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DEVELOPMENT AND EVALUATION OF A MULTIMODAL WIRELESS DATA HUB FOR EHEALTH APPLICATIONS

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Abstract

To address the needs in the field of telemonitoring and Ambient Assisted Living, a multimodal wireless data hub was designed. Based on this design a prototype has been developed that can collect various user data. Several wireless communication technologies were used to acquire vital signs from home monitoring devices, sport and fitness data and environmental data. The prototype was evaluated for monitoring in a real home environment. The results show that a single point of data collection may be feasible. Our results show that multiple users can be monitored with one device set.

Keywords – ***Telehealth, Ambient Assisted Living, interoperability, wireless standards***

1. Introduction

The demographic trend shows a rising proportion of elderly people in the coming decades. Coming along with the aging of the society, the prevalence of chronic diseases like heart failure, diabetes II, high blood pressure and obesity is increasing [1]. Patients suffering from those diseases need special care. Permanent monitoring is needed to treat those diseases adequately but periodical visits are neither comfortable for the patient nor for the doctor or caregiver. Telemonitoring is a viable alternative to regular visits. Using Information and Communications Technologies (ICT) patients are virtually linked with their caregivers to provide their vital signs on a daily basis and to receive treatment instructions in case of worsening [2].

In parallel to telemonitoring Ambient Assisted Living (AAL) is a second potential research field that offers technologies and solutions for increasing autonomy, better symptom control and healthcare for elderly people. The idea of AAL is also linked to Ambient Intelligence, which refers to electronic environments that are sensitive and responsive to the presence of people. Such a system ideally consists of many invisible, unobtrusive devices that monitor the patients' area of life. Sensors incorporated into appliances and furniture would recognize the users and adapt to the users needs [3].

Next to AAL and telemonitoring the field of fitness and sports is an area of application for sensing and monitoring as well as wireless transmission of vital signs. Physical exercise is important; it can contribute positively to maintain a healthy lifestyle. Tracking activity and analyzing data is

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becoming easier for the end user. Fitness systems provide a range of training tools from online analysis to fitness equipment. Such systems can be employed easily to monitor daily activity.

1. 1. Wireless technologies, standards and interoperability

Wireless technologies play an important role in applications dealing with telemonitoring, AAL, and fitness. Technologies such as WiFi, Bluetooth and Near Field Communication (NFC) have already been utilized for monitoring purposes in AAL and telemonitoring. ANT+ and ZigBee offer ideal protocols to be used in the AAL setting too.

Standardization is a prerequisite for a broad deployment and use of ICT in eHealth.. ICT standardization is already a big issue and standardization in AAL Technologies is also rapidly evolving, to achieve the needed interoperability. Continua Health Alliance (CHA) - an industry-driven global consortium - has taken the lead and established design guidelines and a product certification process for health and medical devices [4].

To cope with these requirements AAL has to combine products from different market segments and offered by different manufacturers. Currently most of these products are stand-alone solutions and don't offer interoperability. In the future they should work together or have a common interface. Market segments such as medical devices, home automation and control, environmental monitoring systems and fitness and sports equipment are relevant for eHealth and AAL.

All of them have different standards, different data exchange protocols and different terminology [3]. A future system for AAL could be based on a combination of all technologies to help patients have the best care as possible. By now existing systems for monitoring used only one or two of the above wireless technologies [5, 6, 7].

1. 2. Objectives

The objective of this work has been to design an aggregation manager device based on a broad range of wireless interfaces that are well established in the eHealth market. A prototype of this aggregation manager has been developed to act as an experimental platform to be used in telehealth and AAL applications ranging from patient monitoring and sports tracking to home sensing and control. The system should be designed to allow for seamless integration into the patient’s life without changing his/her daily routine or giving the feeling of using technology. Test users have evaluated this product to assess feasibility and to identify potential areas for improvements.

2. Methods

2. 1. Requirements and design

The task has been to develop a kind of a data hub to be located in the center of a house able to collect all data from one or more persons living in that household as well as environmental data. This hub supports a broad range of wireless personal area and body area network technologies (PAN/BAN) to acquire a variety of sensor data. The process of data acquisition has to work autonomously without any user interaction. Thus, RFID and NFC technology is intended for authentication or even configuration. Bluetooth is used as PAN interface to connect medical sensor devices such as blood pressure monitors and body weight scales. Using the IEEE 11073:20601 protocol on top of the Bluetooth stack as realized by the Bluetooth Health Device Profile (HDP) allows for connecting medical devices certified by the CHA. For fitness and sports devices ANT+ is the interface technology of choice. Due to operation at low energy it is intended for usage in wearable sensors. ZigBee is used in the context of home automation or control. It allows communicating with sensors and actors to collect environmental data or even to control the electrical equipment. The usage of these standard wireless technologies guarantees high interoperability by a broad range of interfaces and hence flexible extension of the system.

