Global Telehealth 2012
A.C. Smith et al. (Eds.)

doi:10.3233/978-1-61499-152-6-104

Automated NFC Enabled Rural Healthcare for Reliable Patient Record Maintainance

Divyashikha SETHIA[1] , Shantanu JAIN and Himadri KAKKAR
Department of Computer Engineering, Delhi Technological University, India

Abstract. Body sensor networks can be used for health monitoring of patients by expert medical doctors, in remote locations like rural areas in developing countries, and can also be used to provide medical aid to areas affected by natural disasters in any part of the world. An important issue to be addressed, when the number of patients is large, is to reliably maintain the patient records and have simple automated mobile applications for healthcare helpers to use. We propose an automated healthcare architecture using NFC-enabled mobile phones and patients having their patient ID on RFID tags. It utilizes NFC-enabled mobile phones to read the patient ID, followed by automated gathering of healthcare vital parameters from body sensors using Bluetooth, analyses the information and transmits it to a medical server for expert feedback. With limited hospital resources and less training requirement for healthcare helpers through simpler applications, this automation of healthcare processing can provide time effective and reliable mass health consultation from medical experts in remote locations.

Keywords. NFC, body sensor network, RFID, telemedicine, ambient assisted living, remote healthcare, e-health, sensor technology, sensor network

Introduction

Healthcare monitoring is a challenging task for remote areas where there are large numbers of patients and expert medical help is not easily available. Such areas could be remote rural areas in developing countries, where a bulk of the population ekes out their living through agriculture. A similar problem is seen when natural disaster strikes populated areas—in such a situation, there is a requirement for large scale medical aid but there not enough qualified medical professionals on the ground. In both these cases, effective remote medical aid can be of enormous help. However, it is not easy to provide a large scale and effective medical aid program remotely. There is a shortage of expert medical doctors and helpers to monitor the health of the large number of patients and maintain their health records.

Advancements in information and communication technologies like new generation Smartphone and wireless sensor networks can provide low cost and reliable solutions in such situations**.** A body sensor network consists of a patient wearing a number of sensors to gather vital health parameters [1]. Various body sensors such as ECG, pulse oximeters and blood pressure monitors are used to monitor vital parameters of the patient for a short period. The gathered patient medical data is stored on a mobile device using energy efficient MAC-based protocols like Bluetooth (IEEE 802.15.1) [2],

[1] Corresponding Author: Divyashikha Sethia, Assistant Professor, Department of Computer Engineering, Delhi Technological University, India; E-mail: divyashikha@dce.edu

IEEE 802.15.4[3], IEEE 802.15.6 and Zigbee [4], and is sent to a local server after a quick analysis of data for further diagnosis by qualified doctors using wireless protocols like GPRS.

Instead of personal healthcare devices being installed at each home, a framework is proposed for remote rural areas where expert medical doctors may not always be available. There may only be some form of local volunteering healthcare helper service at the location. The healthcare service provider would use several body sensors worn on a patient to gather the vital health parameters of patients. The healthcare helper would be provided with the touch-based intuitive mobile handheld-based terminal which would act as a control node for the acquisition and transmission of critical medical information.

The traditional healthcare application on the Smartphone would have a set of interfaces for doing this. One of the interfaces would prompt the healthcare user to enter the patient identification for sending the medical information related to the particular patient and reliably maintaining the records. The other interfaces of the application would help the healthcare user to gather data from the medical sensors and send them across to the medical server for expert medical diagnosis. The drawbacks of this application are:

- Errors may be made when entering the patient record ID
- The manual user interface of the applications would also be time-consuming, which can be a problem in cases of natural disaster and when the number of patients is large. Hence the healthcare helper will be overloaded with work
- Mobile application with different interfaces would require the healthcare helper to be trained proficient in their use.

