Institute for
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European Media, Technology and Everyday Life Research Network (EMTEL)

A social and technological view of Ambient Intelligence in Everyday Life:

What bends the trend?

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IPTS

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EMTEL preface

The *European Media Technology and Everyday Life Network (EMTEL)* was funded by the European Commission (grant number EU FP5 HPRN-CT-2000-00063) under the 5th Framework Programme. It was constituted as a research and training network within the programme, *Improving Knowledge Potential* and oriented towards "creating a user friendly information society".

EMTEL conducted interdisciplinary social scientific research and training between 2000 and 2003. This report is one of 12 submitted to the EU in September 2003 as final deliverables for the project. Copies are available on www.lse.ac.uk/collections/EMTEL.

Contributing partners were as follows:

ASCor, The University of Amsterdam
COMTEC, Dublin City University
IPTS, Seville
LENTIC, The University of Liege
Media@lse, London School or Economics (co-ordinating centre)
TNO, Amsterdam
SINTEF, University of Trondheim.

A full list of the publications can be found as an Appendix to this report.

EMTEL sought to bring together young and experienced researchers in a shared project to investigate the so-called information society from the perspective of everyday life. It undertook research under two broad headings: *inclusion and exclusion*, and *living and working in the information society*, and sought to integrate empirical work and developing theory in such a way as to engage constructively with on-going policy debates on the present and future of information and communication technologies in Europe.

Roger Silverstone
EMTEL Co-ordinator

IPTS Preface

The Institute for Prospective Technological Studies (IPTS) is one of the seven Research Institutes of the European Commission (EC). These Institutes together, make the EC Directorate General known as the Joint Research Centre (JRC), which is the corporate research laboratory of the European Union with sites in Ispra (Italy), Geel (Belgium), Karlsruhe (Germany), Petten (the Netherlands) and Seville (Spain). The mission of IPTS is to provide techno-economic analyses in support of the European policy-making process. IPTS' prime objectives are to monitor and analyse science and technology developments, their cross-sectoral impact, their inter-relationship with the socio-economic context and their implications for future policy development

The ICT Unit of the IPTS carries out prospective analyses in selected and highly-focused ICT areas in an attempt to explore the limits and opportunities of technological advances in these vast and rapidly developing fields. The mission of the Unit is to support the Commission services and Community institutions in the process of policy formulation by interpreting and alerting its clients on the socio-economic implications of emerging Information and Communications Technologies. Therefore, the ICT Unit developed the FISTE 'Foresight on IST in Europe' framework. The FISTE framework provides a consistent methodology for foresight analysis. It seeks to balance the identification of supply-side IST trends with demand-side impact analyses, and in so doing, to detect potential bottleneck areas for innovation and further research in the European Research Area.

As a result new technological developments like Ambient Intelligence are at the core of the Fiste workplan. An overview of what has been done in this field can be found at http://fiste.jrc.es.

Jean-Claude Burgelman

Executive summary

Ubiquitous Computing (Ubicomp) and/or Ambient Intelligence (AmI) refer to a vision of the Information Society where humans will be surrounded by intelligent interfaces supported by computing and networking technology that is everywhere, embedded in everyday objects such as furniture, clothes, vehicles, roads and smart materials. It is a vision where computing capabilities are connected everywhere and always on, enabling people and devices to interact with each other and with the environment. It is envisaged that Ambient Intelligence will be aware of the specific characteristics of human presence and personality, and will be capable of meeting needs and responding intelligently to spoken or gestured wishes. It could even engage in intelligent dialogue.

This vision of Ambient Intelligence is far-reaching and all encompassing. It assumes a paradigmatic shift – not only in computing but also in society – towards what is described as 'human centred computing' where the emphasis is on user-friendliness, efficient and distributed service support, user-empowerment, and support for human interactions. Today, most of the technologies needed for the realisation of this vision are next-generation technologies not currently on the market. They are, however, being researched by many research institutes and company laboratories throughout the world in order to develop the building blocks for AmI. In Europe, the IST Advisory Group (ISTAG) is a strong promoter of the AmI vision. This and its underpinning technologies are also omnipresent in the IST programme of the EU Framework Programme 6 for Research and Technological Development (2002-2006).

The objective of this study is to identify and document major challenges and bottlenecks for Ambient Intelligence in everyday life and to raise relevant social and S&T policy questions that should be taken into account in order to bend the trend towards Ambient Intelligence. Therefore, AmI is discussed in terms of visions, technologies, applications and social challenges, with a particular focus on everyday life and from an everyday life perspective.

The AmI vision has been made possible by progress in the development of key enabling technology fields, i.e. microelectronics (e.g. miniaturisation, processing power), communication and networking technologies (e.g. broadband and wireless networks) and intelligent agents/user interfaces (e.g. speech recognition). Progress in the social acceptance of past and current ICTs has also furthered the AmI idea. It will be argued that the vision of AmI is embedded in the existing technological, social and economic context but that there is a need for research to make this context more explicit.

The vision makes huge claims for the degree to which AmI is people-oriented. However, claims are typical for vision building (e.g., the earlier Information Society vision of smart homes, and even the early 20th century mechanisation of the household). They all promise to transform for the better the way we live, work, relax and enjoy ourselves. The AmI vision, however, specifically aims to avoid technological determinism. It recognises the need for AmI to be driven by human rather than technological concerns. It proposes human-centred design and development guidelines together with other social concerns to advance this process. However, it remains to be seen if and how this manifesto will influence further research, development and design of AmI applications in order for the vision go beyond similar claims made in the past.

This report identifies and highlights some of the major socio-economic and policy-related issues to do with AmI in everyday life. It discusses whether or not the digital divide that exists today will continue with AmI. It also looks at privacy, security and surveillance issues which present a crucial dilemma for the acceptance of AmI. This is part of a larger concern about control over an environment that is highly dependent on technology. The literature on AmI mentioned in this report also raises the importance of business models, standards and the potential economic implications of AmI.

A more radical, sociological everyday life approach (i.e. the 'domestication perspective') is taken when raising other social dimensions of AmI. Domestication, one of the crosscutting themes in many of the EMTEL 2 studies, shows that the process by which new technologies are accepted into everyday life is far more complicated than is usually portrayed. It makes a case for also looking at power relations in everyday life. This approach allows a number of crucial ideas about everyday life in AmI to be raised, in some cases for the first time (e.g. housework). In other cases, where the concepts had already been considered, such as the notion of the home as a sanctuary, it allows significant advance. The domestication perspective on AmI also enabled to highlight a difference between the physical and mental disappearance of computing and to discuss the implication of this for the possible acceptance of AmI. Other issues when looking at Ambient Intelligence from a domestication perspective are that a design balance needs to be found between technologies that leave room for user experimentation and that provide rigidity for guiding users through their uncertain and innovative potential.

There are also many technological challenges (e.g. energy, power, context awareness, and natural interfaces) within the key enabling technology fields to be addressed before the so-called Ambient Intelligence Space can be realised. ISTAG has proposed Ambient Intelligence Space as a layer connecting different AmI environments (e.g. home, car, public spaces) in a seamless and unobtrusive way. Obviously interoperability and standards are crucial in this respect. Context awareness is another issue that needs to be looked into more closely, especially when trying to integrate forms of context that are more sophisticated and user-oriented than current definitions of context.

The development of smart homes is also facing major challenges. This concept has been around for more than a decade with relatively little consumer interest though now new drivers of change based on the idea of 'sharing' might push further. However, mobile communications are, in contrast, one of the biggest success stories of the 1990s ICT consumer market. In the future, a mobile world is envisaged where nomadic users can have access to information, communication and knowledge, independent of the location of the user. of the data and applications, and of the access methods used. This poses not only technological challenges but also challenges our current notions of time and space and of private and public spaces.

The paper concludes with raising technological, social and S&T policy questions that should be taken into account in order to bend the trend towards AmI. It argues for research and RTD policy approaches that connect technological and social research on Ambient Intelligence.

1. Introduction

1.1. Ubiquitous Computing versus Ambient Intelligence?

Ubiquitous Computing (Ubicomp) and/or Ambient Intelligence (AmI) refer to a vision of the future information society where humans will be surrounded by intelligent interfaces supported by computing and networking technology that is everywhere, embedded in everyday objects such as furniture, clothes, vehicles, roads and smart materials. It is a vision where computing capabilities are connected, everywhere, always on, enabling people and devices to interact with each other and with the environment. Computer devices are becoming increasingly small and cheap, interconnected and easy to use in order for them to find application in all aspects of our everyday lives. Computing capabilities will therefore not only be available in computing devices but also in everyday objects. These devices will be able to sense, think and communicate (ISTAG 2001).

This vision is reflected in a variety of terms that have emerged in recent years: ubiquitous computing, pervasive computing, disappearing computing, pro-active computing, sentient computing, affective computing, wearable computing and ambient intelligence. Marc Weiser, a computer scientist at the Palo Alto Research Center (Xerox Parc) coined the term ubiquitous computing however, already in 1988:

> *Since we started this work at PARC in 1988 a few places have begun work on this possible next-generation computing environment in which each person is continually interacting with hundreds of nearby wirelessly interconnected computers. The goal is to achieve the most effective kind of technology, that which is essentially invisible to the user. To bring computers to this point while retaining their power will require radically new kinds of computers of all sizes and shapes to be available to each person. I call this future world "Ubiquitous Computing". (Weiser 1993: 75)*

The different terms used can imply a slightly different focus - sentient computing for instance looks primarily at using the environment as the interface - or can entail a geographical preference - AmI being more prevalent in Europe and ubiquitous computing more in the US. But in general, it should be noticed that the vision is not only about computing that is ubiquitous. These massively distributed computing devices need to be able to communicate with each other and with their users in an unobtrusive, easy way.

Therefore, one could argue for the preference of the term Ambient Intelligence (AmI) as stemming from the convergence of three key technologies: Ubiquitous Computing, Ubiquitous Communication, and Intelligent User Friendly Interfaces. This is reflected in the ISTAG[1] vision statement on Ami. It implies a seamless environment of computing, advanced networking technology and specific interfaces. This intelligent environment is aware of the specific characteristics of human presence and personalities, takes care of needs and is capable of responding intelligently to spoken or gestured indications of desire, and even can engage in intelligent dialogue (ISTAG 2001:11).

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[1] ISTAG is the Information Society Advisory Group, a group of experts from both academia and industry advising the IST (Information Society Technology) program of the European Commission: http://www.cordis.lu/ist/istag.htm

In the remainder of this report, the term Ambient Intelligence will be used to encompass the convergence of ubiquitous computing, communication and interfaces, similar to what Marc Weiser had in mind for ubicomp:

> *The technology required for ubiquitous computing comes in three parts: cheap, low-power computers that include equally convenient displays, a network that ties them all together, and software systems implementing ubiquitous applications (Weiser, 1991).*

1.2. About this study

Work Package 2 of the EMTEL Research and Training Network focuses on the increasingly prevailing ubiquity of information and communication technologies: miniaturisation, portability, wearability and the transparency of communication protocols, for the quality of everyday life. This is pursued through an investigation of Ambient Intelligence in Everyday Life that encompasses a future vision of smart homes and living. Research is centred on the monitoring and analysis of the social and technological developments that are at the centre of Ambient Intelligence.

The central research question touches upon the relationship, if any, between AmI and quality of life issues: How can the potential of these new developments be mobilised effectively to enhance the quality of life of the European citizen and consumer, and what are the social consequences of this ubiquity? What will bend the trend towards AmI in everyday life?

The objective of this study is to identify and detail major challenges and bottlenecks for ambient intelligence in everyday life and to raise relevant social and ethical questions to be taken into account for bending the trend towards AmI. Therefore, in the paper, AmI is discussed in terms of visions, technologies, applications and social challenges, with a particular focus on smart homes and living, and mobile communications.

In chapter 2, the AmI vision is described and analysed. The vision is quite far-reaching and encompassing. It assumes a paradigmatic shift, not only in computing but also in society. This is described in section 2.1. The following section (2.2) gives insights into the context and the origins of the vision: Where did it come from and who promotes it? Section 2.3 argues that the drivers for the AmI vision are not only technological ones, as is usually assumed, but also social and economical ones. Section 2.4 takes this point one step further and discusses the tendency of technology vision building to be technology deterministic and to make ideological claims. If this is also the case for AmI, is discussed in the next section on AmI scenarios and human-centred design (2.5).

Chapter 3 continues with identifying and highlighting some of the major socio-economic and policy-related issues to be raised in relation to AmI. Therefore, it discusses if the digital divide of today risks to be continued with AmI or not (3.1). It also looks into privacy, security and surveillance as a crucial dilemma for the acceptance of AmI in everyday life (3.2). This is part of a larger concern about control over an environment that is highly dependent on technology (3.3). The literature on AmI also identifies the importance of business models, standards and the potential economic implications of AmI (3.4).

Chapter 3 pursues the social dimensions of AmI further on the basis of questions and issues that can be raised from a more radical, sociological everyday life approach, i.e. the domestication perspective (3.5). This is one of the crosscutting themes in many of the EMTEL2 studies (see www.emtel2.org). Domestication is briefly introduced (3.5.1). It argues that power relations in everyday life need to be taken into account. Section 3.5.2 raises different themes that can be discussed from this point of view. Other issues when looking at Ambient Intelligence from a domestication perspective are identified in the remaining two sections, i.e. that there is difference between the physical and mental disappearance of computing (3.5.3) and that a future challenge is to find a balance between adaptability and rigidity of AmI systems and services.

Chapter 4 proceeds with a brief overview of the technological dimension of AmI. The focus is on ubiquitous computing (4.1), ubiquitous communication (4.2) and on user interfaces (4.3) as the key enabling technologies for AmI. The notion of Ambient Intelligence Space (4.4) is also raised as a major challenge for AmI. Another central notion that is identified and discussed at the application level is context awareness (4.5).

Chapter 5 looks at two specific AmI environments, i.e. smart homes and mobile living. Smart or intelligent homes have been around for many years but some believe that now the time has come to really push the idea forward (5.1). This is related to new drivers that are identified for the smart home (5.2). Mobile communications on the other hand have hit a huge market in Europe and elsewhere (5.3). It is believed that changes towards a mobile Europe and a mosaic society will push mobile communications further into personal communication networks (5.4).

Chapter 6 summarises the main findings of the report and offers more food for thought on 'bending the trend' towards Ambient Intelligence in everyday life. Chapter 7 lists the references used. Chapter 8 provides a list of Emtel Key Deliverables. In Annex, extracts from technology roadmaps on smart homes and on mobile personal communications are provided.

1.3. Methodology

Since AmI refers to a vision of the future information society rather than being a current or past reality, it is to be situated early in the study of the ICT innovation process, in particular at the levels of:

- Technology vision building and technology foresight;
- Science & Technology Policy;
- Research & Technology Development (RTD) and design of new technologies.

The entry point for the study consists therefore of monitoring and analysis of the supply side of new technologies but it should be noted that it also raises reflections – inspired amongst others by the various Emtel studies and network debates – on the potential social and user implications of AmI. The study tries to link insights from social and user studies of new technologies to the research and development of new technologies. It therefore envisages to encompass both technology trends and social/user trends and argues for studying new technologies in their social and economical context.

The study is thus inspired by the theoretical approach of the social studies of technologies (e.g. Pinch & Bijker 1987; Schwartz Cowan 1985) while its methodological approach is descriptive and analytical.

The difficulty of course is that, since we are dealing with a possible future of ICTs in society, the social and user trends are reflections and educated guesses rather than being observed qualitative or quantitative current-day trends. The specific methodological focus of the study consist therefore of a critical engagement with the discourses and claims that are made in the AmI vision building process and in Ami RTD projects and policies. The discourses, scenarios and AmI roadmapping activities provide the 'texts' to be read and analysed. These 'thick descriptions' are the main empirical material for the report.

The method used (data processing) is a kind of discourse analysis in order to deduce how meaning is constructed in these documents on the kind of society that is envisaged with Ambient Intelligence and on the pre-configuration of users in Ambient Intelligence. The origin and context of the reference documents for the AmI vision as such is also situated in order to engage critically with it.

Data are gathered**,** as a result, primarily via desk research. S&T policy & RTD documents and scientific reports and publications (prospective research, technology roadmaps, social studies of new technologies, policy-related socio-economic impacts studies of new technologies) are the main data sources used but also online media coverage of technology trends and specialised online technology watch websites are consulted to inform our analysis.

Moreover, primary data input to enhance the interpretative analysis of the report comes from another IPTS/ESTO[2] project on the Science & Technology Roadmapping (S&TRM) of Ambient Intelligence in Everyday Life (AmI@Life). S&TRM is a method used in prospective studies. It consists of the mapping, in a graphical way, current and future technological developments. It is used for displaying and synthesizing networks of past, present and future stages of S&T developments.[3] This project adapted the methodology of technology roadmapping to R&D policy intelligence by implementing a 'function-oriented' approach as an intermediate between technology-push and user-pull approached. It looks at identifying the key functions where AmI might make a difference, based on current-day everyday life practices and then looks at identifying and mapping the technologies needed to realise these functions. The main method used for the project, apart from analysing secondary studies[4], consists of interactive workshops where experts discuss the issues, functions, technologies and roadmaps for AmI@Life.[5]

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2 ESTO is the European Science & Technology Observatory**,** a network of circa 20 European scientific institutions that are mobilized and funded by IPTS to detect, at an early stage, and prospectively shape, scientific or technological breakthroughs, trends and events of potential socio-economic importance, which may require action at a European decision-making level. The ESTO core-competence therefore resides in trans-national prospective analysis and advice on science and technology changes relevant to EU society, economy and policy. http://esto.jrc.es/

3 See for a conceptual and methodological overview of S&TRM: Da Costa, O., Boden, M., Punie, Y. & Zappacosta, M. (2003).

4 Traditionally it is done within the fields of Technology Forecast, Technology Foresight and Futures Research. Most of these researches use Delphi-methods, meaning that expert opinions are used to determine what the direction of new technologies will look like.

5 IPTS/ESTO Science & Technology Roadmapping: Ambient Intelligence in Everyday Life, Draft Final Report, May 2003, IPTS-JRC, EC. See also Da Costa & Punie (2003).

2. The Ambient Intelligence vision

2.1. A paradigmatic shift in computing and society

Ambient Intelligence promises to transform the role of Information and Communication Technologies (ICT) in society and ultimately, to transform the way we live, work, relax and enjoy ourselves. It goes beyond the embedded computing capabilities that have already slipped into everyday appliances such as televisions, washing machines, microwaves, etc. It also goes further than the current use of mobile communications. It is a vision in which ICT, its applications and uses are both widened and deepened. "It is probably one occasion where the overused phrase 'paradigm change' is appropriate" because it implies a radical shift in such dimensions as the users of the technology, its incorporation into different spheres of living and working, the skills required, the applications and content provided, the scale and nature of the markets and the players involved (Miles et al. 2002: 4-9).

It remains to be seen if these changes will be realised but at the level of the vision of Ambient Intelligence, many different shifts are indeed assumed:

- A shift in computing systems from mainframe computing (1960-1980) over personal computing (1980-1990) and multiple computing devices per person (PC, phone, PDA, etc.) (2000 onwards) to invisible computing (2010 onwards).[6]
- A shift in communication processes from people talking to people over people interacting with machines to machines/devices/software agents talking to each other and interacting with people.
- A shift in using computers as a tool to computers performing tasks without human intervention.
- A decoupling of technological artefact and its functionality/use to multi-purpose devices/services.
- A shift in accessibility and networking from on/off over may access points to always on, anywhere, anytime.

