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Editors

AMBIENT INTELLIGENCE

Springer

Ambient Intelligence

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With 143 Figures

Springer

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Preface

The emergence of a new technical concept that profoundly affects human life is a relatively rare event. Yet, over the last centuries and decades, we have witnessed acceleration in the introduction of new society-affecting technologies. While it took a long time for book printing, electricity, the car and television to put their stamp on the world and to affect the daily living patterns, information-technology related technologies have been introduced at an ever-increasing pace. It took the internet and the mobile phone just two or one decades to profoundly change the way we communicate and interact.

It is our belief that yet another paradigm-shifting technology is now on the horizon. "Ambient intelligence" is the most commonly used descriptor of the phenomenon, although in the United States it is often dubbed as sensor (and actuator) networks. As a third wave of computing, it presents a true departure from the way electronic devices and humans interact. In the first wave of computing – mainframes, super-computers, mini-computers, desk- and laptops, the meaning of computation was centered in a single device, and users mostly interacted in batch-mode or through a limited interface. With the advent of the internet and the world-wide web in the 1990s, the picture changed dramatically. Computation and information access became a globally distributed concept with data and computation scattered over a wide range of servers and data storage devices located all over the world. However, the interface remained quite similar to the previous era. To obtain data or information, a user has to proactively initiate an exchange.

The "Ambient Intelligence" paradigm differs in two major ways from these previous generations. First of all, the user interface has become reactive, that is actions are not explicitly requested but are the result of the mere presence of people or their avatars (of course, with their explicit or implicit goals and constraints). Secondarily, the meaning of computation can no longer be associated to a single device or a set of connected devices, but is located in the "collection of devices". This means that the failure of a single component does not mean that the goal cannot be accomplished.

Yet, new technologies do not appear all of a sudden. After initially being in the domain of a mere few (just think about the ARPANET of the 1970s and early 1980s), they gradually emerge into the global market. For this to happen, potential users have to prepared, convincing benefits have to be conveyed, and concerns regarding negative side-effects have to be resolved. "Ambient Intelligence" is such a new concept. To be successful, it is up to the advocates of this vision to preach: that is, to make it known, provide understanding, create demands, shine light onto the concept from various angles, and discuss various peripheral aspects. Only when this is accomplished will the technology find broader penetration and begin to accelerate.

These concerns provided the ultimate motivation for the editors to assemble this book. As true believers, it is our goal to "preach": convey the opportunities and benefits of the ambient intelligence concept, evaluate the current status and identify challenges and concerns.

To that effect, we have organized the book in three major parts:

- Part I discusses a number of potential applications of ambient intelligence, and describes a set of scenarios. The part starts by addressing social, economic and ethical implications. It discusses electronics integrated into textiles, in smart rooms and intelligent buildings that could make our environment more friendly and enjoyable, more user-friendly, more effective, and in addition more energy efficient.
- Part II gives an overview of the networking and infrastructure issues involved in the realization and the implementation of an ambient intelligence environment. A networked infomechanical system, an operating system, a service-based application interface and a locationing and timing service are discussed for peer-to-peer ad-hoc wireless sensor networks. Furthermore, the security issue is discussed. This part concludes by presenting an alternative architecture, namely a network with a star topology, for improved power consumption and efficient data communication.
- Part III describes the basic components and technologies needed for the low-cost, low-power, small-size implementation of these ad-hoc ubiquitous networks of communication and computation nodes. Issues such as programming environment, energy supply, privacy and security, packaging and algorithms for various applications are addressed as well.

This book should appeal to wide range of audiences including the technologists, the system developers, the application programmers, and the potential users. As such, it can be used as a reference document for practicing engineers, but also as a text book for graduate courses that explore the avant-garde of the information technology age.

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Introduction

W. Weber, J. Rabaey, and E. Aarts

Why does mankind always want to predict the future? The science of futurology has invented various methods such as Delphi studies and scenario techniques that try to predict various aspects of upcoming societies. In the past, these forecasts, however, have had limited success. Important breakthroughs such as the success of the Internet came as a surprise to this field of science. However, it has been observed that as soon as ideas become common to opinion leaders, they develop into self-fulfilling prophecies and materialize as powerful and universal trends. "Ambient Intelligence" is a concept that has this potential.

Ambient intelligence is the vision that technology will become invisible, embedded in our natural surroundings, present whenever we need it, enabled by simple and effortless interactions, attuned to all our senses, adaptive to users and context-sensitive, and autonomous. High-quality information access and personalized content must be available to everybody, anywhere, and at any time. Ambient intelligence is characterized by an environment

- where technology is embedded, hidden in the background
- that is sensitive, adaptive, and responsive to the presence of people and objects
- that augments activities through smart non-explicit assistance
- that preserves security, privacy and trustworthiness while utilizing information when needed and appropriate.

