Living in a Smart Environment – Implications for the Coming Ubiquitous Information Society

Vlad Coroama, Jürgen Bohn, Friedemann Mattern
Institute for Pervasive Computing
Swiss Federal Institute of Technology (ETH) Zurich
8092 Zurich, Switzerland
{coroama,bohn,mattern}@inf.ethz.ch

Abstract - *A good instrument for understanding the possible blessings and perils of new technology in general and ubiquitous computing in particular is the development and analysis of scenarios of the future. This paper presents some of the consequences implied by several such scenarios that have been developed in the interdisciplinary research project "Living in a Smart Environment – Implications of Ubiquitous Computing". To show how manifold and far-reaching such consequences might be, the paper emphasizes two particularly relevant implications. First, it discusses some of the deep economic paradigm shifts that could arise from a large-scale deployment of ubiquitous and pervasive computing technologies. Second, it investigates issues of social compatibility and dependability of future ubiquitous computing applications, considering both impending pitfalls and emerging opportunities.*

Keywords: Ubiquitous computing, social implications, scenarios of the future, new economic paradigms, dependability.

1 Introduction

The vision of ubiquitous computing was put forward by Mark Weiser at the beginning of the last decade in his influential article "The Computer for the 21st Century" [15]. Weiser foresaw omnipresent computers that serve people in their everyday lives at home and work, functioning invisibly and unobtrusively in the background, freeing them from tedious routine tasks. This vision, however, remained only a subject for few researchers until the end of that decade – the first international conference on ubiquitous computing (still called HUC at that time – Handheld and Ubiquitous Computing) was held no earlier than 1999 [9].

This has changed dramatically over the last few years. We have seen the emergence of new conferences and workshops dedicated to ubiquitous and pervasive computing, along with a significant increase in research projects. Even more important for the public perception, some ubiquitous computing technologies and applications have recently entered the mass market, such as location systems (i.e., GPS) or electronic handheld devices (e.g., mobile phones, PDA's, digital cameras). Consequently, ubiquitous computing quickly entered the conscience of a large part of the general public. As recent discussions about consumer privacy with respect to the commercial use of RFID tags have shown, the public suddenly realized that this ongoing development may have a long-term impact on everyday life, with far-reaching consequences for the society's ethical values.

As a matter of fact, the public discourse often lacks an exact understanding of the technologies involved, and it sometimes tends to overestimate the short-term risks associated with the deployment of ubiquitous computing systems. However, the fears involved herein are easily understandable if we take a closer look at the vision behind ubiquitous computing. 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 whole lives, day in and day out. While developments in information technology never had the explicit goal of changing society, but rather did so as a side effect, the visions associated with ubiquitous and pervasive computing expressly propose to transform the world and our society by fully computerizing it. And if Mark Weiser's vision of "invisible computing" actually materializes, we would hardly notice that process.

2 Living in a smart environment

The repercussions of such extensive integration of computer technology into our everyday lives as propagated by the ubiquitous computing paradigm are difficult to predict. While considerable effort has been undertaken within the community to analyze the possible privacy threats of ubiquitous and pervasive computing systems, many other societally relevant issues remained largely unaddressed [4]. Thus, not the public is to blame for either ignoring or sometimes exacerbating the risks involved in ubiquitous computing; the community itself has not yet presented a substantial analysis of ubiquitous computing implications and did not make sufficient efforts to seek the dialogue with the society in general.

Bearing this in mind, we initiated in 2002 the project "Living in a Smart Environment – Implications of Ubiquitous Computing" [10]. The three year interdisciplinary project unifies researchers from different areas: computer scientists, engineers, privacy experts, psychologists, sociologists, economists, and philosophers. They try, by putting their various perspectives together, to provide some of the answers expected by the scientific community and the society in general: What are the areas that are likely to be affected by the large-scale deployment of ubiquitous computing technologies – in positive as well as negative ways? And what could be the long-term consequences? Out of this analysis, what conclusions for a socially sustainable technology can be drawn – so that positive developments are encouraged and those with large negative impacts are avoided? What could politics do to shape such a development?

