ABSTRACT
Patients suffering from chronic diseases like congestive heart failure (CHF) can be supported in their self-management process by utilizing telemedicine services based on standard IT and mobile phone infrastructure. Continuous transmission of self measurements of blood pressure, body weight and other health related parameters to a monitoring centre allows the attending physician to monitor those data and to guide the patient to the best possible health status. In such concepts, the most challenging part is still the human computer interface, i.e. to support the user with an adequate system to transmit the self measurements. The objective of this paper is to present a new kind of patient terminal based on mobile phones in combination with the now available near field communication (NFC) technology. This concept provides an intuitive and easy-to-use way to acquire and transmit health related data just by touching medical measurement devices with NFC enabled mobile phones.

KEY WORDS
eHealth, telemedicine, mobile phone, NFC/RFID, heart failure

1. Introduction
Telemedicine services have the potential to improve the quality of life of patients suffering from chronic diseases by supporting them in their daily self management process [1]. Furthermore, such services are able to reduce the costs for the health-care system that are mainly caused by chronic diseases like diabetes mellitus, hypertension or congestive heart failure (CHF). CHF results from structural or functional cardiac disorder that impairs the ability of the heart to pump a sufficient quantity of blood through the circulatory system. The course of CHF is progressive and often requires clinical treatment. It affects about 5 % of all hospitalized patients older than 65 years. These patients have a high risk of morbidity and mortality. About 50 % of them discharged from clinical treatment will be re-admitted to the hospital within six months. Modern CHF management uses telemedicine concepts to prevent the episodes of acute decompensation so as to reduce the burden and costs caused by rehospitalisation [2, 2a].

Mobitel clinical trial
Mobile Telemonitoring for Heart Failure Patients (Mobitel) is an ongoing, randomised, prospective, multicentre study on patients with a recent episode of acute CHF hospitalisation. Mobitel intends to assess the hypothesis that telemedical intervention can significantly reduce the rehospitalisation rate of patients with cardiac events within a period of six month after discharge. In the course of this study participating patients are randomized either to a control group with pharmacological treatment or to a telemonitoring group with pharmacological treatment plus telemedical care. At discharge from the hospital patients randomized into the telemonitoring group are asked track their health related parameters on a daily basis. They document their blood pressure values, heart rate, weight, wellbeing, and individual medication via a telemonitoring system that was developed in cooperation with clinical partners. This system (figure 1) is based on standard IT infrastructure elements to enhance the communication between the patient and his/her physician and consists of the following main parts:

1) remote monitoring centre: A web based system hosts a central database where all data are received, stored, managed, and processed to be shown to authorized users. An automated monitoring process continuously checks the values and turns the physician’s or other caregiver’s attention to the patient when necessary by means of notifications and alerts.

2) physician terminal: A web based user interface allows the physician to view all data that belong to a certain patient. This enables the physician to monitor patient’s health status and to control the course of the therapy.

3) patient terminal: Mobile phones enables the patient to acquire his/her health related parameters and to transmit them to the remote monitoring centre.

Ubiquitous availability and the benefit of absolute mobility of mobile phones make these devices particularly suitable as patient terminal. They provide a direct data connection between the patient and the remote monitoring centre. Besides transmission of the self measurements the patient terminal is able to receive feedback information in order to guide the patient through his self managing process.
The device of choice (available at Mobitel’s launch) has been the Nokia 3510i (Nokia, Helsinki, Finland). This mobile phone provides a color-display and keypad with comparably large buttons which makes it better applicable for elderly people. Additionally, it is endowed with a wireless application protocol (WAP) browser that allows entering the health related parameters into dynamically generated input templates and transmission [3]. To initialize the transmission process, a shortcut key sequence starts the mobile phone’s WAP browser and opens the Mobitel application. Thereafter the user has to perform the following steps using the numeric keypad:

<table>
<thead>
<tr>
<th>step</th>
<th>action/input</th>
<th>Features</th>
<th>keystrokes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>login</td>
<td>username and password</td>
<td>up to 20</td>
</tr>
<tr>
<td>2</td>
<td>body weight</td>
<td>weight with decimal place</td>
<td>up to 10</td>
</tr>
<tr>
<td>3</td>
<td>sys. blood pressure</td>
<td>single value up to 7</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Dia. blood pressure</td>
<td>single value up to 7</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>heart rate</td>
<td>single value up to 7</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>medication</td>
<td>in average 2 to 4 drugs, declare dose in milligram with decimal place</td>
<td>up to 9 per drug</td>
</tr>
<tr>
<td>7</td>
<td>well-being</td>
<td>select from drop down menu</td>
<td>up to 5</td>
</tr>
<tr>
<td>8</td>
<td>transmit/logout</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

\[ \sum = 76 \text{ to } 94 \]