The number of such healthcare helpers in remote areas is comparatively less compared to the large number of patients to be monitored. This leads to poor quality of health services provided to the masses. Also these healthcare helpers may not be very educated since they are part of a local rural community. The use of Information technology in tele-healthcare has lead to the development of e-healthcare solutions in which the expert doctor's advice is taken remotely. Along with this it is also essential for the healthcare system to monitor the patients regularly and maintain the history of the treatment undertaken. If the entire process of treating the patients is done manually, chances of error generation will be high. The large number of people per healthcare helper discourages the system of maintaining a record of patient's history along with treatment undertaken, as this would involve manual data entry by the healthcare helper. There have been number of research works for maintaining patient ID as discussed in section 2 for related work. Also, simpler application interfaces on the mobile phone would require less training effort for the healthcare helpers.

To address these problems, we propose a solution for an automated healthcare system for rural remote areas where the health records can be maintained reliably and easily for the health check-up of a large number of people. For scenarios where there is a requirement for such bulk processing of patients, such as remote rural areas of developing countries, healthcare application with automated patient ID entry and simpler application interfaces would provide benefits.

The concept presented in this work is based upon Near Filed Communication (NFC) [5], a wireless feature that is recently being widely launched in cell phones. Easy connections, quick transactions and simple data sharing make it ideal to be used

for various services. Amongst other capabilities, NFC technology allows a phone to act as a 13.56 MHz RFID reader and writer. NFC enables devices to share information at a distance less than 4 centimetres with a maximum communication speed of 424kbps [5].

The NFC technology uses reader/writer capability available on the new mobile phones and tags (responders) and magnetic induction to power the tag which may not have a power source of its own. NFC tags can be very small (0.5mm2), have memory capacity (from kilobytes to over 1 Megabyte), low priced and are compliant with an international standard (ISO14443) which makes it compatible with many existing contact-less smartcards. There is another RFID technology available comparable with NFC. The advantage of using NFC is that the new phones are equipped with reader/ writer interfaces and makes it easier to use [6]. As a result, NFC offers the potential to create a new and easy-of-use interface that can be used to communicate a person's identity. Generic applications of NFC are based on ticketing, contactless payment, content delivery etc. NFC is also being used in healthcare to improve the healthcare procedures. To avoid errors in medication in hospitals, NFC can be used [6]. It has also been used to treat Alzheimer patients [7] by storing patients incidents onto the NFC tag which can be later be read by an assistant for appropriate rehabilitation and exercises. NFC has been also used for monitoring heart failure patients [8].

This work proposes the architecture for an application that demonstrates how NFC-equipped phones can be used to read passive NFC tags and how medical sensor data can be read and communicated reliably to a web server with fewer steps of user interaction, reduced user intervention with minimum data entry requirement. We see the utility of this architecture for reliable healthcare in remote rural areas with a large number of patients and a lesser number of healthcare helpers. The following benefits will be provided:

- reliable patient record maintenance
- speedier process of monitoring through automated interfaces which will reduce the workload of healthcare helpers
- less training requirement of healthcare helpers.

The layout of the paper consists of our proposed solution in section 1, followed by the experimental setup in section 2. This is followed by related work in section 3, the conclusion in section 4 and future work in section 5.

1. Proposed Architecture

The components of the architecture for the NFC-based Automated Healthcare system are shown in Figure 1.

1. NFC Card based on NFC tags: This will be the patient card which would have the unique patient ID.
2. Medical Sensor Devices (with Bluetooth Technology): Various body sensors like Pulse Oximeter, ECG sensor. These devices would communicate with the mobile device through energy efficient MAC protocols like Bluetooth and Zigbee.

3. NFC enabled smart-phone: This would read the patient ID from the patient tag, which would trigger the healthcare application to automatically gather sensor data, analyse the data and give a preliminary report and send it to the Local medical server if the phone does not have internet facility or directly to the medical server through GPRS.
4. Local Medical Server: Maintains the patient's records database. It can send the records further to the remote medical server for the expert medical advice. The information can be sent through the public internet or through Delay Tolerant Network [18] using USB keys if the remote area does not have internet facility.