Ambient intelligence is used to support human contacts and accompany an individual's path through the complicated modern world. It offers him information and guidance whenever needed. In other words, it improves the control of his surrounding. Control of human health and security functions is another goal of ambient intelligence. Various logistics applications such as tracking of bags in airports or of books in libraries are also sometimes considered ambient intelligence, although a highly developed interface to humans is not key to those. Moreover, ambient intelligence will enable people to express themselves in ways that are unprecedented as natural interaction and augmented environments will become available. This may result in enhanced expressiveness, productivity, and well-being that may improve the quality of life substantially.

From the technical standpoint, ambient intelligence means distributed electronic intelligence. The necessary hardware vanishes into the background. Devices used for ambient intelligence are small, low-power, low weight and (very importantly) low-cost; they collaborate or interact with each another; and they are redundant and error-tolerant. That means that the failure of one device will not cause failure of the whole system. Often wired connections do not exist; thus radio methods play an important role for data transfer.

Some believe that ambient intelligence is only a vision of a very distant future. Indeed, some of these visions lie at least 20 years ahead of us. The realization of intelligent electronic wall paper or smart dust forming distributed intelligence, for instance, will require additional technological achievement. For some of those not even basic feasibility has been demonstrated today. Examples are large-size paper-like display technologies, or printable, ultra-low-cost, ultra-low-power electronics. Experience tells that the introduction to the market of new basic hardware technologies takes a long time even after a basic proof of functionality has been demonstrated.

On the other side, indications of a trend towards ambient intelligence are already evident today. While in the 1970s one computer served many users, and in the 1990s the personal computer served humans on a one-to-one basis, individuals are already served by many computational devices today. Peripheral devices that were dependent on central computing a few years ago now have become independent and contain powerful controllers. It is our vision that this trend towards distributed electronics and intelligence will only accelerate in the near future. In addition, many of the technologies that would enable this revolution are becoming available today. Technologies such as energy-scavenging, low-power and low-cost digital and wireless components, and integrated sensors are making their way into the market. In addition, self-configuring, robust networking techniques are being conceived making it possible to connect 100's of devices seamlessly and effortlessly in a scalable fashion.

The research work on ambient intelligence strives to demonstrate applications and technologies that will enable semiconductor solutions for the technology lifestyle of the individual in the 21st century. In this work, the individual is the subject, whereas electronics is the object. In some sense, this concept is the opposite of virtual reality, in which the user is embedded in an electronic environment that provides sensory inputs. In virtual reality, the user is controlled by the system and becomes the object.

The users of the targeted applications want their daily needs to be met. They want an excellent interface between technology and themselves. Neither specific operational knowledge, nor awareness of the functioning of the appliances or applications should be necessary. It is our vision to provide human individuals with better control of their surroundings, assisted by invisible, highly functional electronic appliances that support personal expression, well-being, and productivity, eventually leading to a better quality of life.

Part I

Applications

Social, Economic, and Ethical Implications of Ambient Intelligence and Ubiquitous Computing

J. Bohn, V. Coroamă, M. Langheinrich, F. Mattern, and M. Rohs

Summary. Visions of ambient intelligence and ubiquitous computing involve integrating tiny microelectronic processors and sensors into everyday objects in order to make them "smart." Smart things can explore their environment, communicate with other smart things, and interact with humans, therefore helping users to cope with their tasks in new, intuitive ways. Although many concepts have already been tested out as prototypes in field trials, the repercussions of such extensive integration of computer technology into our everyday lives are difficult to predict. This contribution is a first attempt to classify the social, economic, and ethical implications of this development.

1 Introduction

The increasing miniaturization of computer technology will, in the foreseeable future, result in processors and tiny sensors being integrated into more and more everyday objects, leading to the disappearance of traditional PC input and output media such as keyboards, mice, and screens. Instead, we will communicate directly with our clothes, watches, pens, and furniture – and these objects will communicate with each other and with other people's objects.

More than 10 years ago, Mark Weiser foresaw this development and described it in his influential article "The Computer for the 21st Century" [1]. Weiser coined the term "ubiquitous computing," referring to omnipresent computers that serve people in their everyday lives at home and at work, functioning invisibly and unobtrusively in the background and freeing people to a large extent from tedious routine tasks. In its 1999 vision statement, the European Union's Information Society Technologies Program Advisory Group (ISTAG) used the term "ambient intelligence" in a similar fashion to describe a vision where "people will be surrounded by intelligent and intuitive interfaces embedded in everyday objects around us and an environment recognizing and responding to the presence of individuals in an invisible way" [2].

