as being central to the realisation of the strategic goal set by the Lisbon European Council in March 2000 where Europe is "to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and social cohesion." There is evidence that AmI is already supporting efforts to implement existing policy strategies related to transport, sustainable development, the environment, enterprise and the health/care of an aging population.

AmI is seen as being central to the realisation of the strategic goal set by the Lisbon European Council in March 2000 where Europe is "to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and social cohesion."

The technical realisation of the AmI vision is but part of the challenge. New regulatory frameworks and the social acceptance of AmI may take even longer than the development of the underlying technologies and infrastructures. Realisation of the AmI vision will also require a paradigm shift in how we organise labour and living involving much more flexible approaches to mobility and the greater acceptance of new concepts such as portfolio careers and lifelong learning.

Despite what remains a problematic and uncertain socio-economic landscape, significant opportunities will particularly exist for AmI in relation to:

- Modernising the European social model particularly in terms of: improving civil security; providing new leisure, learning and work opportunities within the networked home; facilitating community building and new social groupings; providing new forms of healthcare and social support; tackling environmental threats; supporting the democratic process and the delivery of public services.

- Improving Europe's economy in terms of: supporting new business process; increasing the opportunities for teleworking in the networked home; enhancing mobility and improving all forms of transport; supporting new approaches to sustainable development.

It is important to recognise that, in many of the areas where AmI has the potential to help solve socio-economic concerns, other factors may also need to be addressed at the same time that next generation ICTs are being offered as a response to demographic changes and the changing behaviours, attitudes and ambitions of Europe's citizens and businesses. In particular, the development of the AmI space will require:

- a heightened awareness of issues related to confidence and trust;

- a recognition that new technology deployments may need to be matched by simultaneous investment in learning and organisational change strategies;

- European industries committed to innovative research and development and entrepreneurial companies that are capable of delivering the AmI vision.

Chapter 3: Research Challenges

There are a number of almost 'mandatory' research domains or components in which significant progress must be made in order to further develop and realise the AmI vision. Key Research challenges for each of the following domains are identified in the report: Micro/Nano-electronics/systems; Smart materials; MEMS technology & sensor technology; Embedded Systems; Ubiquitous Communication; I/O device technology; Adaptive software; Media management & handling; Natural interaction; Computational intelligence; Contextual awareness; Emotional computing

The WG1 analysis presents a model where the main structuring differentials between the domains are:

- a 'systems'/'environment'/'background' view (~ 'the ambient') versus a 'user'/'person'/'foreground' view (~ 'the intelligence')

- a 'components' view versus an 'integration' view

As we move towards the development of an AmI space, the focus in each of the components or research domains will shift in response to:

- New requests for *service and content access and delivery* (reflecting an increasing emphasis on distributed and possibly mobile demands, the need for automatic and dynamic adaptability, the desire for mass customisation etc.)

- An increase in the *scale and complexity of systems and applications* (as infrastructures become more intelligent, applications become more distributed and embodied in real-world environments etc.)

Chapter 4. Integrating research components/domains

While many of the component areas highlighted in chapter 3 have a degree of maturity, others are less well developed and cannot easily build on established or structured research communities. It is essentially a case of pursuing *new directions* in such established fields as communication and network technologies, software technologies, interface and display technologies, embedded systems, microsystems and materials. Identifying priorities and roadmaps may be more difficult within what are still the emerging research domains of 'Emotional computing', 'Contextual awareness' and 'Computational intelligence' where research methodologies and communities are less well developed.

The development of the AmI space will depend not simply on finding solutions to the research challenges in each domain but on the extent to which mechanisms can be found to ensure the successful integration of components and their convergence into AmI systems. In order to directly meet the real needs of individual users and address broader socio-economic concerns, it is critically important that architectures, methods and tools can be developed that are capable of *converging technologies into AmI systems.* New approaches will also need to be elaborated concerning how technologies can be integrated across different usage environments.

Further analysis and discussion is required by ISTAG concerning the integration dimension. In this report it is suggested that it will be helpful to look initially at issues related to integration in terms of the following three 'layers'

- Platform Design
- Software design, engineering and integration
- Experience prototyping

Finally, mechanisms to ensure the successful integration of components and their convergence into AmI systems may also require that we adopt a more 'cultural approach' to socio-technical research and the design of experience.

Chapter 5. Recommendations on New ways for Research and Development

ISTAG makes seven specific recommendations related to new ways for research and development that it believes are key for the successful implementation of the AmI vision.

1. Put holistic and dynamic user requirements at the centre of the development process and create a multidisciplinary European network of Experience and Application Research Centres.

2. Support open standards in AmI projects and encourage their development via. public sector initiatives and projects.

3. Support open distributed software development and code sharing including the certification of components.

4. Encourage research that supports the 'graceful degradation' of software in complex AmI systems.

5. Place sufficient emphasis on work on the boundaries between research disciplines.

6. Increase awareness of the AmI vision among Computer Scientists and researchers in other disciplines.

7. Improve the ability to track participation in and the impact of AmI research.

Chapter 1. Revisiting the Ambient Intelligence Vision

Background

Ambient Intelligence (AmI) stems from the convergence of three key technologies: Ubiquitous Computing, Ubiquitous Communication, and Intelligent User Friendly Interfaces. According to the ISTAG vision statement, when convergence is achieved, humans will be surrounded by intelligent interfaces supported by computing and networking technology that is 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 should be: aware of the specific characteristics of human presence and personalities; adapt to the needs of users; be capable of responding intelligently to spoken or gestured indications of desire; and even result in systems that are capable of engaging in intelligent dialogue. Ambient Intelligence should also be unobtrusive and often invisible and interaction should be relaxing and enjoyable for the citizen, and not involve a steep learning curve.

Following the publication of the ISTAG vision statement in 1999, Ambient Intelligence became broadly embedded in the IST work programme and is one of the key concepts being used to develop the Information Society aspects of Framework Programme 6.

Later reports have helped expand the AmI vision but have not significantly altered it. There has been the important recognition that, to be acceptable, "AmI needs to be driven by humanistic concerns, not technologically determined ones" and should be "controllable by ordinary people"[1]. In the document Strategic orientations and priorities for IST in FP6[2], ISTAG also elaborates the concept of the *AmI Space* which is composed of collaborative (location or social based) sub-spaces, of devices (including sensor and actuator systems), services (including their interfaces) and the connecting networks. The AmI Space is:

- Open to allow evolution and extendibility with autonomously developed components
- Dynamic, to allow constant reconfiguration
- Trustworthy, to handle issues of safety, reliability, security, privacy and usability.

Once again, the overall emphasis is that an AmI system will "know itself", adapt easily to the needs to the individual, actively look for ways to optimize its workings, be able to protect itself and recover from routine malfunctions etc. – all with a view towards making life easier for the individual who is engaged with the system but may not even know that s/he is consciously 'interacting' with it.

Ambient Intelligence - Definition

As indicated above, the term Ambient Intelligence has a fairly recent provenance. It is difficult in much of the general literature on technology futures to see clearly how AmI is distinguished from older concepts such as "pervasive computing" or "ubiquitous computing", the latter being first described more than a decade ago.[3] This is not necessarily problematic, although it may be somewhat confusing for students and young researchers who are looking for more precise definitions of each term.

Insofar that it sees AmI as "a condition of an environment that we are in the process of creating", ISTAG does not think it necessary to more tightly define the term Ambient Intelligence. ISTAG suggests it is still important to communicate that AmI remains "an emerging property" and that future scenario building and iterations of the vision will benefit from treating Ami as "an imagined

[1] *ISTAG Scenarios for Ambient Intelligence in 2010*, IPTS, February 2001

[2] *Report of the IST Advisory Group concerning Strategic orientations and Priorities for IST in FP6*, ISTAG 2000

[3] Weiser, M. 1991. *The Computer for the 21st Century*. Available online at http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html

concept" that may be particularly visible at the boundaries of where discrete research disciplines impact.

At the same time that the concept of AmI can be seen to be 'evolving', ISTAG also believes that we should not underplay the radical social transformations that are likely to result from the implementation of the AmI vision. While AmI should not be promoted as a universal panacea for social problems, it must also be recognized that it represents a new paradigm for how people can work and live together and provides radically new opportunities for both individual fulfillment and social discourse. A careful balancing act is required here in how we further define, describe and promote the AmI vision; it should not be 'oversold' but neither should ISTAG nor the IST research community shrink from highlighting the exciting possibilities that will be offered to individuals who will live in the AmI space.

Ambient Intelligence - Clarification

Clarifying the nature of 'intelligence'

While not seeing the need for a precise definition of AmI, ISTAG suggests that more effort may be needed to explain what is the nature of the 'intelligence' being alluded to in the AmI vision - in particular where this 'intelligence' resides (in the environment, network, device or content) and its relations to human cognition and older concepts of Artificial Intelligence. This may be especially important when considering improved strategies for communicating the AmI vision.

In Europe we may generally be more sceptical towards the concept of intelligent technology, regarding it as inherently suspect and inferior to human and social intelligence. The common perception is that "people communicate with people" rather than with an abstract 'intelligence'. There may possibly even be a reaction against the concept of AmI as something non-human that completely envelops and surrounds people even if it is unobtrusive or completely invisible.

To help obviate this potential problem, we may need to move beyond a 'command and control' view of the user. With ambient environments and systems, it will, in fact, be impossible to design for that way of looking at things. AmI implies that users and systems need to be viewed more as partners, where a system is constantly aware of a user and his/her context. It will then offer alternative options and adapt in anticipation of user needs. With AmI it becomes less of a case of the system saying to a user 'what do you want?' or 'tell me what to do?' Rather, the system having taken note of the user's history and context, is more likely to say 'I think you will need this', or 'would you like me to adapt for this context?' etc. Following this paradigm of an ambient environment, intelligence is provided through interaction, or participation and can be appreciated more as something that is non-threatening, an assistive feature of the system or environment that addresses the real needs and desires of the user.

However, it still may not be possible to wholly convince users that this form of participation is desirable. There may be a very fine line between an'always on' system that is seen as helpful and of assistance and one that is perceived as controlling or personally invasive. In this case, it remains extremely important that "AmI should be controllable by ordinary people – i.e. the 'off-switch' should be within reach."[4]

New Scenarios

While the focus on AmI as a 'people first' vision should continue, ISTAG suggests that the future development of the vision needs to combine the focus on the citizen and the individual person with more scenarios related to how the vision can be applied at the enterprise level in both large companies and SMEs as well as in public sector and non-profit organisations. Value-chain relationships will change significantly in the workplace under the impact of AmI and will affect every aspect of work processes. More effort is required in order make employers, workers and trade organizations more aware of these potential changes, more able to respond to the new

[4] ISTAG Scenarios for Ambient Intelligence 2010

opportunities offered by AmI and more willing to experiment with the new forms of fluid business networks that permit independent organizations to easily come together in order to benefit from a business opportunity.

In a similar manner, the future development of the vision may need to include other types of AmI scenarios for technology and application developers as well as the end user of ICT. Scenarios are particularly needed to demonstrate how future multi- and interdisciplinary teams of developers of information and communication technologies can benefit from developing products and services in the AmI space.

Currently, however, it is already possible to see how AmI can assist researchers in specific domains. In the field of software development, for example, intelligence can be added to the software development life cycle in several ways. For example, intelligence is needed to help developers find and apply suitable architectural and design patterns and aspects; ontologies can help developers and users understand problem domains; and software engineers can use AmI methodologies to reason and make inferences between design and quality measures or management decisions. An AmI space can also help developers base their decisions on the results of empirical studies. Possibly richer software models are needed here as well as metadata of models to allow for sharing of knowledge bases on which to base design decisions.

There is a need for developers to integrate different models in order to describe different software perspectives and different development stages, e.g. from informal (involving text and sketches) to more rigorous, formal and refined. Different components of an aggregated system also need to be viewed together with different aspects of it that implement quality requirements, both functional and non-functional. *Pervasive computing* can help people create and modify such multiperspective models, make them more readily accessible in their environments and, in some cases, can even connect the models to the corresponding phenomena. *Pervasive communication* can also make models accessible to development teams as they go from the context of the problem domain to their various working environments.

Ambient Intelligence - Impact of the Vision and Best Practice

Assessment of the early impact of the AmI vision is difficult to quantify although there are initial indications that the vision has succeeded in bringing forward a number of best practice projects and initiatives and that Europe is already actively engaged in trying to realise the concepts behind AmI. A number of these best practice projects and initiatives are summarized in Appendix I.

The AmI vision was included in the IST Work Programmes from 2000 onwards as a focal point of the programme activities. The trends in the development of the portfolio of projects against the vision and priorities laid out in successive Work Programmes have been analysed systematically in the IST Programme Portfolio Analysis (IPPA) exercise.

The aggregate analysis of the projects from all eight IST Calls particularly showed in the last two years a stronger concentration on the next generation of technologies and applications. IPPA's main conclusions are also recorded in Appendix I. In summary, IPPA observes that the "development of long term RTD strategies in several fields of the programme is in line with the vision of Ambient Intelligence" and that AmI is particularly visible in those areas where Europe has strong and well-organised industrial and research communities. Cited examples of these fields include the microelectronics, wireless, microsystems, transport (mainly automotive) and health care sectors and many of the sectors addressed in the FET areas. IPPA also notes that "emergence of long term visions is still lacking in some critical fields", notably those where Europe has a weak industry or a non-structured research community. Examples given are the areas of software technologies and knowledge engineering.