In the remainder of this paper, we sketch the future scenarios developed in our project and briefly mention the consequences implied by these. To show how far-reaching such consequences might be, we present two particularly relevant implications – the deep economic paradigm shifts that could arise from a large-scale deployment of ubiquitous computing technologies, and the social compatibility and dependability of future applications based on these technologies.

3 Ubiquitous computing scenarios

Scenarios are a well-suited instrument to analyze future implications of technology for a number of reasons. First, several different technology trends may be extrapolated and combined into a single scenario to analyze the bundled effects that these technologies could induce. This is particularly interesting for the field of ubiquitous computing, which does not form a single technology, but a combination of many technologies. Second, in a scenario the different actors (e.g., producers, supermarket owners, and consumers in a shopping scenario) can be analyzed together with their specific interests, so that a picture of future conflicts of interests can be drawn. Another advantage of scenarios is that they allow an interdisciplinary analysis: Once the technically possible range is set, different approaches and various viewpoints can be applied. For example, by looking at all the steps where data is being collected, a privacy expert can analyze the privacy threats of the systems implied in the scenario and provide design guidelines for them. A sociologist may analyze the same scenario from an inter-human interaction point of view, etc.

The scenarios developed within our project have been published in the report "Leben in einer smarten Umgebung: Ubiquitous-Computing-Szenarien und -Auswirkungen" [6]. Several areas have been depicted in these scenarios, in an attempt to cover different typical life situations, but also to show some new applications enabled through the use of ubiquitous computing technology: The daily shopping in the supermarket, a meeting in an office including the journey of external meeting attendants, and the analysis of public as well as private transportation constitute daily life situations covered by the scenarios. The logistics of medical equipment in a hospital and a vastly enhanced everyday support for the blind are two new application areas of ubiquitous computing technologies that have been investigated.

The scenarios have been analyzed from the specific perspective of the participating experts, identifying potential societal consequences. After several intense discussions, 14 of the most relevant consequences have been collected and presented in [6]. They include socio-technical acceptance aspects (loss of control, dependency on systems, usability and manageability), economic issues (economical interests involved herein, new economic paradigms), social compatibility questions (fairness, digital divide, universal access to information, information reliability), privacy questions, as well as more general problems with the deployment of ubiquitous computing systems (ontologies, providing user feedback).

This collection of possible consequences was intended as a starting point for further investigations of the scenarios. Two of the main topics are presented in more detail in the following two sections of this paper.

4 New economic paradigms

Navigational systems have become standard for middle- to high-end vehicles. Customers of parcel services can track the whereabouts of their shipments in real-time. Business travelers stay in contact and exchange data with their businesses in many airports worldwide and since recently also during flight. Backpackers check their e-mail in Mongolian Internet-Cafés or in Swiss alp huts. Toll ways automatically charge their customers for the driven mileage, without requiring them to stop for accounting. In numerous ski resorts, the ski passes work wirelessly. Companies have up-to-date information about the condition of their assets and the deliveries from their suppliers and may immediately react to exceptional situations [14].

These and similar applications – all emerged over the last few years – show that we are in the middle of a development that makes increasingly more information available at more and more places, with continuously decreasing time delays. This trend, so it seems, could finally lead to an anywhere, anytime, anything information availability – the *ubiquitous information society*. From an economic point of view, this development would not only make today's businesses more efficient, reliable, and customer-friendly, it would also stimulate the transformation of existing business processes and the emergence of entirely new business models.

4.1 Dynamic prices

The shopping scenario developed in [6] is a rather extreme example for business models largely affected by the ubiquitous information society: In a future supermarket, all products are equipped with sensing, computing, and communication capabilities. These smart products are not only aware of their own state (e.g., fabrication date, temperature), they have also knowledge about other products in the vicinity and about relevant ambient conditions (e.g., the outside weather). In such a store, every product has its own price that changes according to a number of parameters. Products with an earlier expiration date, for example, will lower their price to encourage customers to buy them instead of other, more recently produced ones. When the outside temperature rises, soft drinks and ice cream could increase their prices according to an expected increase of demand. Regular customers may receive preferential prices when products "recognize" them.