In short, AmI implies a shift towards 'human centred computing' (e.g. Aarts, Harwig & Schuurmans 2001: 241). Ambient Intelligence as developed in the ISTAG report provides a vision of the Information Society where the emphasis is on user-friendliness, efficient and distributed services support, user-empowerment, and support for human interactions. It claims to place the user at the centre of future development. It provides guiding principles for how technologies 'should' be developed, thereby implying that in current-day technology development, this is not the case:

> *Technologies should be designed for people rather than making people adapt to technologies. AmI should also be unobtrusive, often invisible: everywhere and yet in our consciousness nowhere unless we need it. Interaction should be relaxing and enjoyable for the citizen, and not involve a steep learning curve (ISTAG 2001:11).*

The vision of 'invisible' computing, of computers moving easily from the periphery of our attention to the centre and back, is closely related to 'the future world', as seen by Weiser in his seminal article in the Scientific American in 1991:

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6 One could argue that already today, there is a lot of invisible computing in cars, household appliances, entertainment equipment and others but the idea of AmI is that this would increase exponentially and especially, that currently visible computing would move to the background.

The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it… This is not just a "user interface" problem… Such machines cannot truly make computing an integral, invisible part of the way people live their lives. Therefore we are trying to conceive a new way of thinking about computers in the world, one that takes into account the natural human environment and allows the computers themselves to vanish into the background. Such a disappearance is a fundamental consequence not of technology, but of human psychology…. Only when things disappear are we freed to use them without thinking and so to focus beyond them on new goals. (Weiser 1991)

More recently the assumed paradigmatic shift in computing and society is also reflected in the European Community Framework Programme 6 for Research and Technological Development, in particular in the overall vision of the Information Society Technologies program for 2003-2006:

IST today	***The IST in FP6 vision***
PC based	"Our surrounding" is the interface
"Writing and reading"	Use all senses, intuitive
"Word" based information search	Context-based knowledge handling
Low bandwidth, separate networks	Infinite bandwidth, convergence, ..
Mobile telephony (voice)	Mobile/Wireless full multimedia
Micro scale	Nano-scale
Silicon based	+ new materials
e-Services just emerging	Wide adoption (*e*Health, Learning,..)
< 10% of world population on-line	World-wide adoption

Source: EC 2002: 6.

It is clear that the AmI vision is compelling, far-reaching and ambitious. Some even argue that it is not just a new killer application but a 'killer existence', implying that it will fundamentally alter our perception of the world, our place in the world and our sense of self:

Whether we wear computers on our body, or have them embedded in our environment, the ability of computers to alter our perception of the physical world, to support constant connectivity to distant people and places, to provide information at our fingertips, and to continuously partner with us in our thoughts and actions offers much more than a new "killer app". It offers the possibility of a killer existence. (Abowd & Mynatt 2000: 31-32)

Whether the latter is realistic or desirable will be discussed later, but it clearly indicates that AmI - or in the case of the quote, ubiquitous computing - offers an encompassing vision on the future of computing in society and on society in general. To better understand the vision, in the next session, its context is situated.

2.2. Context of the AmI vision

Since AmI is more a vision of the future than a reality, it is per definition normative, implying a certain (desired) view on the world. It is vision promoted by certain people, companies and institutions. There is nothing wrong with that but in order to understand the vision, its context should be acknowledged.

A major step in developing the vision of Ambient Intelligence in Europe undoubtedly came from the above-mentioned Information Society Technologies (IST) Advisory Group. ISTAG has made consistent efforts for Information and Communication Technologies to get a higher level of focus and a higher pace of development in Europe. In 1999 it published a vision statement for the European Community Framework Programme 5 for Research and Technological Development (FP 5) that laid down a challenge to:

> *Start creating an ambient intelligence landscape (for seamless delivery of services and applications) in Europe relying also upon test-beds and open source software, develop user-friendliness, and develop and converge the networking infrastructure in Europe to world-class.* [7]

Following this vision statement, AmI became broadly embedded in one of the funding instruments of the European Commission, i.e. the IST work programme for 2000 and 2001. To help further develop a better understanding of the implications of an Ambient Intelligence landscape, a scenario exercise was launched as a joint exercise between DG Information Society and the Joint Research Centre's Institute for Prospective Technological Studies in Seville. It reported to an ISTAG working group chaired by Dr Martin Schuurmans (CEO of Philips Industrial Research). The scenarios were developed and tested in two interactive workshops with over 35 experts. This report (ISTAG 2001) has in the meantime become a reference document in the field because it not only developed scenarios on AmI but also identified major key technologies, socio-political issues and a S&T research agenda.[8]

The IST Advisory Group continued to develop the vision of AmI in preparation of the next RTD Framework Programme (FP6). The report was published at a time when confidence in the ICT sector had been shaken, by the burst of the dot-com bubble, by the September 11 events and by a more general slow-down of the economy. Therefore ISTAG argued for an urgent need of targeted and far-sighted investments in ICTs and for FP6 to be a-cyclical: "Those who will come out strongly during the next 'upturn' will be those who have maintained their investment in innovation during the present phase of the cycle" (ISTAG 2002: 3-4).

ISTAG anticipates that during the next ten years a new infrastructure paradigm will emerge: the 'Ambient Intelligence Space'. This is the collection of infrastructures technologies, applications and services that will enable the seamless interoperation of AmI applications and services. ISTAG (2002: 3) sees a real opportunity for Europe to establish a strong position in this new paradigm. In the report it makes ten recommendations to make this possible, ranging from mechanisms and methodologies to identify IST priorities over supporting activities for the realisation of AmI to targeted FP 6 efforts on the AmI Space.

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[7] ISTAG Orientations for WP2000 document (July 1999): www.cordis.lu/ist

[8] (ISTAG 2001) edited by Ducatel, K., Bogdanowicz, M., Scapolo, F., Leijten, J. & Burgelman, J-C. See: www.cordis.lu/ist/istag

Following the work of ISTAG and of other consultative procedures organised by the European Commission, AmI became the key concept in the FP6 IST program for the period 2002-2006. The overall vision is that the IST thematic priority will contribute directly to realising European policies for the knowledge society as agreed at the Lisbon Council of 2000, the Stockholm Council of 2001, the Seville Council of 2002, and as reflected in the e-Europe Action Plan[9]. The strategic goal for Europe in the next decade 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 greater social cohesion". This requires wider adoption, broader availability and an extension of IST applications and services in all economic and public sectors and in the society as a whole (EC 2002: 4-6):

> *The objectives of IST in FP6 are therefore to ensure European leadership in the generic and applied technologies at the heart of the knowledge economy. It aims to increase innovation and competitiveness in European businesses and industry and to contribute to greater benefits for all European citizens.*

To make this possible, AmI is seen as a key concept. Realising the vision requires, according to the IST program (EC 2002: 5), a massive and integrated research effort that addresses major societal and economic challenges and that ensures the co-evolution of technologies and their applications.

With ISTAG and the EU IST RTD funding program, considerable efforts are thus made in the EU to mobilise research and companies towards realising the building blocks for an AmI landscape. The budget of the IST FP 6 program for instance amounts to €3.6 billion for 4 years (against €16 billion for FP6 as a whole).[10] This is considerable, but to put it into perspective, it may be noted that Microsoft on its own spends a similar amount on R&D each year.[11]

The ITEA consortium (Information Technology for European Advancement) offers another pan-European funding program. This Eureka[12] project focuses on stimulating and supporting the development of software technology competencies to enhance to competitiveness of the European industry. ITEA brings together industries from (once) very different applications in the same technological area. Its *'Technology Roadmap for Software Intensive Systems'* also makes reference to AmI 'where the environment becomes the interface'. Building a common vision of future developments and needs is seen as an essential part in developing the roadmap and in supporting the competitiveness (ITEA 2001: 16-18, 64-65).

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9 See for respective documents: www.europa.eu.int

10 Official Journal of the European Communities, 29.8.2002, Decision No 1513/2002/EC of the European Parliament and of the Council of 27 June 2002 concerning the sixth framework programme of the European Community for research, technological development and demonstration activities, contributing to the creation of the European Research Area and to innovation (2002 to 2006).

11 Microsoft spend USD4.4 billion on R&D in the last year (June 2001 - May 2002) accounting for 17% of its total revenues. See 'The Corporote R&D Scorecard 2002', *Technology Review*, MITs Magazine of Innovation, December 2002/January 2003.

12 Eureka is a Europe-wide network for Industrial R&D through which industry and research institutes from 31 countries and the European Union develop and exploit the technologies crucial to global competitiveness and a better quality of life. It funds and support pan-European coöperatieve research and development. (see http://www3.eureka.be). Launched in 1999, with a total duration of eight years (€3.4 billion), ITEA has so far supported more than 50 projects, involving over 7,500 persons-years.

At national level, there is for instance the UK EQUATOR Interdisciplinary Research Collaboration (2000-2006) supported by the Engineering and Physical Sciences Research Council (EPSRC) focussing on the integration of physical and digital interaction, on addressing the technical, social and design issues in the development of new technologies (http://www.equator.ac.uk).

Consequently, RTD investments in both academia and industry[13] are being made and many experiments, prototypes and field tests are emerging in all parts of the world. There is a wide range and high intensity of activity going on in almost all the major research laboratories and universities in Europe and world-wide, as observed by Miles et al. (2002: 5) in a preliminary mapping activity. And with the start of FP6 in Europe, this is likely to increase.

Ambient intelligence thus offers a vision of a next wave in computing and networking with far-reaching societal implications that is promoted by industry, government S&T agencies, technical research laboratories and universities. It is a vision that mobilises professionals, companies and (technical) R&D resources. The goals are to support and stimulate innovation and the S&T knowledge base for growth, competitiveness and well being in the future information society.

2.3. The AmI vision driven by social and technological factors

With the advantage of preliminary hindsight, the idea of AmI can be traced back to technological progress, to the increased diffusion and acceptance of ICTs and to societal trends. Although less recognised in the literature, it is exactly the specific constellation of social - defined in its broadest sense - and technological factors that have enabled AmI to become a true vision of the future rather than being pure science fiction. It is argued that future research should make the socio-technological context of the Ambient Intelligence vision more explicit.

At the level of technologies, progress in the fields of microelectronics, of communication and networking technologies and of intelligent agents/user interfaces has made the conception of AmI possible.

Microelectronics has been driven during the last decades by Moores' law indicating the increasing capacity of computing power and storage at fixed costs. It has made computing capabilities (e.g. tiny, cheap processors with integrated sensors) becoming cheaper, smaller (miniaturisation) and faster in order for them to be embedded in potentially every object or device (Mattern 2003). There is already today a considerable amount of (invisible) computing available in non-Personal Computer products such as cars, household appliances, entertainment equipment, mobile phones and many others. With AmI, this would increase exponentially and especially also currently visible computing would move to the background.

During the last two decades, progress in communication and networking technologies has enabled the idea of these massively distributed embedded computing devices to become networked or connected. Breakthroughs in mobile,

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[13] Industry players use different terms for comparable visions on the future of computing. Philips for instance is a strong promoter of 'Ambient Intelligence' (http://www.research.philips.com) while IBM prefers 'Pervasive Computing' (http://www.research.ibm.com/thinkresearch/pervasive.shtml).

wireless and fixed (broadband) communication networks have increased the capacity (bandwidth), speed and availability of communication networks.

Also computing devices have become user-friendlier with the introduction of the Graphical User Interface (GUI) addressing the blank screen problem that confronted early computer users. The computer gave the user no (visual) indication what the user was to do next. A GUI consists of common characteristic such as windows, icons (e.g. trash can), menus, and push-buttons. It changes the looks and feels of a computer (the interface between the human and the computer) and allows the user to concentrate on the task (Jansen 1998).

Fist generation intelligent agents, i.e. personal software assistants with a certain degree of autonomy have been developed as well. There are many different approaches to agents (e.g. push versus pull agents) but they have in common that they execute tasks on their own authority, albeit initially defined by users or defined by adaptation and self-learning. Examples of existing agents are (personalised) e-mail alert agents informing the user about news, offers, events or changes (e.g. My Yahoo!)[14].

Technological progress in all these fields has contributed to the shaping of the AmI vision, but at the same time, progress in the diffusion and acceptance of past and current ICTs was mutually important. In 10 years time, GSM has grown in Europe to more than 300 million subscribers. In many European countries, penetration rates of mobile phones are above 70% of households. And SMS has given a considerably boost to the mobile services market during the last years. Internet access from home has increased in the EU15 to 40% in June 2002 (against 28% in October 2000) (Eurobarometer 2002). If the increased diffusion and usage of computer, Internet, mobile phone and PDA had not happened, technological progress in these fields would have slowed down.

And acceptance of these technologies is enabled by demographic and social trends such as the emergence of individualism, diversity, mobility, and choice of personal life styles, affecting the structure of groups and community and the ways we live and work. Mobile phones for instance are enablers of lifestyles that are increasingly individual and mobile. Also household structures (family size and composition) are changing, with a decline of traditional nuclear families and an increase of dual income households and single parent/single person households. This causes a lot of everyday pressures, for example on time budgets (Ducatel et al. 2000, Gavigan et al. 1999).

The point is that although technological progress has made the idea of AmI possible, it would probably not have existed if many of the existing ICTs had not been taken up by the consumer market, the latter being driven by demographic and social trends.

Moreover, many of the so-called technological advances are only made possible by the specific socio-economic context in which they are developed. Take the example of Moores' law. It is typically seen as a technological law, i.e. a doubling of the performance of electronic components every 18-24 months at fixed price. But as Tuomi (2002) argues, this prophecy could only hold because of the unique

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14 http://www.cybion.com/ressources/agents_veille.htm; http://www.cs.tcd.ie/research_groups/aig/iag/survey.html

economic and social conditions under which the semiconductor industry operated during the last decades. Moores' law alone was not responsible for that. Tuomi thereby criticises the technological and economic deterministic way in which the law has been used.

Another example is the European success of GSM. Technological progress has enabled this but the European efforts to agree on a common standard, the Global System for Mobile communications, undoubtedly have contributed to its success.

To summarise, although it seems that the vision of Ambient Intelligence is based on technological progress in the fields of microelectronics, communication networks and interfaces, it is also driven by socio-economic factors that go beyond the technologies alone. The problem might be that these are less visible and therefore less acknowledged. A challenge for future research is to make the socio-technological context of the Ambient Intelligence vision more explicit. This would also help to highlight its societal dimensions, as is elaborated in the next section.

2.4. Vision building and ideological claims

Clearly today, AmI is more a vision of the future than a reality. As we know from preceding visions and from forecasting studies, the future reality will most likely be very different from the way it is predicted today. The question therefore, seems to be less relevant if the vision will be completely realised as proposed. It is relatively easy to challenge any vision on the basis of its (un-)realism. Visions seem to face a paradox: the more innovative and futuristic they become, the less they will be grounded on realistic assumptions. The more they are based on the latter, the more difficult it becomes to be really compelling and provocative. Good vision building needs to face a balance between both.

The objective of vision building is to provoke discussion, to depict possible futures and crucially, to mobilise resources into the same direction. Especially the latter is regarded a crucial function of technology roadmapping for instance (See for an overview on roadmapping: Da Costa et al. 2003).

But this should not imply that it is not needed to critically engage with the underlying assumptions of visions. In the above mentioned table on the shifts in computing and society from the EC FP6 IST program for 2003-2006, it is mentioned for instance that world-wide adoption of Internet by 2006 is envisaged. This is rather optimistic, to say the least, and although it is part of the vision-building process, such claims are not realistic.

It should also be noted that technological vision building is not new and that it typically promises a better world. Looking back to the time when 'old technologies were new' (Marvin, 1988) can be useful to put the rhetoric's about the home of the future in perspective. A century ago 'the electrification of private life' and the 'mechanisation of the household' were important issues (Flichy 1995). Forty (1986: 183) describes how electricity was represented as the 'fuel of the future', as a liberating technology promising a clear, clean, healthy and efficient way of life. This discourse served the purposes of the industry looking for ways of using the electricity network outside working hours, i.e. in the home environment. It took place at the end of the 19^{th} century in a period where public and private life became increasingly separated as distinct and gendered spheres for production (work, public activities) and reproduction (leisure, family life, personal identity, care). The home was ideologically and symbolically represented as a 'haven in a heartless world'.

Also the discourses surrounding the introduction of the telegraph, telephone, radio, TV and Videotext consisted of promising a better, faster and happier world. Every time a new technology pops up, revolutionary social changes are promised on the basis of breakthroughs in technologies. The problem with these visions is that they are technological deterministic. They only look at what is technological feasible and have a simplistic account of how social change occurs by ignoring the social and user dynamics involved in the innovation process (Burgelman 2001: 215-216).

In order for Ambient Intelligence to go behind the recurring one-sided claim of consumer technology throughout the twentieth century that it will simplify our lives, save time, and liberate us from toil (Langdon Winner, quoted by Bohn et al. 2003), its societal and user implications should be made more explicit. This would enable crucial questions to be answered such as:

- What kind of society is envisaged with Ambient Intelligence?
- How are the users configured in Ambient Intelligence?

In the Ambient Intelligence scenarios for 2010 developed by ISTAG, a first attempt has been made to deal with these questions.

2.5. ISTAG Ambient Intelligence Scenarios and human-centred design

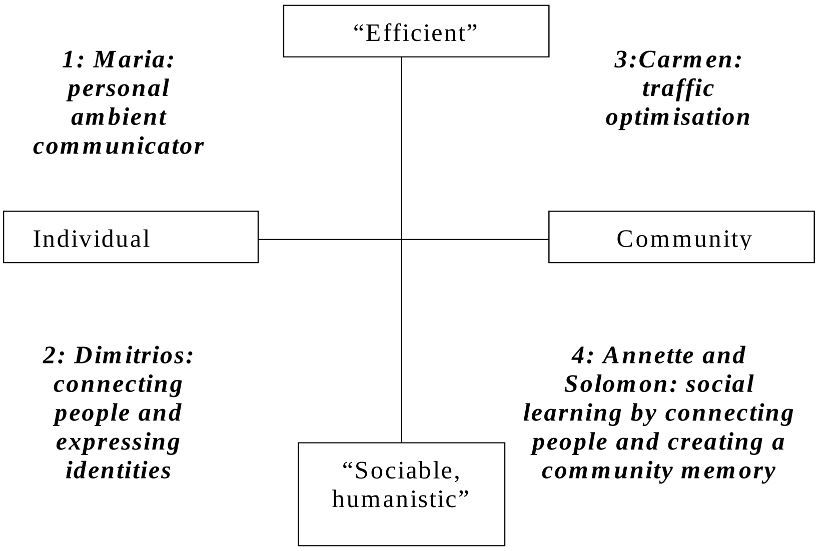
The central feature of the ISTAG AmI scenarios, as argued in the ISTAG report, is that people (not just 'users', 'consumers' or 'employees') are at the forefront of the Information Society. This vision of people benefiting from services and applications whilst supported by new technologies in the background and of people interacting via intelligent user interfaces was essential to the ISTAG notion of Ambient Intelligence (ISTAG 2001: 3).

The four scenarios that are developed in the report underscore this view. They are based on the following structuring differentials:

- Economic and personal efficiency versus sociability/humanistic drivers (goals);
- Communal versus individual as the user orientation driver (actors).

They contrast applications that serve to optimise efficiency (whether in business or in society) against those that emphasise human relationships, sociability or just having 'fun'. They also underline the place of Ambient Intelligence in serving society and the community as well as individuals. The scenarios are not 'orthogonal' in the sense of giving clearly distinct alternative trajectories. Rather they are complementary and sketch out different design emphases and pathways towards Ambient Intelligence (Ibid: 16-17).

Figure 1: AmI scenario scheme



Maria is the business executive scenario where all communications and actions (private and public) necessary on a business trip are being taken care of and handled by a P-com (personalised ambient communicator) she wears on her wrist. The emphasis is on individual efficiency. No major changes in user behaviour are assumed.

