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Ubiquitous Computing

Summary

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SUMMARY

»The most profound technologies are those that disappear« Mark Weiser, Xerox PARC, 1991

WHAT IS UBIQUITOUS COMPUTING?

Under the term »Ubiquitous Computing« (UbiComp) we understand the ubiquity of information technology and computing power, which in principle pervade all everyday objects. Computer power and information technology can thus be applied in many areas ranging from industrial production up to private, everyday life with a new quality.

Conceivable are countless very small, wirelessly intercommunicating microprocessors, which can be more or less invisibly embedded into objects. Equipped with sensors, these mini-computers can record the environment of the object in which they are embedded and provide it with information processing and communication capabilities. Such objects have a new, additional quality – they »know« for example, where they are, which other things are in the vicinity and what happened to them in the past. In the long term, ubiquitous computing can pervade all spheres of life: it promises to increase comfort in the private home area and to improve energy efficiency; »intelligent« vehicles may make roads safer; adaptive personal assistance systems could raise work productivity in the office; and in the medical field implantable sensors and micro-computers monitor the health of the user.

This ubiquity is reflected in a large number of almost identical concepts, such as »pervasive computing«, »ambient intelligence« or »the Internet of things «. In practice, the differences between these terms is of rather an academic nature: common to all is the goal of assisting people as well as a continuous optimization and promotion of economic and social processes by numerous microprocessors and sensors integrated into the environment. The following features characterize ubiquitous computing:

> Decentralization or modularity of the systems and their comprehensive networking,
> embedding of the computer hardware and software in other equipment and objects of daily use,

> mobile support for the user through information services anywhere and any time,
> context awareness and adaptation of the system to current information requirements
> automatic recognition and autonomous processing of repetitive tasks without user intervention.

Typical devices include small mobile computers, further developments of today's mobile telephones, so-called »wearables« like intelligent textiles or accessories as well as computerized implants.

UBIQUITOUS COMPUTING IN AN INTERNATIONAL COMPARISON

In the past ubiquitous computing and related concepts have found their way into the research policy of most developed nations, which however pursue different models. The new technologies are used here as a means to realize very different objectives, which range from maintaining a scientific-technological position of excellence via ensuring and expanding economic competitiveness up to transforming and modernizing society.

In the *United States* ubiquitous computing was already on the agenda of the most important civilian and military research promotion institutions in the late 1990s. Since 1999 issues of ubiquitous computing (universal networking, embedded systems) are represented in the list of the most significant trends in information technology of these institutions, although there was no comprehensive socio-political vision.

In *Japan* the creation of the so-called Ubiquitous Network Society represented an important focus of the state and industrial research agenda, at the latest since 2003/04. Goal of this program, which was largely formulated by industry, was a massive diffusion of fast, wireless networks and consumer-oriented services – quite in the tradition of mobile communications in Japan. This vision is called »u-Japan«, whereby »u« stands not only for ubiquitous but also for universal, user-oriented and unique, which illustrates the individualistic character of the Japanese initiative.

Similar to Japan, *South Korea* also aimed to become one of the leading ubiquitous network societies. In recent years, Korea has especially accelerated the expansion of its broadband network and is otherwise one of the leaders in implementing innovative ICT in products. On the whole, Korea today is a pioneer in realizing the information society and according to the estimates of the International Telecommunication Union, »is already swimming in information today«. Other than in Japan, Europe or the USA, the Korean plans have less an individual than a universal societal benefit in mind.

Singapore is today already completely equipped with broadband and wireless networks and is regarded as an ideal testing bed for new applications. In addition to the network infrastructure, Singapore should develop into a »ubiquitous information society«, according to government plans. Besides economic policy targets, societal benefits such as, for instance, the maintenance of the cultural diversity of the multi-ethnic state of Singapore are specifically addressed.

The *European Commission* preferred the term »Ambient Intelligence« for a long time, in which the needs of people should be foremost and less the technical possibilities. Not only the competitiveness of the European Economic Area should be encouraged, but also the transition to a dynamic knowledge society supported. In this context societal needs have to be taken into account.