Milk bottles that continuously vary their price may not be the most realistic example of dynamic pricing, neither from a feasibility aspect nor from the customer acceptance point of view. The scenario merely shows the degree of power that augmented products may achieve in a ubiquitous information environment. For other goods, however, highly dynamic prices may make much sense. Such goods should exhibit three characteristics: First, they should be expensive enough so that the deployment of the necessary ubiquitous computing infrastructure does not increase their price significantly. Second, both sellers and buyers should benefit – at least a fraction of the consumers that is large enough to represent an interesting market should gain from such augmented products. Third, charging differently for the good should not be uncommon – the stronger and more noticeable today's price discrimination for the good (i.e., charging different customers different prices for the same product), the more likely consumers will accept new types of price discrimination.

4.2 Omniscient insurance companies

Insurances are high-valued goods that seem to fulfill the above-mentioned criteria. Customers are already used to personalized and periodically changing insurance premiums – they vary from insurant to insurant and change from time to time even for the same person. Further, both insurers and a large part of the insurance buyers may expect large savings through the use of ubiquitous computing technologies, as will become clear further down.

Insurers nowadays have quite limited data about their insured goods or persons. Therefore, they will typically split the insured assets into classes, based on only a few criteria collected before the risk coverage starts [13]. Car insurance premiums, for instance, usually depend on the type of the insured car and the driver's experience. Additional information that determines the damage risk, such as the driven mileage, traffic and weather conditions, time and location where the car has been driven or parked, is not used simply because it is unavailable to the insurer. As a result, the premiums are flat and only based on a few differentiation criteria. Within a class, the drivers with a lower damage risk (the ones driving less, at better weather and traffic conditions, or seldom in crowded cities) pay more than they should for their actual risk, while higher-risk drivers pay less. Such cross-financing from lower to higher risks takes place in numerous other insurance branches, where the insurer lacks information about the behavior of its insures, e.g., in transport insurances (how does the carrier handle and store the shipped goods?), or in health insurances (where nonsmokers usually pay the same rate as smokers). This problem has been recognized and coined as *information asymmetry* by George Akerlof in his article "The market for lemons" [2]. The problem turned out to be so significant for insurance markets that the author received the Economics Nobel Prize in 2001.

The more diverse, exact, and up-to-date information the insurer had about the insured assets, the more accurate the insurance rate could be calculated for each individual risk. The classes of insured persons would become increasingly diversified the more information the insurer considers. Ultimately, each class would encompass exactly one insurant, everyone thus paying his or her highly individual premium. Insurance buyers with a low risk within their premium class would most likely welcome the expected savings and possibly ignore the privacy and other threats implied by such omniscient insurers [7]. Insurers, on the other side, would be able to gain market shares in the attractive segment of low-risk insurants by offering better premiums. Since mainly "bad risks" are likely to stick to a flat rate, the corresponding insurance premiums would consequently rise, encouraging even more drivers to change to dynamic models.

Recently, there have been quite a few proposals and pilot projects heading into this direction for vehicle insurances. It has been argued that car insurances could be distance-dependent [11], or account for various other aspects [7][13]. This would not only be more accurate, but would also give incentives towards less driving, which potentially increases traffic security and has positive environmental consequences [11]. Government charges such as the vehicle tax could also be changed to such a "pay-per-use" model – a distance- and time-dependent congestion charge does seem a sensible alternative to today's jammed city centers.

4.3 Generalized pay-per-use

The economic dynamism of the ubiquitous information society could go even further. If such a richness of fine-granular and timely information existed, it could be exploited to create a yet larger degree of economical self-determination for the consumers. For example, call-by-call telephony becomes increasingly popular in Europe. Consumers may change the company from phone call to phone call simply by dialing a specific prefix. Since companies' per-minute price schemes differ largely (one being cheaper at night, another one during daytime, yet another on weekends), consumers do take advantage of this feature. Many people keep a printout of the prices ordered by days and hours next to their phone. Such printouts, however, easily become outdated, potentially misleading the user. More user-friendly are the least-cost-routers that are connected to the phone and free the user of two burdens: they periodically download updated price tables, and they automatically dial the right prefix.