Dimitrios wears a digital-me (D-me) that knows perfectly well his social and personal data and communication preferences and handles accordingly. The emphasis is on play and social interaction rather than 'efficiency'. The changes in behaviour relate mainly to the willingness to reveal (or disguise) personality on-line. Price could be a barrier to a break through to a mass market.

Carmen is the scenario where AmI is used to optimise traffic and goods delivery by creating smart traffic and smart delivery in order to minimise ecological impact and maximise urban efficiency. Carmen is further out on the time horizon because it implies major infrastructure developments. It also makes significant assumptions about changes in public behaviour such as accepting ride shares and traffic management systems.

Annette and Solomon use AmI to enhance the learning experience on a spontaneous basis and to establish a 'collective learning memory'. This scenario is probably the furthest out in terms of time because it implies significant technical developments such as high 'emotional bandwidth' for shared presence and visualisation technologies, or breakthroughs in computer supported pedagogic techniques. In addition, the scenario presents a challenging social vision of AmI in the service of fostering community life through shared interests (Ibid: 13-14).

According to ISTAG (2001: 11-12), the social and political aspects of AmI will be very important for its development. A series of necessary characteristics that will permit the eventual societal acceptance of AmI were identified. They are proposed as possible RTD design guidelines:

- AmI should facilitate human contact.
- AmI should be orientated towards community and cultural enhancement.
- AmI should help to build knowledge and skills for work, better quality of work, citizenship and consumer choice.
- AmI should inspire trust and confidence.

- AmI should be consistent with long term sustainability – personal, societal and environmental - and with life-long learning. In essence, the challenge is to create an AmI landscape made up of 'convivial technologies' that are easy to live with.
- AmI should be controllable by ordinary people – i.e. the 'off-switch' should be within reach: these technologies could very easily acquire an aspect of 'them controlling us'. The experts involved in constructing the scenarios therefore underlined the essential need that people are given the lead in the way that systems, services and interfaces are implemented.

The scenarios are all situated at the human interface. This emphasises a key feature of AmI, which is that the technologies should be fully adapted to human needs and cognition. AmI represents a step beyond the current concept of a 'User Friendly Information Society'. There is a risk, in the scenario of Maria, of the technology driving a high-pressure lifestyle. But the Dimitrios scenario indicates AmI could also act as a facilitator of 'human interaction' especially with friends, family and colleagues. It will be important that AmI builds on its 'community' enhancing potential though offering opportunities for interest groups to develop their own applications (Annette and Solomon) (Ibid: 16-19).

In short, the ISTAG AmI scenarios recognise the need for AmI to be driven by humanistic concerns, not technologically determined ones. This position goes against the tendency of mainstream vision building and technology foresight to be technology deterministic. It remains to be seen however if and how this manifesto will further influence research, development and design of AmI applications. If the human-centred design and development guidelines remain at the level of discourse, and as a result, if they are not translated into real-world actions, then the Ambient Intelligence vision may not be very different from earlier technological visions. It would then only typically promise a better world without taking into account our everyday lives in the real world**.**

The difficulty with human-centred design of AmI is however that is far from clear how this can be realised. Most of the current day system and application design is technology driven. The reason is, according to Riva et al. (2003), that little knowledge and tools are available to incorporate user behaviour as a parameter in system design and product development. A strong effort must be made in the direction of user modelling to achieve in user understanding the same level of confidence that exists in modelling technology.

It should be noted though that some activities towards user-centred design are already developed, such as the ISO 13407 "Human-centred design for interactive systems" (Cf. infra), the "Design for all" standards for accessibility of information technology products promoted by the European Commission, the issue of user evaluation in ambient displays (e.g. Mankoff et al. 2003) or user-oriented definitions of context-awareness (Dey 2001).

Most of these activities are probably mainly based on functional descriptions of how to involve users in the design process. This constitutes a first logical step, but 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. This would go in favour of more ethnographic (e.g. Crabtree 2002, Dewsbury et al. 2001), in-depth studies of users, in for instance, real life settings or so-called living labs. Technology designers seem to believe however that these techniques are too costly and too time consuming to take them on board (e.g. Mankoff et al. 2003). Ethnographic and/or qualitative user studies indeed require considerable investments – more in time than in money however – but rather the question should be if the results it would justify the efforts or not. In section 3.5, a reflection is made on how the Ambient Intelligence vision and scenarios could benefit from a more radical everyday life perspective. But first, in the next section, an overview is given of other socio-economic and policy-related issues that are raised in relation to AmI.

3. Socio-economic and policy-related issues

In this section, a selective overview is provided of the social, societal, economic and policy-related issues that are raised in the literature on Ambient Intelligence/ubiquitous computing.

3.1. From a digital divide to an Ambient Intelligence divide?

According to the Lisbon European Council of 2000 and the e-Europe 2005 Action Plan, the European Union is committed to developing, amongst others, 'an information society for all' and to enable all European citizens to benefit from the knowledge society.[15] The Lisbon process clearly stated that the European knowledge based society should also be a socially inclusive one. This places notions of the digital divide on the policy agenda. It is of concern to policy makers that (new) technologies should not become a (new) source of exclusion in society.

The term 'digital divide' is used and defined in many different ways. It can be observed between regions (e.g. North and South), nations, companies, households and individuals (within nations and across nations; with or without disabilities). Research[16] also suggests that the digital divide is not just a question of access to telecommunications and ICTs services (e.g. Internet) but also of skills, competences, appropriate content, access to the necessary resources (e.g. time and money) and different ways in using ICTs. Voluntary exclusion is also to be taken into account.

Although the diffusion and penetration of ICTs in Europe, especially of Internet and mobile phones have increased substantially during the last years, recent empirical data confirm the persistence of digital divides at different levels (e.g. Corrocher 2002, Eurobarometer 2002; de Haan et al. 2002). At the individual and household level, differences in ownership and usage of ICTs still seem to exist, for instance, between the younger and the older, and between the higher educated financially well-off families and the lower educated, poorer families. Socio-economic criteria (age, sex, education, income, family composition) do influence not only user acceptance but also users' attitudes towards and knowledge of new technologies and their availability of resources (time and money) as well (e.g. Punie 2003, Frissen & Punie 2001). And although women are catching up, gender difference persist in ICT usage, both in terms of quantity (e.g. time spent on the internet) and in terms of quality (e.g. the way ICTs are used).

The question is if and how digital divides will be translated into Ambient Intelligence divides once AmI becomes gradually and partially implemented. It is of course difficult to anticipate or predict the possible acceptance of AmI, but it can be argued, on the basis of current and past research, that people do not accept everything that is technologically made possible and supplied.

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15 Brussels, 28.5.2002; COM (2002) 263 final, eEurope 2005: An information society for all. An Action Plan to be presented in view of the Sevilla European Council, 21/22 June 2002.
Lisbon European Council: Presidency Conclusions, Press Release: Lisbon (24/3/2000) Nr: 100/1/00. www.europa.eu.int

16 See for instance Wyatt et.al. 2002; Gurova et.al 2001, but also www.digitaldividenetwork.org and other EMTEL Deliverables on inclusion/exclusion (www.emtel.org).

Looking back at the introduction of past ICT innovations, it seems that many unexpected failures and surprising successes occurred. In fact, may of the past forecasts on the success of new media proved to be completely wrong (Burgelman 2001: 216-218). In the mid-1980s for example, Videotext was predicted to become the new mass medium in Europe. All European countries invested heavily in it, but apart from the Minitel in France, it never took off (See for an overview on Videotext: Bouwman & Christofferson 1992). Another example is the CD-I, promoted by Philips in the late 1980s as the new multimedia revolution in the home, but abandoned after years of fierce marketing. On the other hand, the recent success of text messaging in Europe surprised most experts and analysts, and also mobile phones surpassed initial expectations. Of course many different factors (e.g. price, content, added value for users, standards) have contributed to both these failures and successes but amongst them are the input and role from the public.

Ambient Intelligence promises to remove some of the barriers for the acceptance of new technologies and thus challenges current thinking on use and acceptance of ICTs. AmI exactly addresses certain issues that are at the core of the digital divide debate, i.e. user-friendliness, relevant (context-aware) services and natural interfaces. The latter for instance envisage human-machine interactions to become more like the way humans interact with each other in the real world (via speech, gesture, touch, senses). It is thought that this evolution away from desk-top graphical interfaces (Cf. Section 2.1 on paradigmatic shifts) would make it easier and faster for everyone to learn to use ambient devices and services (e.g. ISTAG 2002: 29). Therefore, they would attract also the non-users who today lack the skills and competences to use ICTs. Marc Weiser (1991) went even further in its belief that Ubiquitous Computing would penetrate all groups in society and thus be accessible and usable for every citizen, company and country in the world.

Even if AmI is adapted to people and even if interaction will be relaxing and enjoyable for the citizen, and would not involve a steep learning curve (ISTAG 2001: 11), it is difficult to believe that AmI will be able to appeal to all groups of society, certainly not in a similar way and at the same time. Given the above mentioned socio-economic differences and given peoples individual preferences, there will probably always be 'early adopters' and 'late adopters'[17], and even people who will resist to Ami. Although AmI puts huge emphasis on its user orientation and although the above mentioned human-centred design and development guidelines might constitute a step forward[18], there are no guarantees that users will indeed embrace AmI in the way it is proposed or developed today.

Moreover, new and other concerns possibly affecting universal access to and use of AmI services and devices are likely to emerge. New skills, competences and types of literacy could emerge. They could include content selection, content interpretation and creative and innovative thinking (Bogdanowicz & Leyten 2001: 274-275). ISTAG

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[17] The notion of different adopters groups (innovators, early adopters, early majority, late majority and laggards) has been developed by E.M. Rogers, already in 1960s and regularly updated (e.g. Rogers 1995). It introduces a time dimension in the diffusion process, i.e. that not all people adopt innovations at the same time. These adopter categories and other aspects of the diffusionist tradition have been criticised because of their linear, mechanic and behaviouristic connotations (e.g. people can be, in one case early adopters and in another case late adopter) but its time dimension as such seems to remain valid. See for a review and critique of this tradition: Frissen, V. & Punie, Y. (2001).

[18] See Islam & Fayad (2003) and Stephanis (2001) on the need for designing Ambient Intelligence systems in heterogeneous and flexible ways in order for them to appeal to a diversity of users and users.

(2001: 17) sees new skills arising in relation to social know-how and information manipulation. As Ami will increase the means of personal expression and interaction, people will need to learn how to deal with their digital identities and intelligent agents. This also raises concerns over the protection of privacy as will be touched upon in the next section on privacy and security. The privacy invasive potential of AmI might indeed be one the barriers in the social acceptance of AmI. As experts from Philips argue, the question is 'whether people will be able to adapt to the feeling that their environments are monitoring their every move, waiting for the right moment to take care of them' (Aarts et. al. 2002: 249).

3.2. Privacy, security and surveillance

As our lives, homes, cars, neighbourhoods, cities and other environments become increasingly digitized and connected, more and more personal information will be digitally gathered, stored and possible disclosed to other sources, services, institutions and/or persons. This concerns not only basic personal identification data such as age, sex and location but also information and communication content such as events information (past, current and future), working documents, family albums (pictures, video, chat) and other medical and financial records (Beslay & Punie 2002).

With Ambient Intelligence, the monitoring and surveillance capabilities of new technologies can be massively extended beyond the current credit-card and shopping records (e.g. consumer loyalty cards), Internet logs (e.g. e-mail, news postings, discussion forums) and detailed phone invoices.[19] This is possible not only because this intelligent environment is able to detect and monitor constantly what people are doing in their everyday lives, both offline and online, but also because of the possibility to connect and search isolated databases containing personal information. Some argue it might even mean the end of privacy (Garfinckel 2001) 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 latter being one of the first (liberal) definitions of privacy developed by Samuel Warren and Louis Brandeis (1890).

Monitoring and surveillance techniques create new opportunities for so-called 'border crossings' between what is public and private. Gary Marx (2001) identified four borders and argues that the crossing of these borders usually implies that people feel their privacy is invaded. These are natural borders (e.g. walls, doors, clothing, telephone calls, facial expressions), social borders (e.g. social norms and rules indicating expectations about confidentiality and privacy), spatial and/or temporal borders (e.g. conveying only different parts of our identity to different people) and ephemeral or transitory borders (e.g. things or information that go lost or are forgotten).

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19 Moreover, not only humans could be permanently surveyed, also everyday objects that are augmented with sensors or tags. They would never get lost and would have a memory, i.e. a travelling back carrying information on where it was at what time. According to Arraya (1995: 234-235), objects becoming 'surveillable' things would transform fundamentally the human-world relationships. It would mean that humans tend to become unaware of the difference between a digital surrogate and that what it represents. When objects can permanently be identified and traced, they would loose their property of getting lost, their 'otherness'. A fundamental category that governs our dealings with the world would have been deeply altered, and according to Arraya, not necessarily for the better.

The problem is not only that the borders between both are fluid, relative, multi-dimensional and depended on context, situation, culture and personal preferences (Marx 2001) and therefore difficult to generalise, but also that with new AmI technologies, the crossing of these borders becomes easier and possibly more likely. In the name of personal, private or public/national safety and security, monitoring and surveillance could be done by individuals (e.g. spying on your neighbours[20] or on other people[21]), companies (e.g. tracking products[22] and making consumer profiles) and nation states.

The privacy dilemma is that AmI 'needs' to contain historical and current data about individuals' preferences and activities (user profiles) in order to deliver context-dependent, value added, pro-active services. A crucial but inevitable trade-off between having privacy of certain personal information and receiving convenient, efficient services will have to be made (e.g. SRI: 2003).

In traditional societies, access to personal and/or sensitive information was mainly restricted by physical barriers of proximity (e.g. a closed door). Even today, physical space provides observable signs for entering public or private spaces and their perceived levels of privacy. In cyberspace, this is not the case. There are no visuals cues that indicate differences between online private and public spaces. Few social and legal indicators are available for Internet users to judge where private digital territories start or end, nor are there social norms – except for the netiquette – to discourage people from entering private online spaces (without authorization). Already today, ICTs enable the blurring of the physical boundaries between public and private spaces and with cyberspace becoming more and more important in our everyday lives, it can be assumed that this process will be intensified. This lack of indicators does not only imply technological challenges but also urges for clarifications of the social and legal framework of AmI (Beslay & Punie 2002).

Privacy concerns are not only related to accessing private only spaces without clear indicators or prior knowledge of doing so, but also to the digital footprints Internet users leave behind when being online. Newcomers on the Internet typically assume that their activities in cyberspace are private since no one in physical space is observing them as they use their computers. Unless they have been explicitly made aware of the fact that 'click stream data' or 'mouse droppings' leave 'electronic footprints' that become a detailed digital record, they would not realize this was occurring. The automatic capturing of personal information via IP numbers or cookies for instance is not clearly signalled, nor are users noticed about it.[23] People

[20] Privacy invasive threats are usually defined as coming from governments and/or private companies but with AmI technologies becoming available for everyone, people could start to watch each other. Already today, with wirelessly connected CCTV (Closed Circuit TV) it is possible to watch your neighbors with security cameras installed to protect the home. The former obviously raises privacy concerns. See for instance: 'Wireless cameras raise privacy fears', *Newscientist*, 17 May 2003. www.newscientist.com

[21] Just recently, the president of the YMCAs of Australia proposed to ban all mobile phones with a camera from swimming pools across Australia as a 'proactive response to a potential problem' (illicit photographs). BBC Online, 12/06/2003.

[22] For example the recent controversy about the plans of clothing company Benetton to embedd RFID sensors in order to track each peace of clothing, even after it leaves the chops. E.g. 'About What Your Clothes Say About You', http://www.wired.com/news/wireless/0,1382,58006,00.html

[23] It can be argued that today internet user are already informed about the collection and possible use of personal information via 'privacy notices' or 'information practice statements' on websites, but these are typically small font notices users have to look for. Visual cues could be more effective.

may also be unaware that personal information about them is available via search engines. Standard Internet search facilities can today already be used to gather information about where people live and work and what their interests are (Regan 2002: 383-388).

There are possibilities for individuals to control or restrict the flow of personal information but the market in personal information tends to place the burden and cost of this with the citizen. Since information about people is a resource for organizations, they will collect as much as they can unless internal or external costs become too high. Organizations are unlikely to act unilaterally to make their practices less privacy invasive. According to Regan (Ibid: 397-400), unless choices are easy, obvious and low cost, people will go with the default and the default in cyberspace is privacy invasive. As a result, the privacy level available online is less than what the norms of society and the stated preferences of people require.

Without effective privacy protection measures, this brave new world of smart environments and interconnected objects could become an Orwellian nightmare (Mattern 2003; Bohn et al. 2003; ISTAG 2001). Addressing the balance between privacy and security will be a core challenge for the future of Ambient Intelligence. For people to feel at home within AmI, it needs to be able to represent their multiple identities, respect their privacy and establish an acceptable level of security (Beslay & Punie 2002).

Technology can do a lot to protect privacy, but in reality, "it can only safeguard privacy. Figuring out what the safeguards ought to be, and where our zone of privacy actually lies, is a matter of policy, law, and ultimately, social norms". Legal and social questions have to be dealt with in relation to being able to have a say in what information is collected about you and how that information is going to be used. This concern about privacy is part of a larger concern about control, about people having control over their own lives (Waldrop 2003).

This is related to fostering trust and confidence among users, the latter being regarded by the IST program (EC 2002: 5) as one of the major societal and economic challenges to be addressed for the realisation of AmI. Therefore also, AmI should be under control, reliable and dependable, as raised in the next section.

3.3. Control, reliability and dependability

AmI assumes everyday live to be very dependent on its technological surrounding so logically, there is a fear for the loss of control. As noted by ISTAG (2001: 19) AmI should be controllable by ordinary people, i.e. the 'off-switch' should be within reach. These technologies could very easily acquire an aspect of 'them controlling us'. Therefore it is underlined that people are given the lead in the ways that systems, services and interfaces are implemented. AmI should be controllable by ordinary people (ISTAG 2001: 19). Users should know what is happening behind their backs and should be able to control this (Abowd & Mynatt: 51-52).

Otherwise, as raised by R. Lucky (1999) in an IEEE Spectrum column, people could feel to be surrounded by enemies or traitors:

> *My car reports to the local gas station in the evening when it is low on gas, so that it can be filled at night and ready for me in the morning. I like this service, but my car is no longer the friend I once knew. If I exceed the speed limit, it reports me, and if I try to park illegally, it refuses to turn off or to let me open*

the door. With integrated GPS, it continually reports my position. I want to disengage these features, but the car comes with a shrink-wrap agreement whose legalese implies that the purchaser has only licensed its capabilities without any true ownership. The car now owes its primary allegiance to the new mega-company, Motorsoft. I study the car in the quiet darkness of the garage, trying fruitlessly to discern its vulnerabilities. I feel surrounded by enemies and traitors.

Issues of control are especially relevant in relation to intelligent agent technologies executing tasks on their own authority and autonomy. Although under human supervision (e.g. users' consent for an action), users will have to delegate some control and decision power to these software agents in order to benefit from their services (e.g. reducing information and/or communication overload) (Rieder 2003). Any kind of agent-based negotiations or collaborations can only succeed if there is trust and confidence, for instance, that the agents will represent the user at least as effective as the user would do in similar circumstances (Luck et al. 2003: 51-53).