Although aspects of ubiquitous computing were already addressed in *Germany* at an early stage in the context of the Futur process and the strategy debates of the large research organizations, the federal government only started paying real attention to the topic with the Innovation Initiative in the year 2005. In the High-tech Strategy the »Internet of things« finally developed into a »lighthouse topic«, whereby the focus lies less on consumer-oriented than on business or industrial applications.

TECHNICAL BASICS OF UBIQUITOUS COMPUTING

Many factors are driving the progress of information technology at quite different levels: the increased performance of important components and production processes, better methods to create software, more efficient programming languages and operating systems, innovative concepts for man-machine interaction and still many more. As a typical crosscutting technology ubiquitous computing utilizes the whole range of modern information and communication technologies (ICT), whereby the advances in communication technology, microelectronics, the energy supply, in user interfaces, information security, sensors and localization technology are of particular significance.

In the field of *microelectronics* it can be assumed that, according to Moore's Law, in the coming 10 to 15 years logic and memory elements will become even smaller and more powerful, respectively cheaper. *New materials* such as semi-conducting polymers help to ensure that electronic systems will be embedded in almost all conceivable objects and require less energy to operate.

Communication technology, in particular mobile communication, is considered the key technology in ubiquitous computing. Here it is to be expected that besides the »classical« technologies like Ethernet or UMTS, increasingly self-organizing ad-hoc networks and a number of powerful close range technologies will occur. Among the important technologies of the personal area networks belong primarily near field communication (NFC) and ultra-wide band technology (UWB), which enable a secure broadband transmission, as will be common in future in the data exchange between the end devices and between terminal devices and communication infrastructure.

In order to be able to interact with invisible, embedded information systems, *innovative user interfaces* are necessary which permit a »natural« interaction (e. g. by speech or physical interaction). The new type of interaction includes also the *automatic capture of the context*, which is not just about the registration of external parameters (e. g. location), but increasingly also to identify the user's emotional states or his intended actions (e.g. the automatic recognition of critical situations in medical monitoring systems). Only with the most accurate knowledge of each context is it possible to offer services in response to individual locations and situations and to delegate certain tasks completely to technology.

For context detection, powerful, light and cheap sensors are required, which are even today used in some pilot applications (e. g. in monitoring cold chains). Promising for the future are also so-called *sensor networks*, i. e. sensors with communication capabilities, which more or less autonomously monitor their surroundings and transmit the registered data regularly or on request to the operator/user.

Radio frequency identification (RFID) is the most common technique for identifying and localizing objects from a distance. This automatic identification (auto ID) is an important basis for many of today's applications of ubiquitous computing. On the RFID chip a unique identification number and further information can be saved or read and vice versa up to several hundred bits of information can be stored wirelessly on the chip. This takes place in split seconds and at a distance of up to several meters. Today RFID chips including a paper-thin antenna (together called RFID transponders) cost between a few cents and more than

€100, according to their performance. The RFID technology is being driven by possible applications in the field of logistics: if products can automatically reveal their identity on demand, then a continuous tracking and tracing of the flow of goods throughout the complete supply chain without manual interventions can be guaranteed.

In addition to the identification number on the RFID chip, further information pertaining to an object can be saved in a remote database. Thus after reading the identification number this additional information can be retrieved via a mobile or fixed connection, so that any amount of detailed information can be "attached" to things or persons. This opens up application possibilities, which extend far beyond an automatic storage system and monitoring of the supply chain.

Even if the basic principle of automatic identification by means of RFID is relatively simple, a large number of open questions and unresolved problems still prevent broad diffusion. The *costs of the RFID transponders and system integration* are still the greatest barriers to introducing RFID to the consumer goods market. Here, however, through the use of new materials and production processes (polymer electronics) cost reductions and greater cost efficiency are becoming apparent. The realization of economies of scale however depends to a considerable extent on the *standardization of RFID technology*, which is one of the greatest international challenges momentarily. The point is that existing solutions and the different requirements of various applications must be taken into account in the definition of a (generic) standard.

