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INTUITIVE ACQUISITION OF ELECTROCARDIOGRAMS FOR TELEMONITORING VIA MOBILE PHONE

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Abstract

In order to provide a more detailed insight into the patients' health status, the acquisition of ECGs can be indicated when telemonitoring certain chronic diseases. In the course of the present work, a mobile phone based concept for the acquisition of ECG data was developed and implemented prototypically. Usability aspects were especially considered by using a combination of Near Field Communication (NFC) and Bluetooth technology. Results indicate that the acquisition of ECG signals may be accomplished autonomously by the patients in an intuitive and easy-to-use way.

Keywords – eHealth, Telemedicine, Mobile Communication, Near Field Communication, ECG

1. Introduction

Telemonitoring of chronically ill patients allows the continuous monitoring of their health status and, consequently, a therapy management, which is adapted to the specific requirements of each individual patient. A success factor for the implementation of telemonitoring is to provide patients with an easy to use patient terminal for intuitive data acquisition at low cost. Because of their functionality, their widespread usage, and their ubiquitous availability mobile phones have the potential to act as patient terminal in telemonitoring scenarios.

Through the usage of *Near Field Communication (NFC)* enabled mobile phones patients can acquire and transmit different parameters (e.g. body weight, blood pressure, and heart rate) simply by touching the respective device with the mobile phone [6]. This touch-based data acquisition is well accepted but currently restricted to a limited set of sensors. Extending the given solution to acquire further health parameters and even biosignals would help to *provide a more complete insight into* the patients' health status and to adapt the therapy as early as possible.

Acquisition and analysis of ECG signals for the telemonitoring of different chronic heart conditions – e.g. Congestive Heart Failure (CHF) – can provide the attending physicians with additional information concerning several cardiac parameters. In [2-5,7] systems for the acquisition of ECG signals in a telemonitoring scenario are introduced. All systems use mobile phones as patient terminals and *Bluetooth (BT)* technology for the communication between the ECG recorder and the

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mobile phone. Most of the systems require the application of adhesive electrodes to the chest. The ECG quality strongly depends on the patients' ability to apply the electrodes correctly, which may pose a problem for daily usage in a telemonitoring scenario. Furthermore, ECG recorders seem to be too complicated to be used by the patients autonomously.

It has been the objective of the present work to:

1. develop a mobile phone based data acquisition concept, which supports the intuitive acquisition of ECG data.
2. implement a prototype based on this concept, which can be used autonomously by the patients at home.

2. Materials and Methods

2. 1. Wireless communication protocols

Today, the most common way for sending data from a measurement device to a mobile phone based patient terminal is BT. Therefore, prior to transmitting data in between the devices they need to be paired using a PIN the user has to enter into the mobile phone. BT pairing is not an intuitive procedure and may overstrain especially elderly patients. Therefore, an alternative easy-to-use method is required.

NFC is an intuitive communication technology allowing wireless data transmission over short distances. It provides intuitive, simple, and secure communication between electronic devices and smart objects within a short range of typically two to ten centimetres [8]. Data can be exchanged either between two active devices or in between an active device and a passive Radio Frequency Identification (RFID) tag. In the second case, information (e.g. an identification number) can be written on a tag and read out by an active NFC device (e.g. mobile phone). Unfortunately, communication via NFC is rather slow and it is disconnected as soon as the devices are separated by more than a few centimetres. Therefore, transmissions of large data sets (e.g. a whole ECG file), or data streams from a measurement device to a mobile phone via NFC are not possible in a reliable way.

2. 2. Combination of NFC and Bluetooth technology

A promising way to solve the problems of getting a touch-based transmission of a large amount of data on the one hand and to comfortably pair two BT devices on the other hand is to combine these two wireless communication protocols. Currently available NFC enabled mobile phones also support BT communication. The main idea is to use the NFC protocol to read the required pairing information from an RFID tag and to establish the BT connection based on these data. The RFID tag is programmed with a special *NFC data exchange format* (NDEF) record, namely the so called "BT Record", which contains the unique connection data of the present BT module.

