A Mobile Software for Health Professionals to Monitor Remote Patients

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Abstract— There is a lack of timely access to necessary healthcare in remote areas, especially in India. This paper addresses the availability of quality healthcare, by introducing wireless technology to monitor patients, in remote areas. A reliable system to continuously monitor the patients in the remote areas has been developed, this software suite consists of two mobile software platforms. The first mobile software platform uses wearable wireless sensors to collect a Patient's ECG and Blood Pressure based on the patient's health condition. This sensed data is transmitted to the Patient's mobile phone where the first level of analysis is performed and an emergency warning may be indicated. If the patient's parameters are at a certain level a message is sent immediately to the Health Professional's mobile phone. The health data is also transmitted it to a central server for storage and further processing. This database can be of great value to health researchers. The second mobile software platform enables health professionals to view patient's health reports on their mobile phones from the central database. The health professional can also assign the risk levels of each patient, from the health professional's mobile phone. Both platforms communicate with the central database using a web server. This research also considers power optimization in the patient's mobile.

Keywords— smartphones, power optimization, mobile software, health monitoring

I. INTRODUCTION

The prevalence of chronic diseases, such as low blood pressure, hyponatremia, various heart diseases, has risen all over the world especially in India. Such patients require long term health monitoring. Most people with chronic diseases prefer to stay at home rather than in hospitals. Increasingly hospitals are being overburdened. The growing utilization of hospital emergency departments seems to be what hospitals do best. Treating chronic diseases needs a paradigm shift.

India's healthcare provision for patients with chronic diseases has many challenges: Currently, people with chronic diseases need continuous health monitoring and frequent hospital visits, this is expensive and exhausting. The rises in chronic disease have increased the demand for hospitals beds, taking resources that are sorely needed for emergency care. As most highly educated health professionals do not what to stay in the remote areas, most hospitals are in cities, so rural areas are not receiving sufficient healthcare. People in rural areas usually cannot travel such distances frequently due to being ill and lack of finances. Unlike many other countries, India's patients with chronic diseases living in the remote areas lack access the necessary healthcare facilities at the right times.

A new healthcare vision is needed. Hospitals need to be used primarily for emergency care and not chronic disease care. A homecare support for patients with chronic diseases would help the situation. These new healthcare solutions, for India's patients with chronic diseases, need to be accessible, cheap and reliable. This research work is focusing on a technological solution that is as cheap and reliable as possible, so that it can be of benefit to the poorer people who live in the remote places in India. Mobile phones and miniaturized, light-weight, wearable body sensors can be used to achieve Smartphone based health monitoring. We have developed a low cost mobile software platform for monitoring patients with chronic diseases independent of location, far away from cities or hospitals. This is a very viable and accessible primary health monitoring tool, for rural India, as smartphone's are getting cheaper year by year.

This research work has developed two mobile software platforms. One mobile software platform collects sensor data from the body sensors of the patient, stores, processes and transmits the data to the central database situated in the hospital. It also issues warning messages to doctors, relatives etc. The other mobile software platform is developed for the health professional's smartphone. The health professional's smartphone can display patient's ECG and BP reports. The health professional will be able to assign an appropriate risk level to each patient whilst viewing their reports, from the smartphone itself. Dynamic algorithms have been developed to reduce power consumption of the smartphones during real time monitoring of the patients.

Health services will save resources like hospitals beds, hospital facilities, and healthcare skills. Instructions for medication and certain treatments can be provided without hospital visits. The health professionals will undergo a certain amount of job transformation. Monitoring remotely a group of patients, a health professional is freed up to deliver more vital care than just routine monitoring. They will be able to manage larger groups of patients freeing the health professionals for the caring patients. Health professionals will also be free to live in the cities but still care for the rural population remotely.