Questions of *information security* are of paramount importance for the users of RFID, because although RFID systems should be open in order to utilize network effects, they can also allow access to security-essential or competition-critical information. A further complication is that the RFID chips are normally not powerful enough to implement cryptographic procedures. Finally, at present the consequences manufacturing and disposing of millions of disposable RFID chips will have for the environment are still unknown.

From the technical point of view ubiquitous computing will be realized in two phases:

> In the present first phase, the possibilities of auto-ID technologies will be utilized above all, in particular RFID, which contribute towards equipping objects of the real world and persons with information technologies. Especially in the business environment this enables a seamless communication, which is the

basis for a great variety of (new) applications. These are primarily utilized to control processes and material flows more efficiently. For the private user new information services emerge in this phase, through which mobile devices will be upgraded. Technical precondition for the new functions/ features are an increased performance of the devices, further miniaturization and the possibility of ad hoc networking.

> The second phase of ubiquitous computing is characterized by an increasing integration of previously separate solutions and individual end devices to a completely networked information system. This can lead to the replacement of conventional devices by specialized devices (e. g. wearables) or by “ambient interfaces” and “responsive environments” that will be jointly used by many users. The increased use of sensors will enable these systems to recognize their users and environment and thus to process recognized tasks autonomously to a certain extent.

APPLICATIONS OF UBIQUITOUS COMPUTING

Due to its crosscutting character, many applications of ubiquitous computing are possible in the business, public and private fields. This study concentrates on the economically or societally significant and pioneering applications in trade, logistics, industry (especially in automobile production), transport and healthcare, as well as personal identification.

RETAIL

Applications in retailing are based on the use of cheap RFID transponders, which (as a supplement or replacement for barcodes) are attached to product packaging or larger containers. In this way it becomes possible to identify goods at any time and along the supply chain. Based on this information it is possible to predict supply and demand for certain products more quickly and accurately and to organize procurement, picking and packing and distribution more efficiently.

Among the multiple possibilities for utilizing ubiquitous computing in retail are the automatic registration and identification of goods deliveries, a more efficient inventory management and the automatic recording of the inventory as well as of goods in the customer’s shopping basket, the possibility to trace products using an electronic »family tree« and, last not least, improved protection against theft. Precondition for a broad and successful introduction of UbiComp applications in trade are uniform standards, which make an exchange of information along the supply chain possible. Additionally, it is imperative that as many stakeholders as possible participate in the systems. Due to the dominance of a few large commercial chains that can dictate conditions to their suppliers, the conditions are looking good. On the other hand, trade with consumer goods is very competitive and the price pressure correspondingly high. Consequently, the leeway for investing in new IT infrastructures and equipping products with RFID transponders is very restricted. Thus RFID labels are still too expensive for many low-priced goods or those with a very small profit margin. On the other hand, the costs and expected benefits are unequally distributed among the actors. Before ubiquitous computing can become a success story in retail, further technical advances, but also a general agreement of the companies about the distribution of costs and benefits is absolutely necessary. An increase in profits as a result of UbiComp can initially be achieved only by further rationalization and process optimization. Losers in this development are likely to be above all smaller specialist shops and retailers as well as employees with low qualifications.

Economic profit as a result of ubiquitous computing can at best be expected in the mid term and only if the suppliers succeed in developing new additional functions and services for which the customer feels a real need and for which he is willing to pay. In such integrated and individualized shopping worlds all products will be accompanied by extensive supplementary information which permit more rationalization via the automatic recording and accounting of the goods purchased, but also to create new offers for the clients. These range from customized advertising, which mainly benefit the seller, up to information about ingredients or best-by dates, which provide greater transparency for the client. Finally, innovative services are thinkable which range from customized delivery up to customer service offers and from which both sides should equally profit.