Further work is required in order to draw some conclusions on non-IST projects, e.g. work on technologies both for the 'foreground' and the 'background', and co-evolution of core/generic technology developments and the building of specific applications, i.e. both on providing building blocks and on integrating them into applications.

ISTAG has also considered the extent to which the AmI vision has influenced national research programmes and how Ami is currently reflected in national foresight exercises and exchange visions on the future of Information Society Technologies in an Enlarged Europe. The first report from the FISTERA (Foresight on Information Society Technologies in the European Research Area)[5] thematic network has proved extremely helpful in this respect. This review of findings on IST from eight selected national foresight exercises indicates that, while national visions are generally in line with the Lisbon Objectives, many foresights focus on fairly generic technologies. The visionary viewpoint in several of the studies is also limited as a result of a focus on more application-oriented that "cutting-edge" ICT. In the main, studies are described as "parochial" in nature, tending to ignore activities in other European countries and, "The European dimension is almost invariably underexposed, even in an area such as IST, where the challenges of playing a global role are usually too awesome for any single country to tackle." At the same time, the FISTERA study recognizes that, "in a more future-oriented vein, ambient computing is addressed in most studies" and the key concepts behind the AmI vision are implicit in many of the foresights, although not in those of accession countries.

Ambient Intelligence - the European Perspective

It is important to recognize that the development of the vision for AmI in Europe takes place within a R&D culture and environment which has a radically different orientation to that within the United States. In particular, U.S. R&D has a much stronger military/security/defense rationale that has been further emphasized as a result of September 11, the increased focus on 'homeland security' and the recent war with Iraq. Defense R&D represents 55% of the total research and development spending of the federal government and the Department of Defense (DoD), with its $61.8 billion research budget, is by far the largest supporter of R&D in the US. ICT, of course, plays a key role in the Pentagon's present R&D strategy and, over the longer-term, military research looks set to pursue major innovations in many of the fields where Europe is looking to develop its AmI vision – smart materials and self-healing structures, MEMS, nanotechnology, ubiquitous communications, miniaturisation and cost reduction etc.

Recent discussions concerning military co-operation between Member States, including proposals for a European defense research agency, have re-launched the debate on the future of common defense – and defense research – in Europe. To what extent this debate will impact on IST R&D is impossible to predict but ISTAG believes that the current AmI vision in Europe, with its greater emphasis on meeting the needs of citizens and workers, should be maintained. In contrast to ubiquitous or pervasive computing, what distinguishes AmI is that it is essentially a 'people first' vision that addresses the key societal needs of European citizens and workers in a knowledge-based society and economy. ISTAG believes that the AmI vision must explicitly recognize that the European social order is different to that in the U.S. For it to be socially acceptable, the European AmI vision needs to continue to "be driven by humanistic concerns, not technologically determined ones"[6] and be seen as a facilitator of individual human interaction and community building.

In Europe the initial realization of the vision first requires intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognizing and adapting to the needs of 'users' in an unobtrusive way. Further development of the AmI vision, however, needs to progress beyond a discussion of the user - user interface - AmI system environment towards a more holistic understanding of AmI and how it can be applied within a social context. In this iteration AmI is seen more as a feature of the dynamic process whereby people live in and navigate between (both physically and virtually) different interconnected social settings (the home, workplace, school, hospital, social care facilities, cultural institutions etc.) Within each of these settings, the person may also assume different and even multiple roles and may have different needs that depend on both the physical context and even the mood of the individual.

[5] First Report on Review and Analysis of National Foresight: Report on Findings on IST from Eight Selected National Foresight Exercises, FISTERA, April 2003, http://fistera.jrc.es/

[6] ISTAG Scenarios for Ambient Intelligence in 2010, February 2001

Articulating this dynamic social aspect of the AmI vision presents serious challenges and will require innovative approaches to scenario building, requirements engineering and prototyping. However, ISTAG is convinced that the key focus must remain on the potential of AmI to meet the needs of Europe's citizens and workers and that a military or defense agenda should not become a key driver for research in this area.

Chapter 2. Challenges and Opportunities for AmI in Europe

The AmI vision starts with the recognition that the European Union is confronted with a complex set of socio-economic issues resulting from globalisation and the challenges of a new knowledge-driven economy. While they do not represent a universal panacea, information and communication technologies have the potential to enhance virtually every aspect of people's lives[7]. As such, AmI is seen as being central to the realisation of the strategic goal set by the Lisbon European Council in March 2000 where Europe is "to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and social cohesion."

The issues involved in reaching this goal should not be underestimated. The technical realisation of the AmI vision is but part of the challenge. New regulatory frameworks and the social acceptance of AmI may take even longer than the development of the underlying technologies and infrastructures (as evidenced by the development of the European industries for nuclear power and genetically modified organisms). Increased competitiveness, for example, will require a paradigm shift in how we organise labour and living involving much more flexible approaches to mobility and the greater acceptance of new concepts such as portfolio careers and lifelong learning. Over the next decade, the AmI vision will also need to be implemented at a time when the European Union is undergoing a number of radical changes. For example, the European Union will:

- almost double its number of citizens; (EU enlargement, first to 25 and then 27 countries, will raise issues related to the scalability and adaptability of solutions, the ability to close the growing productivity gap with the US and the availability of resources to tackle issues such as the "digital divide");
- contend with important social and economic differences between countries, regions and cities
- have a huge 'greying' population with increasing numbers of the very old (80 and over) resulting in higher levels of dependency
- develop into a 'mosaic' society with lifestyles characterised by greater mobility, diversity and change (the opposite of the traditional family that never leaves its birth place);
- show extreme cultural and religious diversity;
- need to organise its society (learning, work and services) to function around the clock (the 24 hours/7 days a week society);
- have a population that wants, on an individual basis, value for money and personalised services.

It is more difficult to predict what the economic landscape will look like in the same time frame. Current indicators, however, point to a worrying productivity gap between the EU and the US that shows no signs of diminishing. The productivity gap (expressed as GDP per hour worked) between the EU and the US is now 9% and the income gap (GDP per capita) somewhere between 25 and 30%. The reasons for this widening gap are complex and may ultimately be structural in nature. In the EU, network services such as telecommunications, financial services, insurance, healthcare and education still suffer from significant regulatory barriers – the costs of non-Europe being illustrated in the productivity gap.

Finally, the AmI vision must be capable of addressing not only what are currently perceived as the key social and economic priorities in an Enlarged Europe, but must also allow for the fact that unpredicted events (for example, terrorist attacks, or global epidemics) may quickly lead to a re-ordering of priorities or the identification of new ones.

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[7] *The New Everyday: Views on Ambient Intelligence, Emile Aarts and Stefano Marzano*, Philips Electronics 2003, http://www.design.philips.com/news_center/publications/index.asp

Despite what remains a problematic and uncertain socio-economic landscape, ISTAG is confident that AmI has a major role to play in helping Europe to become the most competitive and dynamic knowledge-based economy in the world. As outlined below, ISTAG suggests that significant opportunities will particularly exist for AmI in relation to:

- Modernising the European social model particularly in terms of: improving civil security; providing new leisure, learning and work opportunities within the networked home; facilitating community building and new social groupings; providing new forms of healthcare and social support; tackling environmental threats; supporting the democratic process and the delivery of public services.

- Improving Europe's economy in terms of: supporting new business process; increasing the opportunities for teleworking in the networked home; enhancing mobility and improving all forms of transport; supporting new approaches to sustainable development.

Civil security

Security along with good health is a key determinant of people's general well being. Increasingly, however, the European social fabric is threatened by natural disasters as a result of climate change, a surge in the level of terrorist threats, serious urban vandalism and crime and fears of major acts of political and criminal cyber-terrorism. In the last decade, economic losses due mainly to natural disasters (floods, earthquakes, volcanic eruptions, forest fires and landslides) have increased significantly. Against this background of social malfunction and dislocation, risk management is becoming a key social priority. There is also a growing recognition that ICT is increasingly essential for the prevention, assessment, early warning and mitigation of risks and security situations by providing just-in-time information. Terrorist threats to our airports and urban transport systems plus recent viral epidemics on a global scale are also highlighting the need for new mass screening techniques that will increase the security of social environments without disrupting our growing demand for greater physical mobility.

AmI in this area has the potential to make an important contribution in all phases of the risk management cycle including: risk assessment and hazard identification involving remote sensing and in-situ intelligent surveillance together with new probability models into which is automatically fed the history of events and their consequences; immediate response to perceived threats requiring new decision-support systems capable of processing in near real time huge amounts of data; damage assessment mechanisms requiring the integration of very high-resolution data with cadastral data and decision support.

Community building and new social groupings

While numerous studies indicate that the quality of social bonds is a powerful predictor of life satisfaction, people are increasingly living in a 'mosaic society' with lifestyles characterised by greater mobility, diversity and change. Increasingly many people live at considerable distances from family, friends and feel little connection with community organisations and local and national democratic structures. There is a feeling that face-to-face communication, social gatherings and 'neighbourliness' are in decline which has led a number of commentators to warn that our stock of *social capital* – the very fabric of our connections with each other, has plummeted – impoverishing our lives and communities. Simultaneously, however, ICT increasingly provides us with the capability to share information and to communicate more than ever before via e-mail, mobile phones, SMS, video/audio/online conferencing systems, participation in virtual worlds etc. In spite of concern over increasing levels of social disintegration, there is a compelling case that AmI can play a prominent role in ameliorating the negative effects of physically fragmented communities and can reinforce/extend existing social communities, from the family level, through local communities up to nations and cultures.

Situations where AmI might reinforce social networks and connectedness include: web-based applications and community-based knowledge building environments that facilitate the development of a 'collective', 'living' or 'community memory'; multimedia environments that

enable people to share their thoughts and communicate informally from any location; dynamic knowledge exchange systems that provide intelligent references to the people holding this knowledge as well as to more static databases of information; systems to enable co-ordinated interaction between family members including the increasing number of children of divorced parents who live in different homes at different times.

Home in a networked society

Scenarios for the networked home of the future promise new levels of comfort, control and relaxation including greatly enhanced opportunities for new forms of interactive and immersive multimedia and 3D entertainment. However, at the same time that technology starts to provide us with a wider variety of entertainment choices and channels in the home, commentators lament the 'dumbing down' of our cultural experiences. Similarly, while industry is committed to providing innovation that is centred round what consumers want, the vision of home automation, including a context aware domestic environment which constantly monitors and responds to the needs of its occupants, has an inherently Orwellian resonance for many Europeans. In its *Strategic orientations and priorities for IST in FP6*, ISTAG has already highlighted that, in terms of personal living spaces, AmI may particularly need to guard against becoming "over-intrusive" and pointed to the potential for AmI to create a private domestic sanctuary - "a place where one can lean back and be passive." Given the pace of modern life, this potential of AmI to create a more tranquil, secure home environment will remain important.

At the same time, in order to highlight the added value of AmI, it may be equally important to stress the ability of AmI not simply to cocoon but also to empower and enrich the individual within the home and provide additional and more flexible opportunities for work, learning, entertainment and family/social interactions. Already broadband Internet services to the home, online gaming, interactive television and educational web portals aimed at both adults and school pupils are blurring the lines between 'lean back' (passive) and 'lean forward' (active) forms of entertainment, relaxation and personal development. Neologisms such as 'teleworking', 'edutainment' and 'any time any where lifelong learning' are entering the common vocabulary. New opportunities for remote health care and monitoring in the home are also causing us to seriously re-think our notions of personal privacy and causing us to reconsider who we will let 'enter' our homes on a regular basis. In short, AmI can simultaneously help us to create a haven from the pace of modern life and provide the means whereby we can choose to 'reconnect' to society at times that better suit the needs and interests of the individual. Both these aspects may need to be stressed in order to ensure that we exploit AmI to the full in our domestic environments.

Environment

Current European legislation defines precise obligations relating to informing the public in the event of significant pollution hazards. Each citizen has the right to demand national and local authorities to take action to improve air quality and six structural indicators[8] on environmental protection have been developed in response to the June 2001 Gothenburg European Council conclusions: greenhouse gases emissions; energy intensity of the economy; transport (volume and modal split); urban air quality (particles, ozone); municipal waste (collected, land filled and incinerated); share of renewable energy.

In this area AmI offers the potential to move from traditional monitoring tools to more ambitious end-to-end service delivery development involving advanced forms of decision-support and knowledge management for both pollution prevention and management of resources. Environmental planning may also benefit from AmI tools capable of tracking key environmental parameters (air, water, climate) on both a local level and across large geographic or morphologic regions.

[8] http://europa.eu.int/comm/eurostat/Public/datashop/print-product/EN?catalogue=Eurostat&product=1-structur-EN&mode=download%22#Environment

Governance and public services

Apathy towards democratic institutions and processes at a European, national and local level is a growing concern. At the same time, governments are increasingly using ICT to reconnect with voters by treating citizens as customers who are entitled to a high quality of publicly provided services. It is generally accepted that good use of ICT can make public services more efficient and many of the issues related to the re-engineering of public sector service delivery have already been identified (for example, the changing relationship between the front and back office, one-stop shop approaches for dealing with direct enquiries etc.). High public awareness of the potential of E-Public service (EPS) has also been achieved in many countries.