3. Results

3. 1. Data acquisition concept

Based on the aforementioned wireless communication protocols a concept for the intuitive acquisition of ECG data for patients at home was designed and implemented. A combined blood pressure meter/ECG recorder served as measurement device. A mobile phone with a preinstalled Java 2 Mi-

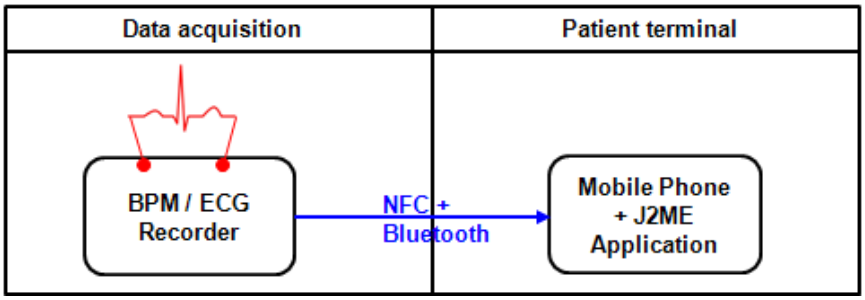

Figure 1: Data acquisition concept. A mobile phone based patient terminal collects data of the combined blood pressure meter/ECG recorder using NFC and BT technology.

cro Edition (J2ME) based application served as patient terminal. It collected the data of the extended blood pressure meter using NFC and BT technology. The schematic in *Figure 1* describes the components of the concept.

3. 2. Data acquisition – Measurement device

In order to simultaneously acquire the ECG (Einthoven I), systolic and diastolic blood pressure, mean arterial pressure, and heart rate, an off-the-shelf blood pressure meter (UA-767 Plus BT, A&D, Tokyo, Japan) was used and extended by the following three modifications (see *Figure 2*):

1. Underneath the blood pressure meter a small case was attached that contained an analogue circuit to amplify and filter the ECG signal, a microcontroller unit (MSP430F2410, Texas Instruments, Dallas, Texas, USA), and a BT module (BNC4, Amber Wireless, Cologne, Germany).
2. Three metal electrodes (left arm, right arm, driven right leg) were fixed to the cover and the backside of the casing. These electrodes were to be touched by the fingers of the left and right hand.
3. An RFID tag (Mifare Standard 1K, NXP Semiconductors, Eindhoven, Netherlands) programmed with the BT record was stuck behind the cover plate right next to the display.

The system was designed to record a single channel ECG signal at a sampling rate of 125 Hz and 8-bit resolution while the user performed a blood pressure measurement. These data were streamed via BT in real time. By means of using a bidirectional BT channel the measurement device was able to receive commands from the remote component. A modification of the meter's start button allowed for starting the blood pressure measurement automatically by sending the appropriate command to the meter.

3. 3. Patient terminal – NFC mobile phone + J2ME

Figure 2: Extended blood pressure meter. The left arrow marks the attached case; the right arrow indicates the position of the RFID tag, the red circles mark the three metal electrodes to be touched by the patient with her/his fingers.

A commercially available mobile phone featuring wireless communication via NFC and BT (Nokia 6212 Classic, Nokia, Espoo, Finland) served as patient terminal. A J2ME based software application was implemented on the mobile phone. The Java Specification Request (JSR) 257 and the JSR 82 were used for implementing the NFC and BT communication. The application launched automatically after touching the RFID tag, which was incorporated into the extended blood pressure meter and established the BT connection using the pairing information stored on the RFID tag.

3. 4. Workflow

For data acquisition, the RFID tag of the extended blood pressure meter had to be touched with the mobile phone. The J2ME application started automatically, read out the pairing information from the tag and established a BT connection to the blood pressure meter. Then the user was asked to put on the cuff of the blood pressure meter and to touch the ECG electrodes with her/his fingers. Next, the J2ME application sent a command to the blood pressure meter, starting the inflation of the cuff. Thereafter, blood pressure measurement and ECG recording were performed simultaneously. The data were transmitted to the mobile phone via BT. The J2ME application analysed the ECG signal and displayed a graphical representation of the current signal quality. As soon as blood pressure data were available, the recording of ECG data was stopped and the acquired data were stored on the mobile phone. The J2ME application guided the patient through the data acquisition process using a visual and acoustic interface – telling the patient which step she/he had to take next.

Several measurements and processing cycles were performed successfully in various healthy volunteers. Usability and feasibility were evaluated and potentials for improvements regarding to device and software design were identified.