In view of the high investment costs for a »networked shopping world« it is still unclear whether such offers can be operated economically. Mixed financing is also conceivable here, in which besides user fees advertising revenue and marketing customer data could be considered, although it is unclear how this would affect the acceptance of such services.

INDUSTRIAL PRODUCTION AND MATERIAL MANAGEMENT

The automobile industry as one of the pillars of Germany industry has for years been a pioneer in the use of RFID, whereby the technology has been utilized until now primarily in in-house processes. It can be regarded as representative for applications of ubiquitous computing in industrial production and material management. The main tasks are the monitoring of raw materials, goods and intermediates as well as the utilization of intelligent transport containers. As in retail and logistics, the optimization of existing processes and increasing efficiency and productivity are the primary focus. Applications emerge particularly for the areas of production logistics, control of machines and equipment as well as the optimization of the utilization and availability of production facilities. The starting point is the information automatically collected during manufacturing, which replaces a great number of manual counting, scanning, data collection and control operations and which can be used to control the production process and the synchronization of the interfaces with other steps in the value creation chain. This can reduce waste and production stoppages because of lacking loading equipment and almost completely avoid misdirected items.

Manufacturing companies use ubiquitous computing however not only internally to increase production efficiency, but also for other reasons. For instance, recall actions can be planned more precisely if only single batches or tranches are involved which are documented in detail in data records. Further applications are in container management or in quality control for certain tools.

Most of the RFID projects currently being undertaken in automobile production are pilot projects. A continuous support of the goods and information flow combined with a closed container loop from the supplier up to traders and repair workshop via ubiquitous computing are among the long-term plans of the manufacturing companies. Similar to the situation in retail, however, a worldwide standardization of the technology and the data formats used would be beneficial. Parallels to retail applications exist also in the challenges which arise from the branch structure, with a few manufacturers and a large number of mostly medium-sized component suppliers. Here too the question must be answered, who can make the necessary investments and how an additional benefit can be fairly distributed among the stakeholders.

TRANSPORT LOGISTICS

In logistics it is important to know where the goods are at any time. In the long term ubiquitous computing furthers this goal, in that transport objects are equipped with communication and computing capabilities. For a more efficient flow of goods and information from suppliers to enterprises, containers, pallets and products will be universally equipped in the mid term with RFID transponders, which improve traceability and transparency in the supply chain. Thus the logistics processes can be optimized from the process planning and steering up to the handling of goods and information flows. Improving efficiency in the form of automatization and rationalization is necessary for firms in the hotly contested international logistics business, for reasons of competitiveness alone. The rationalization potentials lie not only in internal processes, but also in the cooperation with partners from industry and trade, with whose systems the technology used must be compatible.

Medium- to long-term goal is the creation of logistic networks, in which »intelligent objects« that detect their surroundings through advanced sensors can autonomously find their way to the addressee. However, a number of technical pre-conditions must be fulfilled first: the definition of international standards for the technology and applications or the exclusive reservation of further frequencies, if possible agreed on with the USA and Japan.

Through the use of UbiComp logistics service providers will increasingly become all-round service providers, managing the data resulting from the monitoring of the goods flows.

PERSONAL IDENTIFICATION AND AUTHENTICATION

The proof of a person‘s identity is an important feature of many applications of ubiquitous computing. Today this plays a role primarily in applications for access control or payment procedures. The significance of this function will increase in future, because innovative applications should not only be location- and context-dependent, but tailor-made to suit the individual user.

German passports, for instance, have been equipped since November 2007 with a RFID chip on which the digitized prints of both index fingers are stored, besides the usual personal data. After initial doubts about the security mechanisms against unauthorized reading were expressed, now even non-governmental organizations such as the Chaos Computer Club assess the technology used as safe. Much more controversial, however, are the general reliability and usefulness of biometrics.