This contribution is based on an earlier journal article "Living in a World of Smart Everyday Objects – Social, Economic, and Ethical Implications", Human and Ecological Risk Assessment, Vol. 10, No. 5, October 2004.

The vision of a future filled with smart and interacting everyday objects offers a whole range of fascinating possibilities. For example, parents will no longer lose track of their children, even in the busiest of crowds, when location sensors and communications modules are sewn into their clothes. Similar devices attached to timetables and signposts could guide blind people in unknown environments by "talking" to them via a wireless headset [3]. Tiny communicating computers could also play a valuable role in protecting the environment, for example as sensors the size of dust particles that detect the dispersion of oil spills or forest fires. Another interesting possibility is that of linking any sort of information to everyday objects, allowing for example future washing machines to query our dirty clothes for washing instructions.

While developments in information technology never had the explicit goal of changing society, but rather did so as a side effect, the above-mentioned visions expressly propose to transform society by fully computerizing it. It is therefore very likely that this will have long-term consequences for our everyday lives and ethical values that are much more far-reaching than the Internet with all its discussions about spam e-mails, cyber crime, and child pornography. With its orientation towards the public as well as the private, the personal as well as the commercial, it aspires to create technology that will accompany us throughout our entire lives, day in and day out. And if Mark Weiser's vision of "invisible computing" actually materializes, we won't even notice any of it.

It seems to be clear that with these technical developments – pushed through largely unnoticed by the general public and extending quite rapidly into our everyday lives – unanticipated (if not unacceptable) standards could soon be set for the rest of our lives. In the following, we examine the driving factors behind the visions of ubiquitous computing and ambient intelligence – from a technical as well as an economic perspective – and we try to illustrate the social and ethical implications of a "smart world" that connects everything to everything else, where anywhere can potentially be contacted from anywhere else, and where everybody could conceivably interact with anybody (and anything) else.

2 Technology Trends

The driving force behind continuing technological progress in the field of information technology is the long-term trend in microelectronics: Moore's Law [4], drawn up in the late 1960s by Gordon Moore and roughly stating that the power of microprocessors doubles about every 18 months, has held true with astonishing accuracy and consistency. A similarly high increase in cost-efficiency can be observed for some other technological parameters such as storage capacity and communications bandwidth. To put it another way, prices for microelectronic functionality with an equivalent amount of computing power are falling radically over time. This trend, which is expected to continue for at least another 15 years, means that computer processors and storage components will become much more powerful, smaller, and cheaper in the future, so that there will be an almost unlimited supply of them.

Even more important are the results of microsystems technology and nanotechnology. These could lead, for example, to flexible displays or electronic paper. Another interesting development is radio sensors that can report their readings within a few meters distance without an explicit energy supply – such sensors obtain the necessary energy from the environment or directly from the measuring process itself.

Electronic labels (so-called "smart labels" or RFID tags) also operate without their own energy supply. Depending on their construction, these are less than a square millimeter in area and thinner than a piece of paper. In some ways, this is a further development of the well-known anti-theft technology involving security gates in department stores. However, this is not just about the binary information "paid/stolen"; within milliseconds, several hundred characters could be read and written "wirelessly" up to a distance of a few meters [5].

What is interesting about such remote-inquiry electronic markers is that they enable objects to be clearly identified and recognized, and therefore linked in real time to an associated data record held on the Internet or in a remote database. This ultimately means that specific data can be associated with any kind of object. If everyday objects can be uniquely identified from a distance and furnished with information, this opens up application possibilities that go far beyond the original purpose of automated warehousing or supermarkets without cashiers.

Significant advances have also been made in the field of wireless communications. Especially interesting are recent short-range communications technologies that require very little energy, making it possible to produce designs that are much smaller and cheaper than today's mobile phones. Intensive research is also being carried out into improved options for indicating the position of mobile objects. As well as increased accuracy (currently around ten meters for the GPS system), the aim is also to make the devices much smaller.

If you summarize these technology trends and developments – tiny, cheap processors with integrated sensors and wireless communications capability, attaching information to everyday objects, the remote identification of objects, the precise localization of objects, flexible displays based on polymers, and electronic paper – it becomes clear that the technological basis for a strange new world has been created: everyday objects that are in some respects "smart," and with which we can even communicate under certain circumstances.

There are various ways of implementing such communication with things. As one example, imagine everyday objects such as furniture, packaged food, medication, clothing, or toys being equipped with an electronic label