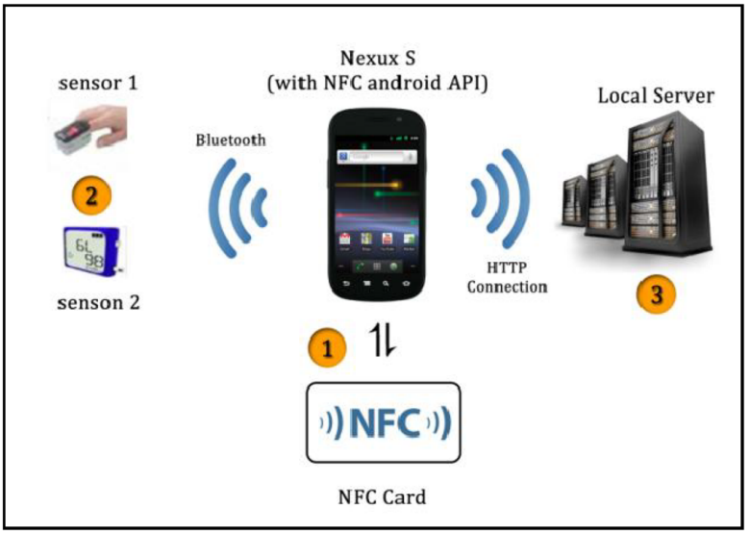

Figure 1. Architecture of proposed healthcare system

A traditional system could use the following steps:

1. enter patient ID manually
2. choose application option to gather body sensor data
3. choose application option to send the data to the remote server.

The proposed system consists of the following steps:

1. Patient ID is read from the NFC Tag
    - If patient is new, register on the local server.
2. Automatically connects to the various health device sensors
    - Gathering of healthcare data from the various health body sensor devices to the handheld mobile device acting as control node
    - Analysis of the recorded data on the handheld for preliminary report generation or alert generation.

3. Uploading the report on the server for further analysis by the qualified doctors.

The proposed application architecture as shown in Figure 2 reduces the steps of intervention by the healthcare helper by automating the healthcare process through contactless reading of NFC patient ID tags.

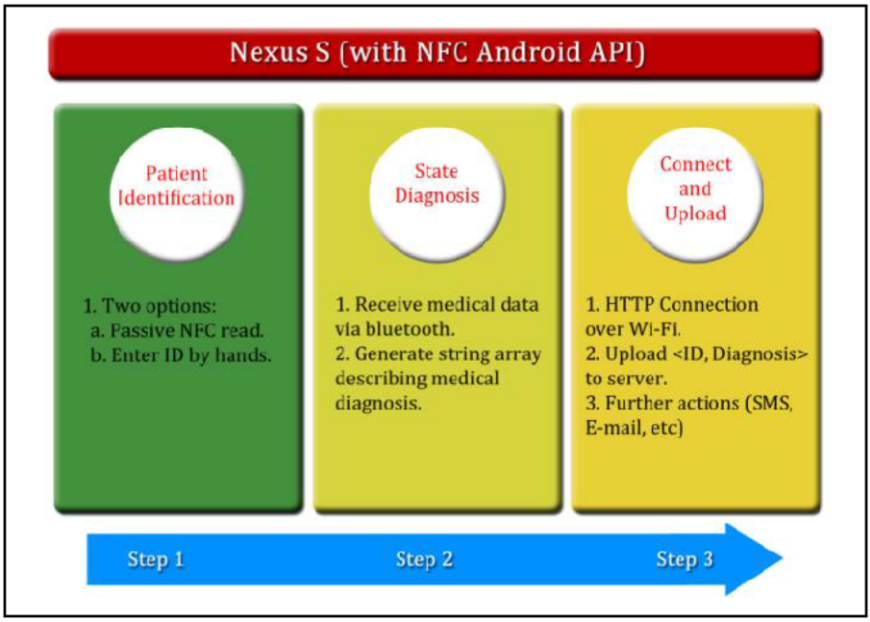

Figure 2. Dynamic architecture of the Proposed System

2. Experimental Setup

We have developed the architecture infrastructure for the proposed automated healthcare application, consisting of:

1. automated application on the handheld device for reading the NFC tag, gathering sensor data through the Bluetooth interface, analyzing the data and sending it remote medical server.
2. medical records with database.