Also already very widespread is the use of UbiComp technology, especially RFID, in *entrance tickets for events* or *ski passes*. Although only few potentially critical data are collected in these contexts, the use in public space and the operation of the systems by private sector companies is not without problems, because in some cases very detailed patterns of movements and behaviour can be collected which can be utilized not only for the purposes of public safety, but for marketing. The RFID usage for the entry tickets for the FIFA Football World Cup in 2006 was considered by data protection authorities to be inappropriate and not compatible with data protection regulations.

Of particular concern from an ethical and data protection perspective are *RFID implants*, which are used explicitly in the long-term surveillance of »chipped« persons, even if this ostensibly serves a good purpose, such as preventing kidnappings.

HEALTHCARE SYSTEM

It is expected that the use of ubiquitous information technology can also help to meet the societal challenges posed by demographic change. Specifically, it is hoped that an increase in process efficiency and productivity will limit the costs in the healthcare system. Simultaneously, ubiquitous computing opens up possibilities for a better quality of care. The healthcare applications have a rather medium- to long-term implementation perspective, as they place much higher demands on the technology performance, in particular of sensors. The proponents of »pervasive healthcare« see possible applications in diagnostic, therapeutic, nursing and documenting functions. Within healthcare facilities, for example, a higher quality is expected through more extensive information of the medical and nursing personnel and relieving them of administrative tasks.

In assisting elderly and/or chronically ill people in their home environment, information technology is regarded as an essential resource that can be deployed to improve the quality of life and enrich everyday life in old age. Ubiquitous computing has been addressed in this context for some years under the terms health telematics and more recently, »ambient assisted living« (AAL). AAL includes concepts, products and services, which combine the new technologies and the social environment of the parties involved. The Goal is to improve, respectively maintain, the quality of life for elderly and ill persons at home.

A component of such systems is the automatic remote and self-monitoring and diagnosis for patients, which improve the possibilities for home care and medical care and support self-sufficiency and independent living. For this purpose vital parameters and motion data of the patients are recorded; also the home environment is monitored. The necessary sensors can be integrated in clothing and the collected data is sent for example to a microcomputer embedded in a belt. In emergency situations an alarm is set off, depending on the seriousness of the situation. The modelling of age-related, medical-psychological scenarios presents a special challenge in this context.

Ambient Assisted Living has been massively promoted in recent years, but up to now there are hardly any marketable products or even a market for AAL products and services. In addition to the large number of involved stakeholders from the ICT industry, the healthcare professions, manufacturers of medical equipment and the housing industry, the lack of interoperability of technical solutions, lacking standards as well as the issue of financing within the German health insurance system are considerable innovations and market barriers.

The use of ubiquitous computing to optimize processes in the healthcare system largely follows the same logic, which is found in trade, industry and logistics. Such systems for integrated patient or hospital management should ensure an increased planning and scheduling security of medical examinations and high utilization of medical equipment. Today‘s systems, however, support only single processes such as access management and obligatory documentation, automatic localization of patients, materials and equipment or the mobile monitoring of measured data. For the transition to integrated hospital management, a timely and detailed coverage of the current situation by means of different sensors and input devices is technically necessary. In particular, the location of equipment, persons and patients within the entire hospital environment must be ascertainable by means of suitable techniques. In order to be able to appropriately support the personnel and patients, different contexts must be automatically recognized. Some doctors however are questioning whether such scenarios individually or as a whole can really contribute towards facilitating work or simplifying processes or only encourage the tendency towards the »transparent patient«.

On the whole, the healthcare area is certainly the most difficult environment for the introduction of ubiquitous computing, for multiple reasons. Medical data are for instance the most sensitive personal data and thus require appropriate data protection measure, such as tiered access procedures, the prevention of new transient data accesses or undesirable secondary use. The financing of »pervasive healthcare« could also be problematical under the existing reimbursement regulations and trigger distribution battles among the various actors, for instance, about the issue of whether the home environment should be promoted as a healthcare and nursing location. For these reasons alone applications in the healthcare sector have rather a long-term perspective and must be implemented step-by-step. Finally, a number of further ethical issues arise which can be summarized under the captions security, autonomy and participation.