In spite of this, EPS in Europe remains too portal based and is not yet providing services that are personalised or adapted to the individual needs of the citizen. This may explain why EPS today faces the problem of more supply than demand (many web portals available but few are consulted heavily). Serious challenges to the delivery of EPS also exist in the form of issues related to privacy, security and data protection. Citizens often have low expectations of government and demonstrate a lack of trust in government information. Privacy problems may be so great that they will act as a serious brake to extending online services from government agencies, although in other sectors such as eHealth there may be greater perceived benefits from a more open approach to personal data. In ambient environments authentication will particularly be a major problem due to the fact that location based identities will largely disappear or, more accurately, will be linked to the space we are moving in. This also implies a shift from thinking in terms of geographical determined identity (as it is now) to developing virtual identities/residences (linked to digital territory).

Despite these challenges, AmI offers many opportunities in this sector enabling social support systems (including those related to child care, education and care of the elderly or infirm) to be delivered around the clock as befits a 24-hour economy and society. AmI also offers the possibility to deliver EPS and mobile and electronic 'me' government in a mass customised and location independent way so that EPS can become truly citizen, customer and business friendly, anyplace and anywhere. Opportunities also exist for AmI to enhance social mobility related to public services by allowing automatic or intelligent mapping between national regulatory environments – e.g. how or adapt to new social security regulations and legislation when moving to a new country or how to set up a business in other countries.

The potential for AmI to support EPS may, of course, be constrained by the willingness of administrations to make the necessary investment in ICT from the public purse or to increase public sector borrowing to pay for long-term projects. EPS are, by definition, very costly; effective deployment requires systems to be capable of addressing the maximum number of users in an undifferentiated way. Failure of large-scale EPS projects also tends to be both financially and politically damaging and a number of countries have recent examples of initiatives that have not lived up to expectations. If the potential of AmI is to be realised in this area, it is important that cost-effective approaches to system development are elaborated and shared at both a national and European level. With this in mind, ISTAG suggests that code sharing, the use of open source or interfaces and *de facto* standards should be built into the practice of e-governance. Open source approaches could reduce not only the cost of deploying EPS, but could be equally important in terms of minimising the costs of adapting and repairing failures. Successful EPS deployments will also need to pay special attention to issues related to trust and security as one of the most common needs for e-administration will be to verify identity online and to validate the authenticity of documents.

Healthcare and social support

Health is an absolute priority for Europeans, who generally are less materialist than often expected. In their ranking of the main determinants of their quality of life, Europeans put health

before income and place family life as a close third priority.[9] This priority is likely to be maintained, particularly as the EU has to cope with 'accelerated ageing'; over the next 15 years the number of very old (80+) Europeans will increase by 50 per cent. These major demographic changes will particularly require us to re-think how we can provide higher levels of medical care and social support for those elderly persons who choose to maintain their independence by continuing to live in their own homes and who wish to avoid a move to institutional care facilities. (Given the leap in the numbers of the very elderly, increasing the availability of institutional places for those with long-term health and disability problems may not be an economic option for the state or public sector care providers.)

In this area AmI provides many opportunities to support an aging population through: enabling the containment of the overall costs of care; the remote monitoring of activity and physical well being (including smart clothing); adaptive interfaces for people with physical disabilities; and a responsive and proactive environment (rather than a collection of devices) which enables easy communication with professional carers, friends, family and the wider community (see also Community Building above). Several of the AmI applications in this area can also be applied to the care of other vulnerable groups in society; for example, monitoring the location and safety of children both within and outside the home.

Improvement of business processes

There is now a large body of evidence for how Industrial value chains are being affected by the extended use of ICT. Businesses are already working in networks of independent organisations rather than as standalone companies and business survival in a networked economy increasingly requires companies to re-think traditional business models and come together in new partnership hybrids characterised by 'coopetition'. This trend has been observed for some time but is now fully confirmed and is increasing with still stronger interdependencies becoming apparent for companies within upstream and downstream markets. Anticipated benefits reported by firms as a result of increased ICT use include: cost reductions; increased transaction speed and reliability; improved management capabilities; enhanced collaboration capabilities; and better customer relations management. Logistics has already been revolutionised by the introduction of GPS systems and is set for another revolution as intelligent tagging systems feedback information in real time on goods to logistics management centres.

Further opportunities for AmI in this area are considerable particularly with regard to the set-up, operation and dissolution of virtual enterprises and to the fluid configuration of business processes and the seamless inter-operation of underlying information systems. Enhanced interoperability of ICT platforms for commercial collaboration and mechanisms to allow these environments to be easily reconfigured on the fly will allow companies to participate easily in several networks simultaneously without the need to radically alter their company cultures and preferred methods of working. AmI also has the potential to improve the competitiveness of enterprises by enhancing productivity and workflow and allowing SMEs to interact with large repositories of information and companies outside their main area of business.

Through working together in networks, European companies can add high value to existing services and open up new markets by providing new products and services via innovative processes. The successful application of AmI at the enterprise level, therefore, has the potential to narrow the widening productivity gap between Europe and the US and ameliorate some of the effects of the structural and regulatory obstacles faced by European companies. However, more than new technology is required at the enterprise level. Significant development of models and methodologies for collaborative business are also needed. Firms currently reporting positive impacts from the use of ICT have also invested seriously in learning and organisational change strategies (see below, Realising the Potential of AmI). Most importantly, for European companies to be able to exploit the potential of AmI in this area, sufficient emphasis must be given to the development of open standards.

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[9] *The Social situation in the European Union 2001*, European Observatory on the Social Situation, Demography and Family, 2001

Beyond the individual enterprise, the economy as a whole could benefit from AmI. Real-time and intelligent information systems can help optimise the use of natural resources, prevent pollution, and provide better management of the environment. At the same time, however, there is a growing awareness that there may also be risks associated with the increased use of AmI in business and the economy[10]. For example, automating business processes heightens the need for software reliability. The ability to capture and store consumer preferences also potentially exposes the buyer to invasive and manipulative forms of marketing. The perceived opportunities for AmI to enhance business processes, therefore, must not be considered uncritically.

Mobility and transport

European citizens of all ages are increasingly enjoying more time and opportunities for leisure activities. This trend will be accentuated as the number of retired people live longer, enjoy better health and wish to travel both for pleasure and to visit family members who are more likely to live at a distance in the new 'mosaic' society. People will not only require mobility but will also demand full access to ICT services that can support work, safety and leisure while on the move.

Moving people and goods in Europe has been calculated as a business equivalent to 9% of GDP. However, problems of congestion, accidents and environmental pollution persist creating a negative effect on economic performance and new demands created by electronic commerce (e.g. the exponential increase in small parcel deliveries) put existing distribution systems under extreme pressure.

The opportunities for AmI related to mobility and transport are considerable. With AmI all "actors" (people or goods) on the move can be location-aware and communicate with each other. Intelligent objects and networks for logistics can be integrated with intelligent mobile systems for people, creating Virtual Mobile Environments (VMEs). Systems can be developed to support and manage seamless services across networks and terminals for the optimised mobility of goods and people. This will address both the physical fulfilment of e-commerce (through, for example, cargo-logistics) and the seamless services across networks and terminals for nomadic users, limiting the need to travel and optimising mobility. On-board systems will provide services integrated with the vehicle itself, including travel information, payment packages and monitoring of vehicle functions. Other systems will support personalised information access.

AmI also offers many opportunities for improving the safety of the vehicle, its occupants and other road users. On board driver assistance systems can provide the driver with greater vehicle control, enhance human vision (at night and in difficult weather conditions), anticipate other vulnerable road users, monitor the condition of the driver, provide collision warnings, automatically send emergency calls, provide speed and traffic management and parking aids. Beyond this, there exists the possibility of creating an advanced intelligent transport infrastructure incorporating advanced management and control systems with the potential to cope dynamically with demand and improve network efficiency without further investment in physical infrastructure expansion.

Airline travel can also benefit from AmI. The advances in surveillance and communication in air traffic technologies open up the possibility for increased throughput and generally more efficient and reliable air traffic control. The evolution of heterogeneous technological, organizational and regulatory contexts, both of airplanes and air traffic centres, requires special attention as they move towards advanced technological environments. Ambient intelligence can potentially be of assistance in terms of both operations and training.

10 *A social & technological view on Ambient Intelligence in Everyday Life: What bends the trend?*, Yves Punie, A deliverable from the European Media, Technology and Everyday Life Research Network (EMTEL), IPTS June 2003

Sustainability

Three categories of the effects of ICT on environmental sustainability have been identified. Primary effects occur due to the design, production and disposal/recycling of the technology itself (including software), the result being energy consumption and electronic waste. Secondary effects directly result from the application of the technology; there may be a decrease in transport due to people being able to work and communicate more easily from home as a result of using ICT. Finally tertiary or rebound effects may be observed; there are indirect or "unforeseen" effects resulting from the application and use of the technology; for example, having better access to information on exotic destinations and how to get there may encourage people to travel more frequently and further afield. A key challenge in this context is to understand how AmI can have both positive and negative effects on environmental sustainability. For example, even if impact may be clear in simple cases with specific conditions, generalisation from specific cases is often not realistic (e.g. the transport reduction potential of telework). Nevertheless, while compound effects make the assessment of ICT impact on sustainability extremely complex, there are several areas where AmI could make an important difference.

Primary effects from current use of ICT include: the production of more and more devices with shorter life spans leading to increased levels of ICT waste; energy consumption of ICT systems; and energy consumption and air pollution resulting from ICT production, distribution and recycling processes. Opportunities exist here for AmI to reduce the impact of these negative effects by: placing a greater emphasis on design for re-use and dismantling; moving away from dependence on batteries to energy on the fly; and by introducing clean manufacturing due to AmI production processes.

With regard to secondary effects, AmI provides opportunities to both replace physical mobility with virtual mobility (reduces the need to travel to enjoy certain forms of entertainment, shopping, public and other services) and to optimise physical mobility (greater access to timetables, traffic information, navigation systems). Ami also offers the possibility to optimise energy efficiency in homes and buildings and to improve waste management (smart tagging to improve waste sorting and better food chain management to reduce the amount of wasted food).

The extent to which there will be opportunities for AmI to successfully address unpredictable rebound effects is more difficult to assess. Optimising physical mobility results in satisfying latent transport demand (easier transport equals more transport). Better and ubiquitous access to information makes it easier to live/work anywhere, creating more demand for other types of mobility (e.g. for schooling, culture, leisure etc.). Similarly virtual mobility does not necessarily lead to a reduction in demand for physical mobility and actually going places (people seem to have unlimited reserves of time and budgets when it comes to conventional shopping and 'retail therapy'). The history of telematics in transport has shown that these sorts of rebound effects are always overlooked or underestimated and the most challenging aspect in this area is designing AmI so that it can deal with the unpredictability of these sorts of effects.

Realising the Potential of AmI

It is important to recognise that, in many of the above areas where AmI has the potential to help solve socio-economic concerns, other factors may also need to be addressed at the same time that next generation ICTs are being offered as a response to demographic changes and the changing behaviours, attitudes and ambitions of Europe's citizens and businesses.

Confidence & Trust

The development of the AmI space will require a heightened awareness of issues related to confidence and trust in several of the above areas. From a legal point of view, it might be argued that, since domestic networks are part of the home, they should be treated as a private space. This is challenged however by the trend towards distributed computing or grid based systems, and therefore an extension to this concept is required. With future domestic technologies like health at home or the growing online management of utilities and facilities (electricity, gas, water,

etc.), the management of risks and of the security of this domestic infrastructure will increasingly become critical for the citizen.

As our lives, homes, cars, neighbourhoods, cities and other environments become increasingly digitised and connected, more and more personal information will be gathered, stored and possibly disclosed to third party sources, services, institutions and/or people. This concerns not only basic personal identification data such as age, sex and location but also information and content such as events information (past, current and future), working documents, family albums (pictures, video, chat) and even medical and financial records. Within the AmI space, the monitoring capabilities of new technologies can be massively extended beyond the current credit-card records, calling logs, and news postings. Some argue it might even mean the end of privacy since it will be very difficult for people to find a place where they can hide themselves, where they will have the right to be left alone. The anticipated benefits of Ambient Intelligence may be numerous but, given that AmI enabling technologies are also facilitating monitoring, surveillance, data searches and mining, AmI space deployment is likely to be of great concern to citizens, civil liberties groups, governments and industry.

Addressing the balance between privacy and security will be a core challenge for the future, related to the fundamental but complex interrelationship between what constitutes the private and the public space of the citizen. A way to tackle this issue may be to define, develop and establish the concept of "Virtual Residence[11]".

Making progress on issues related to confidence and trust, however, may be difficult as hacking, id theft, security breaches, privacy invasive measures, and unsolicited surveillance are considered as offences and even crimes against the citizen and tend to attract media attention. They all contribute to define the dark or unacceptable scenarios of the AmI space. Because risks can only be managed well (or at least accepted) if they are clearly identified, it is of prime importance to build scenarios in order to create, as the European Commission underlined in its communication[12], a safer Information Society.

For this to happen unobtrusive, robust support mechanisms need to be implemented in the background. An open systems development approach (leading to world wide common standards and highly interoperable, interconnected and interdependent systems) is required to create such a trusted AmI space. People will demand systems that provide them with a high level of perceived trust as the security of the underlying infrastructure will be expected to protect the individual from various types of intrusion while collaborating with law enforcement requirements and maintaining dynamically managed private (family and friends) and wider community interaction. On-line trust can be defined [13] to include three perceived factors, that of credibility, ease of use and risk. One factor of credibility is predictability. If users obtain good consistent feedback from the system and experience few errors they will perceive the system as being predictable. The third factor contributing to trust is risk. A good sense of control will lead to less risk, where risk is identified as any situation that can lead to a failure. Reputation systems may also lessen the perceived risk for the user. As with any other products, failure histories can affect the users' perception of trust.