This software also revolutionizes the quality of life of some patients with chronic diseases. Patients will no longer need to have frequent face-to-face traditional monitoring, they will be

location independent. This location independence will mean that patients can potentially continue working, keeping their livelihood, and subsidizing their health finances and family responsibilities. The patients could have more freedom heal and move about in their own homes and communities whilst still having the health security they need. Thus this research work helps the poor people staying in the remote places of India, by providing a quality health monitoring system at low cost. The system also considering the involvement of the doctors for assigning the risk levels of the patients.

The paper is structured as follows. Section II presents the related work in the mobile platform development, health care systems and energy estimation of mobile power. Section III describes the System Architecture. Section IV deals with the algorithm designed to support the system for energy optimization. Section V discusses the implementation of the system. Finally, conclusions are drawn in section VI.

II. RELATED WORK

The system is proposed based on the review of some previous work in the body sensor network area and the use of mobile phones in health monitoring. Yang et al [1] experimented the use of smart phone in health monitoring with some smart phone applications. Based on their experimental results and observation they concluded that a single smart phone is not enough for the health monitoring and smart phone functionality. Based on the experiment results and the observations, Yang et al [1] proposed PHM-Gate. PHM-Gate is a low-cost device that is capable for mobile health monitoring and the independence from a smart phone [1]. In the reference paper [1] they are using a separate hardware device called PHMGate between the smart phone and the human body sensors. Carrying such a hardware device is inconvenient and also the cost increase as the user need to carry an additional device.

John Whipple et al [2] explored the Android Operating System (OS) and software development environment. They evaluated its capabilities by constructing a working application[2]. Their application is capable of collecting speed and location information from the Global Positioning System (GPS) receiver. They also used the Google Maps Application Programming Interface (API) to determine the location of nearby schools. Their application is also capable of producing an alarm if a person drove over the speed limit in a school zone [2]. They are not considering the limitations in a smart phone like power constraint.

Heming Pang et al[3] proposed a monitoring scheme based on android smart phone. By collecting and processing data at server, sending data to smart phone terminal via socket, their system is able to monitoring the target site anywhere and anytime under the coverage of wireless network and it also enhances the flexibility of surveillance system greatly[3]. They are just collecting the sensor data from the temperature sensor, humidity sensor, infrered sensor and CO_2 sensor and displaying it[3].

Wanhong Wu et al [4] proposed a system which doesn't need a specific caregiver aid. It just employs small wearable sensors for collecting the real-time vital signal continuously and transmit using a Bluetooth device to the mobile phone, and the mobile phone will do some local processing in phone itself and the mobile phone can use its GSM module to periodically send the users health status to the healthcare centers[4].During emergency situation it issues alert for medical aids. They are not considering the mobile phone power for building this application, they are just receiving the data and transmitting it hourly basis to a healthcare centre database using GSM.

Shye et al [5] studies the high level characteristics of smart phone usage. For that he did analysis of real smart phone usage by studying the real user activities during a period of six months involving 25 users. As per his analysis and observation the users recharge their phones on a daily basis, and use their phones until the battery is low in 20%and there is a significant variation in the usage behavior of the people. Also he estimated as active phone use consumes 53.7% of the total system power. Shye et al [5] studied the various components in phone that cause battery drain and they studied the user's characteristics that cause battery drain but not implemented the energy optimization part.

Pathak et al[6] propose a new, called system-call-based power modeling approach which consider both utilization based and non-utilization-based power behavior. The paper [6] present the detailed design of such a power modeling scheme and its implementation on Android and Windows Mobile. By the experiments and studies in [6] their proposed a power modeling scheme is able to estimate the energy consumption of mobile applications. They also demonstrate the power consumption behavior of system calls but not considered the energy estimation.

Falaki et al [7] discuss his experiments and results on the Diversity in Smartphone Usage and energy estimation. They use 255 users, and conduct a comprehensive study of smartphone usage. They find immense diversity among users and they differ by one or more orders of magnitude.According to the study in [7] Energy drain depends on two factors like user interactions, applications, platform hardware and software. They also demonstrate the user behaviors to predict future energy drain on the smartphone. They are not proposing any energy optimizing functionality in smartphone so that the phone will run long time before the next battery recharge.