In total, the discussion must break free from its technical focus and deal with systemic questions, e. g. the openness of the systems or the integration in the national and regional healthcare system. Ultimately, the crucial question must be asked, which of the new services provide real added value?

MOBILITY AND TRANSPORT

The utilization of ubiquitous computing in the area mobility and transport is regarded as a basis for a new generation of strongly networked and integrated systems to control transport flows and to inform road-users. Starting point here are solutions such as electronic tickets based on RFID or near-field communication, navigation and traffic recording systems as well as the traditional traffic telematics, which are currently being supplemented by so-called »vehicular ad hoc networks«.

In the long term, the supporters assume a comprehensive integration of such systems into a universal traffic management system based on real time data and offers operators as well as users of the traffic systems equal advantages:

> In the field of individual transport diverse functions are conceivable: (1) services to increase safety during travel (state of vehicle, accident prevention), (2) services to optimize traffic flows (navigation, optimization of fuel consumption) and (3) services for more comfort for the passengers (location-dependant information, entertainment, Internet access).
> For public transport the primary goal is better networking with other transport sectors and assistance for travellers when booking and setting off on the journey, or information about the itinerary, and possible connections.

Similar to the trade applications, it must be remembered that there will be impacts on individual sovereignty and privacy, if road users and vehicles themselves become (active) parts of the transport system. In particular, the extensive recording of transport data facilitates new opportunities to control traffic, for instance, the creation of incentives (or penalties) for using certain roads at certain times. According to experience this will find little acceptance among transport users. It is also doubtful whether a renewed attempt to optimize traffic flow will be more promising than in the past . Paradoxically, it appears that strengthening the individual user as foreseen in the scenarios tends to lead to less autonomy for the individual in the long term.

UBIQUITOUS COMPUTING MIRRORED IN THE PRESS

The public presentation of science and technology influences decision-makers and their actions and is again momentous for science and research. For this reason, journalists' reports in the national daily papers about ubiquitous computing, in particular RFID, were analyzed. This shows what image of ubiquitous computing has been communicated to the public in recent years and what important impacts have been addressed. It also emerged which different positions the various actors wished to convey.

Basically, it can be said that the first, occasional articles about UbiComp have been appearing since 1997. Since about 2004 the issue has been continuously reported on, with a (slightly) increasing tendency. The early articles describe developments in the field of »smart homes« and appear to be fascinated by the new world of »house elf technology«. Besides the positive application possibilities, however, these articles also already mentioned the surveillance potential of ubiquitous computing and the challenges for data protection, which increasingly influenced the reporting in subsequent years.

Due to the presentation of the issue in the press, it could be assumed that *data and consumer protection* were the most problematical aspects of ubiquitous computing. In 2005 the *Süddeutsche Zeitung* warned against the tendency towards the transparent human being. Such warnings corresponded with the opinion of many consumers who considered the data protection risks to be higher than the additional benefits. The more business-oriented press reacted to these reservations by pointing out that most of the applications planned today hardly involve person-related data. Important industrial representatives occasionally argue in the press that the emphasis on data and consumer protection is not only unwarranted, but also stifles innovation, while data and consumer protection is regarded by clients as an important regulatory area.

Security and privacy protection are closely connected in ubiquitous computing – and the press reports about this with corresponding enthusiasm. Whereas more security is regarded without exception as a desirable objective, the press coverage conveys the impression that in return for this security a price must be paid in the form of more surveillance. Part of the press emphasizes in connection with public safety that curiosity on the part of state and industry can contain new dangers. In this context, however, the discussion only rarely addresses to what extent more monitoring can preventively lead to more security and what level of security is (financially and socially) feasible at all.

