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A Framework for Intelligent Remote Blood Pressure Monitoring and Control System for Developing Countries

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Abstract High Blood Pressure (HBP) or hypertension is the major cause of adult mortality across the globe. Developing countries are the most hit of this death toll due to poor medical practices, lack of medical expertise and unreliable Electronic Medical Information (EMR) systems for citizens. Due to the increasing prevalence of HBP related issues, became necessary to continue to seek out for effective methodologies that would facilitate the diagnosis, prevention, monitoring, and treatment of HBP intelligently and to put under control its associated diseases. This paper presents a flexible framework for improving the existing processes for collecting vital signs required for the management of HBP through remote telemonitoring. It is a study that leverage wireless communications and remote sensing technologies to monitor and manage health related vital signs of patients with HBP and also to afford health care providers with necessary information for the treatment of patient with HBP and its associated chronic diseases like diabetes mellitus, chronic heart failure and chronic obstructive pulmonary disease (COPD). The result of the framework is a software model tested on windows mobile 5.0 emulator, Nokia 5200 handset and a backend web application with i-net clear report support for reporting various decision parameters to hospital medical experts and providing counseling and advisory supports on healthy living for the remote patient. The paper concluded that this platform will provide an avenue to accelerate quality health care delivery to the hinterlands where telecommunication advancement using wireless devices can reach.

Keywords: *Electronic Medical Information (EMR), high blood pressure, remote telemonitoring, vital signs health care*

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1. Introduction

The recent advancement in wireless communication technologies especially in Wireless Sensor Networks (WSN) coupled with the immeasurable advantages of Information superhighway- the internet and the overall miniaturization of their associated hardware are leading to the development of several potential applications that have gained usefulness in academic researches and in particular, the ability to remotely monitor patient vital signs in real time from a centralized location. The later has continued to be a growing area of interest in medical sciences.

These applications are becoming part of fully integrated health care data collection, analysis and reporting systems that communicate to multiple nodes of various health care systems. Such integrated systems provide alerts when health conditions decline, allowing patients and medical practitioners to intervene and modify treatment plans as needed. WSNs advancements was engineered by the fact that wireless sensor nodes are becoming cost effective, reliable, compact and energy efficient and might not require the installation of expensive wired infrastructure.

Alenxader, et al (2007) explained that the uncontrolled case of hypertension caused by high Blood Pressure (BP) is an ongoing challenge to health care providers worldwide. They added that BP surveys in most countries show that <25% of patients with hypertension are under good BP control.

Wolf-Maier, et al (2004) stated that among the reasons for this fact include patient-related factors, inadequacies of the health care system, and the clinical inertia of health care providers. Other reasons include type of hypertension with lower control rates for systolic BP, and the presence of diabetes mellitus (McDonald, 2002 and Philips, 2001).

One strategy to improving the health care system globally is to create or design technologies that will facilitate the collection of health data remotely and intelligently. This can be achieved by enabling web based applications that receive vital signs from patients irrespective of the location of the health care system and the patient accessing such system.

The developed countries with its medical experts, reliable communication system and effective Electronic Medical Record (EMR) systems are already in the forefront in deploying these applications and technologies towards leveraging and improving their healthcare system. In the developing countries context, poor EMR, poor communication reliability and inadequate health infrastructure and experts have hampered the healthcare system. The digital gap, as a result of emerging technologies both in research and telemedicine, is gradually fading out as more technologies are been designed, developed and installed in the administration and management of health resources readily accessible via mobile devices. Harnessing these potentials will afford the developing countries great opportunities to improve their healthcare systems by building applications that will be integrated into existing medical processes in designated healthcare institutions that will be accessible by mobile users. It will also afford collaborations between the developing country health care system and the developed countries.

2. Background of Study

Globally, hypertension is a major chronic disease and it is considered by the World Health Organization (WHO) to be a leading cause of death and disability in economically developing countries (Lopez, 2006). Untreated, uncontrolled and unmonitored hypertension increases the risk of damage to the arteries, heart attack, stroke, and it is responsible for other conditions such as pre-eclampsia and other cardiac illnesses. Remote Blood Pressure Monitoring (RBPM) is the use of Information and Communication technologies to provide useful vital signs of blood pressure readings of patients to medical experts who are located either in a health centre (in-service health providers) or out of health centre (out-service health providers) who use these vital signs to provide quality services to patients and the general health care stakeholders. It is a branch of e-health or telemedicine called telemonitoring. Telemedicine consists of the transmission of biologic or physiologic data from a remote location to another location for data interpretation and decision-making and it increases quality of life dramatically. (Guler and Ubeyli, 2002, Meystre, 2005)

Improvement of quality of life by telemedicine is demonstrable in heart failure, diabetes mellitus, rhythm disorders, psychiatric diseases and blood pressure. (Schmidt, 2009).