Since Android [14] is an open-source mobile platform and is increasingly becoming popular with mobile handheld devices we chose a NFC-based Android mobile device for our setup. We setup a local server for maintaining the medical record database. Due to lack of resources we could not have access to body sensors. Hence we simulated an oximeter on the laptop to send oximeter readings through Bluetooth to the Android-based mobile device.

The setup comprised the following:

1. An NFC-enabled android smart phone like Samsung Galaxy Nexus. Patient ID is read from the NFC tag using an NFC-enabled handheld device as shown in Figure 3.
2. The tags used were Type 2, Mifare Ultralight and Type 1, Topaz with 144 bytes memory capacity [15], which stores the patient ID.
3. A Java Bluetooth application on the laptop (Linux) using bluez [16] and bluecove [17] to simulate the physiological sensor that sends the data to NFC-enabled android mobile phone. The application snapshot is shown in Figure 4.
4. Pulse oximetry data has been taken for the set-up. It monitors the oxygen saturation level in the blood, used for continuous monitoring of patients suffering from diseases like apnea, asthma.

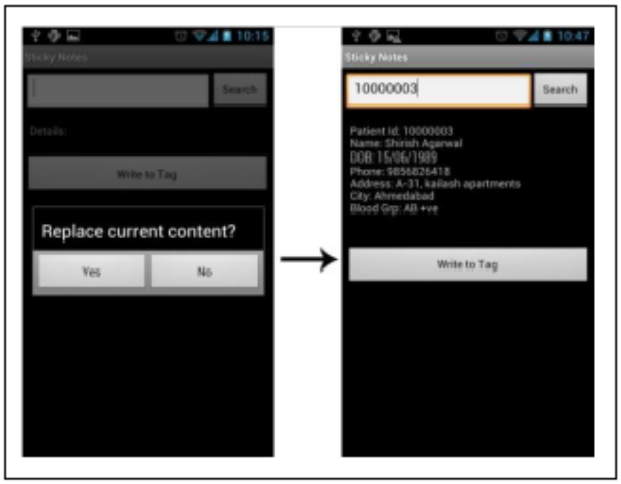

Figure 3. Application to read and write Patient ID to NFC tags.

Figure 4. Capturing the Streaming Data from the simulated sensor

5. An Android application that can run on Android version 2.3.3. This is used to gather the sensed data from the sensors. A preliminary report is generated in the application and sent to the server.
6. A Laptop or PC as a local server with Wi-Fi facility where the application uploads the report.

3. Related Work

Healthcare with the objective of providing medical support to rural areas of developing countries is important, so that majority of the people can lead a quality life even though they are remotely located and cannot afford expert medical treatment. A wireless telecare network perspective of rural healthcare in China is given in [9] where they looked into the reliability of network communication for remote areas that are affected by climatic conditions like heavy rain.

Through remote healthcare, medical practitioners can provide medical services to more people, along with saving money and human resources and also reducing response time for a critical condition [8].

There have been several projects implemented using the mobile as well as the NFC-based healthcare technology. The HealthGear [10] project implemented a wearable real-time monitoring solution for the detection of apnea events. A pulse oximeter was connected to a mobile phone using the Bluetooth protocol. The project demonstrated the feasibility of storing and processing of physiological data on a mobile phone [11].

There has been an application already deployed in Karachi that uses NFC technology and mobile phone application to facilitate identification, diagnosis, and messaging of parameters of health of patients with a central server over an unreliable connection medium, for tracking pneumonia [12]. The medical data is entered manually.

NFC-based tags are being used to improve the patient's safety in the hospital by tagging the medicines and associating them with the patient ID [6], for smooth patient treatment with a low number hospital staff under heavy workload pressure. They suggest that by using patient ID tags and medication tags, healthcare errors can be reduced. Similar work with integration of NFC and Bluetooth has been conducted by Fikry et al., (2006) [13] for medical data acquisition.