In order to communicate with a backend system for synchronizing the acquired data, an Internet connection is needed. This can be realized by simply adding a mobile Internet modem or in case of a given infrastructure by using WiFi connection. *Figure 1* shows an overview of the intended concept.

Figure 1: System overview of the prototype Aggregation Manager

2. 2. Development of a prototype

An aggregation manager device acting as a wireless hub was developed prototypically. The core of this experimental platform was represented by an embedded microcontroller system based on x86 architecture with a couple of USB sockets to enable the system with NFC, Bluetooth, ANT+, and ZigBee capabilities by connecting the corresponding wireless transceiver dongles.

In order to ease the software development process for a LINUX operating system (Ubuntu 11.04, Canonical Ltd, London, UK) a Netbook computer was used for this prototype. Several applications and services running on the hub were deployed to collect all data from the dongles and to store them locally. By connecting a contactless smart card reader (ACR122U, Advanced Card Systems Ltd., Hong Kong) the system was able to recognize the presence of RFID cards. For identification, a user put his/her RFID card onto the reader to indicate that subsequent data belonged to him/her. To communicate with health devices the open source IEEE 11073:20601 stack library Antidote (Antidote, Signove, Campina Grande, Brazil) was used. This service allowes applications to access health devices via HDP. A Python (Python 2.7.1) application acquiring medical data was developed. Data from ANT+ devices were received and stored in “tcx” file format. Environmental data received via the ZigBee dongle were stored in a separate file without user assignment.

2. 3. Autonomous data acquisition

a) Medical data

For the medical data acquisition a blood pressure meter (UA-767PBT-C, A&D Medical, Tokyo, Japan) and a body weight scale (UC-321PBT-C, A&D Medical, Tokyo, Japan) were used. These devices were linked to the hub using Bluetooth and HDP. The devices had to be paired to the hub once when setting up the system. Then they transmitted the data automatically to the hub after each completed measurement. In order to identify the person who had performed the measurement the user had to put his/her RFID card onto the reader prior to that.

b) Fitness and sports data

In order to track the patient's fitness and sports activities a sport watch (Forerunner 405cx, Garmin, Olathe, Kansas USA) was used. This device features GPS recording capability and a wirelessly connected heart rate monitor (chest belt) and a step counter. Distance, pace and heart rate were logged and stored in the memory of the watch-like device. When the user came close to the hub the watch synchronized the data automatically via ANT+ without any user interaction.

c) Environmental data

To sense environmental data a development board with ZigBee based wireless transceiver (eZ430-RF2500, Texas Instruments, Dallas, TX) was used. To measure temperature, humidity, luminance and ambient air pressure an add-on board with appropriate sensors was developed and linked to the target board. The firmware of this wireless sensor prototype was developed to acquire and send these data to the hub periodically to be stored centrally for further calculations and/or visualizations.

2. 4. Evaluation

In the first test two students were asked to evaluate the system. The students used the system over a period of two weeks on an irregular basis. The aim was to test the system's stability and accuracy.
In a second test to evaluate the usability of the prototype a test environment was prepared to be used by computer illiterate persons. A couple aged 56 years and 46 years with no computer experience at all was asked to use the system over the period of one week. Both had to measure their weight and blood pressure twice a day with the same device set. To assign parameters correctly the participants were asked to place their RFID card on the NFC reader before taking measurements. Additionally, one test person was asked to wear the sports watch, heart rate monitor and step counter when cycling to work or going for a walk. The hub was placed at an easily accessible position in their living room and the environmental data sensor was located outside of a window in a northward direction. The goal of this test was to show if the prototype can be used by computer illiterate people and to get feedback about usability and robustness in a real home environment. *Figure 2* shows the utilized test environment.

Figure 2: Patient environment consisting of a data hub (netbook), smart card reader, blood pressure meter, weight scale and sports watch

3. Results

In the course of both evaluation cycles the following data were recorded and stored to be analyzed afterwards. A total of 77 logins was registered. During both periods 158 weight and blood pressure values were recorded. 31 sport sessions were tracked in total using the sports watch. Environmental data measurements were not taken consistently, monitoring was done on four different days to test the developed circuit.