III. SYSTEM ARCHITECTURE

If the patient's condition is more stable, the frequency of data collection will be less, therefore power reductions can be. This system collects sensor data from the body sensors of the patient, stores, processes and transmits the data to the central database server situated in the hospital. It also issues warning messages to doctors, relatives etc. Wireless body sensors sense and transmit health information such as ECG and Blood Pressure from the patient, based on the risk level assigned by the health professional. The mobile software in the patient's smartphone is able to receive the sensor data transmitted by the body sensors using Bluetooth. The system temporarily stores the received data in the smartphone, using an SQLite database. SQLite database is used because of its high security capability as confidentiality is of the utmost importance in healthcare.

Figure 1. System Architecture

Once received data is stored in SQLite, a first level analysis of the data is done based on the analysis algorithm. If the smartphone analysis shows any abnormality, then a warning message will be send to the health professional's phone. Also the stored data will be retrieved from the SQLite Data base and transmitted the entire data to the central database server situated in the hospital. If the patient's condition is more stable, if the smart phone analysis shows normal then transmission of data to the central server will only occur when the buffer becomes full. A web server is used, between the patient's mobile phone and the centralized database server. This web server helps to save the data, to the database server located in the hospital. The system architecture is shown in the figure 1.

In health professionals mobile warning msg will receive as a normal sms. The mobile software in the doctor's phone helps to view a patient's ECG report on his mobile phone, by selecting the patients name and patient id. Then a request will be sent to the central database server through the web server for retrieving the sensor data for that particular patient based on his name and patient id. When the web server receives the doctor's request, it will retrieve the data from the central server database and transmit back it to the doctor's mobile phone. This mobile software provides a User Interface for viewing the ECG and Blood pressure in his smartphone. The doctor can also assign risk levels of each patient from his phone itself.

IV. POWER ESTIMATION AND OPTIMIZATION

Apart from the normal smartphone application there are other energy consuming applications and functionalities that also consume a smart phone's power. A smart phone's power can be consumed by the brightness of the screen, adobe flash, widget updates, entertainment applications (i.e. games), unused networks (i.e.: Wi-Fi, GSM, Bluetooth), and other web applications (i.e.:skype, facebook, gmail, twitter etc.). Our application calculates the balance energy in phone. If the balance energy is less than a threshold, then it will perform energy optimization. For high risk patients we disable some of the smartphone applications. For low risk patients we disable some of the smartphone applications and also the data stored in the phone is prioritized. The prioritized data will be transmitted to the central database server. This energy reduction method for both high and low risk patients includes: reducing the brightness of the phone, switching off unused networks (WiFi and GSM), switching to airplane mode, adjusting widget updates timing and disabling applications that are not used.

The algorithm is based on different states such as Active, Normal, SemiActive and SemiNormal and Recharge. In Normal state the normal smartphone functionalities will work. In Active State our health monitoring application also will be active apart from the normal functionalities of phone,the functionalities include reception of data and save the received data temporarily in phone itself, analysis of the data . If the risk is high the data is transmitted to the central database also send warning message to the health professional. If the risk is low transmission to the central database happens when the buffer gets full. If a warning level is reached, energy consumption will depend on the transmission to the centralized database server and the number of emergency numbers for that particular patient.

In every state balance battery power is calculated. If the balance power is below a threshold then power optimization will do. If the balance power is reaching in the Normal state then it will go in the SemiNormal state. If the balance power is reaching the threshold in the Active state then there will be a state transition to the SemiActive state. If the balance power reaches below 20% the transition to the Recharge will happen. After recharging the phone when the power reaches above 20% it will go to either SemiActive or SemiNormal. If the power reaches above 50% it will go to either Active or Normal states.