It should be emphasised that, in addition to certifications or seals of approvals about the software functionalities or technologies, like security or reputation systems, software, such as observed failure rates, performance and usability can affect users' perceived trust in the system.

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[11] Beslay, Punie, *The concept of virtual residence*, IPTS Report special Issue*, The future of identity and privacy*, Vol. 67, Sept 2002, http://www.jrc.es/pages/iptsreport/vol67/english/

[12] *Creating a Safer Information Society by Improving the Security of Information Infrastructures and Combating Computer-related Crime*. January 2001 http://europa.eu.int/ISPO/eif/InternetPoliciesSite/Crime/CrimeCommEN.html

[13] Corritore, Cynthia L. and Beverly Kracher, Susan Wiedenbeck, *On-line trust: concepts, evolving themes, a model*, International Journal of Human-Computer Studies 58 (2003) 737-758

Moreover, in the physical world, domicile and residence are carefully developed and recognised concepts in terms of privacy and security protection in its broadest sense, i.e. legal, social, economic and technological. In contrast with the real world, there are few social and legal indicators of what constitutes a (protected) private space or (open) public space in the virtual world. A comparable level of sophistication is needed in the future for people to feel at home within their smart homes (with their online activities) and facilitate the personalisation of their everyday environment in order to enhance their mobility. The concept of virtual residence may be useful here to help indicate privacy borders.

Specific actions that might help address some of the considerable challenges related to confidence and security include:

- development of unobtrusive indicators which will reflect the citizen's digital territory socially and legally defined in the Information Society
- business models facilitating the adoption of Identity Management Systems (IMS) enabling e-administration interaction with the citizen and the business sectors
- mechanisms that enhance and guarantee the dependability of the critical infrastructures for domestic environments
- development of tools for the citizen in order for him/her to protect (actively) his/her defined virtual residence (intrusion detection systems, etc.)
- development of a database on future threats
- adoption of open standards for IMS in Europe

Organisational Change

It is now widely accepted that organisational change is a key factor in determining whether investment in ICT leads to sustained productivity growth. Anticipated productivity gains may simply not materialise if the technology is superimposed on old organisational infrastructures and business practices that were not developed for trading in an electronic networked economy. Widespread deployment of AmI for E-public service may also depend on finding ways to address the often strong resistance to changing organisational processes and work practices within government departments. In the health and social care area, efficient development of remote monitoring and telecare may be jeopardised if these are simply viewed as a labour saving tools rather than as an additional way of delivering care and support services. Whether people respond positively to the opportunities presented by AmI in a variety of areas may depend heavily on the extent to which AmI complements rather than replaces existing methods of work and social discourse and the extent to which it requires fundamental changes to organisational structures.

Learning processes have also been identified as key differentiating factors in determining the speed and direction of ICT diffusion and whether it results in positive economic impacts. Research indicates that learning is a key factor in ICT demand and investment in learning can enable both public and private sector organisations to assimilate ICT more rapidly. A shortfall in the skills and competency base for applying AmI may well slow the diffusion process and reduce the economic impact of the investment. In short, the opportunities highlighted for AmI may only be realised if the commitment to new technology deployments are matched by simultaneous investment in learning and organisational change strategies.

Industrial support

At an even more fundamental level, the ability of AmI to help solve the above socio-economic concerns will only happen if Europe has industries committed to innovative research and development and entrepreneurial companies that are capable of delivering the AmI vision. The ISTAG SWOT analyses in *Strategic Orientations and priorities for IST in FP6* has already highlighted in some detail industries where the European competitive position is currently strong and other sectors where new mechanisms and initiatives are needed in order to exploit European technological capabilities which cannot yet be counted a strength. It is not necessary to repeat the analysis again in this report. However, regular monitoring by ISTAG of the potential of

European industries to deliver the AmI vision is something that will be necessary as new socio-economic challenges appear and existing priorities are reassessed.

AmI in support of EU policy objectives

It is important to recognise that AmI not only has the *potential* to help address and solve socio-economic concerns over the longer term but that AmI technologies and environments can already support efforts to implement existing policy strategies, objectives and targets. Some initial areas where AmI can impact on existing policy strategies and objectives are outlined below.

Transport

The White Paper, European Transport Policy for 2010: Time to Decide, places users' needs at the heart of the European transport strategy and recognises that "now is the time for less concrete and more intelligence in the transport system." ISTAG suggests that AmI can particularly make a major contribution towards providing: more efficient infrastructure management involving new positioning and navigation systems; improvements in traffic management and control including a reduction in congestion; and innovative mechanisms for managing the globalisation of transport. It has also been estimated that only 6 % of road accidents appear to be unavoidable and beyond the reach of improved technology. AmI can play a key role in ensuring that the transport White Paper achieves its ambitious goal of halving the number of road deaths by 2010, a target that is also supported by the 'accident-free driving' initiative of the European Automotive Industry.

Sustainable Development

The European Union's strategy for sustainable development[14] recognises that, in the long term, economic growth, social cohesion and environmental protection must go hand in hand. Sustainable development offers the European Union a positive long-term vision of a society that is more prosperous and more just, and which exploits technology while at the same time promises a cleaner, safer, healthier environment - a society which delivers a better quality of life for all citizens. ISTAG's 'people first' vision for AmI takes a similarly holistic view of how technology can be applied within a socio-economic context and suggests that AmI can be instrumental in the development of new technologies that: use fewer natural resources; optimize energy efficiency; help reduce pollution or risks to health and safety; and are cheaper than their predecessors.

Environment

The EU's Sixth Environment Action Programme[15] points to major achievements in improving air and water quality but recognizes that we still face major problems and in some cases the environment is actually getting worse. As indicated above, AmI has the potential to help achieve more environmentally friendly forms of production and consumption and support the sustainable use of natural resources and waste. AmI can also assist the environment and health agenda in its fundamental overhaul of the Community's system for managing risks from chemicals by improving the monitoring of environmental indicators and providing more intelligent decision-support tools for pollution prevention and the management of both natural and man-made disasters.

Enterprise

ISTAG suggests that AmI will be able to support the Commission's enterprise policy in a knowledge-based economy[16] and the multi-annual programme for enterprise and entrepreneurship (2001-2005). New information and communication technologies are already

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[14] *A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development* (Commission's proposal to the Gothenburg European Council) Brussels, 15.5.200COM(2001) 264

[15] *Environment 2010: Our future, Our Choice*. COM (2001) 31 final. January 2001

[16] *Enterprise policy in a knowledge-based economy*. Commission Communication COM (2000) 256 final/2, May 2000

seen as key to the achievement of enterprise policy goals particularly in terms of promoting innovation among European SMEs via the use of the Internet and electronic commerce. AmI can make an important contribution here in terms of the development of virtual enterprises and new forms of fluid business networks that permit independent organizations to easily come together in order to benefit from a business opportunity. AmI also has the potential to support enterprise policy by helping entrepreneurs to cope with bureaucracy and administrative formalities; for example, via automatic mapping between national regulations on how to establish a business in different countries.

Health and care of an aging population

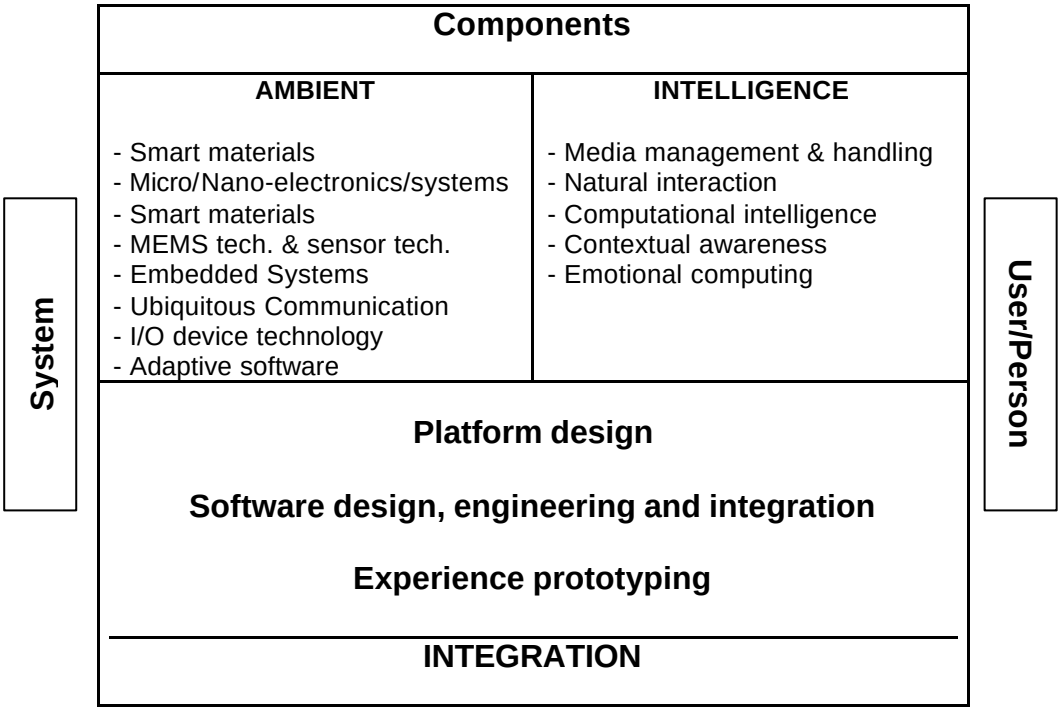
Recent studies related to the future of health care and care for the elderly[17] acknowledge that technical progress will result in new products, treatments and services that may lead to productivity gains but that any increase in the effectiveness of treatments or support could at the same time lead to greater intensity of treatment and thus higher overall spending. Demand for better heath and social care is unlikely ever to be satiated. Overall, it is also suggested that, if the basic trends towards a steadily ageing population are confirmed, the "spontaneous" effects of demographic ageing could increase the proportion of public expenditure on health and long-term care from 1.7 to almost 4 GDP points. The funding issues involved here are complex but the conclusion seems unavoidable that "The elderly require long-term care, which presents a special challenge both in terms of financing and as regards making the necessary adjustments on the supply side, particularly as regards institutionalisation of long-term care." Without wishing to overstate the potential of ICT in this sector, ISTAG suggests that the ability of AmI to monitor and support the well being of the chronically ill and elderly in their own homes may have an important impact on the economic viability of future health and social care policies.

[17] *The future of health care and care for the elderly: guaranteeing accessibility, quality and financial viability*. COM (2001) 723 final, December 2001

Chapter 3. Research Challenges

There are a number of almost 'mandatory' research domains or components in which significant progress must be made in order to further develop and realise the AmI vision. The analysis presented here attempts to move beyond that provided in the ISTAG paper on *Strategic orientations and priorities for IST in FP6*. In the following model the main structuring differentials between the domains are:

- a 'systems'/'environment'/'background' view (~ 'the ambient') versus a 'user'/'person'/'foreground' view (~ 'the intelligence')
- a 'components' view versus an 'integration' view



As we move towards the development of an AmI space, the focus in each of the components or research domains will shift in response to:

- New requests for *service and content access and delivery* (reflecting an increasing emphasis on distributed and possibly mobile demands, the need for automatic and dynamic adaptability, the desire for mass customisation etc.)
- An increase in the *scale and complexity of systems and applications* (as infrastructures become more intelligent, applications become more distributed and embodied in real-world environments etc.)

Micro/Nano-electronics/systems

It is anticipated that in the micro-electronic industry the minimal critical dimensions used to produce ICs continuously will extend below 50 nm before 2010 and will continue to fall for perhaps a further decade. This will bring microelectronics rapidly into the nano domain, providing the capability to explore quantum effects for switching, processing, storage or to execute other functions. At the same time, molecular technology to grow larger molecules and nanotechnology to manipulate molecules at atomic level is maturing. As a result a new field of Micro/Nano-electronics/systems is evolving which combines different engineering and scientific disciplines including elements of biology, chemistry, physics and traditional engineering practices. Scenarios

and roadmaps are being developed in which microsystems are expected to make extensive use of new improved material properties, new functional materials and new device properties developed by nano-technology research.

Research challenges in this area include:

1. Bringing nano-technology and new functional materials inside micro and macro applications and addressing the nano to macro interface.
2. Using nano-devices and micro and nano-systems for the integration of sensing, actuating, processing in very large systems or environments (including related system approach) not restricted to one or the other material, environment or purpose.
3. Develop interconnect and integration technologies needed to establish the nano to macro interface and to have the 'nano' interacting with their ambient.

Smart materials

Smart materials modify their behaviour under specific circumstances, changing their shape, stiffness, position, natural frequency or other mechanical characteristics in response to changes in temperature or electro-magnetic fields. Such materials are already in use in the aerospace and engineering industries. There are several different types of these materials. Shape-memory alloys, for instance, are metals which, at a certain temperature, will return to their original shape after having been stressed. Piezo-electric materials expand and contract in response to an applied voltage, while magneto-strictive materials expand in particular magnetic fields. There are also liquids which increase in viscosity in response to a stimulus. These materials display a kind of intelligence which makes them seem 'alive'. Lighting will also play an important role in AmI in terms of providing a 'personalised' ambience. In addition, we can envisage textiles that transform their structure, counter allergens, shield against electromagnetic smog, apply a range of medical therapies, release fragrance, moisturise, and contain electronic networks and miniature electronic processors and communications technology.

Research challenges in this area include:

1. Develop new materials that can emit light efficiently; i.e., electronic wallpaper or large synthetic foils that can emit light.
2. Develop new materials that can be used for touch and tactile movement.
3. Develop synthetic materials that enable mass storage and processing of digital data, and that can be integrated into fabrics or carpets.