To pass all steps illustrated in table 1, the user has to execute 76 to 94 keystrokes depending in the number of taken drugs. Login and declaration of medication are the most extensive inputs. An intermediate analysis of the completed patients randomized to the telemonitoring group shows that most of them performed the data acquisition and transmission process very well. But a few of them lacked the required technical skills or the motivation to handle the mobile phone. This indicates, that the patient terminal is still a challenging part in home-monitoring concepts. Cumbersome user interaction with a small keypad and display can be a limiting factor for using the mobile phone as a patient terminal for elderly patients.

Thus, a major focus of our research activities has been to develop and test new solutions for home based health data acquisition. The aim has been to provide a mobile phone based data acquisition method that bypasses the common way of manual transcription. Additionally and to increase usability it should fulfill all criteria of an ideal patient terminal like error-resistance, offline data acquisition, high flexibility, and adaptability [4]. Recently, the Near Field Communication (NFC) technology became available which seems to make this intention realizable.

2. Methods

NFC is a communication protocol developed by Philips and Sony that enables wireless data exchange between two electronic devices within a short range. It is based on Radio Frequency Identification (RFID) and contactless smart card technologies. A typical RFID system consists of a reader/writer unit and one or more passive transponders. A passive transponder is an electronic data storage medium without own power supply. It can be read out or programmed contactlessly within a certain distance from the reader. Classical RFID technology is asymmetric in the sense that there are different roles for the reader and the transponder unit.

Compared to RFID systems NFC – as the subsequent development – breaks the functional separation of the two units and allows bidirectional communication between two NFC enabled devices. This means that each of the two devices is able to start the communication. This peer-to-peer connection works in the unlicensed 13.56 MHz frequency band and allows a data rate of up to 424kBit/s within a range of about 10 centimeters. Additionally NFC is able to access (read and write) passive RFID and contactless smart card products provided by Philips (MIFARE) and Sony (FeliCa) [5].

Data exchange starts automatically by bringing two devices close together without the need of any further interaction or initial configuration. The connection keeps established till all data are exchanged or the distance increases above a certain limit again. This is the intended purpose and the basic idea of NFC - to enable data exchange between two devices in an intuitive, easy to handle, and secure way.

Security is provided on the physical layer since the communication can only be tapped within a very short distance and in upper layers by means of data encryption. Consumer electronics has been envisaged to be the main application area for NFC. NFC enabled devices (e.g. notebooks, cams, MP3 players, etc.) can exchange data without complex configurations or user interactions.

Another big issue that could and will be covered by NFC is mobile ticketing and payment because of NFC’s contactless smart card functionality. Thus, NFC is qualified to be integrated into mobile phones [6]. In November 2004 Nokia released a special NFC shell to enable a certain mobile phone (Nokia 3220, Nokia,
Helsinki, Finland) with full NFC functionality (Figure 2, a). The shell contains a single chip NFC communication module with a coil-like antenna.

Figure 2: Nokia 3220 with NFC shell (a) and MIFARE RFID tag (b)

The fact that NFC is based on RFID, allows the mobile phone to write on and read information from RFID tags. RFID tags are thin RFID transponders in sticker form (figure 2, b). The NFC shell can be accessed by a Java 2 Platform Micro Edition (J2ME) based software application running on the mobile phone. This concept allows to develop individual J2ME applications. The application starts automatically after bringing the phone close to another NFC device or even an RFID tag. Establishing a communication without any further user interaction makes this technology indeed interesting for home monitoring applications.

3. Results

In the course of the present project a NFC module has been designed and developed. The NFC module can be integrated into various medical devices to provide data to be fetched from the device via a NFC enabled mobile phone.

Figure 3 shows the module implemented in surface mounted design (SMD). It contains the single chip NFC component (PN531, Philips Semiconductors, Gratkorn, Austria) and an embedded microcontroller (PIC 16F88, Microchip Technology Inc., ORT, Land). The microcontroller operates the NFC chip and handles data exchange with the medical measurement device. For this purpose the NFC module is equipped with various I/O ports [7].