Another aspect of control is that AmI needs to be dependent, reliable and predictable. If technologies do not deliver what they promise; if they do not react in ways they are supposed to react; and do not function when they are needed, then, it will be very difficult for them to be accepted by the public (Beslay & Punie 2002: 21). With an exponential increase in networked devices and appliances, the probability of failure for any single device increases proportionally, so it is highly desirable to achieve a high degree of robustness and fault tolerance. Moreover, accountability is an issue, i.e. if the system makes an error, who is going to be responsible (Bohn et al. 2003)?

The difficulty with intelligent agents is that they are almost per definition less predictable than current-day computers. A traditional computer command always triggers the same action(s), regardless of time or situation. But agent software has the ability to learn, to adapt its configuration and even its program structure. As a result, an agent may react differently on the same command at different points in time. In facts, as agents learn, their behaviour becomes less predictable (Rieder 2003). Otherwise, they would not be regarded as intelligent or smart. People will have to learn to deal with these issues, raising again new skills and competences needed with AmI (Cf. infra AmI divide) and highlighting the importance of trust and confidence.

3.4. Business models, open source and standards

Given the rich diversity of technologies featured in the AmI landscape and the broad variety of potential applications, it is believed that the economic prospects for AmI are legitimizing current and future investments. But there are many questions about how to build upon existing and emergent socio-economic demands and how to make money out of AmI, especially after the negative experiences of the dotcom bubble. ISTAG 2001 experts recognized that the business-case for AmI is not self-evident, but identified five main drivers of demand for AmI:

- Improvements in the quality of life (including satisfying intangible needs such as better community life and health as well as rising material demands);
- Enhancements in the productivity and the quality of products and services, and applications in process innovations;

- New and emerging AmI firms will themselves be a key source of demand for AmI because of secondary demands for new products and services;
- Applications of AmI in industrial innovation and new products (e.g. household and office equipment, clothes, furniture);
- Applications in public services, e.g. in hospitals, schools, police or the military. (ISTAG 2001: 16)

The question is how these drivers will be translated into real applications but envisioning and realising concrete, attractive applications in ways that are affordable for businesses is not easy. The potential seems to be very high, if objects can co-operate with each other, can access any information stored in databases or on the Internet, and can use any suitable Internet-based service available. For instance, an automatic lawn sprinkler will profit not only from being networked with humidity sensors in the ground, but also from obtaining the current weather forecast from the Internet. Another example is pens that digitise everything they write, and communicate this to an appropriate location. Many more applications are imaginable. The limits are less of a technological nature than of an economical one (Mattern 2003).

But the idea of finding and betting on the right 'killer application' might also be not the best way forward. Given the flexibility and adaptability AmI promises, its goal would be to provide many single-activity interactions that together promote a unified and continuous experience between humans and computational services. The objective is not a single interface or single application to accomplish all tasks, according to Abowd & Mynatt (2000: 53-54) but a general-purpose utility (and challenge) of combining ubiquitous interaction with computational resources. Probably an amalgam of minor improvements in everyday activities and compelling applications will drive the move towards AmI rather than assuming that the one and only killer application will do the trick.

AmI could contribute to changes in the economy, in the way business is done. Since it enables, through RFIDs for instance, to obtain extensive real-time information on the location and delivery of products, services and people, the just-in-time trend could be extended towards 'now economies'[24] whereby extensive stocks are reduced and thus costs are saved. For consumers, this could generalize the 'pay-per-use' model that already today is explored in relation to digital rights management. Downloaded music that for small amounts of digitally exchanged money can be listened to only ten times after which it would become inaccessible. It would mean that the traditional ownership model disappears in favor of non-stop paying for usage (or a combination of both models). Almost any object equipped with sensors and communications capabilities is suitable for pay-per-use leasing rather than outright purchase. People will be able to shop on the move, on the streets, in buses for any product they come across (e.g. cloths that other people wear). Smart objects can also do purchases on their own (e.g. photocopier ordering paper) (Bohn et al. 2003)

The economy as a whole could also benefit from AmI. Through its access and usage of real-time information, it can contribute to a more sustainable economy via optimization of the use of resources (e.g. energy, water), via monitoring and prevention of pollution and via reducing risks to safety (e.g. food) and health. It

[24] Siegele, L., How about now? A survey of the real-time economy. The Economist, 362(8257):3-18, January 2002. Quoted by Bohn et.all. 2003.

could favor environment-friendly consumption via dynamic taxing schemes (e.g. lower taxes on biological food, lower prices for products close to date of validity). A smart refrigerator could, for example, recommend healthy eating tips (Ibid).

But despite a whole range of economic advantages, there are many dangers and risks associated with the use of AmI in the economy. An automated economy with little human intervention faces the risk of collapsing when software malfunctions appear. Reliability and dependability will be crucial (Ibid). Also, as products become smarter, companies might use these possibilities to the extreme in trying to influence and manipulate consumers (e.g. via interactive, personalized marketing). If automatic purchases are made, companies will try and use powerful software to make sure that their products are on top of the list. How transparent will this system be?

In addition to possible drivers and business models (e.g. stand-alone products and service models), ISTAG identified the development of common platforms and standards as one of the key requirements for AmI since it is based on seamless interoperation of many different devices on many different networks. This could be achieved through a deliberate effort to develop open platforms or could arise from proprietary pacts between industrial suppliers. The adoption of a common standard for mobile communications (GSM) in Europe, has contributed significantly to its success.

3.5. Questions and issues from a 'domestication' perspective

3.5.1 Introducing the domestication perspective

Domestication is an approach for studying the information society from the users' point of view by focusing on the acceptance of, or resistance to ICTs within the context of everyday life. It is inspired by social-constructivist approaches to science and technology, by audience and user research in media studies and by the sociology and anthropology of everyday life. Domestication (Merete & Sørensen 1996; Silverstone 1994) refers to the capacity of individuals, families, households and other institutions to bring new technologies and services into their own culture, to make them their own. Domestication conceives the ICT innovation process as an interactive process between social and technological change whereby users and non-users play a crucial role – as well as other social actors such as producers and designers – in the construction of meanings to technologies and in accepting, modifying and/or rejecting them. [25]

Domestication as a qualitative approach can be seen in contrast to more quantitative approaches to studying the user side of technological innovations. Until the mid-eighties of the past century, the 'diffusionist' approach was one of the major research strands in this field. 'Diffusion' refers to the macro-process by which innovations become accepted in a specific social system, while 'adoption' refers to the individual process of acceptance on a micro-level. Most prominent for this perspective is E.M. Rogers with "the diffusion of innovations", now in its fourth revised edition (Rogers, 1995; first publication in 1962). By looking at the diffusion of innovations through time, differences among users in their adoption of innovations resulted in the well-known distinction between innovators, early adopters, early majority, late majority and laggards. On a macro level this temporal

[25] See also other EMTEL Key Deliverables for a more detailed description of domestication patterns.

model enabled Rogers (1995: 257-258) to describe the diffusion process in terms of another well-known feature, i.e. the S-curve for diffusion.26

Various constructivist approaches (e.g. Bijker, Hughes & Pinch 1987; MacKenzie & Wajcman 1985) to the study of science and technology have criticised this understanding for, among other things, its deterministic, behaviourist, linear and overtly rationalistic conceptions of the process of innovation. Constructivist approaches have rejected the technological determinism that lies at the heart of such theories, where technology is perceived to develop independently of society, having a subsequent impact on societal change. On the contrary technologies are seen as social constructions whereby 'seamless webs' of technical, social, economic and political actors and factors shape the development of technologies. Initially these approaches focused on the development and design of technologies but did not pay enough attention to the use of the technologies. As Akrich argued, they stopped 'à la porte de l'usager' (Akrich, 1990: 84). However during the 1990s this gradually changed and the 'domestication approach' was a vital contributor to this change. Within constructivist theories technological development is regarded as a process, a mutual shaping process where technology and society are shaped at the same time.

Domestication, with its focus on cultural integration processes in everyday life, has among other things provided a fruitful analytical approach to the study of how these processes take place (Berg 1996). It highlights that the process by which new technologies are accepted into everyday life is far more complicated than usually is portrayed. That is because 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. This means that ICTs are negotiated within household and/or everyday life structures and patterns that are entrenched by power relations. An everyday life perspective exactly implies that the power relations of class, gender, age, ethnicity and others are taken into account.

Domestication is thus not necessarily harmonious, linear or complete. It is presented as a struggle between the user and technology, where the user aims to tame, gain control, shape or ascribe meaning to the technological artifact.

> *"By domestication I mean something quite akin to the domestication of the wild animal…a process of taming or bringing under control. Technologies, television and television programmes must be domesticated if they are to find a space or place for themselves in the home" (Silverstone, 1994: 83).*

Domestication also means there is a difference between ownership, usage and integration of ICT's in everyday life. Technologies can be owned and not used but they can also be used without being domesticated. The latter indicates a state of mind whereby ICT's are not merely perceived as technologies, as machines, but rather as 'natural' or taken for granted. From this point of view, it is noticeable that relatively few ICT's are really domesticated. In fact, only television, radio and telephone (including mobile) have acquired that status, in contrast with computers,

[26] The S-curve visualises that in the beginning of an innovation process only a limited number of people talk about this innovation and in fact buy the new product. This principally gives the innovation process a slow start. As a growing number of people accept the innovation, people will talk about it more and this will lead to a higher degree of adoption in a faster speed. After a while, the diffusion process will slow down again when the last categories of reluctant users will be seduced to buy the new product.

the Internet and the VCR. These are still regarded as technological artefacts (Punie 2003).

Characteristic of this approach is also that technological objects, such as ICTs, are not only seen as material objects. Their meanings are both functional (e.g. giving them a physical place in the home) and symbolical (e.g. the meanings of ICT's within household relationships). An innovation is not only materially produced but is also 'loaded' with all kinds of symbolic meanings by producers, designers, marketers etc., and users have to interact with these meanings when considering to buy ICTs or when using ICTs in their everyday life (Frissen & Punie 2001: 25-26).

3.5.2 Power relations and everyday life at home

By taking an everyday life perspective on acceptance and use of ICTs in the micro-social context of the household or of other social settings (e.g. school, work), domestication studies do not only look at the technologies but also, crucially, at how the technologies are negotiated within household and/or everyday life structures and patterns. Such a perspective implies that the enactment of structural power relations of class, gender, age, ethnicity and others are taken into account, based on sociological theories of social stratification. Domestication would argue that people's activities are not completely determined by these power relations (structural determination), nor that they are completely absent (individual freedom) but rather that these power relations are negotiated within the regularities and irregularities of everyday life (Punie 2003).

Gender and feminist studies for instance, illustrate how socially and culturally prescribed roles of masculinity and femininity shape differences in attitudes, acceptance and use of ICTs. The typical example in the 1990s was the remote control (TV, VCR) that is handled – in many households – primarily and sometimes exclusively by men (the father or the son). It was seen as a visible symbol of ICT related masculine power in the household where the men determine and/or decide over possible family viewer conflicts (e.g. Lull 1988).

Another example of gendered ICT practices is provided by Gray (1992) on differences in ICT competences. Her observation is that woman do use very sophisticated pieces of domestic technology, i.e. the so-called white goods (e.g. microwave, washing machine) but they feel alienated from operating electronic brown goods (e.g. VCR, hifi). In some cases however, it is the result of a strategic choice not to be able to use ICTs, labelled by Gray 'calculated ignorance' in the case of the VCR. Woman know that if they can operate these devices, that it would become their job to do so above all the other household work that has to be done.

These examples may now seem a bit outdated – not only in relation to the technologies but also in relation to changes in household composition (e.g. dual income households) and accordingly in social structures (e.g. emancipation supported by woman also being a 'breadwinner') – but they do indicate that use and acceptance of ICTs are negotiated within power relations of the household, be it gender, age, class, ethnicity and combinations of these.

It can be argued that with future Ambient Intelligence systems and services in everyday life, these structural relations will persist, although most likely in different forms and formats. The point is that in the literature and also in the visions on AmI and ubiquitous computing, little or no considerations of power relations in the home are made. Future studies and visions would benefit by taking power and everyday life structures and patterns more explicitly into account. This would ground them in sociological notions of everyday life. It would also contribute to a further development of the following issues:

HOME AS A SANCTUARY?

Home as a sanctuary is raised by ISTAG (2002: 25-26) as a possible relaxing and harmonious environment where people can rest, relax and escape from an over-intrusive AmI environment. Although the symbolic meaning of home as a private space that is legally and socially protected can not be underestimated, the notion of home as a sanctuary hides the tensions, struggles and inequalities that occur in the lives of most families, especially in relation to gender. In many households, home for woman is not just a place to relax and to have leisure, but also a site of housework.

But home could indeed become a place where one can say no to AmI that is supposed to be everywhere and anytime. The notion of ubiquity assumes total openness of consumers to the infinite multiplication of devices and services in all facets of their everyday life. But observable behaviours show people's 'technological fatigue' and possible saturation points, both at quantitative level (e.g. hours of use) as qualitative (e.g. pervasiveness of ICTs in all activities). Beyond simple saturation, such ubiquity challenges various facets of people's private and public life. The claim for a 'switch-off button' rather than 'always-on' technologies is probably a growing one.

EVERYDAY COMPUTING AND HOUSEWORK?

The noticed shift in the AmI vision towards 'human centred computing' with an emphasis on user-friendliness and user support for human interactions claims to place the user at the centre of future development. Other researchers also have argued that the whole purpose of application-centred ubicomp research is to understand how everyday tasks can be better supported and enhanced by the introduction of ubiquitous technologies. For Abowd & Mynatt (2000: 30-31), this is one of the major challenges for ubicomp research in the new millennium. They call it 'everyday computing', i.e. wanting to support the informal and unstructured activities typical of much of our everyday lives. These activities are continuous in time, a constant ebb and flow of action that has no clear starting or ending point. Familiar examples are orchestrating tasks, communicating with family and friends, and managing information. Designing for everyday computing requires addressing these features of informal, daily activities (Ibid).

A particular type of everyday activities in the home however, i.e. housework, is considered rarely in claims about human centred and/or everyday computing. This may be surprising since housework (e.g. cleaning, washing, ironing) is still one of the most repetitive and time-consuming tasks to be executed in the home. There are exceptions, such as an 'intelligent vacuum cleaner'[27] that is already for sale on the market and scenarios describing an intelligent washing machine communicating with the intelligent clothes it is washing, and of course, shopping practices, but in general, housework seems to be relatively absent in vision and projects about the future of computing.

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27 http://www.roombavac.com/

Feminist research on smart homes in Norway in the beginning the 1990s observed a similar trend. Developers and designers of smart homes ignored housework and overlooked woman as a potential target consumer group. According to Berg (1996: 87-89), this illustrates the gendered nature of the technological innovation process. Technology is traditionally a masculine domain and the smart house that results from that is a masculine concept. This may perhaps clarify the above mentioned observation on Ambient Intelligence and the absence of housework, although the situation might have become less straightforward compared to almost ten years ago. On the other hand, home automation and the mechanisation of the household has been subject of ideological claims already for more than a century (See section 2.4 & Forty 1986).

CONTEXT AWARE SERVICES, INTELLIGENT AGENTS AND NEUTRALITY?

The crosscutting idea for many of the AmI projects and applications is context awareness, currently primarily based on the identification of the user and his/her location. Context awareness renders AmI applications, to a certain extent smart since they adapt their behaviour based on information sensed from the physical and computational environment (See also section 4.5). Intelligent agents can be part of context-aware services.

Both context awareness and intelligent agents appear to be neutral, i.e. not taking a position within social relations. The question is if and how this position will be sustainable when confronted with users and non-users in their everyday life. Since these services are pro-active, they can not be completely neutral. They have to present certain choices and/or take some decisions for users, therefore preferring certain options above others. This neutrality runs the risk of causing problems and even conflicts in everyday life since the latter is not neutral, as argued above, but shaped by peoples' socio-economic positions (class, gender, ethnicity), their history (parents, education, etc.) and symbolic positions in society (e.g. social capital).

Preliminary results of a project called "Ambient Intelligence Homelab" launched by the electronics manufacturer Philips in 2002 confirm this issue. The Homelab consists of a fully equipped home in order to test prototype Ami technologies and peoples' behaviour and reactions in a semi-real life environment. The intelligent agent dealing with entertainment schedules was criticised by the son because it favoured the preferences of his farther. Can intelligent agents take a position within family relations and who is to blame for unequal access within the family?[28]

Rieder (2003) argues that intelligent agents should not only be regarded as software programs, but also as 'social actors' since they inevitably take position. Agents present a certain view on the world. Making the machine more subjective and thus bringing it closer to everyday life is exactly the objective of new generations of agents under development. There is a risk however, that agents' functioning becomes a new 'black box' since it is not obvious to understand the algorithms used to get certain results. How will users be informed about this process? And what is the position of authority of agents' results? Are they exclusive or better than other sources of information? It is clear that social and user-oriented research is needed to better understand the position of intelligent agents in everyday life.

[28] Aerts, E. (Ed.) (2002) Ambient Intelligence in HomeLab, Published by Philips Research for the occasion of the opening of the HomeLab on April 24, 2002, Philips Research, Eindhoven. http://www.newscenter.philips.com

SCENARIOS, IDEAL TYPE USERS AND A PERFECT WORLD?

Scenarios describing possible futures, in general but also in relation to AmI, tend to portray ideal type users in a perfect world. The ISTAG (2001) scenarios for instance, despite their emphasis on humanistic and social concerns, are constructed among four ideal types for the future: the assertive trans-national businesswoman, the relaxed and connected upper level employee, the up-to-date and active housewife, and the learning community. Although the objective of the scenarios is to provide glimpses of possible AmI futures rather than being exhaustive, it seems that only those that 'succeed' in life are portrayed. And these are typically the early adopters of new technologies (Cf. infra diffusionism). The less well of on the other hand (e.g. lower educational levels, poorer households, ethnic minorities) are rarely considered in scenarios.

In addition to ideal type user groups, the portrayed everyday life in the scenarios is primarily a perfect life where users are able to cope, successfully, with their lives. Scenarios have a tendency to ignore the struggles, uncertainties and irregularities that are characteristic for everyday life as well. They are inclined to portray only the bright side of life.

Especially in relation to technologies, this implies that malfunctions, breakdowns and user-unfriendliness are hardly envisioned, while current-day computing for instance is not without problems, errors and software bugs. In the same way as users seem to cope successfully with their lives, they are also using the technologies in an unproblematic way. User research in contrast, especially from a domestication perspective, argues that the process of use and acceptance of technologies is less straightforward and obvious.

Worst-case scenarios would for instance also contribute positively to a better understanding of future challenges. An example of such a scenario is given in a technology roadmap on software agents whereby a simple spelling error results in completely destroying a persons' life (Luck et all. 2003).

3.5.3 Physical versus mental disappearance of computing

At the core of Ambient Intelligence is the idea that computing becomes 'invisible' by embedding it in the environment and in everyday objects. Computing should be in the background, in the periphery of our attention and should only move to the centre if necessary, hence the existence of RTD programs such as 'the disappearing computer', an EU funded activity in Future and Emerging Technologies (FET) of the IST research program.[29]

At first sight, there is a striking parallel with the domestication approach. Ultimately, technologies are domesticated when they are 'taken for granted', when they reach a state of mind of being a 'natural' part of everyday life. As such, they are not anymore perceived as technologies, as machines, but rather as an almost natural extension of the self. By claiming to move technologies to the background and people to the foreground, Ambient Intelligence promises a disappearance of the technical artefact and its underlying technologies. As a result, it can be seen as the ultimate stage of domestication.

[29] http://www.disappearing-computer.net

However, domestication also highlights that the process of acceptance and use of ICTs is not necessarily harmonious, linear or complete. Rather it is presented as a struggle between the user and technology, where the user aims to tame, gain control, shape or ascribe meaning to the technological artefact. It is not a sign of resistance to a specific technology but rather of an active acceptance process.