MEMS and sensor technology

Advances in silicon-based technology are making it possible to develop extremely inexpensive, highly capable, low-power sensors. Micro-Electro-Mechanical Systems (MEMS) involves the integration of mechanical elements, sensors, actuators and electronics on a common silicon substrate through microfabrication technology. MEMS has the potential to revolutionise every product category by the realisation of complete systems-on-a-chip allowing the development of smart products which augment the computational ability of microelectronics with the perception and control capabilities of microsensors and microactuators. MEMS are already used to detect the degree of deceleration that a car undergoes during a collision to make the airbag inflate at the right moment. MEMS also make it possible to sense smell. New advanced sensors for sound, visible light, infrared, and extremely low light, combined with ever faster and cheaper digital signal processors, will make large-scale system sensing practical and commonplace. Work is also currently underway to develop intelligent sensors for military purposes; sensors that can be dropped from planes and that automatically establish connections among themselves in order to monitor enemy and battleground activity.

Research challenges in this area include:

1. Develop ultra low power (mechanical) effectuators, i.e., micro motors, valves, and widgets.
2. Develop new sensor devices or bridging between the physical world and the cyber world, i.e., touch, vision, smell, etc.
3. Develop technology to integrate micro systems and microelectronics.

Embedded systems

Embedded systems, where operating systems and micro-processing are integral to a range of non-computer devices, are essential to the realisation of the AmI vision. These special purpose computing systems, either fixed in capability or programmable, can sense their environments directly and respond appropriately and often have the ability to operate in an environment where there may be limited power, limited communications bandwidth and limited memory. Embedded systems may be designed for a particular kind of application device or be incorporated in industrial machinery, cars, medical equipment, cameras, household appliances, airplanes, vending machines, buildings etc. Often embedded systems will be required to provide a real-time response and they must be able to accommodate changes in the overall system configuration or in their operating environment.

Research challenges in this area include:

1. Develop re-configurable real-time embedded computing platforms.
2. Develop technology for remote diagnostics and repair of embedded systems.
3. Develop methods and techniques for security and trustworthiness of embedded systems.

Ubiquitous communication

In the AmI vision ubiquitous communication will let objects communicate in real time with one another and with users through a wireless network. The various requirements of wireless technology that result from the AmI vision range from high data rate links for bulk data transfer and video streaming, through to low bit rate links for automation, control and simple data exchange. With ubiquitous communication friends, families, work colleagues or business partners will be able to take part in new forms of mobile communities technically enabled by peer-to-peer ('mobile ad hoc') networks between personal mobile devices (including wearable electronics). The vision for ubiquitous communication also extends to the development of versatile and transparent in-home networks based on a 'pull' model for the delivery of audio-visual services.

Research challenges in this area include:

1. Develop ubiquitous pico-radio networks for active and passive tagging.
2. Make virtually any physical object Internet accessible.
3. Realize ubiquitous broadband access to content and data.

I/O device technology

The AmI vision anticipates not only the 'disappearing computer' but also the transformation of the current generation of input and output technologies that we use to interact with computing platforms and devices. Touchpads and haptic technology must be more easily accessible. Displays in AmI spaces will need to be large, small, flat, thin, flexible and wearable and be able to sense and communicate with the available lighting system to create optimum viewing conditions on the display in question. Microphones and cameras will need to evolve so that audio and visual information processing enables systems to recognise the user's appearance, gestures and even moods based on their tone of voice or the person's facial expression. By being able to 'see' and 'hear', the AmI systems can not only facilitate interaction with the user but move to new levels where such interaction automatically adapts to the user's tastes and preferences. If technology has disappeared into the surrounding environment and is no longer tangibly visible, our interaction with it will increasingly have to be hands-free. In these cases the use of natural language, especially speech control will be a key desired AmI solution. The intelligent environment will also be listening continuously and will need to distinguish between remarks that are part of a normal conversation and remarks specifically addressed to the system that require a response.

Research challenges in this area include:

1. Develop ubiquitous hands-free speech control.
2. Develop ubiquitous touch pads and whiteboards.
3. Turn virtually any surface into a display.

Adaptive software

Adaptive software uses information from the environment to improve its behaviour over time. It is particularly important in complex AmI environments where there will be an increasing need to develop systems that are self-managing or that have self-adjusting capabilities based on learning algorithms that can detect when a computer system or network infrastructure is healthy or in decline. The algorithms can automatically sense when resources need to be reallocated and can make the necessary adjustments without human interventions. Software that incorporates self-teaching algorithms can also automate much of the system configuration work that now has to be done manually. The ultimate goal is to manage all elements of an AmI environment from operating systems and networks to applications and middleware.

Research challenges in this area include:

1. Develop open source software platforms that support self-configuration and adaptation.
2. Develop customisable component software.
3. Develop intuitive programming environments.

Media management and handling

Multimedia and the Internet have provided us with vastly improved ways of interacting with data, content and media and highlighted the need for our educational systems to address digital and media literacy as well as spoken and written language development. AmI will also offer new possibilities for managing data and content using all available media types so that any unstructured or uninterpreted information in digital form can be accessed anywhere, anytime on any device and can be presented to the individual based on predictive models of user behaviour. Intelligent media management and handling will require progress to be made into associative information retrieval where user feedback and contextual information is taken into account. For this to happen significant progress will need to be made in the area of metadata representation and handling including the semi-automatic metadata extraction (e.g. feature extraction). Developments related to the concept of the Semantic Web will also be important for the automation, integration and re-use of data across various applications.

Research Challenges in this area include:

1. Develop media presentation languages that support “produce once” and “present anywhere”.
2. Develop methods and tools to analyse content and enrich it with metadata.
3. Develop intentional media browsing tools exploiting the Semantic Web.

Natural interaction

Natural interaction typically refers to advanced modalities such as natural speech- and gesture recognition, as well as speech synthesis, which will allow a much more intuitive and human-like communication with digital devices and platforms than is currently possible. Current paradigms and metaphors for how we interact with technology are largely determined by the limitations of existing man-machine interfaces where the technology is essentially seen as passive and unresponsive until it is animated or explicitly challenged by a living entity. AmI will change this perspective as multimodal interfaces become commonplace and more capable of coping with the imprecise and sometimes ambiguous modes of speaking, writing, gesturing and sketching that are a normal feature of much human discourse. More natural forms of interaction will also be possible as AmI systems start to ‘recognise’ and ‘anticipate’ the needs of the user and adapt accordingly. As we move beyond a ‘command and control’ view of the user with AmI we may even start to envisage scenarios where users are regarded more as ‘participating’ in technology-enabled environments rather than interacting with them (see also Chapter 1).

Research challenges in this area include:

1. Combine speech, vision, gesture, and facial expression into a truly integrated multimodal interaction concept.

2. Develop novel interaction concepts that allow human beings to interact with virtual worlds through physical objects.
3. Develop highly intuitive interfaces that allow human beings to browse through large databases.

Computational intelligence

Electronic systems may be said to be intelligent when they exhibit three characteristics: the ability to solve problems, the ability to predict and adapt, and the ability to reason. Computational intelligence is the scientific and technological pursuit of designing and analysing algorithms that, when executed, give electronic systems such intelligent behaviour. There are a number of approaches that seek to address one of these three characteristics. A variety of well-known methods are used to tackle the question of problem solving; machine learning techniques are applied to produce prediction and adaptation; and expert systems are used to generate the ability to reason.

Research challenges in this area include:

1. Develop conversational search and dialogue systems.
2. Develop behavioural systems that can adapt to human behaviour.
3. Develop computational methods that can help in carrying out complex tasks in search and planning.

Contextual awareness

AmI requires context-aware devices and systems that are sensitive and aware of what the user is likely to want to achieve in any given situation, and then apply rules (given or learned) to make a sensible decision about what to do. This may involve a consideration of both the physical and personal context of the users. Analogue neural networks, for example, can be used as adaptive sensing devices that detect and adjust low-level signals within domestic or mobile environments to control, regulate and personalise environmental conditions, such as temperature, humidity, draft, loudness and lighting. When reacting in response to the natural speech and movements of its users, AmI systems will also need to recognise who is talking (or more generally interacting) with whom, in what mood (see also emotional computing) and perhaps even why they are talking in the first place.

Research challenges in this area include:

1. Develop systems that support context aware navigation in public environments, i.e., for traffic navigation, navigation in airports and hospitals.
2. Develop service discovery systems that enhance the shopping experience of customers.
3. Develop context aware control and surveillance systems.

Emotional computing

Emotional computing (and affective computing) is an area of computer science where the primary objective is to either model or embody emotions in the computer, or build systems that can respond to or recognise the emotions of the people using those systems. Systems capable or responding to the emotional states of their users (for example, as they become bored, frustrated or annoyed with a product) may be able to take supportive or corrective actions that appear to be almost ‘intuitive” from the users’ perspective.

Research challenges in this area include:

1. Develop methods to design animated characters that exhibit emotion.
2. Develop emotional interfaces, i.e., emotional interface robots.
3. Develop concepts that provide systems with emotional feedback.

Chapter 4. Integrating research components/domains

It is important to recognise that, while many of the component areas highlighted in chapter 3 have a degree of maturity, others are less well developed and cannot easily build on established or structured research communities. For example, it is essentially a case of pursuing *new directions* in such established fields as communication and network technologies, software technologies, interface and display technologies, embedded systems, microsystems and materials. Identifying priorities and roadmaps may be more difficult within what are still the emerging research domains of 'Micro/ Nano-electronics/systems', 'Emotional computing', 'Contextual awareness' and 'Computational intelligence' where research methodologies and communities are less well developed. It remains to be seen whether this disjuncture between more established and newer research domains will have an impact on the speed at which research challenges can be addressed within each domain.

The development of the AmI space, of course, will depend not simply on finding solutions to the research challenges in each domain but on the extent to which mechanisms can be found to ensure the successful integration of components and their convergence into AmI systems. In order to directly meet the real needs of individual users and address the broader socio-economic concerns highlighted in chapter 2, it is critically important that architectures, methods and tools can be developed that are capable of *converging technologies into AmI systems.* New approaches will also need to be elaborated concerning how technologies can be integrated across different usage environments.

Further analysis and discussion is required by ISTAG concerning the integration dimension. In this report it is suggested that initially it will be helpful to look at issues related to integration in terms of the following three 'layers'

- Platform Design
- Software design, engineering and integration
- Experience prototyping

1. Platform Design

Each of the component technologies identified in chapter 3 and the associated AmI research challenges have a have strong internal coherence and build on certain basic facts and assumptions. These differ from one component technology to the other. The challenge of Platform Design is to provide the foundations, environment and tools for the mutual integration/cooperation of these fundamental components. Specific topics/properties to be confronted in AmI platform design may include the following:

Abstraction
Future AmI platforms must cope with heterogeneity, intelligence and variability. There is a strong need to develop new concepts and extract suitably abstract models.

Automatic Composition
Interfaces, reusability and interconnectivity should be understood in the new context of intelligent and dynamic models of system configurations. Self -organization of the platform is a formidable challenge here.

Interaction Management
The necessary interaction, inside the platform, of the ambient infrastructures and their intelligence, calls for a new look at issues related to co-ordination and orchestration. Intelligent collaboration of dynamic entities or conglomerates requires innovative interaction management techniques, based on the emerging field of "algorithmics of interactions". The anticipated vast number of real time, cooperative or competitive interactions calls for breakthroughs in issues related to coping with complexity, selfishness, distributed system issues and non-determinism.

Computational Efficiency
Platforms in AmI need to demonstrate high levels of performance related to complex intellectual tasks, perhaps surpassing the human level. To achieve this, not only a new framework in knowledge engineering and elegant reasoning is needed, but also a deeper understanding of the nature and limits of (feasible) computations. New methods of coping with high computational/combinatorial complexity are required, especially in the case of huge multi-technology applications. Highly optimised computations, (perhaps based on several nonconventional machine sets like quantum or DNA based), or on fundamental abstract notions (like randomness, incomplete information, interactive proofs) might be critical for the development of the vision of "superhuman AI"in the platform. In addition, new metrics of the ability to reason about action and change must emerge, in order to allow for the comparison of tools and techniques. This will allow the utility of such platforms to be measured accurately and will make the integration very efficient and well balanced with respect to the needs of each focal point of intelligence.

Creativity
The new platforms will be required to support actions beyond mere productivity. They should enable programmer-created design, and facilitate innovation and expression of personal style.

Scalability and Evolution
Platforms should facilitate the management of huge clusters, MEMS and architectures; migration of tasks and transparent load balancing is still a major challenge. The intelligence of the whole platform should allow for self-evolution of the whole system together with clever management of critical resources.

Dependability
The platform should allow for trouble-free systems used by millions of people worldwide. Here, consistency and trust are basic properties . This will require new high-level specification languages, able to support proofs for security, and having innovative self-learning protection mechanisms.

2. Software design, engineering and integration

The realisation of the AmI vision will require the development of extremely large, complex, distributed systems built on a platform capable of providing seamless networking. This distributed system, consisting of a myriad of interacting embedded software components, will need to be intelligent, self-configuring, self-healing, self-protective, and self-managed.

ISTAG has identified approximately a dozen domains in need of breakthrough research to bring the AmI vision closer to realisation. Researchers will undoubtedly produce new software in each domain. A major challenge will be to find ways in which these discrete software components can be integrated so that they converge into systems/environments and can be applied in a number of different usage scenarios.