Telemonitoring has been used mostly to monitor sick patients (Dzenowagis, 2007). It can benefit healthy patients including athletes and astronauts to improve training and to watch over them in severe environments. Physiologic functions are monitored by peripheral devices, which distinguish them from simple videoconferencing systems. Peripheral devices enable medical experts to better approximate an onsite examination (Satava et al, 2000, Oohashi et al, 2002, Field and Grigsby, 2002 Vitalink, 2001) and modern biotelemetry (Guler and Ubeyli, 2002).

The healthcare system is gradually shifting from a traditional hospital based system to a more patient centered approach (Sri Lamka, 2008). The application of Information and Communication Technology (ICT) in health sector also known as e-health have powered several subsystems including telemonitoring which have demonstrated a 50% reduction in mortality and over 50% in productivities within the health care systems (Celler et al, 2003, Greenberm, 2005).

The developed countries experiences of e-health subsystems have been very outstanding and progressive (Monteagudo et al, 2005, Miyazaki, 2005, Davies, 2008). Infodev (2006) revealed that a significant number of professionals and users of ICT in health have not explored e-health gains in the developing countries. Poor telecommunications infrastructure, limited number of Internet Service Providers (ISP), lack of access to international bandwidth, and high Internet access costs were the major barriers to widespread use of e-health systems (Egiebor, 2008).

However, low standard of living in some developing countries has not prevented them from introducing ICT to force better healthcare system (Mishra, 2008, MCNamara, 2006, Donner, 2004).

3. System Modeling

The Unified Modeling Language (UML) was used to capture and model most of the functionalities in the system. There are two main types of diagrams in UML: Structure diagrams and behavior diagrams. Structure diagrams which includes class diagrams, object diagrams, component diagrams, and deployment diagrams are used to describe the relationship between classes while behavioural diagrams describes the interaction between the users and the use case. Bahaviourial diagram includes use case diagrams, state-chart diagrams, collaboration diagrams, sequence diagrams and activity diagrams (Osuagwu, 2008 and Whitten, et al, 2001). In an attempt to develop a conceptual framework, the use case and sequence diagrams were used. The standard flow of events within the system is portrayed by case diagrams in Figure 1. In the diagram, there are two types of users: the remote patient who is wearing a wireless sensor and the healthcare experts in an ICT healthcare institution. Based on medical practices and acceptable medical policies, the medical experts are granted limited access right to information of certain class or categories of users of the system in order to monitor who (medical practitioners) uses the service provided by the e-health system. The users can only view responses in the form of Short messaging service (SMS) alerts sent to their mobile devices from medical experts and automated processes integrated in the Management Information System (MIS) of the e-health system.

The sequence diagram is a derivative of the use case analysis and shows the interactions, relationships and methods of the objects in the systems. The remote user initiates the application via their mobile devices (Phones, PDAs, Smart Phone, IPad, and Tablets) which are connected to the remote sensor via wireless connection. The requests in the form of electronic pulses are sent from the wireless sensor to the mobile device which is equipped with Wireless Application Protocol (WAP) application that runs on these devices and convert it to readable format that can be transmitted via WAP gateways. The application establishes an internet connection to heath care provider web server. The web server then connects the database server through J2ME platform where the collected vital signs data are stored.