In recent years reporting has been most comprehensive on the use of RFID for various applications, above all in the areas logistics, retail, healthcare and housing. The issues raised here are relatively clear: in logistics and retail the *rationalization of processes* is the main focus, whereby retailers occasionally provide an additional benefit for the consumers. In applications in the fields of healthcare and housing, the main emphasis is on providing assistance to live a healthy and independent life even in old age. The press makes it clear that on the whole applications within or between companies have the greatest significance at present and cost-benefit considerations are decisive for the introduction of technology.

The issue of *technology introduction* is usually reduced by the press to the mere question of the price of RFID chips, which has fallen in the course of the years, without however reaching the level necessary for a market breakthrough. Nevertheless, the media estimate the realizable efficiency gains or savings through ubiquitous computing to be quite considerable. In which cost categories savings can ultimately be made is usually not mentioned, even if it can be assumed that rationalization can primarily reduce personnel costs. Thus some articles mention that the introduction of RFID will significantly endanger simple jobs, as many processes can be simplified and automated by using RFID.

On the whole, the press coverage of ubiquitous computing in recent years has undergone a typical attention curve: first of all, it was uncritically praised to the skies, and then after the first failures excessively criticized. Finally, with implementation and tests of first applications, a more realistic estimate of the real advantages, but also of the limits of ubiquitous computing has emerged. Overall, it can be stated that the press reports factually, in a balanced fashion and not uncritically about the issue.

LEGAL ASPECTS OF UBIQUITOUS COMPUTING

Ubiquitous computing and its various applications present a considerable challenge for the further development of data and consumer protection. The legal challenges are to be seen primarily in the protection of users‘ informational self-determination in relation to the legally protected business interests of the operators of UbiComp applications. In addition, questions may arise from the expected utilization of autonomous information systems under private law. As technology developments are characterized by prognostic uncertainty, the question of the correct regulatory instruments also arises in addition to the substantive requirements of specific regulations to ensure the best possible balance of the actors‘ interests. The spectrum of possible regulatory approaches ranges from classical regulatory law to new, self-regulating instruments such as association agreements.

In order to ensure informational self-determination, the German Federal Constitutional Court has defined a number of substantive requirements and procedural safeguards which collide with the basic ideas of ubiquitous computing:

> The principles of purpose limitation and data minimization conflict with the goal of ubiquitous computing to support users invisibly, spontaneously and comprehensively. The requirement for informed consent also poses a serious challenge to the any collection, processing and utilization of data in a UbiComp environment. Usually this puts a heavy burden on the user as well as the data controller.
> The citizens' rights to access and correction cannot be asserted, due to the complexity of the data processing operations.
> The wide range of participants leads to a diffusion of responsibility for data-processing operations.

Against this background, it is questionable whether the traditional data protection law is still able to meet the challenges of ubiquitous computing. In an assessment of the adequacy of the law, one must wonder whether the framers of the Federal Data Protection Act (BDSG) formulated principles assuming that there are few applications that would not change a lot over time. This was true for public sector applications in the 1970s given the formality of administrative procedures. Today, this basic condition no longer holds true for private sector applications.

Therefore it is not surprising that the substantive and procedural regulations of the BDSG and the relevant telecommunication law have been found wanting in regard to RFID applications, and as a result the danger of legal uncertainty exists for providers and users of UbiComp applications. In order to address these uncertainties, the protection program of the Federal Constitutional Court should be revised and the Federal Data Protection Act modernized accordingly.

At the same time, the constitutional basis is of decisive importance in the question of »how« the new orientation should be designed. The legal questions about UbiComp are embedded in the overall discussion about the design of the future »Information Law«. Here two diametrically opposed opinions exist. On the one hand, in the private sector, personal information is understood largely as private property and therefore as a commodity. On the other hand, personal data is judged as an essential part of human rights and therefore as particularly worthy of protection. Which of these two points of view predominates has far-reaching impacts on the state mandate for action and the necessary substantive changes.