Today’s software is often based on two main integration principles. Firstly, software is often partitioned into abstraction layers with fixed, simple interfaces between layers. Secondly, systems are often vertically integrated with fixed, proprietary linkages between components. The AmI vision challenges both these principles. The need to anticipate user behaviour, to gather contextual information, to detect and adapt to all kinds of changes etc. entails a corresponding need for extensive cross-layer interactions that ‘break open’ the interfaces between layers. The need to augment all kinds of everyday things with computing, to harness sensory data, to disseminate information through a hyper-connected world etc. entails a corresponding need for horizontal integration that goes far beyond the simple dynamic service discovery mechanisms that are the basis of new middleware paradigms such as Web Services.

Researchers working in areas closely related to AmI have been aware of the software integration problem for some time and the following is an attempt to highlight some early observations.

- Event architectures appear interesting as the connective 'glue' between components.[18] However, questions arise regarding how events are distributed, how event architectures may scale, and the semantics of events. Declarative policies may be an interesting management tool for event systems.
- To support interactions between a broad range of heterogeneous devices and platforms, including resource constrained embedded systems, communication should be based on very simple WWW protocols such as HTTP and XML. Ultimately though, such a simplistic approach will have limitations.[19]
- Tuple spaces are a favourite among researchers (but shunned by developers) to achieve sufficient decoupling (support for asynchronous and indirect communication) for flexible patterns of interaction between components[20].
- User interface toolkit researchers are looking at ways of abstracting away from the idiosyncrasies of input and rendering devices by introducing concepts such a plasticity[21] and generalization[22].
- Component frameworks based on cybernetic control theory may serve as a foundation for integrating embedded systems into self-configuring, adaptive systems[23].
- Mobile agents are often proposed as a well-suited paradigm for AmI software. After a decade of research, the usefulness of mobile agents is still questionable and demands for a homogeneous, virtual machine, run time environment are problematic.
- Perhaps one of the most often cited technologies for achieving horizontal integration in distributed systems is service discovery protocols such as Jini, Upnp, and UDDI. A key requirement of widespread deployment of such protocols is standardization on service types. Progress has so far been limited.
- Peer-to-peer architectures may be well suited for information appliance interactions[24].

The above list of proposed technologies for addressing the AmI integration problem is not exhaustive but gives a flavour of the state of the field today. Currently there is a need for new mechanisms or a 'venue' where integration technology can be tested, where researchers can reuse and improve upon earlier results, and where comparisons based on metrics can be conducted. New AmI simulation tools promise to offer such a venue. Before considering the state-of-the-art of such tools, however, it may be useful to examine some important AmI software issues that further underline the need for simulation tools.

As indicated in chapter 1, the AmI vision seeks to address the real needs of users and to develop intelligent systems and environments that are not simply unobtrusive but in many cases are also invisible. This emphasis on the user and the user's experience will also manifest itself in the software development process. Quick cycles of (re-)design, prototyping, and evaluation in the field will need to be supported. Software correctness will not be the only important evaluation criterion. How to properly evaluate the user experience offered by prototypes of AmI applications

[18] Cambridge Event Architecture. http://www.cl.cam.ac.uk/Research/SRG/opera/projects/

[19] G. Abowd. *Software Engineering Issues for Ubiquitous Computing*. In Proc. Intl. Conf. on Software Engineering. April 1999.

[20] N. Davies et al. Limbo: *A Tuple Space Based Platform for Adaptive Mobile Applications*. In Proc. Intl. Conf. on Open Distributed Processing/Distributed Platforms. 1997.

[21] G. Calvary, J. Coutaz, D. Thevenin. *A Unifying Reference Framework for the Development of Plastic User Interfaces*. In Proc. 8th IFIP Intl. Conf. on Engineering for Human-Computer Interaction. May 2001

[22] G. Banavar et al. Challenges: *An Application Model for Pervasive Computing*. In Proc. Intl. Conf. on Mobile Computing and Networking. August 2000.

[23] C. Herring, S. Kaplan. *Component-Based Software Systems for Smart Environments*, IEEE Personal Communications. October 2000.

[24] B. Sharpe. *Information Appliances. Appliance Design 2002* and M. Minoh, T. Kamae. *Networked Appliances and their Peer-to-Peer Architecture* AIMDEN. IEEE Communications Magazine. October 2001.

and environments is currently unknown and is an important research field in itself[25]. Another issue related to the emphasis on supporting the user in an intelligent manner is the notion of computer intelligence itself. True human-like intelligence is probably not achievable in the foreseeable future but some think it might materialise within 20-30 years[26]. Developers will need to resort to approximations - approximations that are likely to be wrong - resulting in confused and frustrated users[27]. Trial, error, and evolution will be central. Currently, however, no body of knowledge exists about successes and failures of deployed systems.

Of the many recent advances in AmI and related areas, one of the more promising is the emergence of simulation tools[28]. Potentially, such tools allow devices, networks, protocols, scenarios, etc. for AmI to be simulated. Currently, no simulation experiments have been conducted, but this is understandable as the tools have become available only very recently.

Tools such as UbiWise (an open source project freely available for download at http://www.handhelds.org/) allow researchers to model the physical world and to render and explore it using 3D visualization engines such as Quake Arena III. The physical world model can be populated by users, devices, and all kinds of services and infrastructure. It is easy to imagine that user trials could be conducted inside such tools. Also, if provided with typical usage data gathered from the real world, simulations of extensive use could also be conducted in an inexpensive manner. Tools such as this, therefore, point the way to how simulation models could be distributed and literally serve as a 'venue' or a meeting ground for researchers and, in the process, facilitate experimentation and reuse of proposed integration solutions.

3. Experience prototyping

The AmI vision anticipates that ICT will increasingly become part of the invisible background to peoples' activities and that social interaction and functionality will move to the foreground resulting in experiences that enhance peoples' lives. This not only requires insight into the design of sophisticated distributed systems; it also requires a deep understanding of how user needs can be translated into functional requirements. New approaches to prototyping are likely to be key to the successful development of AmI products and services.

Prototypes of user interfaces allow developers to obtain formative and summative information about a user's experience with a new product. Prototypes can motivate users to discuss new ideas about task requirements, concepts, dialogues, new interaction modes, navigation or presentation of the real world artefacts or phenomena. 'Performance' approaches to the exploration and testing of new information technology products are increasingly being adopted and are potentially useful for the design of products for AmI environments. Fictitious roles are created and scenarios are converted to scripts that are performed by actors. Giulio Iacucci, Carlo Iacucci and Kari Kuutti[29] provide an overview of papers that have been published describing how group performances are used to model and experience ideas during early design phases. Experience prototyping is included in the overview as is their own case of Situated and Participative Enactment of Scenarios.

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[25] Workshop on Evaluation Methodologies for Ubiquitous Computing. Online Proceedings. http://zing.ncsl.nist.gov/ubicomp01/, 2001.

[26] B. Joy. Why the Future Doesn't Need Us. Wired. April 2000.

[27] C. Lueg. *On the Gap Between Vision and Feasibility*. In Proc. Intl. Conf. on Pervasive Computing. August 2002.

[28] J. Barton, V. Vijayaraghavan. UBIWISE: *A Ubiquitous Wireless Infrastructure Simulation Environment. HP Labs Tech. Report* . http://www.hpl.hp.com/personal/John_Barton/ur/ubiwise/publications/ubiwise-05MAY02.pdf. 2002 and M. Bylund. F. Espinoza. *Testing and Demonstrating Context-Aware Services with Quake III Arena*. Communications of the ACM, January 2002.

[29] Giulio Iacucci, Carlo Iacucci, and Kari Kuutti, Imaging and experiencing in design, the role of performances, *NordiCHI 2002 Proceedings of the Second Nordic Conference on Human-Computer Interaction*

Experience Prototyping[30] can be described as a form of prototyping that enables design team members, users and clients to gain first-hand appreciation of existing or future conditions through active engagement with prototypes. Experience prototyping can be used to understand existing user experiences and their contexts, explore and evaluate new designs, and communicate ideas to designers and stakeholders.

Prototypes can be used for classical user evaluation and they can be a useful way to measure the effectiveness/efficiency of users' tasks and the level of user satisfaction. Prototypes can further be used to observe cognitive tasks, such as a user's attention, perception, projections for next steps and evaluations of the prototype's response. Prototypes allow developers to test new ideas either in a laboratory setting or in more realistic contexts in the field.

Prototypes can either be low fidelity - constructed with pencil and paper, or high fidelity - constructed with development tools. The developer chooses how much s/he can invest in the prototype development.

The spiral model of the software process (by Boehm [31]) introduced the idea of prototypes to evaluate risks early. Prototypes enable developers to carry out user-centred design with feedback from users being obtained as early and as often as the standard ISO 13407 on human-centred design processes for interactive systems recommends.

Insofar that experience prototyping places the emphasis on the quality of the user's interactions and experience and less on the pure functionality and technology of the solution, it seems well suited to the AmI goal of addressing real user needs that reflect socio-economic problems. As AmI scenarios become more complex, it is also possible to see how further development of the experience prototyping approach could be an important means of making highly innovative, yet complex and abstract ideas physical and understandable. Nevertheless, a number of research challenges must also be addressed for experience prototyping to fufil its promise. In particular there is a need to:

- Integrate prototypes with model-based user interface design, thus satisfying both users and developers.
- Develop a lifecycle for prototypes supporting different abstraction levels and fidelities.
- Annotate prototypes with metadata such as the results of performances, user testing, expert evaluation and participatory evaluation.
- Develop exploration and evaluation methods of prototypes that integrate cognitive processing, system tasks and the interaction between them.

It is suggested in the following chapter that many of these challenges can usefully be addressed by the formation of a network of Experience and Application Research Centres (EARCs).

Finally, mechanisms to ensure the successful integration of components and their convergence into AmI systems may also require that we adopt a more 'cultural approach' to socio-technical research and the design of experience. This may be an approach that is relatively unfamiliar to the current research community but it is one that requires greater emphasis if experience prototyping is to produce meaningful results.

AmI Research – a cultural approach

AmI research will need to enhance human capability by providing a suitable environment for the activity, or activities, which people perform within it. The environment is one in which local needs and remote needs - such as communication with colleagues - can be optimised. In short, the environment is the relationship between behaviours, both social and technical, and user experience. To arrive at a correct 'fit' for the design of the products, services and systems which people will use in different places and at different times of the day, it will be necessary to consider how to optimise for particular activities whilst, at the same time, providing some enhancement of

[30] Marion Buchenau, Jane Fulton Suri, Experience Prototyping, *Proceedings of the conference on Designing interactive systems: processes, practices, methods, and techniques August 2000*

[31] Barry W. Boehm, *A spiral model of software development and enhancement* . Computer, 21(5):61-72, May 1988.

experience between and across activities. Thus the overall behaviour of the system over time - in relation to a particular user or group of users - needs to be considered. It will also be necessary to study the social behaviours which can be enhanced through Ambient intelligence technologies and construct models of socio-technical systems in which users and technologies cooperate synergistically to enhance human capability and quality of life.

As products and services become increasingly networked and distributed, it may be necessary to provide 'conceptual maps' and representations to the user in order to ensure an understanding of the systems with which they are engaging. It is not enough to simply present an interface as a 'front end' to a system: it may be necessary to create 'maps' to engage the user in the wider interaction with the system, or alternatively, allow the user to develop maps based on their own explorations of a system. This represents essentially a new area of design in which visual representations of evolving systems are created. In these representations, it will be necessary to study the cultural appropriateness of the maps – visual language, literacy and interpretation are highly culturally dependent.

A successful integration of AmI components/domains, therefore, is likely to require new forms of experience design and prototyping involving social, cultural and psychological research and requiring that we pilot interactions, interfaces and conceptual maps across different cultures or cultural groups (see recommendation on Experience and Application Research Centres on chapter 5). This is needed in order to provide a systemic research base for the cultural factors which are needed to design appropriately for different ethnic groups, countries and regions. In other words, we should not assume that one dominant cultural paradigm ‘fits all’.

Chapter 5. Recommendations on New ways for Research and Development

A number of new mechanisms and processes are needed to facilitate AmI research and to help remove the stumbling blocks that are currently impeding realisation of the AmI vision. As already indicated in chapter 3, there is the general observation that communities in some of the newer research domains upon which AmI depends may be in need of further development and could require special forms of support.

In this chapter, ISTAG makes a number of specific recommendations related to new ways for research and development that it believes are key for the successful implementation of the AmI vision.

Recommendation 1: Put holistic and dynamic user requirements at the centre of the development process and create a multidisciplinary European network of Experience and Application Research Centres (EARCs).

In order to develop quality services and products for AmI it will be necessary to understand the complex set of technical, social and economic constraints under which they are built. Research is required to elicit the problem domain and the boundaries of the system to its environment, including people, natural systems, physical systems, and other AmI components. In AmI these boundaries become more critical since there is a need to take into account an all-encompassing view of extremely complex systems and decisions have to be taken as to what the requirements of systems will be over extended periods of time. Research is required to understand how software designs are constrained by requirements related to quality and resource usage and also how design choices are made and validated. Design decisions are crucial in AmI since there will a wider variety of components and devices.