During the test period with the computer illiterate group a total of 33 logins was registered. Placing and removal of the RFID card was monitored and stored in a log file.

In this group a total of 69 health values was transmitted to the hub. 32 values could be matched to the female test person, 26 to the male test person. 11 health data values could not be assigned to any of the test persons. *Figure 3a* shows the health data of the 46 year old female participant. The data were stored locally in xml files and interpreted after the trial via Microsoft Excel.

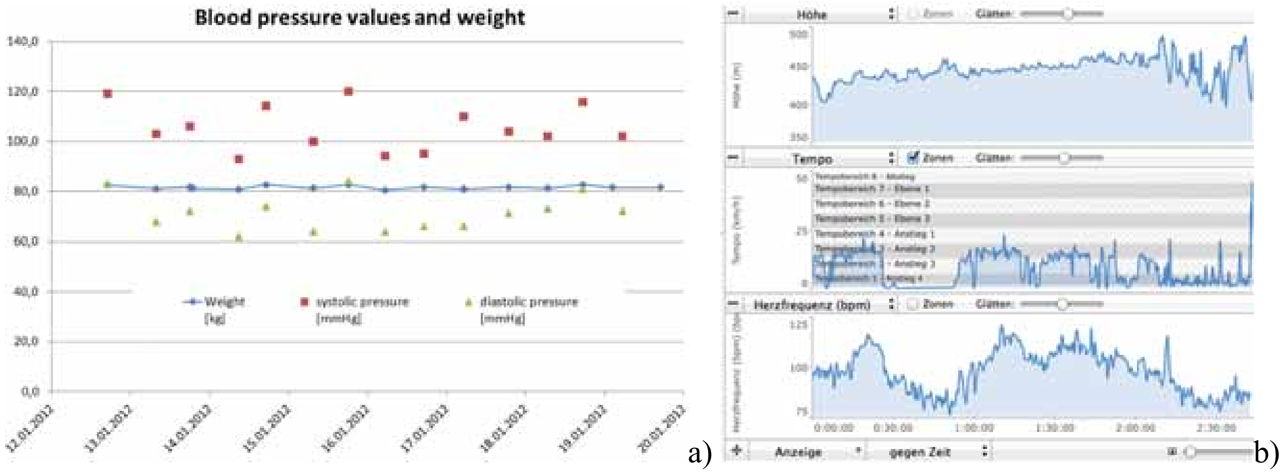

Figure 3: a) Health data of a 46 year old female test person acquired via Bluetooth, b) person activity record during cycling of a 56 year old male test acquired via ANT+

The results shown in *Figure 3b* illustrate activity of the 56 year old test person during cycling. GPS position, altitude, distance and pace were monitored. For the test period with the computer illiterate participants 17 data values do exist, 8 of them could be used for data analysis. The remaining “tcx” files contained no activity data.

Temperature, humidity luminance and ambient air pressure was monitored successfully. These data were sampled every 10 seconds and stored in log files.

4. Discussion

The feasibility tests showed that the prototype was able to monitor health parameters. In some rare cases data were not completely sent to the hub after measurements were taken. Devices were disassociated and disconnected to early, which shows the instabilities of Bluetooth. However, measurement data were not lost because devices stored the data to send them at next boot up/ turn on.

NFC identification worked fine in all cases, and time stamps of placing and removing the RFID cards were logged correctly in all cases. In this prototype device pairing was done manually, for a future development pairing via NFC could be realized.

Monitoring activity worked out fine but feedback from the user with no computer experience was that the handling of the sports watch was too tricky. The touch bezel didn't always respond to the user, also the establishment of a GPS connection took too much time. This problem could probably

be managed by using a user friendly sports watch with touchscreen or a Bluetooth enabled pedometer. This will be taken into account in a future version of the Aggregation Manager.
Monitoring environmental data with a frequency of 0.1Hz makes only sense if the user has a display to visualize the environmental data in real time. Sampling every hour would be sufficient in case of storing these data centrally.

NFC, Bluetooth, ANT+ and ZigBee technologies were used for this prototype due to the fact that off the shelf consumer electronic exists. So the system can be easily extended in the future.

5. Conclusion

We developed a prototype of a multichannel and multimodal wireless data hub to collect various vital parameters and sports data in a multiuser environment together with environmental data. Although the prototype showed potential for optimization, the basic features could be tested successfully. The results show that a single point of data collection may be feasible so serve several eHealth applications, i.e. telemonitoring, AAL, environmental monitoring as well as sport and fitness tracking. Our results show that multiple users can be monitored with one device set.

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