The material invisibility of technological artefacts – aimed at through miniaturisation and/or embedding – may well rather harm than facilitate their acceptance exactly because they are invisible, and thus become uncontrollable. Making technologies disappear, while assuming that it will reduce the tension, could on the contrary make it insoluble.

The point is that there is a difference between the physical and mental disappearance of computing and that it is incorrect to assume that physical disappearance will lead automatically to acceptance and use, and thus to mental invisibility.

3.5.4 Adaptive computing and intended use versus effective use

Domestication and other user studies of technological innovations have indicated that there is a difference between the intended use of ICTs by its designers and their real, effective use by users. Users and uses are pre-configured in the design of ICTs. This pre-configuration shapes to a certain extent the way ICTs will be used. One can not go out of this frame, as a user, but there is freedom for users to experiment with ICTs, to invent new uses and to make them their own (Flichy 1995). It seems that users take up this activity and that technologies can be put to quite different uses than the uses foreseen by the developers. This can lead to surprises, such as the recent success of SMS. Another typical example is the French Minitel of the 1980s. This videotext system was set up to be used as an informational service but the French users 'invented' another, more successful use, i.e. communication and erotic services (Bouwman & Christofferson 1992). And also the telephone answering machine is used in a way not originally foreseen, i.e. for screening incoming calls, and thus actually for increasing un-accessibility in stead of accessibility (Frissen & Punie 2001: 22).

These studies highlight that for ICTs to become accepted, it is important to have some degree of flexibility for users to experiment and find their own uses. With AmI this degree of flexibility can be increased significantly because new services will be driven by software and thus be easily programmable. Re-programming might become possible both for developers and for users. This is partly incorporated in the idea of adaptive computing. Ami devices and services will have a high degree of heterogeneity. Their functions and possibilities are changeable on the basis of user preferences. Truly personal devices will become possible (e.g. Islam & Fayad 2003).

Also multimodal appliances are envisaged. A cellular phone can be used as a remote control for instance. This does not mean one device will everything but that there will be different devices which can handle multiple media related to their specific task. Standards for interoperability will be essential in this context (ITEA 2001: 59).

Devices and services that are completely open to users or that are completely adaptable may face the risk however, of becoming unusable or unappealing for users. Certain degrees of flexibility are necessary but pre-configured uses and users are also needed for potential users as guiding forces. They reduce the complexity and uncertainty which typically emerge when users are confronted with innovations. They also help users understand what is new about innovations. Completely open tools risk leaving users without directions. A challenge for adaptive computing and for AmI in general is to find an acceptable balance between openness and adaptability versus user guidance and rigidity.

4. The technological dimension

There is still a lot of technological progress needed to establish the technological foundations for the AmI vision. The key technologies to enable it are coming from a wide range of technological fields and sub-fields. Since we are talking about a paradigm change, AmI will necessarily draw upon a wide range of underpinning technologies, potentially even the entire range of IT components and systems, and a good share of technologies within which IT can be embedded (Miles et al. 2002: 8-9).

In general though, since AmI is stemming from the convergence of three key technologies, i.e. ubiquitous computing, ubiquitous communication, and intelligent user-friendly interfaces, at least these three key technologies need to be considered for an understanding of the technological dimensions of AmI. These are highlighted briefly in this section. Also the notion of context awareness is discussed here since it presents a major challenge for developing relevant and useful AmI applications.

It should be noted however that the overview is not exhaustive and that a number of other key technologies such as software design and engineering, knowledge and content technologies and privacy, security, trust and confidence technologies is contributing to AmI as well.

4.1. Ubiquitous Computing

Ubiquitous computing refers to a shift in computing systems from (central) mainframe computing over personal computing and multiple computing devices per person (distributed computing) to computing embedded in everyday objects. The latter is supposed to make these objects 'smart', for instance by adding sensors to them.

The development of smart devices depends on the following technological trends: miniaturisation of computing capabilities, new materials, sensing technologies and software technologies. Also the embedding of computing and networking capabilities into more and more objects and environments results in distributed and real-time forms of computation that place new and severe demands onto micro-/optoelectronic devices in terms of functionality, design, power, robustness, wireless communication, packaging, and cost (Lindwer et al. 2003).

4.1.1 Miniaturisation of computing capabilities

It is mainly Moores' law that has been used to describe the increasing capacity of computing power, in particular a doubling of it every 18 months a fixed costs. It hereby highlights the rapid change in information processing technologies and in the microelectronics industry during the last three decades. Computing capabilities have become cheaper, smaller and faster in order for them to be embedded in potentially every object or device.

This trend however, was made possible by the unique economic and social conditions under which the semiconductor industry operated during the last decades, rather than by Moores' law alone, as argued by Tuomi (2002) and thereby criticising the technological and economic deterministic way in which the law has been used. The implication of Tuomi's critique is that Moores' law in general and miniaturisation in particular may not automatically go on for the next ten years or so, as is generally assumed, since the socio-economic context has changed for the semiconductor industry and for other related technological industries.

Further miniaturisation for hardware to become unobtrusive may rather come from breakthroughs in new materials (ISTAG 2001: 22). More mobility, less energy consumption, more performance, smaller size and weight, lower cost, high reliability, more flexibility and ubiquity have up to now been achieved with miniaturisation. The stage might be reached however where further scaling will create opposite effects such as growing energy consumption in standby mode and performance restrictions in active mode. Therefore, completely new solutions in micro-/optoelectronics are needed. A major challenge will be to integrate contributions at the nano-scale level into overall system architectures. This requires rare interdisciplinary expertise (Lindwer et al. 2003).

4.1.2 New materials

Molecular and atomic manipulation techniques will be increasingly required to give rise to advanced materials, smart materials and nanotechnologies. Nanoelectronics and other nanotechnologies permit miniaturisation trends to extend beyond the limits of micro-devices through hybrid nano-micro devices. Nanodevices would yield lower power consumption, higher operation speeds and high ubiquity (ISTAG 2001: 18).

Recent developments in the field of materials science and solid-state physics could give computers of the future a completely different shape, or even blend them completely into their surroundings. Light-emitting polymers (illuminating plastic), for instance enable flexible displays, i.e. displays that are thin and bendable. In the future, you could see weather info from the Internet on the bedroom window instead of a thermometer or barometer. Laser projection from within spectacles directly onto the retina of the eye is another option currently being investigated (Mattern 2003).

Research is also taking place into electronic ink and smart paper. This would transform the properties of current paper media into digital (mobile) input/output media. It follows that paper can be altered into a computer or, conversely, computers into paper (Mattern 2003). It will have substantial implications for the delivery and consumption of media and information.

Smart dust[30] is another technology that is developed. It is a cloud of tiny particles, each one of a millimetre dimension, of active silicon. It senses, communicates and is self-powered. As tiny as dust particles, it can be spread throughout buildings or into the atmosphere to collect and monitor data. Each particle converts sunlight into electricity, locally elaborates information, localises itself, both in absolute and relative to other particles, communicates with other ones within a few meters. Smart dust devices have applications in everything from military to meteorological to medical fields. A similar technology is smart painting, a random network of wall painted computers studied at the MIT (Riva e.a. 2003).

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[30] http://www-bsac.eecs.berkeley.edu/~warneke/SmartDust/

Many different new materials are thus studied and developed. Some prototypes already exist, but it will take many more years for them to become viable alternatives to existing materials.

4.1.3 Sensing technologies and augmentation of objects

Everyday objects will be augmented with sensors and/or activators in order for them to be able to sense physical activity and consequently, to act or communicate this information. Sensors can react to light, acceleration, temperature and weight but recent sensors also analyse gases and liquids and can recognise certain patterns (for example fingerprints or facial forms). One interesting development in this regard is radio sensors that can report their measured data within a few meters distance without an explicit energy source. Electronic labels also operate without a built-in source of power (so-called passive smart labels or RFIDs – Radio Frequency Identification). Their advantages are manifold compared to existing barcodes for instance. Several hundred of bytes could be read and written "wirelessly" up to a distance of about two meters depending on the underlying technology. It enables objects to be identified and recognised, and therefore linked in real time to an associated data record held on the Internet or in a remote database. This opens up application possibilities that go far beyond the original task of automated warehousing or supermarkets without cashier (Mattern 2003).

One of problems for embedded computing in small object is the issue of power sources. Although the search for alternative power sources is under way (e.g. fuel cells, self-generating power), generally, there is a trade-off to be made between processing power and energy use. Also for mobile and portable devices, power consumption is crucial, bit trade-off there is more between displays and energy use (Lindwer et al. 2003).

An example of an augmented everyday object is the MediaCup, developed by TecO (Telecooperation Office, University of Karlsruhe). Coffee cups are augmented with sensor, processing, and communication facilities to obtain basic cues on what people do. The sensor data process three distinct cues: cup is stationary, drinking out of the cup, and playing with the cup. Temperature data is also mapped: filled up, cooled off, and actual temperature. This is a prototype to indicate how smart working environments could be envisioned on the basis of telepresence, i.e. giving someone the feeling that someone else is present while they are actually not co-located (Beigl, Gellersen & Schmidt 2001). It is an experiment, typical for ubiquitous computing projects, in embedding everyday objects with sensors in order to merge the physical and virtual world.

4.2. Ubiquitous Communication

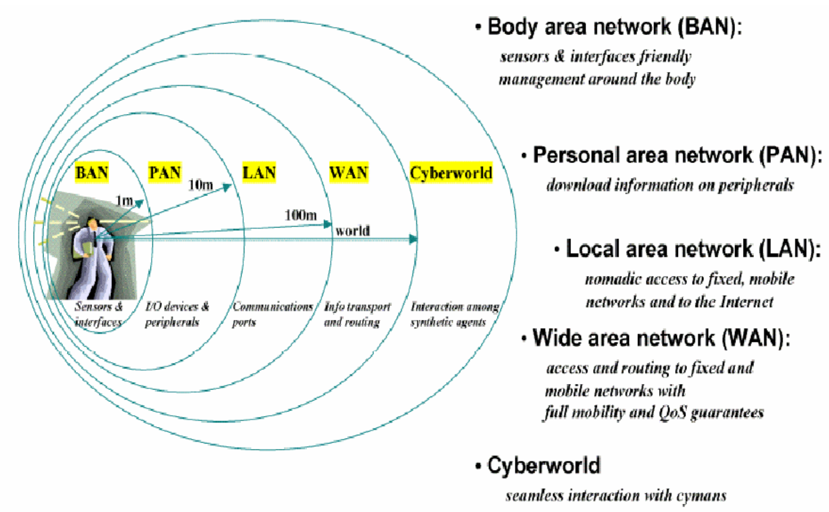
Massively distributed devices are only to become really meaningful if they are networked or connected. From a technical point of view, this poses new challenges, especially for the computer systems community. Mobility is a newly added dimension that sits at the very heart of the AmI environment (Lindwer e.a. 2003). Providing continuos interaction changes the relationship between humans and computers, from a localised tool (traditional desktop) to a constant companion (Abowd & Mynatt 2000: 29). The feeling of permanent connectivity exist already today through mobile phones.

Whatever the technologies and networks at the background are, users will expect access to the right information or networked service, at the time they want them, from the place they select them, using their preferred device and with the information or services presented in a useful format. For such a heterogeneous distributed system, computing nodes may join or leave the network at any moment and then becoming unreachable due to users' mobility, energy sources depletion, intermittent failures, etc. Consequently, designing embedded systems for such environments characterised by high volatility of the network topology is going to be very different compared to standard practice in digital design. It implies a lot of flexibility and adaptability on the part of the appliances and the networks. Also, it will put a high emphasis on the aspect of interoperability and standards (Lindwer et al. 2003, ITEA 2001: 60-63).

Within an AmI environment, a seamless interoperability between different network levels needs to be realised. Generally, the following network levels are to be identified:

- Body area network (BAN) connecting sensors, chips or devices attached to the body/clothes or implanted in the body;
- Personal area network (PAN) consisting of personal and/or shared devices or peripherals;
- Local area network (LAN) for the nomadic access to fixed and mobile networks, and to the Internet;
- Wide area network (WAN) for the access and routing with full mobility;
- The "Cyberworld" where users and their intelligent agents (avatars) interact.

Figure 2: Communication network levels in AmI



Source: Riva et al. 2003: 14-15.

This model is proposed as a reference model for the interaction between the user and the surrounding technologies.[31] From a service point and users point of view,

[31] A similar 'multi-sphere reference model' is to be found in the Book of Vision 2001 by the WWRF (Wireless World Research Forum), See WWRF 2001.

seamless switching and interoperability between these different network levels is crucial. This includes ad hoc networks, i.e. networks that are created, on the spot, for a specific purpose and that are dissolved once the purpose is achieved. For example, an ad hoc network can be established in a meeting room, dining hall or an airport between two or more people who want to share and exchange documents. The network card available in their devices just has to be switched to 'ad hoc mode' to form a small wireless LAN.[32]

Wireless LANs are today already available on the market. Wireless hot spots for Wifi or IEEE802.x give access to the Internet and are installed all over the world (e.g. in airports, cities, etc.). For some, this is the new hype after the Internet[33]. Wireless Personal Area Networks are also under commercial development and are expected to take-off during the next years. They have a short range-of-use (10-100 meters) and are intended to set up connections between personal devices. The best known standard is Bluetooth enabling for instance a keyboard, computer, printer or digital camera to be connected without cables (OZONE 2002: 27).

Applications for body area networks (BAN) are also being prototyped. They encompass smart devices the user can wear (e.g. smart watch) or implant in the body. Smart clothes can have many different applications such as e-health (e.g. patient monitoring of hart rate, blood pressure, etc. but also monitoring for sports activities), adaptable clothes (e.g. according the outside temperature in arctic environments) and self-cleaning clothes[34]. Chip implants in the body are perhaps a bit further in the future although Kevin Warwick, a professor in Cybernetics, received his first implant in 1998. He uses these implants to connect his nervous system with a computer and thus with the Internet.[35]

Devices are connected dynamically to these different networks. As the function of most devices is driven by software, it results in multimodal appliances. A cellular phone can also be used as remote control for instance. This does not mean that we will end up with one device that does everything but we will have devices which can handle multiple media related to their specific task. Standards for interoperability will be essential in this context (ITEA 2001: 59).

4.3. User interfaces

Interfaces, especially user interfaces are one of the crucial building blocks for AmI because they define the experience the user will have with the intelligence surrounding him/her. Major importance is attached to so-called natural feeling human interfaces and to multimodel interfaces. Vision technologies and displays are part of the interfaces as well. Breakthroughs in user interfaces are important for consumer acceptance, not only for the mass market in general but also for people with disabilities in particular.

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32 http://www.cs.ucla.edu/ST/home_main.html
http://www.80211-planet.com/tutorials/article.php/1451421

33 E.g. 'Analysts predict wireless hot-spot crash', CNET News.com, June 19, 2003.
http://news.com.com

34 E.g. Kunze et al. 2002; Rantanen et al. 2000; Shonfeld, E. 'Let the monitoring begin', Business 2.0, 20 October 2000 http://www.business2.com/articles/web/0,1653,8746,00.html

35 http://www.kevinwarwick.org.uk/

The vision of AmI assumes that the physical interaction between humans and the virtual world will be more like the way humans interact in the real world, hence the term natural interfaces. Humans speak, gesture, touch, sense and write in their interactions with other humans and with the physical world. The idea is that these natural actions can and should be used as explicit or implicit input to AmI systems. Interfacing should be completely different from the current desktop paradigm (GUI-Graphical User Interface) based on keyboard, mouse and display. This also means that interfaces should be multi-model, as humans communicate in a multimodel way against machines that typically operate in a single mode. Moreover, with current interface technology humans must learn and understand the computer language; in the future this would be the other way around (Wilson 2001; Abowd & Mynatt 2000: 30).

Haptic interfaces focus on the human sense of touch, i.e. using objects in the physical world to manipulate a computer-generated world. For example, if a user tries to grab a virtual cup there isn't a non-visual way to let the user know that the cup is in contact with the user's virtual hand. Haptic research attempts to solve these problems, via force (kinesthetic) feedback and tactile feedback. The former is for instance used in games (e.g. steering wheel) while the latter deals with the devices that interact with the nerve endings in the skin which indicate heat, pressure, and texture[36].

Tangible interfaces focus on everyday objects. Ambient displays are everyday objects used for information display without interrupting the user or without a deliberate search attempt from the user. They are abstract and aesthetic peripheral displays portraying non-critical information on the periphery of a user's attention.. The goal is to present information of secondary importance, hence non-critical, without distracting or burdening the user. Future research should however not only concentrate on designing ambient displays but also on evaluating its effectiveness. Very little is known about this (Mankoff et al. 2003, Wisneski et al. 1998).

With ambients, the physical environment becomes an interface to digital information rendered as subtle changes in form, movement, sound, color or light. Commercial ambients are already on the market. The Ambient Orb for instance is a small globe, wirelessly connected, that changes color according to users' preferences for monitoring custom stock portfolio or receiving local weather forecasts.[37]

Previous efforts have focused on speech input and pen input but it was very difficult for these interfaces to handle robustly the errors that naturally occur with these systems. A difficult problem for natural interfaces, especially when used for recognition-based tasks consists of the mistakes and errors that occur. Completely eliminating errors may not be possible but recognition accuracy does not seem to be the only determinant of user satisfaction. Even humans make mistakes when dealing with these same forms of communication (e.g. handwriting recognition). Rather the question is how to handle occurring errors in ways that are acceptable for users (Aboyd & Mynatt 2000: 34-35).

There is a huge amount of work undertaken in natural interfaces. A major challenge for multimodal interfaces consists indeed of integrating stand-alone graphical, aural, speech and tactile interfaces. This is crucial, not only for multimodal interactions

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36 http://haptic.mech.nwu.edu/

37 www.ambientdevices.com

with computer systems at a particular moment, but especially also for seamlessly migrating and adapting these to different user environments (Cf. AmI Space).

In relation to displays, ISTAG distinguishes long-distance entertainment type of interfaces and short-distance mono-personal interfaces. Today, the former consists usually of an infrared remote control, in reality of a proliferation of these controls, and a game pad. They are used for interactions at more than 1 meter from the screen. The short-distance mono-personal interface is today dominated by the personal computer GU Interface (with a keyboard and a mouse). In the future, ISTAG (2002: 27-30) believes that most interactive applications will have to deal with both long-distance and short-distance interfaces and insists that these interfaces need to be easy to use by people of all ages. Using existing personal computer interfaces has the risk of creating a "digital divide", as these solutions are too expensive and too difficult to learn.

Displays do not follow Moore’s law and they therefore represent a large part of the total cost and power consumption of most appliances. Displays are often the blocking point for a massive deployment of new applications. ISTAG (2002: 29) sees a need for several types of displays in the home, all of them being flat displays:

- Large (50 cm to 1 meter diagonal) with high resolution (1,000 lines) for multi-person viewing of TV, movies, images and games. Relevant technologies are plasma and projection LCD. The major issue is cost.
- Medium size (40 to 50 cm) but still high-resolution displays for desk-top applications (such as a PC monitor) and mono-personal entertainment. The relevant technology today is LCD.
- Small, low-resolution displays with a broad range of sizes, resolutions, color or monochrome to be used in nearly all home appliances (white goods, home control, audio systems). Relevant technologies are OLED, PLED.

Breakthroughs in input/output devices including new displays, smart surfaces, paints and films that have smart properties are regarded as fundamental to enable people interacting with their intelligent environment (Ibid: 22).