Figure 3: The developed NFC module provides SMD plugs to connect various medical devices

A first prototype has been developed by extending the off-the-shelf available blood pressure meter boso medicus PC (BOSCH + SOHN GMBH U. CO. KG, Jungingen, Germany) with the NFC module. This prototype allows fetching the recent measured values (blood pressure, heart rate and time stamp) by bringing the mobile phone right next to the meter’s display (Figure 4). At this position the NFC module is fixed inside the case [8]. After receiving the data via NFC the software application installed on the mobile phone starts automatically and initializes data transmission to the monitoring centre. Thereafter, these data can be accessed on the Web site after logging on with user-name and password unique to a given device [9].

Figure 4: The working prototype has been extended with a NFC module that allows the recent measurements via NFC to be fetched via an NFC enabled mobile phone by simply bringing them close together.

The developed prototype has been tested by several users. More than 300 blood pressure values with time stamps have been transmitted successfully. Initial experiences indicate that NFC enabled mobile phones could meet all requirements of a user-friendly patient terminal in a monitoring scenario.

4. Discussion

Possibilities in the framework of the Mobitel trial
Since NFC is compatible with certain RFID tags these tags could be used to handle additional tasks in the Mobitel data acquisition chain in combination with a software application running on the mobile phone. This application – a so called “health data manager” – could eventually completely replace the WAP based method by handling all data received from any active NFC enabled device or passive RFID tag.

In relation to the current WAP based data acquisition chain (see table 1), NFC and RFID technology could simplify the data acquisition process in each step:

1. Login: A RFID tag – for example placed behind a photo of the patient – can be used to identify the user. By touching this identification tag that contains the login information the application starts automatically.
2. -5. Health data acquisition: These steps can easily be performed by equipping measurement devices with the developed NFC-module.
3. Medication: Attaching RFID tags – holding information like drug name and the dose of a single
pill – to pill boxes enables easy logging of medication receipts. After touching a tagged pill box the user only has to enter the number of pills he/she has taken. Thereafter the application stores the name of the drug, the actual timestamp and the entered number of taken pills (Figure 5, a).

7. Well-being: Entering this information could be done by using a table with icons representing different stages of well-being graphically. These various icons are furnished with RFID tags, providing the same information to be transferred to the mobile phone just by touching.

7a. Activity: Additional, RFID could simplify the documentation of the user’s activity. By attaching tags to items enables to log the corresponding action. For example a tag can be fixed on a bicycle. After cycling the patient touches the tag and enters the duration of his/her activity. This way, activity, duration and the actual point of time are stored in his/her mobile health data record (Figure 5, b).

8. Data transmission: To synchronize all collected data a tag could be programmed to trigger the application to open a GPRS or UMTS connection and transmit the locally stored data.

Figure 5: Display after bringing the mobile phone close to a tagged pill box (a) and a tag place on a bicycle (b)

Home monitoring scenario for CHF patients
A possible home monitoring scenario of patients suffering from CHF based on this concept could work as follows:

The patient is equipped with a NFC enabled mobile phone, a blood pressure meter, a body weight scale, a well-being icon table, an identification tag, and tagged pill boxes. The procedure of data capturing starts in the morning by touching the identification tag (e.g. photo of the certain patient). This action starts the “health data manager” application on the mobile phone. The application stores upcoming inputs into a local database corresponding to the respective user. After measuring body weight and blood pressure the patient simply touches these NFC enabled devices to fetch the values. In the next step the received medication is entered by holding the mobile phone close to the tagged pill box and typing the number of taken pills. Declaration of the well-being is done by touching the adequate icon on the well-being icon table. This action closes the morning procedure that takes less than one minute and requires only a few keystrokes to enter the number of taken pills.

All other entries distributed over the day like intermittent drug receipts, doing some activities or further measurements at midday or in the evening will be stored in the same way. In the evening after the whole data were captured during the day, the user touches the synchronization tag to initiate the data transmission process. This action closes the daily data acquisition procedure, that is easy to handle and not complex even for technically unskilled people.

Compared to data acquisition via numerical keypad (e.g. using the mobile phone’s browser) the interactions required from the user can be brought to a minimum.

5. Conclusion

Telemedicine services for technically unskilled and elderly patients suffering from chronic diseases require an adequate technical solution to be fully accepted. The newly available NFC technology seems qualified to establish a new paradigm in (health) data acquisition by acting as an easy-to-use interface between humans and the technical infrastructure. The intuitive action of touching devices and items gives the impression of actively taking part in therapy management without being technically overstrained and it guarantees high acceptance because of high usability.

References


