APPLICATION OF UBIQUITOUS COMPUTING IN PERSONAL HEALTH MONITORING SYSTEMS

C. Kunze[1], U. Großmann[1], W. Stork[1], K.D. Müller-Glaser [1]

[1]Institut für Technik der Informationsverarbeitung, Universität Karlsruhe, Deutschland

kunze@itiv.uni-karlsruhe.de

Abstract— *A possibility to significantly reduce the costs of public health systems is to increasingly use information technology. The Laboratory for Information Processing Technology (ITIV) at the University of Karlsruhe is developing a personal health monitoring system, which should improve health care and at the same time reduce costs by combining micro-technological smart sensors with personalised, mobile computing systems. In this paper we present how ubiquitous computing theory can be applied in the health-care domain.*

Keywords— *ubiquitous computing, wearable computing, telemedicine, home monitoring*

Introduction

Health-care utilization highly depends on the demographics of the population. Obviously health-care costs rise with the age of the patients. Upon analysis it can be shown that rising hospital expenses are the main factor for these rising costs. [1]. Many hospitalizations are only needed for health monitoring and could be prevented if adequate home-monitoring systems would exist.

The Laboratory for Information Processing Technology (ITIV) at the University of Karlsruhe is working on the development of a Personal Health Monitoring System [2] that should change this situation. It is a platform consisting of wearable smart sensors measuring vital signs and of a base station communicating wirelessly with the sensors. The base station also acts as the user interface of the system and is connected to an Internet-based Electronic Patient Record (EPR) database. Such a system can be regarded as an ubiquitous computing environment.

Ubiquitous Computing

Ubiquitous Computing, also called Pervasive Computing, is a concept for future computing environments, where the user is surrounded by a large amount of small application-specific, network-connected information appliances. In order to reduce user interference, ubiquitous computing devices have to be unobtrusively embedded into their environment. The following two terms: *invisible computer* and *augmented reality* are often used in this context. Ubiquitous computing is characterized by:

- Physical and cognitive embedded systems
- Networking
- Ubiquity
- Context-awareness
- Application specific devices (appliances)

Examples for ubiquitous computing applications often come from the household domain, including internet-connected fridges or even instrumented coffee mugs. While these examples demonstrate the concepts of Ubiquitous Computing, the likelihood of a real need for such systems in the near future is questionable, whereas health Monitoring is a promising application domain. The costs for integrating the necessary communication abilities are affordable compared to the potential for cost savings and to the medical advantages:

- Context-aware, cognitive-embedded systems result in a better usability, which is essential for the use in a home-monitoring scenario (the device is adapting itself to the user and not vice-versa).
- Patient mobility is maximized by physically embedding the devices into wearable or implantable distributed systems
- Networking compensates decentralization. Thus high performance services, such as pattern recognition with neuronal networks, can be provided anywhere to the mobile devices.

Application in the health-care domain

In the following section we present how the concepts of Ubiquitous Computing can be applied in the health-monitoring domain and what problems can emerge thereby.

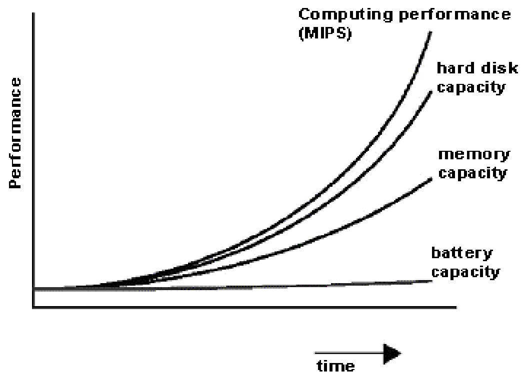

Figure 1: Performance roadmap of electronic components

Embedding: To ensure patient mobility both the vital sensors and the base station have to be wearable. Besides miniaturization, design for wearablity has to pay attention to body placement, human movement, weight, size and other constraints. Design guidelines for wearable systems can be found in [3].

However, the main problem in the design of wearable systems is the power supply. With the rapidly increasing performance of processors, memories and other components, their power consumption is also rising. On the other hand, the capacity of batteries is only improving very slowly (Figure 1).

The widely-used lithium-ion technology demonstrates the development of energy storage: Today, lithium ion cells have a specific energy capacity of 120 Wh/Kg. Estimations show that the specific energy capacity will reach the limits of Li-Ion-Technology at 210 Wh/Kg in 2010 [4]. Allowing an accumulator weight of 20 g for mobile applications, the average power consumption has to stay below 20 mW in order to achieve a running time of five days. Therefore low power consumption is the major design constraint for wearable system development.

Networking: Networking is providing ubiquitous access to central information services. This has to be achieved with low power consumption and ensuring a high level of security.

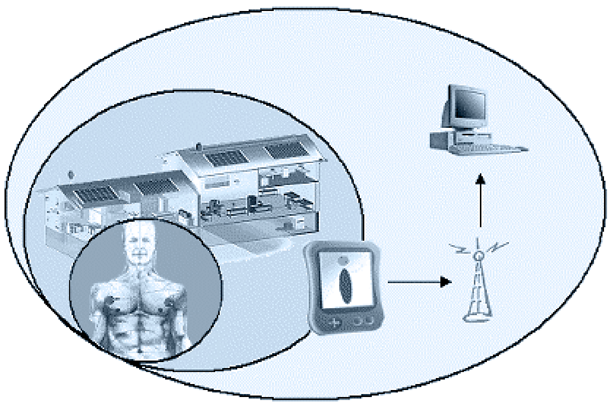

Figure 2: Communication in personal health monitoring

The communication in personal health monitoring applications can be divided into different scopes:

- Body Area Network (BAN) for communication between sensors on the patients body
- Personal Area Network (PAN) for communication in the personal environment of the patient
- Wide Area Network (WAN) for the connection to a central data pool and information services

3G mobile communication standards (like UMTS) are best suited for WAN communication since they offer substantial advantages to contemporary systems (like volume-oriented pricing) and a wide distribution can be assumed in the near future.