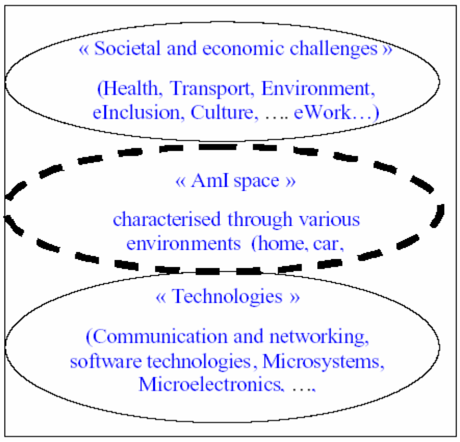
Widespread implementation of interfaces with multiple input/output mechanisms is only to be expected between 2010 and 2020 however, not only due to technological challenges but also due to uncertainties in relation to return-on-investment and to consumer acceptance. Moreover, the computer industry's track record in improving the ease of use of their applications is not particularly great (Wilson 2001).

4.4. Ambient Intelligence Space

ISTAG proposes a new approach to realise the AmI vision by focussing on what it calls the Ambient Intelligence Space, i.e. the ‘middle layer’ (or medium) to bridge the gap between technologies and societal and economic challenges. The AmI Space consists of the collection of technologies, infrastructure, applications and services enabling AmI. Crucially however, this space is not only the collection of its constituting elements, but genuinely the seamless integration and migration between them. The socio-economic challenges will be met only if new services based on new technologies are integrated and managed so that they span the different spheres of life with seamless operation across various environments (ISTAG 2002: 7).

This *Ami Space* should not be construed as a physical layer of infrastructures, hardware platforms, services, or applications, but as collection of these things in combination, characterised through various environments. Therefore, ISTAG adopted a '3-layer'model, with the societal and economic challenges as the top layer, technologies as the bottom layer, and AmI Space as the 'middle layer'.

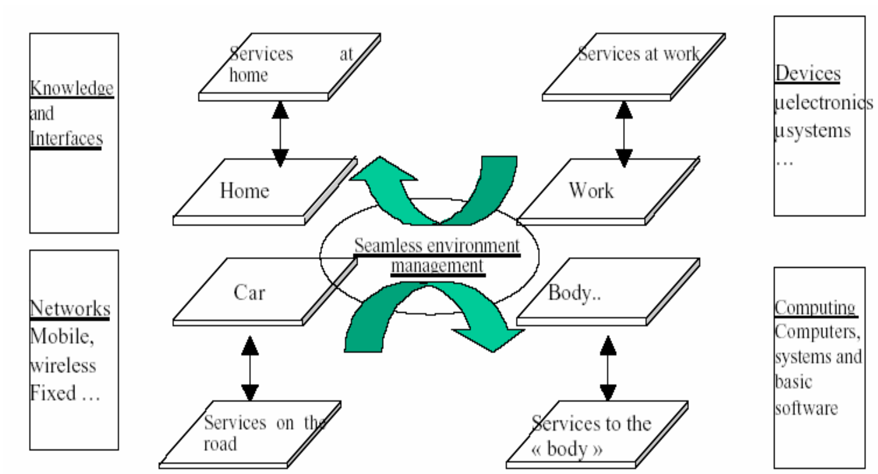
Figure 3: The middle layer: Ambient Intelligence Space



Source: ISTAG 2002: 15.

Originally, Ami Space was an abstraction with properties based on specific physical or social environments such as the family, the home or the car. It evolved towards a space where seamless integration and migration between technologies, services and users are crucial.

Figure 4: Seamless AmI environment management



Source: ISTAG 2002: 16.

The AmI Space 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 must "know itself" and its components, configure and reconfigure itself under varying and even unpredictable conditions and must be an expert in self-protection in a heterogeneous and open world.

The AmI Space should contain applications and services to actively support humans in achieving specific tasks. It should interact with the user, model and know user behaviour, control security aspects to ensure the privacy and security of the transferred personal data and deal with authorisation, key and rights management. It should also ensure the quality of services as perceived by the user.

ISTAG realises this is not a trivial task, and certainly not only a technical one. Other issues are availability and protection of copyrights, privacy and security, regulations and open standards, and viable business models (Cf. infra). It also needs detailing this vision, the concepts and a research agenda (ISTAG 2002: 18-20).

4.5. AmI Applications: The notion of context awareness

Progress in the above mentioned key enabling technologies is needed to realise the AmI vision but in essence, "applications are the whole point of ubiquitous computing" (Weiser 1993). Since much AmI research is application-centred, the amount of projects under development is huge. One of the early examples of ubicomp applications is indeed locating people and objects, pioneered by the Olivetti Research Labs in Cambridge (UK) with the Active Badge system.[38] Functions provided by Active Badge are for instance automatic phone forwarding, locating an individual for a meeting, and watching general activity in a building to feel in touch with its cycles of activity (Weiser 1993).

It is impossible to give a full account of the many AmI applications that are under development, but the crosscutting idea for many of them is inspired on context awareness and thus location based services. Therefore, in this section, the central notion of context awareness is situated.

Context awareness starts with identifying a relatively simple piece of context, i.e. user location, and uses this information to provide relevant services. These location-aware appliances are perhaps the first demonstration of linking implicit human activity with computational services that serve to augment general human activity. They illustrate the objective of the application-centered AmI research, i.e. to understand how everyday tasks can be better supported, and how they are altered by the introduction of ubiquitous technologies (Abowd & Mynatt 2000: 31). A mobile phone for instance will always vibrate and never beep when you are in a concert or a meeting if the system knows the location and the calendar (Moran & Dourish 2001).

Context awareness renders AmI applications, to a certain extent smart since they adapt their behaviour based on information sensed from the physical and computational environment. According to Weiser, there is no revolution in artificial intelligence needed for that. On the contrast, ubicomp as conceived in the 1990s is completely opposed to artificial intelligence:

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[38] The Active Badge system, in use at different universities since 1992, provides a means of locating individuals within a building by determining the location of the Active Badge. This small device worn by personnel transmits a unique infra-red signal every 10 seconds. Each office within a building is equipped with one or more networked sensors which detect these transmissions. The location of the badge (and hence its wearer) can thus be determined on the basis of information provided by these sensors. See: http://www.uk.research.att.com/ab.html; http://www.ics.agh.edu.pl/ABng/papers.html

Today's computers have no idea of their location and surroundings. If a computer merely knows what room it is in, it can adapt its behavior in significant ways without requiring even a hint of artificial intelligence...
In our experimental embodied virtuality [AmI], doors open only to the right badge wearer, rooms greet people by name, telephone calls can be automatically forwarded to wherever the recipient may be, etc... No revolution in artificial intelligence is needed--just the proper imbedding of computers into the everyday world. (Weiser 1991)

On the same line, ubicomp is, according to Weiser (1991) diametrically opposed to "virtual reality," which attempts to make a world inside the computer. He does not questions its purpose, but virtual reality is about simulating the world while ubicomp focuses on invisibly enhancing the world that already exists.

Location is a common piece of context used in application development. The most widespread applications have been GPS-based car navigation systems and handheld "tour guide" systems that vary the content displayed (video or audio) by a hand-held unit given the users' physical location in an exhibit area (e.g. The Lancaster Tourguide: Cheverest et al. 2000).

Although numerous systems that leverage a person's identity and/or location have been demonstrated, there are many development and implementation problems. There is, for instance, more to context than just the position and identification of people. Most context-aware systems still do not incorporate knowledge about time, history (recent or long past), other people than the user, as well as many other pieces of information often available in our environment. Although a complete definition of context is illusive, the "five W's" of context are a good minimal set of necessary context, the last two being the most challenging: Who, what, where, when and why. Other challenges are related to the virtual representation of context and to context fusion, i.e. to increase the confidence value for a particular interpretation since sensing technologies are not 100% reliable (Abowd & Mynatt 2000: 35-36).

Defining context is not obvious but it should be, in essence, user-oriented. This is much more than simple user profiling and service profiling. The context-oriented systems will be able to answer questions, such as: Where are you? Whom are you with? What resources are close to you? What is your mood today? (Riva et al. 2003).

Such a user-oriented approach has recently received the status of international standard, through the International Organization for Standardization's ISO 13407 "Human centered design for interactive systems". According to the ISO 13407 standard, human-centered design requires:

- active involvement of users;
- clear understanding of use and task requirements;
- appropriate allocation of function;
- the iteration of design solutions;
- a multi-disciplinary design team.

It is based around the following processes: understanding and specifying the context of use; specifying the user and organisational requirements; producing designs and prototypes and carrying out user-based assessments.[39]

Despite all these initiatives, context remains relatively problematic for the design of interactive computer systems because of poor understanding what it is and how it can be used (Dey 2001). Moreover, definitions of context are context dependent. The weather, for instance, may be crucial for out-door activities but irrelevant when doing the same things indoors. A challenge is also that many context-aware services assume that the context they use is completely accurate while in reality, both sensed and interpreted context is often ambiguous (Dey et al. 2002).

Realistic context awareness should also take into account context in its sociological sense, i.e. peoples' socio-economic positions (class, gender, ethnicity), their history (parents, education, etc.) and symbolic positions in society (e.g. social capital). This seems to be even more complicated and as a result, its incorporation in the design of interactive systems will probably even further away in the future compared to using location and identification for context aware services.

39 http://www.iso.org; http://www.usabilitynet.org/tools/13407stds.htm; http://www.ucc.ie/hfrg/emmus/methods/iso.html.

5. Smart homes and living

5.1. From home automation to smart homes

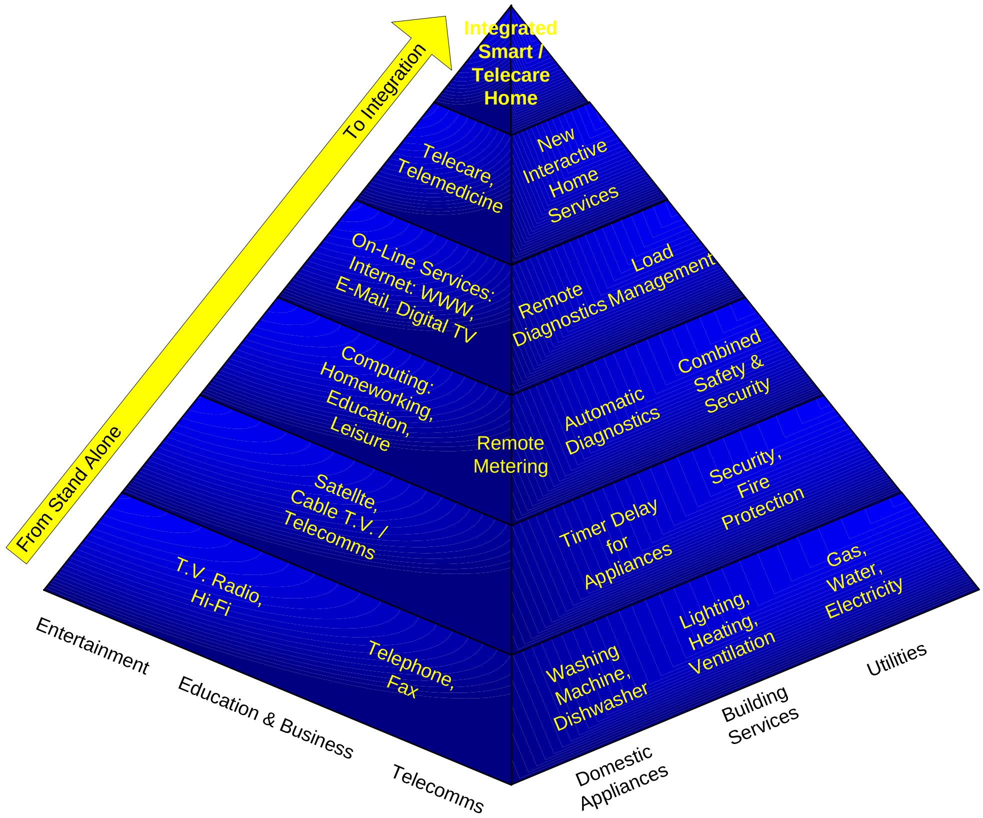
Smart houses have been around for more than a decade but have up to now not really been able to tackle a large consumer market. Partial progress was attained in networked household alarm systems, and some high-end entertainment systems, but the lack of standards and interoperability, and the absence of really pressing new functionality provided at an attractive cost can be listed as the main causes (Miles et al. 2002: 13).

It is expected however, as prices will decline and functionality will increase, that the worldwide connected home market, consisting of home networking equipment and software, residential gateways and home control and automation products will grow considerably, from US$1.4 billion in 2001 to US$9.2 billion by 2006, according to In-Stat/MDR. The information appliances market is projected to impact many sectors of the consumer electronics industry (manufacturing of TV, set-top box, PC, game console, home appliances & mobile devices). Market research firm eTForecasts predicts that worldwide information appliance shipments which includes web-enabled cell phones, PDAs, handheld computers, entertainment appliances and personal access devices, will reach 830 million units in 2007, with a market value of more than US$167 billion (quoted in Infocom 2002a: vii-viii).

Similar market forecast have been done in the past, and have proved to be rather overoptimistic. The problem with many past smart home projects has been that they primarily are technology-driven rather than demand-driven. A typical example of this supplier approach is the notion of fully-integrated home of the future, as illustrated in Figure 5 below. It illustrates how different subsystems of functional components can be combined to provide new services in the home. Many demonstration projects have followed this model and involved major capital investment to deliver a utopian vision of the 'home of the future'. While this has certainly stimulated interest, it has not provided consumers with a realistic model that can be immediately implemented in an affordable manner. The integrated nature of many available systems and products requires technologies and standards to be mature, but also specialist knowledge and/or training from the users' side before they can be installed and used (IPTS 2001: 121-123). It was also not able to live up to its promise to substitute or reduce significantly the unpaid and most time-consuming work in the home, i.e. housework (Berg 1996: 89).

While potential users have a set of similar needs from their homes (e.g. housework), the context in which these are expressed varies widely. Homes are diverse in terms of physical design, layout and age, and people's lifestyles vary considerably as a result of age and circumstances. The value-added to the consumer of a smart home is in its perceived benefit, not its 'smartness' or 'intelligence'. Consumers have basic needs which revolve around labour saving and simplification, ease in operation, remote controlling, entertainment, and cost reductions. Bringing the concept of smart homes to the market requires suppliers to address the needs of potential consumers to demonstrate additional functional and subjective benefits. Consumers need to feel they will benefit (Ibid).

Figure 5: Smart home integration



Source: IPTS 2001: 123

But the potential for smart homes products and services may now looking more hopeful than at any time in the past. This is the result of major ICT players developing a more sophisticated perspective on the market, the rise in the use of personal computers, mobile phones and Internet, the digitisation of voice, data and imaging, and the emergence of e-commerce. The size of the future market for smart homes is, as yet unclear. However, it will be shaped by demographic and socio-economic trends as well, especially the ageing population and the differentiation in household types (e.g. single parent households), the mosaic society and moves towards new ways of using the home for work and telecare (Ibid; Haddon 2003).

Home networks, i.e. the relevant Local Area Network for the home environment, include both networks to the home (access networks) and networks throughout the home. The domestic network connects all appliances and displays in the home and interacts with the personal area network and the body network of each person in the home. Within homes, local networks with potentially different underlying implementations can be combined, or at least be managed as one logical network. These may be networks using power lines, phone wires, Ethernet (coax, twisted pair), IEEE 1394, wireless (Hiperlan, IEEE802.11, IrDA, Bluetooth, HomeRF, wireless 1394). The need to support interoperability services such as bridges or gateways between different networks, in the backbone as well as in access networks and local networks grows (ITEA 2001: 60).

According to ISTAG (2002: 25-28), communications within the home will go broadband in 2010 on the domestic network (wireless, cable line, power line) with bandwidth capable of high definition video (20 megabits per second). Communications to the home will have evolved from dedicated solutions (copper wire for telephony, coax cable for TV) to multiple overlapping and competing communication media (copper wire, coax cable, digital terrestrial, satellite, wireless local loop). Each of these communication media will be capable of voice, data and video. Depending upon the type of homes, the installed base and the national regulations, in order for these to co-exist there will be need for physical interface standards and communication protocols for all media.

5.2. New drivers for the smart home

Many different socio-technological drivers are identified in the literature. The Infocomm Technology Roadmap on connected homes (See also Annex) proposes three relatively new drivers based on the notion of sharing, in particular of sharing broadband connections, sharing data and resources and sharing information:

- **Increasing broadband subscribers and sharing broadband connections:** As more households get accustomed to the benefits of high-speed Internet access, there is a need for multiple users to share the broadband connection simultaneously from different PCs, as duplicating connections through separate modems to the Internet makes no economic sense for consumers. Moreover, people who have migrated over to broadband access will find it unacceptable to revert back to narrowband access, especially as more rich media content will become available.
- **Rise of household PCs, multiple PC ownership and sharing resources:** With the rising popularity of desktop PCs, notebooks PCs, PDAs, mobile phones, printers, scanners, external storage devices and other LAN peripherals in the home, homeowners will want to be able to connect these equipment together to share data and resources, saving cost and maximise resources. This will inevitably drive the need for greater connectivity between these devices and the home network. A market research report from eTForecasts indicated that the PC industry will continue to see long term growth potential, despite the short-term uncertainty. In 2001, the worldwide number of PCs-in-use has surpassed 535 million units, and will reach 1.1 billion units in 2007 with home PCs accounts more than half of them.
- **Emergence of smart home platforms with built-in standard connectivity for ease of sharing digitised information within the home**: The recent years saw an increase of smart digital platforms in conception. They range from entertainment equipment to information devices to kitchen appliances with added intelligence and network connectivity to enable them to function in a smart manner. Through home networking, users could enjoy better management and control of personal activities through greater collaboration of this equipment, e.g. sharing digital photos or video clips that are directly downloaded into a home central server via the wired or wireless technologies. However, digital rights management, personal and/or third party intellectual property protection remain key challenges. (Infocomm 2002: 2-3)

Improved convenience and greater functionality is also identified by ITEA (2001: 80-81) as driving consumer acceptance. It is more attractive:

- to have devices with a universal function (e.g. one remote control to control all appliances that support remote control features);
- to work with information that has universal content (e.g. an Internet page that is rendered on a PC screen or a mobile phone screen depending on the environment) (ITEA 2001: 80-81).

Bandwidth as such will not be the major issue for in-home networks. Rather wireless connectivity (and interoperability) providing mobility to users within the home will be crucial. Also, Infocomm (2002a: 71-75) does not think that smart kitchen appliances will be a major driver during the coming years. They typically allow users to watch the morning news, download MP3, listen to music, download recipes, send and receive e-mail, do web surfing, or leave video messages for family members. Their added value in a kitchen environment would not justify the cost. Rather, home automation and control, home security and surveillance and healthcare are seen as more promising.

ISTAG (2002: 40-41) also stresses the social challenge for the future intelligent home to provide relaxation and harmony and to support socialisation:

- **Sanctuary, relaxation and harmony:** In a world that changes rapidly, broadcasts negative news, brings pressures of work, has effectively destroyed the nuclear family and in which religious pastoral care is in decline, the home is an important sanctuary. This sanctuary should afford a relaxing and harmonious environment that is secure and private - a place where one can lean back and be passive.
- **Socialisation space*:*** Home for most people is not just a personal sanctuary but is also about personal relationships and nurturing of children. The supportive home enables the family to communicate, observe, enjoy, respect, learn, be healthy, and wonder about life in safety. In addition to the household members the home is a meeting place for friends and family. These meetings can take on physical presence but also in the AmI vision a virtual presence. The 'killer application' of the AmI may yet prove to be that which enables enhanced nurturing and socialisation of a virtual nuclear family.