V. IMPLEMENTATION

'HTC Google Nexus One' was chosen for the development of the software and for algorithm implementation [9]. According to research [6] [7], a smartphone with normal usage has a maximum battery life of 24 hours. The company specifies that the talk time available, before recharge is required, is 10 hours over 2G and 7 hours over 3G[9][10]. However, the battery life of the 'HTC Google Nexus One' smartphone, used for this experiment was found to be only 20-24 hours, with normal usage. When there is no optimization the phone battery power will last for a maximum of 24 hours for a normal user, maximum up to 20 hours for a high risk patient and maximum up to 22 hours for a low risk patient. By implementing the energy optimization this application helps to extended battery life by 5-6 hours more.

Some of the implementation of the application in the health professionals mobile is shown in the Fig 2 and 3. Fig 2 shows the UI available in the health professional's smartphone for showing the risk level assigned to the particular patient. The health professional can change or assign new risk levels for each patient. When the health professional assigned the risk it will be saved in the central database also. And the patient phone collects the sensor data based on the risk levels. If the patient risk is continuous the sensor data will receive continuously in the patient phone. The Health Professional can also be able to view the ECG report and Blood Pressure in his phone.
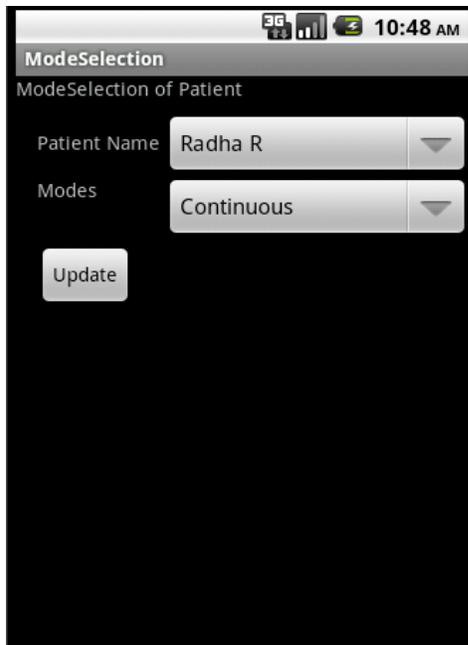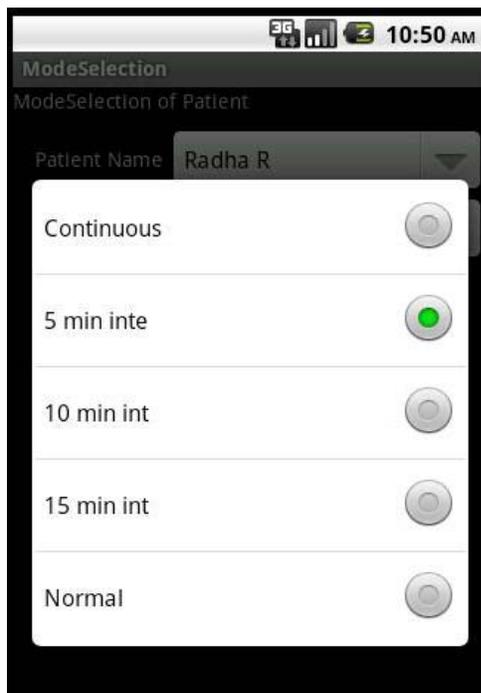
Figure 2.   Risk Assignment User Interface

Figure 3 User Interface for showing risk levels

VI.   CONCLUSION

The proposed system enables any android smartphone to be used for collecting and temporarily storing patient's health monitoring data. The system performs the first level analysis the patient's phone. If any monitoring abnormality occurs, a warning message can be automatically sent to the doctor. The system also provides a Graphical User Interface for the doctor's mobile phone. This research introduces an energy optimization algorithm to increase the battery life of smartphone by 6 hours.

As a future work we can integrate this system with an existing Hospital Information System. Security issues will also be considered in the future work. Also the integration of other health monitoring systems such as EMG, EEG, diabetes etc. could be added.

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