Similar to the telephony market, a model that we call *ride-by-ride insurance* could become technically feasible in the future. Customers could then change their insurance on a regular, maybe even daily basis. Since insurers are likely to use different risk estimation strategies, they will probably offer different rates for different conditions. One company could offer the best rate on weekends, another insurance company would have the best price per kilometer on highways, and a third one could offer the best savings when driving at night in rainy conditions. As with telephony least-cost-routers, the car could autonomously choose the most favorable insurer for that day – for example, after the driver entered the destination in the car's navigation system.

With ubiquitous information, pay-per-use could be generalized to virtually any transaction and to an almost arbitrary degree of refinement [8]. A rather provocative example could be ride-by-ride insurances that are contracted not for full-days only, but also for smaller sections of a journey. The car would then automatically switch the insurer according to the best insurance offer – when exiting the highway, or on entering a wet road, for example. Even more provoking pay-per-use-ideas have been put forward. Accenture Technology Labs, for instance, presented a prototype of a chair that monitors its usage and creates a monthly billing statement [1].

Such ideas, however, raise various concerns. If consumers were to accept so far-reaching pay-per-use schemes and the monitoring of their personal habits implied by these, this would not only threaten their privacy. It would also give companies a permanent channel to their customers, enabling them to exercise control over the use of their products and services. Furthermore, it is not clear whether the trend towards more and more pay-per-use models does necessarily lead to more fairness throughout the society. Pay-per-use does indeed guarantee that costs are distributed more precisely to their originators. Often, however, this is politically unintended or societally undesirable, and flat payments are rather perceived as being fair. An example are public health insurances in Europe. In several countries (e.g., Germany), the health insurance premiums do not depend on the risk factors of the insured persons, but on their incomes. The health insurance premiums are thus also a way of social cross-financing with the goal of offering a good medical standard to the entire society. This model of societal fairness is widely accepted, even by most who pay more than they would if the premiums were risk-based. On an individual level, people also sometimes wish not to be charged continuously, but pay once and then use a service for a certain period of time. In many restaurants the morning buffet is not "pay-per-use", but "flat". Skiing resorts could easily charge skiers per-use, yet virtually all of them use a flat model. People seem to prefer the freedom that flat rates buy them over having to reflect every time they board a ski lift whether the descent is going to be worth the price.

Nevertheless, pay-per-use can be a feasible and for some domains desirable model. Since people tend to restrain their consumption when being continuously reminded of the price they pay, this model could also become a valuable tool for politics for steering developments (e.g., reducing the traffic through a mileage- and time-based tax). While such schemes could not be deployed on a large scale in the past because of lack of information, we are likely to witness the spreading of pay-per-use business and economic models in the upcoming ubiquitous information society.

5 Dependability and social compatibility

In the preceding section we have seen how deep a ubiquitous information society may affect typical situations and aspects of our everyday life. Today, in most cases, we are still able to decide for ourselves whether we want to participate and live in such smart environments based on ubiquitous computing technology. But in a largely computerized future it might no longer be possible to escape from this sort of technologically induced dependence, which leads to a number of fundamental social challenges. Privacy is just one of these challenges, though currently probably the most prominent one [4].

The augmentation of everyday objects with sensing, computing, and communication capabilities per se has a priori no negative implications. Augmented real world objects can contribute to the realization of novel services and applications which can be to the benefit of the individual and the society as a whole. An individual person, for instance, may consider the provisioning of context-dependent information while moving through smart environments (such as tour guides, navigation systems, or virtual collaborative work spaces) convenient and helpful. Furthermore, everyday environments augmented by ubiquitous computing technology can also provide means to alleviate the difficulties and disadvantages of marginal groups who find themselves at the fringe of society. A number of projects target elderly and physically disabled people, for example with electronic "memory aids," reading aids, and navigation systems [12], which enable such persons who are often neglected as marginal groups to participate more actively and autonomously in everyday life. A concrete example is the Chatty Environment [5] – a context-aware application which helps visually impaired people to orient themselves in new, unknown environments, thereby enabling them to lead a more independent life. Furthermore, the digital augmentation of real-world objects can help to compensate for deficiencies of cognitively challenged people. A smart jigsaw puzzle, for example, may not only help children or people with cognitive deficiencies to solve complex puzzles, letting them partake in the experience and feeling of achievement, but it also facilitates to match the capabilities of unbalanced players by providing aids to the "weaker" players [3].