Home as a sanctuary is related to the notion of 'residence'. There is a case to be made for developing and establishing the notion of virtual residence as an extension of the physical residence. It could help to tackle concerns of identity, privacy and security for peoples' online activities. It could contribute to a better perception and consideration of ones' personal digital territory and could help to tackle the blurring boundaries of what is public and private in the online world (Beslay & Punie 2002). As most people will have a 'permanent residence in cyberspace', they will expect consistency between the actions of their avatar and their own actions in their professional and private lives as they answer phone calls, organise meetings and organise events (ISTAG 2002: 44). Also, as sensing and recording capabilities are more commonly found in an AmI environment, people need to be aware of how they are being sensed. Just as people can ascertain their visibility in physical space, we need cues to convey our visibility in virtual space (Abowd & Mynatt: 51-52).

Other potential drivers that emerge are e-learning, entertainment (digital TV, digital video recorder, gaming), environmental control, accessibility for the disabled, support for the elderly, work from home and e-commerce, etc.

5.3. From mobile phones to personal communication networks

Mobile communications are, in contrast with home automation, one of the biggest success stories of the 1990s ICT consumer market, first with the popularity of cellular phones, and then with text messaging (SMS). Unusually, these were fields where European markets and firms took a lead, in large part because of agreed standards and simplification of tariffs (e.g. prepaid cards). Mass consumer demand for communication while on the move took the industry by surprise, but efforts to create a mobile Internet via WAP met with little consumer enthusiasm, at least in Europe (in contrast with I-Mode in Japan). Poor content, slow and unreliable downloads, and lack of much added functionality on top of SMS, seemed to be behind this disappointment (Miles et al. 2002: 13-14).

Personal Area Networks are characterised by their high mobility. People on the move become networks on the move as the devices they carry network together and connect with the networks around them. Some of the networks will be moving at high speed in cars, trains and planes. This requires new network architectures, multi-access and re-configuration capabilities in the networks, new self-configuring wireless network capabilities to support communication between the multitude of sensors and communicating devices (ISTAG 2002: 43-44). Network management has to ensure proper load and network balancing, based on accurate models, not only of processing performance, power consumption and network bandwidth, but also for energy sources, mobility and quality of service (Lindwer 2003).

Today, the usability of mobile devices is limited by constraints such as narrow bandwidth, small screens, incompatible networks, incompatible applications and data, ignorance of the specific current context of the user. In the future, a world of mobile computing is envisaged where nomadic users can work with their applications and data independent of where they are, where the data and applications are and how they get access to the data and applications. The emphasis with personal communication networks is on the mobile or 'nomadic' user who should be able to:

- use of the same applications/services/content as at home or at work, at any time and in any place with the same quality, even whilst moving from one place to the other.
- have specific applications/services/content supporting mobility.
- use these applications whilst driving, walking, moving and physically working (ITEA 2001: 103-104).

5.4. Drivers for personal communication networks

Personal communication networks (PCN) are expected to become increasingly important since they enable and/or reinforce the social and demographic changes that are taking place in Europe. These are coined with the term ‘mosaic society’. This is a scenario of emerging lifestyles characterised by greater mobility, diversity and change. It will be made possible by changes in (1) demographics (e.g. greying society); (2) families and households composition (e.g. single parent households); (3) work and employment schedules (e.g. flexibility); (4) education and learning (e.g. lifelong learning); (5) leisure, lifestyle and consumption (e.g. 24 hour society, individualisation) (Scace 1999). The enlargement of the European Union will also provide challenges, for instance by almost doubling its number of consumers/citizens.

Greater mobility in time and space, more diversity and flexibility are enabled by ICTs, especially by mobile personal communication networks that offer permanently being connected ('always on') with social networks and other (virtual) communities. The support for socialisation as a critical function for PCNs is also raised by ISTAG (2002: 41).

6. What bends the trend? Challenges for AmI in Everyday Life

The objective of this study was to identify and document major challenges and bottlenecks for ambient intelligence in everyday life and to explore the relevant social and ethical questions that should be taken into account in order to bend the trend towards Ambient Intelligence. AmI is therefore discussed in terms of visions, technologies, applications and social challenges, with a particular focus on everyday life and from an everyday life perspective.

The AmI vision, as it is being developed in the European research area (industry, government S&T agencies, technical research laboratories and universities), is quite far-reaching and all encompassing. It assumes a paradigmatic shift, not only in all the components of computing but also in society. It is a vision that motivates stakeholders to support and encourage innovation in particular, and the S&T knowledge base in Europe in general in order to favour growth, competitiveness and well-being in the future Information Society.

The difficulty with technological vision building in general is that it tends to be deterministic, i.e. it assumes that technology will change society. It is also inclined to be rhetorical - in other words, it promises a better world without really working towards that goal. The AmI vision, however, specifically aims to avoid both of these pitfalls. It recognises the need for AmI to be driven by human rather than technological concerns, and it proposes human-centred design and development guidelines together with other social concerns to advance this process. It remains to be seen though if and how this manifesto will influence further research, development and design of AmI applications in order for the vision to go beyond similar claims made in the past.

It is far from clear how this can be realised. Some activities towards user-centred design have been identified but most of them are probably mainly based on functional descriptions of how to involve users in the design process. Though this constitutes a first logical step, the real challenge lies in involving users in a more sociological, ethnographic and/or qualitative sense. A crucial question for further investigation would be whether the results generated by such an exercise justify the time and effort involved and sufficiently reflect the diversity of users.

To investigate the potential of such an approach, a preliminary analysis of AmI from a domestication perspective was undertaken in this report.

Domestication studies the Information Society from the users' point of view by focusing on the acceptance of, or resistance to ICTs within the context of everyday life. It is inspired by social-constructivist approaches to science and technology, by audience and user research in media studies and by the sociology and anthropology of everyday life. Domestication highlights that the process by which new technologies are accepted into everyday life is far more complicated than is usually portrayed. This is because 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. This context, that of everyday life, is shaped by power relations such as class, gender, age and ethnicity.

These structural relations are likely to persist in the future Ambient Intelligence Space, but probably in different forms and formats. The literature and visions on AmI however, seem to overlook this fundamental issue. Therefore, it is argued that future studies and visions would benefit by taking the structures and patterns of power and everyday life explicitly into account.

The implication of such an approach is that a number of crucial ideas for AmI in everyday life could be significantly advanced or raised for the first time. Home as a sanctuary is an example of the former. It is recognised that the home of the future could indeed become the place where people enjoy being disconnected from an over-intrusive AmI but it also needs to be said that the notion of home as a sanctuary hides the tensions, struggles and inequalities that occur in the lives of most people. An example of ideas that have yet to be included within the framing of AmI in everyday life is housework. This particular type of continuous and time consuming everyday work at home is rarely touched upon in claims about human centred and/or everyday computing.

The domestication perspective also enabled us to highlight the fact that it will be difficult to sustain the treatment of context awareness and intelligent agents as socially neutral when they are confronted with users and non users in their everyday lives. Agents should not only be regarded as software programmes, but also as 'social actors' since they inevitably take a position. There is a need for social and user-oriented research to better understand the position of intelligent agents in everyday life in order to avoid agents' becoming a new 'black box' in society.

Scenarios describing possible futures in relation to ICTs and AmI are criticised on the basis of their tendency to portray ideal, successful users in a perfect world. Not only do they present stereotyped user groups, but they also seem to ignore the struggles, uncertainties and irregularities that characterise everyday life. The scenario scripts contain few tensions and malfunctions, and breakdowns and user-unfriendliness are hardly considered. User research, in contrast, demonstrates that the process of use and acceptance of technologies is not straightforward, obvious or without struggles.

Ambient Intelligence promises the disappearance of computing as an object by embedding computing intelligence in the environment and in everyday objects. Domestication also speaks about technologies and technological artefacts that are domesticated when they are 'taken for granted', when they are thought of as a 'natural' part of everyday life. There is a substantial difference between these two perspectives, however. AmI assumes the material or physical disappearance of computing while domestication refers to the mental invisibility of the technology. The two might exist together but not per se: the physical disappearance will thus not lead automatically to mental disappearance and hence to smooth acceptance and use of AmI. The former may even rather harm than facilitate acceptance exactly because AmI is invisible, and thus difficult to control.

Another design challenge for adaptive computing and AmI is to find an acceptable balance between adaptability versus rigidity. Devices and services that are completely open or that are completely adaptable may face the risk of becoming unusable or unappealing to users. Certain degrees of flexibility are necessary but pre-configured uses and users are also needed to guide potential users. They reduce the complexity and uncertainty which typically emerge when users are confronted with innovations. They also help users understand what is new about innovations, while completely open tools risk leaving them without direction.

There are more social, societal, economic and/or policy-related issues to be discussed as regards AmI in everyday life. The likeliness of a digital or rather AmI divide is one of them. Although the current concept of the digital divide is criticised, the question of whether, or how, this digital divide might become an Ambient Intelligence divide remains an important one. It is of course difficult to anticipate or predict the possible acceptance of AmI, but current and past research shows that people do not accept everything that is technologically made possible and supplied. Although AmI promises to remove some of the current barriers for the acceptance of new technologies (e.g. ease of use), it is unlikely that AmI will appeal to all groups of society - certainly not in the same way or at the same time. Socio-economic and cultural resources are unequally distributed in society and personal preferences differ as well. Moreover, other new concerns that could possible affect universal access to and use of AmI services and devices are likely to emerge. New skills, competencies and types of literacy are expected to result in different degrees of acceptance and even rejection of AmI.

The increased possibilities for AmI' to invade privacy might be a new barrier for its acceptance. With Ambient Intelligence, the monitoring and surveillance capabilities of new technologies can be extended far beyond the current possibilities. Traditionally, governments and companies have been regarded as the main potential invaders of privacy but with AmI, citizens too can watch or monitor each other more easily. Moreover, AmI faces a privacy dilemma. It needs to contain historical and current data about individuals' preferences and activities (user profiles) in order to deliver context-dependent, value added, pro-active services. A crucial but inevitable trade-off between protecting the privacy of certain personal information and receiving convenient, efficient services will have to be made. Other problems are related to the blurring of the boundaries between private and public in the online world where there are no visual cues that indicate differences between them. Technology can do a lot to protect privacy, but it can never be more than a safeguard. The more fundamental concern is about control – people's control over their own lives. AmI supposes that everyday life will be very dependent on its technological surroundings so, logically, there is a fear about loss of control.

Intelligent agent technology is part of this issue. Although these agents are under human supervision, users will have to delegate some control and decision power to them in order to benefit from their services. The difficulty is that software agents become less and less predictable as they become more intelligent. Solutions are needed to address this problem in ways that are acceptable for both suppliers and users.

Reliability and dependability, trust and confidence are also very important. If technologies do not deliver what they promise; if they do not react in ways they are supposed to react; and do not function when they are needed, then it will be very difficult for them to be accepted by the public.

Questions related to the economic implications of AmI are important as well. Given the rich diversity of technologies featured in the AmI landscape and the broad variety of potential applications, it is believed that the economic prospects for AmI will eventually justify current and future investment. However, it is far from clear how to build upon existing and emergent socio-economic demands and how to make money out of AmI, especially after the burst of the dotcom bubble. Some even argue that the limits for AmI are less technological than economic. The best way forward is probably not trying to find and bet on the right 'killer application'. Progress towards AmI may be better achieved by an amalgam of minor improvements in everyday activities and compelling applications, rather than the one and only killer application. AmI is also expected to change the way business is done, and to contribute to changes in the economy. Here too there are dangers and risks associated with the use of AmI.

Though the pace of technological progress is rapid, breakthroughs and advancements are still needed in the key enabling and other technologies to lay the foundation for AmI. There are still major technological issues related to further miniaturisation, power sources and energy consumption of embedded devices, new materials, software technologies, communication technologies and user-friendly interfaces. Since one of AmI's strengths is the fact that it is networked, standards and interoperability are regarded as crucial but highly uncertain issues, on which the future of AmI will partly depend.

The development of smart homes is also facing challenges since it has been around for more than a decade with relatively little consumer interest. It seems however that the proposed drivers of change are moving away from the traditional home automation services towards sharing technology resources, providing relaxation and harmony in a rapidly changing world, and supporting the home as a socialisation, communication and entertainment space. Mobile communications are, in contrast with home automation, one of the biggest success stories of the 1990s ICT consumer market. In the future, a mobile world is envisaged where nomadic users can have access to information, communication and knowledge independent of the location of both the users and the data and applications and of methods used to access the data and applications. This poses not only technological challenges but also challenges our current notions of time and space and of private and public spaces. Here, the innovative aspect of AmI, is that rather than adapting the nomad to the changing world, the environment should be adapted to the nomad.

Although it seems that the vision of Ambient Intelligence is based on technological progress in the fields of microelectronics, communication networks and interfaces, it is also driven by socio-economic factors that go beyond the technologies. The problem is that these are less visible and therefore less acknowledged. The challenge in bending the trend towards AmI for research and RTD policy approaches is to connect technological and social research on Ambient Intelligence and to make the socio-technological context of AmI more explicit.

7. References

Aarts, E., Harwig, R. & Schuurmans, M. (2002) Ambient Intelligence, pp. 235-250 in Denning, P. (ed.) *The invisible future. The seamless integration of technology in everyday life,* New York: McGraw-Hill.

Abowd, G. & Mynatt, E. (2000) Charting past, present, and future research in ubiquitous computing, *ACM Transactions on Computer-Human Interaction*, Vol. 7, No. 1, March 2000, 29-58.

Arraya, A. (1995) 'Questioning ubiquitous computing', in *Proceedings of the 1995 ACM 23rd annual conference on Computer science*, pp. 230-237, 1995. http://doi.acm.org/10.1145/259526.259560

Beigl, M., Gellersen HW. & Schmidt, A. (2001) Mediacups: Experience with Design and Use of Computer-Augmented Everyday Artefacts, *Computer Networks*, Vol 35 No 4, March 2001. http://www.comp.lancs.ac.uk/~hwg /

Berg, A-J. (1996) Digital feminism, Rapport Nr. 28, Centre for Technology and Society, Norwegian University of Science and Technology, Trondheim.

Beslay, L. & Punie, Y. (2002), 'The virtual residence: Identity, privacy and security', *The IPTS Report*, Special Issue on Identity and Privacy, No. 67, September, 17-23.

Bogdanowicz, M. & Leyten, J. (2001) Sympathy for the cyborg: Research visions in the information society, *Foresight*, Vol3, No.4, 273-283.

Bohn, J., Coroamã V., Langheinrich, M., Mattern F. & Rohs M. (2003) Disappearing Computers Everywhere. Living in a World of Smart Everyday Objects, Paper for the EMTEL Conference, London 23-26 April 2003. www.inf.ethz.ch

Bouwman, H. & Christofferson, M. (1992) (eds.) *Relaunching Videotex,* Dordrecht/Boston/ London: Kluwer Academic Publishers.

Burgelman, J-C. (2001) How social dynamics influence information society technology: Lessons for innovation policy, pp. 215-222 in OECD, *Social Science and Innovation*, OECD: Paris.

Cheverst, K., Davies, N., Mitchell, K., Friday, A. & Efstratiou, C. (2000), Developing a Context-aware Electronic Tourist Guide: Some Issues and Experiences, *Proceedings of CHI 2000*, Netherlands, April 2000, pp 17-24. http://www.guide.lancs.ac.uk/research.html

Corrocher, N. (2002) Internet diffusion dynamics in Europe: demand scenarios and the digital divide. STAR Issue Report No. 29, Databank Consulting. (www.databank.it/star)

Crabtree, A. & Rodden, T. (2002) Technology and the Home: Supporting Cooperative Analysis of the Design Space, In *CHI 2002*, ACM Press, April 2002. http://www.equator.ac.uk/papers/Authors/crabtree.html

Da Costa, O., Boden, M., Punie, Y. & Zappacosta, M. (2003) 'Science and Technology Roadmapping: from Industry to Public Policy', *The IPTS Report*, 73, April 2003.

Da Costa, O. & Punie, Y. (2003) Ambient Intelligence in Everyday Life: A function-oriented Science & Technology Roadmapping Project, Paper for the New Media and Everyday Life in Europe: EMTEL Final Conference, European Media, Technology and Everyday Life Research Network, London, LSE, April 23-26 2003. [ORA: 63743] de Haan & Huysmans, F. in collaboration with Becker, J., Breedveld, K., de Hart, J. & van Rooijen, M. (2002) E-cultuur: Een empirische verkenning, Sociaal en Cultureel Planbureau, Den Haag (Netherlands), June 2002.

Dey, A. (2001) Understanding and using context, *Personal and Ubiquitous Computing,* Vol 5(1), 4-7. http://www.cs.berkeley.edu/~dey

Dey, A., Mankoff, J., Abowd, G. & Carter, S. (2002) Distributed mediation of ambiguous context in aware environments, Paper presented at the UIST 2002 Conference, User Interface Software & Technology, Paris, 27-30 October 2002. http://www.cs.berkeley.edu/~dey

Dewsbury, G., Taylor, B. & Edge, M. (2001) The process of designing appropriate smart homes: including the user in the design, Paper presented at the 1st Equator IRC Workshop on Ubiquitous Computing in Domestic Environments, University of Nottingham, 13-14th September 2001. http://www.equator.ac.uk

Ducatel, K., Burgelman, J-C., Scapolo, F. & Bogdanowicz, M. (2000) Baseline scenarios for Ambient Intelligence in 2010, IPTS Working paper, July 2000.

Eurobarometer (2002) 'Internet and the public at large', Flash Eurobarometer 125, Eos Gallup upon request of the EC, DG Information Society, July 2002, Brussels: European Commission.

European Commission (EC) (2002) Information Society Technologies. A thematic priority for Research and Development under the Specific Programme "Integrating and strengthening the European Research Area" in the Community sixth Framework Programme, IST Priority, WP 2003-2004, EC: Luxembourg. http://www.cordis.lu/ist

Flichy, P. (1995) L'innovation technique. Récents développements en sciences sociales. Vers une nouvelle théorie de l'innovation, Paris: Editions La Découverte.
Freed, K. (2002) American cable adopts Europe's iTV standard, www.media-visions.com/itv-openmhp.html.

Forty, A. (1986) Objects of desire. Design and Society 1750-1980, London: Thames & Hudson.

Frissen, V. & Punie, Y. (2001) Present users, future homes. A theoretical perspective on acceptance and use of ICT in the home environment, Delft: TNO-STB Paper, May 2001.

Garfinkel, S. (2001) Database Nation. *The death of privacy in the 21st Century,* OReilly.

Gavigan, J., Ottish, M. & Greaves, C. (1999) Demographic and social trends Panel Report, Futures Report Series 02, IPTS, JRC, European Commission.

Gurova, E., Hermann, C., Leijten, J. & Clements, B. (2001) The Digital Divide: A research perspective. A Report to the G8 Opportunities Task Force, IPTS-Sevilla, JRC-EC, Eur 19913 EN.

Gray, A. (1992) Video *Playtime: the gendering of a leisure technology*, London & New York: Routledge.

Haddon, L. (2003) Intelligent Homes Research, A report by I&I for English Partnerships, Garston, UK, March 2003.

Infocomm (2002a) The connected home. 4th Infocomm Technology Roadmap Report 2002-2007, Infocomm Development Authority of Singapore, November 2002. www.ida.gov.sg

Infocomm (2002b) Mobile wireless. 4th Infocomm Technology Roadmap Report 2002-2007, Infocomm Development Authority of Singapore, November 2002. www.ida.gov.sg

IPTS (2001) Future bottlenecks in the information society. Report to the European Parliament Committee on Industry, External Trade, Research and Energy (ITRE), IPTS & ESTO, Sevilla, EC.

Islam, N. & Fayad, M. (2003) Towards Ubiquitous acceptance of ubiquitous computing, *Communications of the ACM*, February 2003, Vol. 46, No.2, 89-91.