For successful AmI development new ways must be found in order to help developers and stakeholders learn from experiences and exploit the resulting knowledge in future development. ISTAG suggests that this will only happen if functional, technical, social and economic requirements of systems, gathered from users and stakeholders, are put in the centre of the development process and are revisited throughout design, implementation, checking, and testing. This approach, however, is extremely challenging and extends well beyond the kind of requirements for software design which are in practical use today. Thus, it is essential that research is conducted on mechanisms that can capture the new meaning/semantics and performance goals. Such an effort will benefit substantially from the design of innovative extensions to precise formal/mathematical ways of stating new, stronger, and more diverse requirements, and the development of techniques, methodologies, and automated tools for checking such requirements. Innovative extensions of the interface of the new requirements with the design process are also needed.

Important steps towards increased user-centred design have already been taken, such as the ISO 13407 "Human-centred design for interactive systems" and the "Design for all" standards for accessibility of information technology products. However, more needs to be done in this area. For example, requirements engineering for AmI systems design can no longer be seen as a task that can be accomplished primarily through the development of scenarios and the translation of use cases into system requirements. System functionalities that generate true user experiences can only be determined in a reliable way from feasible prototypes providing proofs of concept. These are called *experience prototypes (Chapter 4)*, and, in order to support their effective and efficient development, prototyping environments are needed that facilitate both feasibility and usability studies. More specifically this means that laboratories are required which contain infrastructures that support fast prototyping of novel interaction concepts and that resemble natural environments of use. Experience prototyping centres should also be equipped with an observation infrastructure that can capture and analyse the behaviour of people that interact with the experience prototypes.

A number of centres in both the Europe and the US [32] are already showing the benefits of the experience prototyping approach. The Philips' HomeLab, for example, is a combined feasibility and usability laboratory that investigates through extensive empirical research which embedded interaction technologies are really perceived by people as life enhancing experiences[33]. HomeLab engineers build prototypes of embedded distributed systems that implement novel interaction concepts developed by industrial designers; these prototypes are subsequently evaluated by cognitive psychologists through extensive user tests. This advanced research centre consists of a feasibility nucleus surrounded by a usability shell. The feasibility nucleus is identical to an ordinary house with a hall, a living area, and a kitchen on the ground floor, and a parents' bedroom, a children's bedroom, a den, and a bathroom on the first floor. The usability shell consists of a sophisticated observation system with cameras, microphones, display monitors, and a storage systems that van be used to record observed behaviour that can be analyses to validate certain working hypothesis supporting the use of novel interaction paradigms. For Philips the HomeLab has become a major instrument in the development of insight into user needs and their translation to functional requirements for distributed embedded systems. In Norway, Telenor has had similar success with its home of the future project and has gained important feedback from users not just on technical usability but also on the commercial viability of broadband services via. a large-scale VDSL trial involving 750 households in Stavanger.

Building on these and similar approaches to experience prototyping, ISTAG suggests that AmI research increasingly needs "to allow people to live in their own future" in order to bring that research closer to the needs of citizens and business. ISTAG recommends that instruments should be developed to create a European network of Experience and Application Research Centres (EARCs) for this purpose which could operate on a number of layers:

1. Science and Technology centres: where basic research is conducted on component technologies for ambient intelligence.

2. Feasibility and Usability centres: where components are integrated into real user environments on a small scale and investigated with regard to their usability.

3. Validation and Demonstration centres: where promising prototypes are fully integrated into large scale real-life situations and validated through extensive user tests.[34]

Within EARCs It will also be useful to think of 'open systems' in terms of a design approach that allows for adaptivity over time, taking into account peoples' preferences, individual routines and

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[32] Interaction Design Institute Ivrea:
http://www.interaction-ivrea.it/
Philips: Homelab:
http://www.philips.com/informationcenter/global/farticledetail.asp?larticleid=2118
Electricité de France: "The Home of Tomorrow":
http://retd.edf.fr/gb/futur/mois/framemois.htmLiving Tomorrow: www.LivTom.be
FhG Duisburg: InHaus:
http://www.inhaus-duisburg.de/
Boeing: Passenger Experience Research Center:
http://www.boeing.com/commercial/news/feature/tour.html
MIT House_n:
http://architecture.mit.edu/house_n/web/
MicroSoft Concept Home:
http://www.microsoft.com/presspass/features/2000/01-06mshome.asp

[33] Aarts, Emile, and Berry Eggen, Ambient Intelligence Research in HomeLab, Neroc Publishers, Eindhoven.

[34] In this context, the approaches taken by a growing number of real world experiments and urban renewal initiatives merit further study. For example,
Arabianranta project, http://www.helsinkivirtualvillage.fi/Resource.phx/adc/inenglish/arabianranta.htx
Crossroads project, http://www.crossroadscopenhagen.com/project_b.htm
22@bcn http://www.bcn.es/22@bcn/engl/presentacion/index.html

ways of doing things. With these factors in mind, it is possible to consider three levels of activities:

micro
This level addresses the individual's interaction with a product, service, environment or system - this is the traditional domain of user interface design or human-computer interaction.

meso
This is the level of the group, or community which involves a multi-user locale with links to a distributed network. Examples are: the home, the school, the business, the hospital.

macro
This is the level of the individual's movement across places and through time. In this scenario the focus is on time rather than place, and design needs to reflect the individual or group's experience across locales and activities. This is therefore a more holistic design approach which addresses societal interactions.

In any aspect of design the optimum outcome is that all three levels are coherent and integrated from a user point-of-view. For example, it is not desirable to design an interface at the micro level without taking into account the meso level of the context of the activity. Thought of in this way, the role of the EARCs is to study the three levels of experience, based on insights from psychology and sociology in order to propose relevant, culturally appropriate (see chapter 4) and context and location specific AmI systems.

In conclusion, EARCs are required that provide multi-dimensional strategies for how to involve users in the design process and which respond to the growing recognition that acceptance of ICTs is not only shaped by their technological possibilities or by their functionality, but also by the micro-social context of the household or of other social settings. As the recent EMTEL (European Media, Technology and Everyday Life Research) study[35] observes, some technology designers have questioned whether in-depth studies of users in 'living labs' or real life settings are too costly or time consuming. ISTAG recognises that the cost implications of establishing a European network of EARCs are significant but also suggests that the successful realisation of the AmI vision requires a new approach to user centred design, prototyping and validation. The EMTEL study concludes that, "the real challenge may lie in involving users in a sociological sense, i.e. by taking into account the micro-context of their everyday lives." ISTAG recommends that EARCs can be an important instrument in helping to address this challenge.

Recommendation 2: Support open standards in AmI projects and encourage their development via. public sector initiatives and projects.

In order for the potential of AmI to be realized, it is important that cost-effective approaches to system development and deployment are followed and shared at both a national and European level. With this in mind, ISTAG recommends that code sharing, the use of open source and/or open interfaces, and the development of open (*de facto*) standards should, as far as possible, be built into the design and practical implementation of AmI projects.

An open systems development approach can potentially:

- lead to the rapid establishment of European-originated, world-wide common standards and to the sort of highly interoperable, interconnected and interdependent systems which are required to make the AmI space a reality;

[35] A social and technological view on Ambient Intelligence in Everyday Life: What Bends the Trend? Yves Punie, EMTEL/IPTS, June 2003

- help ensure the security and reliability of software and minimize the costs of adapting and repairing bugs and failures;

- provide significant economic growth and European added value; open software already shows signs of being an area where European industry can have a competitive advantage.

As indicated earlier[36], ISTAG suggests that code sharing, the use of open source or interfaces and *de facto* standards should particularly be built into the practice of e-governance. The development of a common open source base could also be promoted through procurement process. For example, some administrations in Europe have already taken the position that they will only accept software with sufficiently detailed documentation that allows another contractor to make modifications or additions. More detailed discussion is required on mechanisms that can support the development of open standards but ISTAG suggests that public sector initiatives and projects have an important role to play here.

Recommendation 3: Support distributed software development including the certification of components.

ISTAG believes that the development and exchange of software in the form of reusable, open components will facilitate AmI development and should be encouraged. Open distributed software development will both speed and lower the cost of AmI software development. The wide availability of libraries of components, which implement diverse functionality will also provide essential support for more upstream projects, including fundamental research, related to the development of frameworks, methodologies and technology for the development, certification and exchange of such components.

For advances to be made in this area, significant progress is required in the development of automatic tools for storing and locating components based on their functionalities, improved techniques for describing such functionalities (specifications), and improved methodologies and tools for ensuring (certifying) that components indeed meet such specifications. ISTAG, therefore, recommends that a major effort should be made to progressively move towards the certification of such software components as far as the state-of-the-art in code validation allows. More effort is also needed to foster extensive research into the development of more cost-effective and automated software verification technology.

Finally, while the component-based approach brings many theoretical advantages, it must be appreciated that, in practice, it can also have some negative consequences; for example, it can result in the production of larger executables, since more general functionality is included by default. Thus, both fundamental research and the development of tools for the optimisation of systems built from components (including partial evaluation, code slicing, static analysis, etc.) should also be encouraged.

Recommendation 4: Encourage research that supports the 'graceful degradation' of software in complex AmI systems.

AmI software needs to be dependent, reliable and predictable. If it fails in any of these aspects it will be very difficult for AmI to gain public acceptance. However, given the growing complexity of software and the limitations of current software verification technology, it is often not economically feasible to guarantee or even obtain complete correctness of a very large, distributed system. In view of this fact ISTAG recommends that research should be encouraged related to adaptive, self-healing software that allows for a 'graceful degradation' of services and applications. This means that in any AmI system the most important and vital functions will be preserved while less important features gradually stop functioning. Put another way, there will always remain some parts of a complex software system that drive the most critical functions whose correctness must

[36] see section on Governance and public services, page 15

be ensured. In fault tolerant systems it must also be possible to affect a smooth recovery of the damaged system to one that is fully functional. Failures during operations will require on-line repair and reconfiguration.

To achieve this goal significant research will be needed in order to develop methodologies and tools which can make it economically feasible to ensure the correctness of such components. In a more general sense, research is required that will facilitate the development of software whose fundamental components (which implement the core of the application and/or the "failsafe" mode) are certified in such a way that, even in case of malfunction, the overall system does not put people at risk or result in user frustration. More specifically, research should be aimed at developing techniques and tools for software developers that allow them to detect and correct software bugs as early as possible during the application development process. This includes the development of: more intelligent program analysis technology and tools; more intelligent program verification and debugging technology and tools; high-level program transformation tools (e.g., specialization from generic libraries to specific functionalities); higher-level programming paradigms and languages; advanced software development and maintenance environments; advanced distributed programming models and implementation techniques (e.g., distributed hash tables); advanced techniques for the distributed development of software; programming models and tools capable of dealing with resource information (e.g. memory consumption, communication cost, execution cost); program optimisation, specially for distributed execution; advanced models of distributed and mobile computation, etc.

Recommendation 5: Place sufficient emphasis on work on the boundaries between research disciplines.

Today the boundaries between many science and technology disciplines are becoming blurred at an accelerating pace. Progress in one area quickly seeds advances in another. New tools can serve many disciplines, and even accelerate interdisciplinary work, giving rise to new and unexpected breakthroughs. There are many examples in which other disciplines are impacting on ICT research. From biology, for example, come important insights about the behaviour of complex dynamic systems. Cognitive science is providing insights about how to present information to human beings so they can use it most effectively. Conversely, ICT is also impacting on research in other fields. For example, ICT plays a crucial role in both research and the design of the structure and properties of materials, and in the design of complex molecular and microscale structures. Also, without advances in ICT it would not be possible to take full advantage of biotechnology in areas such as decoding the human genome and modelling the dynamic structure of protein molecules.

The overall conclusion is that *exciting things happen at the interfaces* - although research aimed at improving and extending the knowledge in core scientific and technology domains remains a necessity, it is the research in areas on the boundaries between scientific domains that will yield the biggest return. In short, AmI can only be fully developed by a holistic approach, encompassing technical, economic and societal research. ISTAG recommends that new directions for AmI research and a paradigm shift in research methodologies are most likely to emerge as a result of stimulating the cross-fertilization of knowledge and ideas and research between disciplines and supporting mechanisms that encourage the formation of multidisciplinary research teams.

Recommendation 6: Increase awareness of the AmI vision among Computer Scientists and researchers in other disciplines.

Many European researchers working on foundational and software-related issues in Computer Science are motivated by fundamental technical problems in their field which are posed by, e.g., research in US or by their European peers and which constitute the frontier of their research areas. They are moved by a need to make contributions that are considered research

achievements at an international level and publishable via the best competitive conferences in their fields, at which they meet annually, and which maximize the impact of their work. [37]

However, an analysis of conference proceedings suggests that computer scientists working on foundational and software-related issues only seldom discuss the applicability of their results in the context of the AmI vision. Judging by the acknowledgments sections of conference papers they also seem to have a low level of participation in AmI-inspired research funding programmes. In short, it would appear that many leading European computer science researchers with international reputations are not explicitly focused on AmI research.

Nevertheless, even if rarely presented in AmI's terms or funded by AmI-oriented research programs, it is clear that many of the contributions made by European computer scientists and presented at conferences represent fundamental advances in areas that have been identified as being enablers of or having direct relevance to the AmI vision. This includes advances in the understanding of software specification, software debugging, software verification, advanced programming languages, application-specific languages, resource awareness techniques, algorithms, distributed systems, concurrency, parallelism, security, cryptography, semantics, etc.

To address this issue ISTAG recommends that:

1. Sustained efforts must be made to increase awareness of the AmI vision among top European computer scientists (including presentations at key conferences) so that first-class research which is of direct relevance to the AmI vision is more explicitly presented in an AmI context.