Because of the great uncertainties in foreseeing future developments in technology and business models, the initiatives of the European Commission in this area largely advocate self-regulating instruments rather than regulatory measures. For implementation in national law, however, targets should be defined in order to ensure that self-regulation does not lag behind existing legal provisions. In addition, the state should reserve for itself the possibility of taking new regulatory measures in the event that self-regulation proves to be inadequate.

Substantively, legal adjustments must be made in view of the expected changes in both EU data protection directives. Even if the practical impacts of ubiquitous computing are still low, because of limited utilization of RFID in public communication networks, the Telecommunications Act (TKG) should clearly state that RFID applications could fall within its scope. In addition, the scope of the BDSG should be clarified to make it explicit that simple RFID chips are within its purview. The requirement to provide written consent for data protection purposes should also be revised. There should be new provisions to ensure transparency in regard to long-term structural information. Furthermore, there need to be revisions to the legislation in regard to data protection requirements in the data collection phase. Protections are needed to address data mining. Finally, enabling class actions under data protection law as well as an independent data protection law for employees would be further useful options.

Simultaneously, there should be provision for privacy by design, i.e., so that data protection should be designed into technology. This should be made explicit in legal regulations more strongly than is now the case. A suitable way would be an obligation to integrate a minimum set of access restrictions on the level of application protocols. This should be formulated in a technology neutral way. On this basis, using appropriate application software, the user would permit only those uses of his personal data that he so chose. As the experiences with technology regulation involving the Internet show, the legislation should focus more on formulating goals than on giving detailed specifications for a concrete technology design.

CONCLUSIONS

Although RFID technology has already achieved a high degree of technical maturity, other *technical aspects* of ubiquitous computing still require considerable research and development work before the hoped for functionalities are suitable for practical use. These are above all:

> Methods and techniques to create safe systems with predictable behaviours and good ability to diagnose errors,
> procedures for more reliable context recognition with at the same time good configurability by the user,
> innovative approaches to use »invisible« computers without traditional in- and output media.

Ubiquitous computing has a considerable *economic potential*, on the one hand to increase efficiency and thus competitiveness. For this reason these uses will probably prevail in the medium term. On the other hand, ubiquitous computing enables a great number of new services, whose usefulness for citizens and economic viability must still be proved. In order for these potentials to be actually realized, however, a number of pre-conditions must be fulfilled:

> international frequency harmonization and standardization,
> creation of a timely access to UbiComp technologies for medium-sized companies and their integration in the standardization processes,
> balancing the data and consumer protection interests of users and citizens or customers with a view to specific uses by initiating and moderating a discussion with all those concerned participating,
> modifying the disposal and recycling processes with regard to the expected mass utilization of RFID and simultaneously development of more environmental-friendly solutions.

Besides the economic impacts, there are a great number of possible effects of UbiComp for which a scientific and/or societal dialog must carefully weigh up whether the costs and benefits are acceptably correlated.

The most striking impact of ubiquitous computing is on *privacy or informational self-determination*. Both are currently being re-defined in the light of the ubiquity of data and data processing, whereby neither the size nor the sustainability of this new definition are completely predictable. The following activities could be useful:

> adapting the data protection law to the opportunities offered by ubiquitous computing to monitor and obtain personal data even from otherwise uncritical data sources,
> creation of a data protection law for employees,
> societal discourse about the origin and use of data tracks in ubiquitous computing as well as the
> systematic monitoring of new technologies and evaluation of their impacts on informational self-determination.

In addition, the *societal compatibility* of ubiquitous computing should be further discussed, best of all using concrete examples. Important questions concern the sustainability of ubiquitous computing, not only from an economic and ecological, but also societal viewpoint. Ensuring universal access to and participation in the advantages of new offers is as important in this context as issues of system dependency and possibility to elude, loss of control, monitoring and normalization of behaviour. Besides the necessary social discussion and other social science research tasks, there are a number of concrete approaches:

> early consideration of user interests in the development process through ethnographic studies and »living labs« and
> creation of *real* choices by labelling UbiComp systems and an opt-in model, in which the utilization of certain functions must be explicitly confirmed.

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