More generally, intelligent interfaces and the concept of ubiquitous information access are often seen as key developments for bridging the digital divide, where different sections of the population have different abilities to participate in the information society. However, as discussed in [4], having more information opportunities does not necessarily mean more justice or freedom, simply because the potential dependencies and opportunities for manipulation would be so numerous they could overwhelm individuals, making it even more difficult to assess the trustworthiness of the information's source. Information that is uncritical or sponsored by advertisers (and therefore one-sided) could become available free of charge, while independent, high-quality information would cost money, thus widening the digital divide even further. Since ubiquitous computing is not just about information itself, but is inherently linked to real-world objects, these new means of access and content control could easily lead to the digital divide becoming a real and perceivable rift in our everyday lives.

Therefore, an augmentation of real-world artifacts with information processing and communication capabilities should not become an end in itself. Instead, the expected benefits should, from the beginning, be weighed against potential negative side-effects. It may be advisable to deliberately stop the augmentation process at some point before the original fundamental qualities and characteristics of the augmented physical object are threatened to be lost. This not only preserves knowledge sustainability (it used to work this way and it still does), but also allows the user to deliberately opt-out and revert to the classical unaugmented utilization of the object. Another advantage of such a "soft" augmentation is that the usability of the augmented object is still sustained even in case of a technical failure of the augmented functionality. If, however, the inherent qualities and functionality of the original object are irrevocably changed, the usability of the augmented object depends on the availability and proper functioning of the technologies used in the augmentation process.

Either way, the application of ubiquitous computing technologies for the augmentation of physical objects and for the realization of ubiquitous information environments is very likely to induce new societal and technological dependencies. In particular, as the number of smart devices and interacting objects in our environment increases, the technical *dependability* of the thus provisioned services becomes an important issue. Traditionally, a user explicitly works with dedicated computer equipment which often consists of reliable quality components. With the expected coming of the ubiquitous information society, however, users find themselves suddenly acting right in the middle of a computerized smart environment. They have to cope with being caught in a crossfire of mass-produced smart artifacts and spontaneously interacting objects, each of which is prone to malfunctions due to technical defects or depleted batteries, for example.

This raises the question whether there exist technical solutions to counter these difficulties, for example physical redundancy. However, as incorporating computing and communication technology into everyday artifacts requires small form factors and minimal energy consumption, it is often impracticable to employ hardware redundancy on the single devices to increase the fault-tolerance and robustness of smart object infrastructures, which further aggravates the situation.

An answer to these challenges may be found in alternative, more user-centered concepts and mechanisms in order to overcome service interruptions and device failures, such as an explicit diversification of system functions, for instance. Such a *diversification* can be achieved by providing fully independent ways of carrying out the same task, preferably based on separate sets of system resources wherever feasible. By having different types of devices, platforms, or communication means for achieving a certain goal, the available redundancy stemming from the heterogeneity of the surrounding smart object infrastructure can be exploited for achieving a *horizontal* diversification. Further, as a cheap individual device may be prone to technical defects and malfunctions, a solution may lie in dramatically increasing the availability of a certain type of device, for example by providing it in large, abundant quantities. As a consequence, it is feasible to make the transition from requiring the availability and accessibility of one particular device to being in a position to use any device of a certain type at hand, which can be described as a *vertical* diversification. This ensures that one can exactly use the kind of tool which is most suitable in a certain situation or for a certain task, instead of reverting to a different, potentially less suitable tool as it has to be done in the case of horizontal diversification.