2. While formulating a precise definition of what AmI is not considered essential, (see chapter 1) ways must be found to ensure some correspondence of terminology in order bring European researchers (both computer scientists and researchers in humanities and the social sciences – including economics) closer to the AmI centre. The formulation of a number of major AmI Technical Challenges (involving prestigious prizes and awards) that can be understood by the whole research community may assist this process. This must be carried out in co-operation with the key European computer science associations (such as EATCS, EAPLS, etc.), and national bodies (such as German GI, or the French AFCET).

3. Programmes that fund research which support the AmI vision must be more aware of the importance and relevance of fundamental research and more clearly state their emphasis and implement support for fundamental research. It is important that Europe's top scientists are convinced that their leading-edge research can be funded by AmI programs and that they feel more directly part of a growing AmI research community.

Recommendation 7: Improve the ability to track participation in and the impact of AmI research.

As IST Framework Programs evolve it is essential to be able to quantitatively track the level of contribution and impact (i.e., of scientific excellence) of the work funded. For the IST Sixth Framework Program and beyond ISTAG recommends that, in addition to tracking the progress of funded projects and other actions in terms of the deliverables nominally produced, new quantitative measures of contribution and the scientific impact of funded actions should be gathered. To this end, universally accepted indicators of excellence in research performance should be used: i.e., publications in the most competitive conferences and journals (measured by the number of citations to papers in these conferences and journals and by the type of peer

[37] Examples of important conferences which are often held in Europe include: ICALP, ESA, DISC and STACS (and the east European Conferences MFCS, FCT, etc.) for Theoretical Computer Science community; SAS, ETAPS, ICLP, ICFP, CP, PLI, PPDP, LOPSTR, TAPSOFT, etc. for the Software/Code Correctness / Languages community; EUROPAR, CONCUR... for the Parallel/Distributed/Concurrent Computing communities,etc.

review) and direct citations to the papers, as well as other auxiliary measures such as new PhDs, books, etc. Recently this task has been recently greatly facilitated by the availability of automated tools[38] which provide free, reliable rankings of conferences and journals, authors, or individual papers.

In addition, it will also be important to develop indicators which illustrate the relative position of European AmI research compared to similar research projects in the US, Japan, Canada, Australia etc. and which enable a reliable assessment of those fields where Europe is taking a lead. In short, a wide revision of criteria and indicators for the assessment is urgently recommended.

[38] See, for example, http://citeseer.nj.nec.com/impact.html for an impact-based objective ranking of conferences and journals in computer science, or http://citeseer.nj.nec.com/ to obtain rankings of authors by citations and citations of authors or individual papers.

Appendix I: Best Practice Projects

Assessment of the early impact of the AmI vision is difficult to quantify although there are initial indications that the vision has succeeded in bringing forward a number of best practice projects and initiatives and that Europe is already actively engaged in trying to realise the concepts behind AmI. A number of best practice projects and initiatives are summarized below.

IST projects

The AmI vision was included in the IST Work Programmes from 2000 onwards as a focal point of the programme activities. The trends in the development of the portfolio of projects against the vision and priorities laid out in successive Work Programmes have been analysed systematically in a so-called Integrated Programme Portfolio Analysis (IPPA) exercise.

The aggregate analysis of the projects from all eight IST Calls showed a welcome trend to greater focus on next generation technologies and applications. IPPA's main conclusions were:

1. "**The programme has a complementary set of activities and a wide coverage of technologies and applications**. The portfolio of projects has evolved significantly from the first Calls onwards. The analysis shows a stronger concentration in the last two years on the next generation of technologies and applications. These are in line with the programme vision of AmI: "Anytime, anywhere natural and intuitive access to knowledge based applications and services". For several sectors across the programme the combination of instruments and the balance of the coverage has generated a coherent effort contributing to the vision. In other critical sectors, the effort is still fragmented."

2. "**Development of long term RTD strategies in several fields of the programme is in line with the vision of Ambient Intelligence**. Ambient Intelligence can now be seen in the ambitions of several sectors of the programme. These sectors correspond to the areas where Europe has strong and well-organised industrial and research communities that can define, and work together towards long term goals. Projects in these sectors target their objectives to the implementation of segments of the Ambient Intelligence vision. In most of these fields, the proposals constitute a coherent and balanced effort to reach high-impact goals over a ten-year timeframe. Examples of the above fields include the microelectronics, wireless, microsystems, transport (mainly automotive) and health care sectors and many of the sectors addressed in the FET areas."

   The following **sample extract of IST RTD projects** were identified by IPPA as having a time to market of 5-10 years and to address more than one technology. They were also highlighted in the recent publication 'IST 2002 : Partnerships for the Future' (see below):

- Example in the area of microelectronics / wireless: Configurable structures allow the use of the same chip for several applications or for the functionality to be adapted during the lifetime of the product. The **AMDREL** project (IST-2001-34379) develops methodologies, tools and intellectual property blocks to be integrated in a mixed granularity dynamically reconfigurable System-On-a-Chip implementation platform for the efficient realisation of wireless communications systems.

- Example in the area of microsystems : The **LIPS** project (IST-2000-30128) develops an interconnect/packaging and sub-system integration technology for low-cost millimetre-wave communication and radar applications including consumer products. This is being achieved by adapting existing high-density interconnect and bare die attachment technologies to operate in the millimetre-wave range. Two demonstrators will validate the developed technologies for volume production: a 60 GHz Tx/Rx module for the next generation WLAN; and the front-end of a 77 GHz automotive collision avoidance radar.

- Example in the area of health/eInclusion: The **SYNFACE** project (IST-2001-33327) develops exploitable multilingual technology for a speech-derived synthetic face giving essential visual speech information to hearing impaired users of telephone and other voice channels. This multi-modal speech approach will be of assistance to other user groups in noisy environments, and also to users with a different native language than that of the spoken message. Hearing-impaired people are significantly handicapped in access to spoken information and the availability of visual face movements is already proven as a highly effective means of enhancing speech intelligibility for the hearing-impaired. Unlike videophones, there will not be a need for special equipment at the source of the spoken message nor for individuals to suffer loss of privacy

- Example in the area of consumer oriented applications: The **OZONE** project (IST-2000-30026) that investigates, defines and implements/integrates a framework to enable consumer oriented ambient intelligence applications. The envisaged framework consists of three architectural layers that will be designed and implemented in the project. The top layer takes care of the service enabling with an emphasis in the context awareness or sensitivity, the middle layer is responsible for the software environment where seamless task migration is an crucial issue while the bottom layer delivers a powerful computing platform where high performance computing at a low power level is the differentiating factor.

- Example in the area of business support tools: The **INDIA** project (IST-2000-28413) that develops an Internet-based software suite which will assist companies to find suppliers, specify tasks and generate the necessary commercial agreements. It will help transform the structure of a traditional company value chain, from a sequence of activities involving a limited number of partners to a dynamic organisation with constellation of enterprises. The suite will be based on Artificial Intelligence, Natural Languages Processing and Information Retrieval technologies.

- Example from the FET areas:

    - The FET **Global Computing** initiative (<http://www.cordis.lu/ist/fetgc.htm>) was launched in 2001 to address the fundamental challenges posed by rapidly evolving systems composed of very large numbers of autonomous, interacting and mobile computational entities In these global systems, activity is not centrally controlled, the configuration varies over time, and the information about the environment is incomplete. The ultimate goal is to provide a solid scientific foundation for understanding, analysing and designing such systems so that they are flexible, dependable, secure, robust and efficient. The 13 running projects, with a total funding of 18 M€, bring together the best of European theoretical computer science groups, complemented by strong teams in agents, databases, and systems and network engineering.

    - The FET **Disappearing Computer** initiative (<http://www.i3net.org/> and <http://www.disappearing-computer.net/>) was launched in 2000 and to some extent derives from work in the previous i3 proactive initiative The aim is to explore ambient intelligence environments from three points of view: the development of artefacts where IT "disappears" into everyday objects, the communication architectures for collections of artefacts, and the interaction of people with information in such environments, including the emergence of new functionality from interactions between artefacts. Participant groups come from a great variety of disciplines, such as design, computer architectures, electronic engineering, psychology, the arts etc. The initiative currently brings together groups from 16 projects with a funding of 22 M€.

3. "**Emergence of long term visions is still lacking in some critical fields**. In the areas of the programme which lack projects addressing paradigm shifts, there is also a lack of a vision

for the area. These are often the fields where Europe has a weak industry or a non-structured research community. Examples are the areas of software technologies and knowledge engineering."

4. "**In the interfaces area, the integration of sensor technology**, now poised to mature towards commercial use, **could lead to the a new generation of enhanced reality applications**, covering all areas of applications in the 5 to 10 year time frame. The development of visions for these areas would be essential under FP6."

   The following **sample extract of IST RTD projects** in the area of technologies for interfaces and interaction were identified by IPPA as having a time to market of 5-10 years and to address more than one technology. They were also highlighted in the recent publication 'IST 2002 : Partnerships for the Future' (see below):

- Advances in IT are making possible new tools for human-human communication. Integration of speech, vision and dialog offers the possibility of a new class of tools to aid communication between people from different cultures using different languages. The **FAME** project (IST-2000-28323) addresses the problem of integrating multiple communications modalities blending the physical and virtual worlds to provide support for multicultural communication and problem solving. The major challenges are automatic perception of human action and understanding of human free dialog between people from different cultures. The consortium constructs an 'information butler', which demonstrates context awareness in a problem-solving scenario using computer vision, speech and dialog modelling.

- The **COGVIS** project (IST-2000-29375) provides the methods and techniques that enable construction of vision systems that can perform task oriented categorisation and recognition of objects and events in the context of an embodied agent. The functionality will enable construction of mobile agents that can interpret the action of humans and interact with the environment for tasks such as fetch and delivery of objects in a realistic domestic setting.

- The **CONSENSUS** project (IST-2001-32407) aims to overcome the time-consuming process of manually adapting user interfaces to various mobile devices. This is achieved by developing building blocks for an automatic adaptation process that considers usability constraints for the targeted devices, by including application knowledge into the adaptation process.

A series of **publications** - notably:

- '**IST 2002: Partnerships for the Future**'[39],
- '**IST 2001: Technologies Serving People**' and
- '**IST 2000: Realising an Information Society for All**'

illustrate the many project results and outlines key scientific-technological challenges and policy issues relating to specific areas of the programme.

In addition to the above IST projects highlighted by IPPA, **Usability Net** (IST-1999-29067) provides an interesting example of a project that provides resources and networking for usability practitioners, managers and EU projects.

[39] part 1: ftp://ftp.cordis.lu/pub/ist/docs/ist2002_1.zip
and 2: ftp://ftp.cordis.lu/pub/ist/docs/ist2002_1.zip

Other projects and initiatives

Beyond the IST programme the following projects and initiatives provide noteworthy examples of how the AmI vision is currently being explored and applied both in Europe and world-wide.

EUROPE

AIR&D Joint Virtual Laboratory for Ambient Intelligence 2001-2006
http://www.air-d.org/
The AIR&D consortium was founded in November 2001 by INRIA, Philips and Thomson Multimedia for a duration of five years. AIR&D is a project-driven collaboration in support of co-operative research related to consumer applications in the ambient intelligence field.

ITEA Ambience project
http://www.extra.research.philips.com/euprojects/ambience/
The ITEA Ambience project is concerned with generating concepts of Context Aware Environments (CAE), and developing architectures, methods and tools that allow their development.

ITEA Adanets project
http://www.itea-office.org/documents/project_proposals_results/Adanets_profile_oct-02.pdf
The ITEA Adnets (Adaptive Networks and Service) project (June 2002-March 2004) focuses on adaptive networks and services for mobile use. it will define a generic service/network model to enhance the development of mobile network management platforms, including a comprehensive framework for differentiated QoS provisioning.

ITEA Nomadic Media project
http://www.itea-office.org/
The ITEA Nomadic Media project (July 2003-July 2005) identifies solutions that allow consumers to enjoy content and intercative services at the times and in the places they prefer. The ambition is to reduce restrictions on the user imposed by current platforms and devices.

Open Mobile Alliance
http://www.openmobilealliance.org/overview.html
The Open Mobile Alliance aims to grow the market for the entire mobile industry by enabling subscribers to use interoperable mobile services across markets, operators and mobile terminals. This is achieved by defining an open standards based framework to permit applications and services to be built, deployed and managed efficiently and reliably in a multi-vendor environment.

USA

IBM's Pervasive Computing initiative
http://www-3.ibm.com/software/pervasive/index.shtml
IBM's Pervasive Computing initiative promotes a vision of personalised computing power freed from the desktop, enabling information access anywhere, anytime, on demand. IBM’s Pervasive Computing Unit creates e-business solutions that leverage the new class of connected client devices such as handheld Internet appliances and screen phones.

Microsoft .NET initiative
http://www.microsoft.com/net/
Microsoft .NET is a set of software technologies, based on Web Services, for connecting information, people, systems, and devices. It has developed out of a vision of an online world where constellations of PCs, servers, smart devices and Internet-based services can collaborate seamlessly and a new computing model, based on XML, that enables a standard way of building applications and processes to connect and exchange information over the Web.

Project Oxygen

http://oxygen.lcs.mit.edu/index.html

Project Oxygen was begun as a collaboration between MIT's Laboratory for Computer Science (LCS) and Artificial Intelligence (AI) Lab together with major corporations and with seed funding provided by DARPA. The Project Oxygen Alliance vision is to make computation and communication as abundant and natural to use as oxygen in the air. The goal is to free people from computer jargon, keyboards, mice and other specialized devices, allowing them to meet their computation and communication needs any time, anywhere.