Several technologies can be taken into account for BAN/PAN communication, including near-field intra-body communication [5] (data transfer through the body). Wired connections should only be used if they are not restricting the patient's mobility, like in smart clothes (Figure 2) with embedded components and wires. Interconnections can also be directly incorporated into textiles by weaving conductive fibres into ordinary fabrics [6].

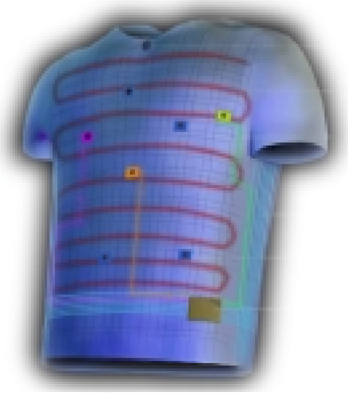

Figure 3: smart clothing [6]

However, wireless communication technologies are most important. At the moment we are evaluating the use of the Bluetooth radio technology [7]. Bluetooth is particularly suitable for Ubiquitous Computing applications because of its ad-hoc-networking abilities and it's extensive integrated functionality, such as service discovery, self-configuration, encryption, and authentification. It also will likely be widely used in commercially available mobile communication units.

Protection of privacy and communication security are especially important in health-care applications. An examination of the security requirements showed that the security features integrated in Bluetooth [8] are sufficient for the PAN-communication in case of a correct configuration, but additional security measures have to be taken for the mobile internet connection. We suggest the use of a Virtual-Private-Network- (VPN-) connection.

Context-awareness: The usability of information appliances can be considerably improved by the use of context-aware systems. Ideally, many functions can be controlled without explicit interaction. Therefore it is an important task to seek out useful context information and simple ways to retrieve them. Context can be classified in low-level context and high-level context. The first represents information that can be directly sensed by sensors, while the latter refers to more complex context information derived from the combination of different information sources. For example, it's possible to draw conclusions about the users social context by combining the personal location, time and the calendar of the user. A detailed description of context-aware computing can be found in [9]. Simple and often-used context information include:

- Personal identification. Personalized health monitoring systems provide functions, such as reminder services or medication support depending on measured vital signs and individual disease patterns.
- Time. A very simple but important context used for the timing synchronisation of distributed sensors, for example.

- Location. Location is the most commonly used context information. In health monitoring applications it is needed for locating patients in case of emergency. Many systems use GPS for localization, but localization through mobile communication providers [10] and in ad-hoc networks [11] will gain in importance in the future.

The evaluation of further context information that can be used for the user-friendly design of personal health monitoring applications is an important task for future research work.

Results

A demonstrator has been developed to evaluate the concepts of the personal health monitoring system. It consists of a wearable ECG-sensor with integrated signal processing and communication abilities, a PDA acting as mobile base station and of a bluetooth-enabled mobile phone for Internet connections (s. Figure 4).

Figure 4: Demonstrator of the PHM-Project

The demonstrator will be used to study the application of ubiquitous computing concepts (embedding, net-working, context-awareness) to health monitoring. Future work includes further system integration, development of self-configuration application protocols for mobile medical system communications and the enhanced use of context information.

Acknowledgements

This work is supported by the BMBF. We also thank E-Plus and Ericsson Germany for their support.

References

[1] Statistisches Bundesamt, *Gesundheitsbericht für Deutschland*, Wiesbaden: Statistisches Bundesamt, 1998

[2] ITIV Uni Karlsruhe: Personal Health Monitoring System, http://www.phmon.de

[3] F. Gemperle et al., “Design for Wearability”, *Proceedings of the Second ISWC*, IEEE Computer Society Press, 1998

[4] K. Green, J.C. Wilson, “Future Power Sources for mobile communications”, *Electronics and Communication Engineering Journal*, vol. 13-1, pp. 43–47, 2001

[5] T. G. Zimmermann, “Personal Area Networks (PAN): Near-Field Intra-Body Communication”, Massachusetts Institute of Technology, 1995

[6] Sensatex Cooperation: Sensatex Smart Shirt, http://www.sensatex.com

[7] Bluetooth Special Interest Group (SIG), http://www.bluetooth.org

[8] M. Jakobsson, S. Wetzel: “Security Weaknesses in Bluetooth”, *Lecture Notes in Computer Science*, vol. 2020, Springer, 2001

[9] G. Chen, D. Kotz: “A Survey of Context-aware Mobile Computing research”, *Dartmouth Computer Science Technical Report TR2000-381*, Dartmouth College, Hanover, 2000

[10] Federal Communications Commission: Enhanced 911 Home Page, http://www.fcc.gov/911/enhanced/

[11] N. Bulusu, J. Heidemann, D. Estrin: “GPS-less low-cost outdoor localization for very small devices”, *IEEE Personal Communications*, Volume: 7 Issue: 5, Oct. 2000