4. Discussion

4. 1. Usability

In order to acquire an ECG for telemonitoring purposes a patient has to accomplish two tasks:

1. *Acquisition:* The patient has to acquire an ECG with sufficient quality, which can be interpreted by physicians. The combined blood pressure meter/ECG recorder outlined in chapter 3.2 offers the possibility to simultaneously acquire blood pressure and ECG data. The patient does not have to apply adhesive electrodes to her/his chest. She/he just has to touch the electrodes fixed on the adapted blood pressure meter. This may allow her/him to manage the acquisition of ECG data autonomously at home. However, to prove the usability of the prototype in real patients it still has to be evaluated in a clinical trial on a representative user group.
2. *Transmission:* The patient has to transmit the acquired data from the measurement device to the patient terminal and consequently also to linked information systems (e.g. a monitoring centre). Using the presented prototype the patient can be supported in data transmission in an intuitive and easy-to-use-way.

The advantage of mobile phones compared to other patient terminal technologies are their ubiquitous availability at low cost and their mobility. Limited resources concerning memory capacity and processing power, as well as the small keypad and display are the main disadvantages of mobile phones. In the present work, the usage of NFC and BT technology completely eliminates the need to use the mobile phone's keypad for data entry. However, the limitation concerning the small dis-

play is still present, even though much (but not all) information is provided to the patients visually and acoustically.

4. 2. Safety and security considerations

Up to now, the BT connection between the measurement device and the mobile phone established via NFC is a workaround managed by a J2ME application. At the moment, this is the only way to combine a mobile phone's NFC and BT features. Unfortunately, J2ME does not support full control of the BT chip resulting in an unauthenticated and unencrypted link between measurement device and mobile phone. In order to use the system in a clinical setting an alternative way of establishing the BT connection via NFC may be required.

A promising way would be to join NFC and BT on the hardware or at least on the mobile phone's firmware/OS level. In 2007, the BT Special Interest Group (SIG) announced the new version of the BT core specification, namely BT 2.1. BT 2.1 uses NFC technology in order to automate and simplify the pairing process [1]. The only user interaction required for pairing is holding one device close to the other. Pairing can be done by reading the static pairing information out of an RFID tag or by exchanging dynamic pairing information via the NFC IP1 peer-to-peer protocol resulting in higher security. This concept is also intended to be used for setting up WIFI connections. Unfortunately BT pairing via NFC is an optional feature of BT 2.1 and mobile phones currently available only support this as a hard coded demo feature for sending images to electronic picture frames or printers. However, it is expected that in future this feature will be implemented in all BT devices.

4. 3. Possible application areas

The concept and the prototype outlined in the present work were developed in the course of the project "eT – eHealth terminal"[1]. The goal of the project was to develop a mobile phone based patient terminal to provide CHF patients with an easy-to-use and intuitive method to acquire data, especially ECG data, in a telemonitoring scenario. Besides the usage of the prototype in a telemonitoring scenario, additional application areas are conceivable. The presented prototype could be used as an event recorder. Patients could use it to acquire ECG signals and transmit them to e.g. a telemonitoring centre if they are not feeling well. Furthermore, the prototype could be utilised by general practitioners to acquire ECG data during house calls or visits in retirement homes.

4. 4. Future prospects

The concept described in the present work is based on the combined usage of NFC and BT technology. Only a few mobile phones currently available support both of these wireless communication protocols. As mentioned in *chapter 4.2* it is expected that future BT devices will support pairing via NFC, which may act as a catalyst for the presented concept. Compared to other approaches like the "Vitaphone VP1300 GPS-Handy"[2] or the "H'andy sana 210"[3] patients will not have to buy special mobile phones in order to acquire ECG signals autonomously at home. Instead, they can use their standard mobile phones for the intuitive acquisition of data not only from ECG recorders but also from other BT enabled sensors.

[1] et.ehealth-systems.at
[2] www.vitaphone.at
[3] www.handy-sana.com

5. Conclusion

A concept for the mobile phone based acquisition of ECG data was developed and implemented prototypically. By means of joining NFC with BT technology, an easy-to-use interface between measurement device and mobile phone was realised. This data acquisition concept may enable patients to autonomously acquire ECG data in an intuitive way.

6. Acknowledgments

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