Our application is novel as it uses both the NFC technologies as well as Bluetooth wireless sensing to provide automated patient care for mass health monitoring in rural areas. Our application framework would facilitate patient identification as well as automating the reading of sensors to read health parameters followed by diagnosis without the need of a local trained healthcare helper, along with the automation in the health care monitoring of a large number of people.

4. Discussion and Conclusion

Our proposed architecture offers a reliable maintenance of patient records along with the automation of the mobile interface for smooth health care monitoring of patients which can be done by healthcare helpers without requiring repeated training sessions. We see a utilization of this architecture for improving health monitoring in remote rural

areas of developing countries with mass population and fewer numbers of trained healthcare helpers. In remote rural areas of developing countries, people are generally from a poor background as well as less educated. The healthcare helper would be identified as one of the people from this place who can provide service for health checkups of the rural people. With a complex interface some training sessions would be required so that the process is followed consistently. Here we propose to automate the process in the mobile application so that by a keyless entry, the healthcare helper can gather health statistics of rural people whose numbers may be large. NFC tags provide a reliable mechanism by which the application can monitor patients effectively as well as reliably maintain their health records. Such an application will be useful where the number of patients is large and healthcare helpers are less in number and would like to use less training and simpler interfaces to work with.

Here we have shown how we can use a secure and contactless way of NFC technology to identify the patient. Reading the NFC tag triggers the Smartphone to gather healthcare vital information from the body sensors attached to the patient through Bluetooth communication. It further automates to generate a preliminary report of the patient from the data received from various sensors through Bluetooth and then uploading to the local server which can then send information to the remote medical server.

The old way to get the data from the sensors was to connect them to a PC and then generate the report. This simulation is cost effective in the way that it only requires a smart phone to get the data, generate the report and upload it to the server.

NFC and Bluetooth are among the least energy consuming communication technologies. Thus it is worth considering the power consumption of this simulation, where all the events require less energy to finish. Since the patient has to carry a passive NFC card or tag, it reduces the consumption of the paper to print the report, and thus promotes the notion of eco-friendliness.

Automating and reliably maintaining patient records will benefit reliable patient record maintenance, reduce the workload of the healthcare helper through simpler interfaces, and finally, automation would lead to time efficiency and less training of healthcare helpers. This will be very useful in mass healthcare coverage in remote rural areas of developing countries.

5. Future Work

The main aim of the project is to deploy the application in a rural remote area along with the wireless sensors and mobile Bluetooth application. Since both these technologies are low cost and easily available, these systems can be established to rural areas very easily and provide a reliable effective healthcare monitoring system.

With the application infrastructure being tested to automate reading of patient ID from a tag and to gather sensor data from a simulated oximeter and transmit it to the medical server, we are motivated to test this with real sensors and deploy this application for reliably monitoring the health of a large number of people in remote areas.

We plan to integrate it with real sensors and gather the timely effectiveness and reliability that it will provide by automated NFC touch initiating the entire process of health care monitoring to reliably storing records. We have surveyed the work of telemedicine by World Health Partners as NGO providing remote healthcare services to

remote rural areas in India using the ReMeDi [19] medical kit. We would like to explore automating the wireless ReMeDi kit with our proposed architecture and provide efficiency and reliability.

For future aspects, an application can be developed for the patient-end where the NFC-enabled android smart phones stores the patient ID and all the previous reports of the patient. So, the patient can send the report to the doctor for further consultancy. Future work also includes receiving the data from various health sensors such as an ECG simultaneously with the pulse rate in the given application. The use of efficient algorithms to process the data acquired from the sensors on the mobile platform and the generation of a graphical representation of corresponding physiological signals would enable an analysis by the doctors done later. Any social healthcare provider service, which can give medical help to people, can come up with the internet service in the rural areas, so that various reports generated can be collected and directly sent to the main server. This main server is responsible for providing a robust and expandable web application where all the reports can be presented in a graphical form. Thus doctors can analyze the reports of the various rural people, give attention to the critical cases (if any), and provide necessary cures to the disease.

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