6 Conclusions

This paper made the case that ubiquitous computing as an enabling technology for smart environments could have far-reaching consequences on the society. It is certainly not the washing machine querying our dirty clothes for washing instructions that will change the world. But what if parents will never lose track of their children because location sensors and communications modules are sewn into their clothes? And will producers of smart goods get a permanent channel to their customers, enabling new pay-per-use business models and having control over the use of their products and services? Would people feel being surrounded by an invisible and comprehensive surveillance network with all the smart objects and wireless sensors that we envision? And if artifacts become more autonomous and humans move gradually out of the loop – who is responsible if something goes wrong?

Obviously, there are more questions than answers and only the future will tell. But, maybe, we can take advantage by speculating about the possible consequences of this technology and evaluating it within the framework of established concepts from fields such as sociology or economics. The careful analysis of well-thought scenarios is a promising approach in that respect. It may thus be possible to steer the development of smart environments and the underlying ubiquitous computing systems in a direction that has more in common with Weiser's optimistic vision of the 21st century [15] than with the depressing views of some popular but not necessarily unrealistic cyberpunk scenarios.

Acknowledgements

This work has been partly funded by the Gottlieb Daimler- and Karl Benz-foundation, Germany, as part of the interdisciplinary research project "Living in a Smart Environment – Implications of Ubiquitous Computing".

References

[1] Accenture Technology Labs, "Pay-per-use Object", http://www.accenture.com/xd/xd.asp?it=enweb&xd=services\technology\tech_payperuse.xml, 2001.

[2] G. Akerlof, "The Market for Lemons: Qualitative Uncertainty and the Market Mechanism", *The Quarterly Journal of Economics*, 84(3):488–500, 1970.

[3] J. Bohn, "The Smart Jigsaw Puzzle Assistant: Using RFID Technology for Building Augmented Real-World Games", *Workshop on Gaming Applications in Pervasive Computing Environments at Pervasive 2004*, Vienna, Austria, April 2004.

[4] J. Bohn, V. Coroama, M. Langheinrich, F. Mattern, M. Rohs, "Social, Economic, and Ethical Implications of Ambient Intelligence and Ubiquitous Computing", *Journal of Human and Ecological Risk Assessment*, Volume 10, No. 5, October 2004.

[5] V. Coroama, "The Chatty Environment – A World Explorer for the Visually Impaired", *Adjunct Proceedings of Ubicomp 2003*, Seattle, Washington, October 2003.

[6] V. Coroama, J. Hähner, M. Handy, P. Rudolph-Kuhn, C. Magerkurth, J. Müller, M. Strasser, T. Zimmer, "Leben in einer smarten Umgebung: Ubiquitous-Computing-Szenarien und -Auswirkungen", Technical Report No. 431, ETH Zurich, December 2003, www.inf.ethz.ch/research/publications/techreports.

[7] V. Coroama, N. Höckl, "Pervasive Insurance Markets and their Consequences", *First International Workshop on Sustainable Pervasive Computing at Pervasive 2004*, Vienna, Austria, April 2004.

[8] E. Fleisch, M. Dierkes, "Betriebswirtschaftliche Anwendungen des Ubiquitous Computing", in F. Mattern (Hrsg.) *Total vernetzt*, Springer-Verlag, 2003.

[9] International Symposium on Handheld and Ubiquitous Computing (HUC 99), www.teco.edu/huc/.

[10] Ladenburg Collegium "Living in a Smart Environment – Implications of Ubiquitous Computing", www.smart-environment.de/.

[11] Todd Litman, "Distance-based vehicle insurance", Victoria Transport Policy Institute, 2003.

[12] P. Makris, "Accessibility of Ubiquitous Computing: Providing for the Elderly", *Proceedings of the Workshop on Universal Accessibility of Ubiquitous Computing*, Alcácer do Sal, Portugal, May 2001, ACM Press.

[13] C. Müller, H.-D. Zimmermann, "Beyond Mobile: Research Topics for upcoming Technologies in the Insurance Industry", *Proceedings of HICSS'03*, Hawaii, 2003.

[14] L. Siegele, "How about now? A survey of the real-time economy", *The Economist*, 362(8257):3–18, January 2002.

[15] M. Weiser, "The Computer for the 21st Century", *Scientific American*, 265(3):94–104, September 1991.