ISTAG (2002) Strategic orientations and priorities for IST in FP 6, Report of the IST Advisory Group, EC: Luxembourg. www.cordis.lu/ist/istag

ISTAG (2001) Scenarios for Ambient Intelligence in 2010, Edited by Ducatel, K., Bogdanowicz, M., Scapolo, F., Leijten, J. & Burgelman, J-C., IPTS-ISTAG, EC: Luxembourg. www.cordis.lu/ist/istag

ITEA (2001) Technology Roadmap on Software Intensive Systems, Information Technology for European Advancement (ITEA), ITEA Office Association, Eindhoven. www.itea-office.org/index.htm

Jansen, B. J. (1998) The Graphical User Interface: An Introduction. *SIGCHI Bulletin*. 30(2), 22-26. http://jimjansen.tripod.com/academic/pubs/chi.html#History

Kunze, C., Grossman, U., Storck, W. & Müller-Glaser, K. (2002) Applications of ubiquitous computing in personal health monitoring systems, http://www-ibt.etec.uni-karlsruhe.de/bmt2002/paper/1199.pdf.

Lindwer, M., Marculescu, D., Basten, T., Zimmerman, R., Marculescu, S., Jung, S., & Cantatore, E. (2003) 'Ambient Intelligence visions and achievements. Linking abstract ideas to real-world concepts, To appear in *Design Automation and Test in Europe,* DATE 03 Proceedings, Munchen, 3-7 March 2003, IEEE Computer Society Press: California, USA. http://www.ics.ele.tue.nl/~tbasten

Luck, M., McBurney, P. & Priest, C. (2003) Agent Technology: Enabling next generation computing. A roadmap for Agent Based Computing, Agentlink EU FP5 NoE. http://www.agentlink.org/

Lucky, R. (1999) Connections, Bi-monthly column in IEEE Spectrum, March 1999. http://www.argreenhouse.com/papers/rlucky/spectrum/connect.shtml

Lull, J. (ed.)(1988) *World Families Watch Television*. Newbury Park, CA: Sage Publications.

Mankoff, J., Dey, A., Hsieh, G., Kientz, J., Lederer, S. & Ames, M. (2003) Heuristic Evaluation of Ambient Displays, to appear in Proceedings of the CHI 2003 Conference on Human Factors in Computing, Florida, 5-10 April 2003, ACM. http://www.cs.berkeley.edu/~dey

Marvin, C. (1988) When Old Technologies were New. Thinking about electric communication in the late nineteenth century. Oxford: Oxford University Press.

Marx, G. (2001) 'Murky Conceptual Waters: the Public and the Private', in *Ethics and Information Technology*, Vol. 3, no. 3, 2001: 157-169. http://web.mit.edu/gtmarx/www/murkypublicandprivate.html

Mattern, F. (2003) Ubiquitous Computing: Scenarios for an informatized world, ETH Zurich, Paper to be published. http://www.inf.ethz.ch/vs/publ/index.html

Miles, I., Flanagan, K.. & Cox, D. (2002) Ubiquitous Computing: Toward understanding European Strengths and Weaknesses, European Science and Technology Observatory Report for IPTS, PREST: Manchester, March 2002.

Moran, T. & Dourish, P. (2001) Introduction to the Special Issue of Human-Computer Interaction, *Human-Computer Interaction,* Vol 16, 2001. http://www.hci-journal.com/editorial/index.html

OZONE (2002) Ozone technology inventory, Deliverable D2A for the OZONE project 'New Technologies and Services for Emerging Nomadic Societies', IST-2000-30026, May 2002. http://www.extra.research.philips.com/euprojects/ozone

Punie, Y. (2003) Een theoretische en empirische benadering van adoptie, gebruik en betekenis van Informatie-en Communicatietechnologie in het dagelijkse leven, in Carpentier, N., Pauwels, C. & Van Oost, O. (eds.) (2003) Het on(be)grijpbare publiek: Een communicatiewetenschappelijke exploratie van publieksonderzoek, VUBPRess: Brussel, In Press.

Pinch, T. & Bijker, W. (1987) 'The social construction of facts and artefacts. Or how the sociology of science and the sociology of technology might benefit each other', in E. Bijker, T. Hughes, T. Pinch (eds.), *The social construction of technological systems. New directions in the sociology and history of technology,* Cambridge/Massachusetts/London: MIT Press, 17-50.

Rantanen, J., Karinsalo, T., Mäkinen, M., Talvenmaa, P., Tasanen, M., Vanhala, J., Alfthan, N., Impiö, J., Malmivaara, M., Matala, R. & Reho, A. (2002) Smart Clothing for the Arctic Environment, Proceedings of the Fourth International Symposium on Wearable Computers (ISWC'00), Institute of Electrical and Electronics Engineers.

Regan, P.M. (2002) Privacy as a common good in the digital world, Information, Communication & Society, 5:3, 382–405.

Rieder, B. (2003) Agent technology and the delegation-paradigm in a networked society, Paper for the EMTEL Conference, London 23-26 April 2003. www.emtelconference.org

Riva, G., Loreti, P., Lunghi, M., Vatalaro, F. & Davide, F. (2003) Presence 2010: The Emergence of Ambient Intelligence, in G. Riva, F. Davide, W.A IJsselsteijn (Eds.) *Being There: Concepts, effects and measurement of user presence in synthetic environments*, Ios Press: Amsterdam.

Scace, R. (1999) Demographic and Social Trends Issue Paper: Mosaic Living, IPTS Futures Project, Series No. 7, IPTS, Sevilla, EUR 18969 EN.

Silverstone, R. & Haddon, L. (1996) 'Design and domestication of information and communication technologies: Technical change and everyday life', pp. 44-74 in R. Mansell & R. Silverstone (eds.), *Communication by design. The politics of information and communication technologies.* Oxford: Oxford University Press.

Rogers, E. M. (1995) *Diffusion of innovations.* New York: The Free Press (Fourth Edition).

Sleeth, C. (2002) Pervasive Computing, Explorer Technology Map, SRI Consulting Business Intelligence. www.sric-bi.com

Schwartz Cowan, R. (1985b) 'How the refrigerator got its hum', in D. MacKenzie & J. Wajcman (eds.), *The social shaping of technology. How the refrigerator got its hum*, Milton Keynes/Philadelphia: Open University Press, 202-218.

SRI (2003) Distributed Identities: Managing privacy in pervasive computing, SRI Consulting Business Intelligence, Explorer Viewpoints, May 2003.

Stephanidis, C. (2001) 'Ambient Intelligence in the context of Universal Access', Special Theme on Ambient Intelligence, ERCIM News No.47, October 2001, 10-11.

Tuomi, I. (2002) The Lives and Death of Moore's Law, *First Monday*, Volume 7, No. 11, November 2002). http://firstmonday.org/issues/issue7_11/tuomi/index.html

Waldrop, M. (2003) Pervasive Computing. An overview of the concept and an exploration of the public policy implications, Paper for the Future of Computing Project, Foresight and Governance Project. www.thefutureofcomputing.org

Warren, S. & Brandies, L. (1890) The Right to Privacy, *Harvard Law Review*, Vol IV, No.5. http://www.lawrence.edu/fac/boardmaw/Privacy_brand_warr2.html.

Weiser, M. (1993) 'Some computer science issues in ubiquitous computing', *Communications of the ACM*, July 1993, Vol. 36, No.7, 75-84.
http://www.ubiq.com/hypertext/weiser/UbiCACM.html

Weiser, M. (1991) 'The computer of the 21st century', *Scientific American*, September 1991, pp.94-101.
http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html

Weiser, M. & Brown, J-S. (1996) The coming age of calm technology. ACM paper.
http://www.ubiq.com/hypertext/weiser/acmfuture2endnote.htm

Wilson, L. (2001) The interface evolution. SRI Consulting Business Intelligence, August 2001. http://www.sric-bi.com

Wisneski, G., Ishii, H., Dahley, A., Gorbet, M., Brave, S., Ullmer, B., & Yarin, P. (1998) Ambient Displays: Turning architectural apace into an interface between people and digital information, *Proceedings of the First International Workshop on CooperativeBuildings* (CoBuild '98), February 25-26, 1998, Springer.

WWRF (2001) The book of vision 2001, Version 1.0, Wireless World Research Forum, December 2001. http://www.wireless-world-research.org

Wyatt, S. Thomas, G. & Terranova, T. (2002) 'They came, they surfed, they went back to the beach: Conceptualising use and non-use of the Internet', pp. 23-40 in S. Woolgar (ed.) *Virtual Society? Technology, Cyberpole, Reality,* Oxford: Oxford University Press.

8. List of Emtel Key Deliverables

Berker, Thomas (2003) Boundaries in a space of flows: the case of migrant researchers' use of ICTs, NTNU, University of Trondheim.

Cammaerts, Bart and Van Audenhove, Leo (2003) *ICT usage among transnational social movements in the networked society*, ASCoR/TNO, University of Amsterdam.

Durieux, Dorothy (2003) *ICT and social inclusion in the everyday life of less abled people*, LENTIC, University of Liege and ASCoR, University of Amsterdam.

Georgiou, Myria (2003) *Mapping diasporic media across the EU; addressing cultural exclusion*, Media@lse, London School of Economics and Political Science.

Hartmann, Maren (2003) The Web Generation: the (de)construction of users, morals and consumption, SMIT-VUB, Free University of Brussels.

Punie, Yves (2003) A social and technological view of Ambient Intelligence in everyday life, IPTS (JCR-EC), Seville.

Ward, Katie (2003) An ethnographic study of internet consumption in Ireland: between domesticity and public participation, COMTEC, Dublin City University.

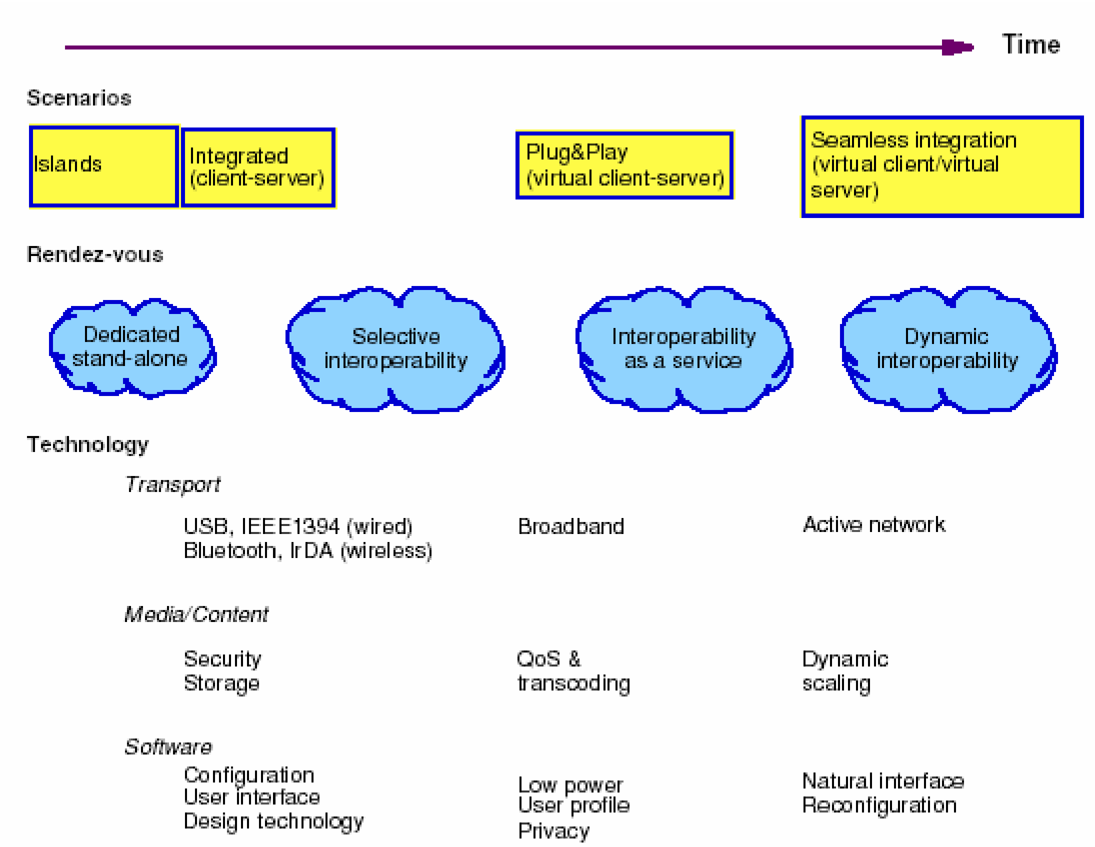
Annex: Technology roadmaps

A1. A roadmap towards the intelligent home

ITEA proposes a roadmap towards the intelligent home. It consists of a sequence of four scenarios:

- Islands: The situation today with limited interconnection between internally connected islands. For example, a video recorder and/or dvd player is connected to a television set, a printer and PDA to a PC. Another island is clustered around Hi-fi. Connections between the islands are rare.
- Integrated: The different islands are connected to a common 'home backbone'. This generic transport bus recognises the different individual parties, and contains more than the typical 'master-slave' connections.
- Plug&Play: This scenario is an evolved version of the Integrated Scenario. Devices and appliances can be added and removed easily. When they are brought into the home network environment, they will then further define and fulfil their final functionality. For instance, a remote control might program itself according to the different appliances that can be found in the home.
- Seamless Integration: The most advanced scenario is a further evolution of the Plug&Play situation. The home network will gain an identity and/or intelligence by itself. Rather than simply routing information from servers to clients, it will start creating server functionality by itself. One example is the implementation of user profiles. Each appliance can store a user profile (to enhance a specific operation like music choice, colour choice, etc.). With seamless integration, the network itself should be able to generalise the characteristics of a certain user, and make it available to any new appliance entering the home network (ITEA 2001: 82-83).

ITEA Roadmap towards the intelligent home



Source: ITEA 2001: 82

The rendez-vous concept introduced in the ITEA Roadmaps, as shown in figure 7 indicates a progress marker, a moment whereby parallel evolutions merge.

ITEA (2001: 85-86) developed also a similar roadmap for access technologies based on four scenarios: unrelated access (today with different, isolated networks for TV, phone, internet, etc.), broadband access (via different networks), universal access (services uncoupling from dedicated networks) and nomadic personal access (services tied to the user regardless access point). The timeline used for access networks and in home networks scenarios spans four periods: now, short term, medium term and long term.

The Infocom Technology Roadmap on the connected home provides a more detailed roadmap for 2002 -2007 (Infocom 2002a). It summarizes the technology platforms for the home environment, the different home networking technologies and some market figures, not only for Singapore but also world-wide (See: www.ida.gov.sg).

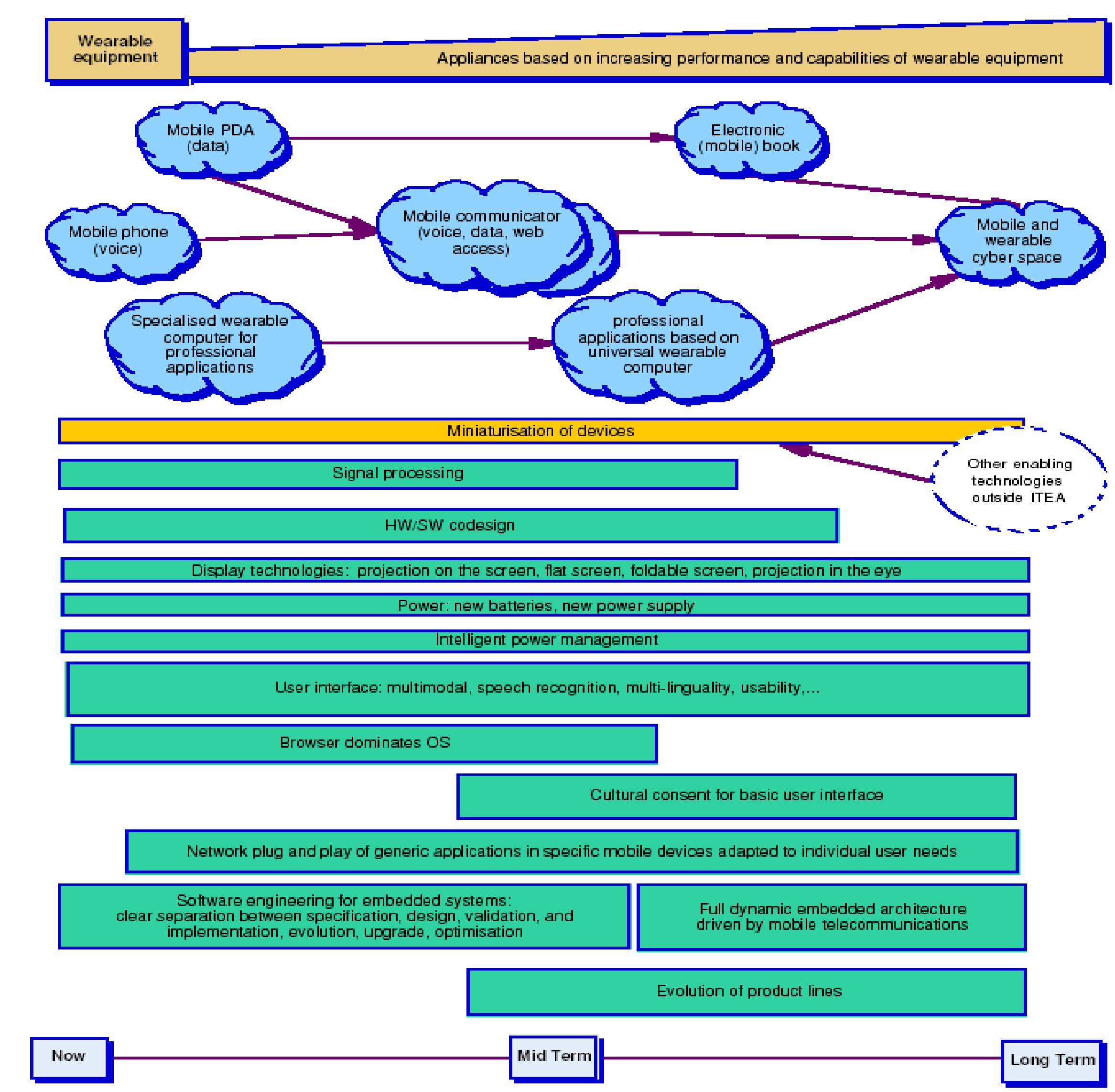
A2. A roadmap towards personal communication networks

Similar to the above-mentioned scenarios on the intelligent home, ITEA developed scenarios for the mobile domain. The focus is on issues related to 'being mobile'. The main technical challenges are related to wearable equipment, vehicle ported equipment (e.g. non-personal 'public' devices for computing) and mobile network computing for using the network as the seamlessly integrated platform of computing in any place and at any time (ITEA 2001: 103-104).

The scenario for wearable equipment is supposed to go from (Figure 6):

- isolated appliances with access to one kind of network;
- over mixed appliances (Personal Communicator, Personal Travel Assistant, Electronic books, Personal Entertainer,…) with access to several different networks;
- and co-operating appliances seamlessly integrated with distributed applications (Cyberassistant);
- to general purpose platform for applications with access to several networks. (ITEA 2001: 107).

ITEA Roadmap for wearable equipment



Source: ITEA 2001: 111

The Infocom Technology Roadmap on mobile wireless provides a more detailed roadmap for 2002 -2007 (Infocom 2002b). It takes into account network trends, trends in enabling technologies, applications and services and summarises also market figures, not only for Singapore but also world-wide (See: www.ida.gov.sg).