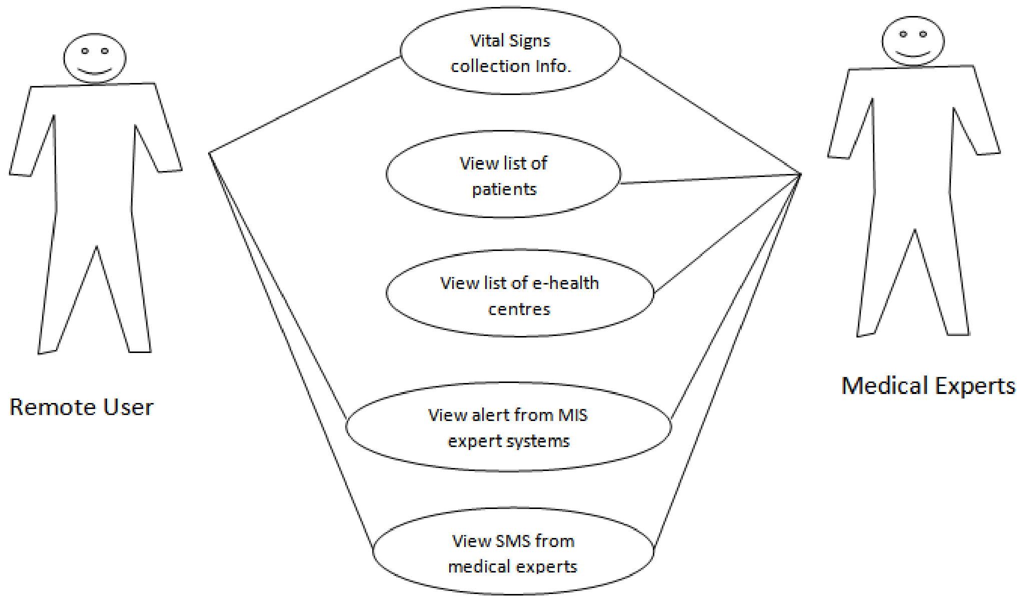


Figure 1. Remote blood pressure monitoring system (Use Case Model Diagram)

The MIS expert system collects the data and generates useful decision information for medical expert to use in the decision making processes. Special alerts are also generated to be sent to users regarding their health status and other general health tips. This is depicted in Figure 2.

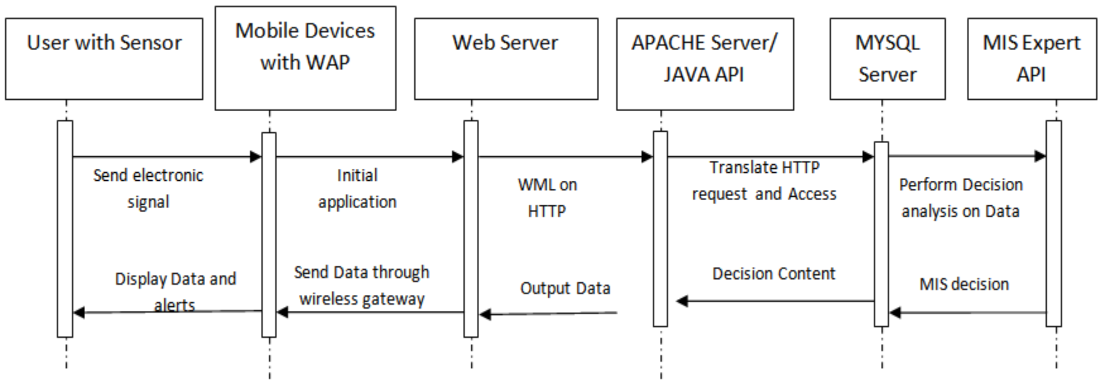


Figure 2. Remote blood pressure monitoring sequence diagram

4. Systems Design Methodology

The structured System design methodology was adopted during the design stage of the application. The remote blood pressure monitoring system was designed such that it will help remote users to easily assemble and connect the wireless sensor to their mobile devices which is equipped with a portable J2ME application that connects the wireless sensor to the mobile device and to the internet. Vital Signs collected from the wireless sensor readings are captured based on the time set on the application setup settings. The wired sensor will be designed such that special clocking techniques will be uses to vary the time frame for capturing vital signs from the patient which will be stored in a memory buffer in the wireless sensor device. The data collected by the application in the mobile devices is transmitted to the hospital web server via a registered Patient ID which must be issued by a registered e-health institution that supports and provide telemonitoring systems. The transmitted data is further translated by the Apache server enabled application and are stored in MySQL database. Intelligent decisions making process is extracted from the database by the MIS expert system and appropriate alerts are forwarded to doctors for further diagnosis and counselling. Intelligent SMS alerts are immediately forwarded to remote patients on their health status, and routine health tips are also sent to remote users.

In this system, the APACHE server serves as the web engine for translating JAVA servelets and Java server Pages (JSP) and it interact with MySql server database installed in the health institution and the data sent via the J2ME application from the mobile device. Java applications run on billions of devices and hence it was the choice language used for developing this application. The MIS expert system is a collection of management modules that was integrated into the web application that runs on the hospital web server. This expert system acts like an intelligent agent that monitors vital signs of patients as they are stored on the data repository. Figure 3 shows the data flow diagram of the intelligent remote blood pressure monitory system and Figure 4 shows the basic System architecture of the system.

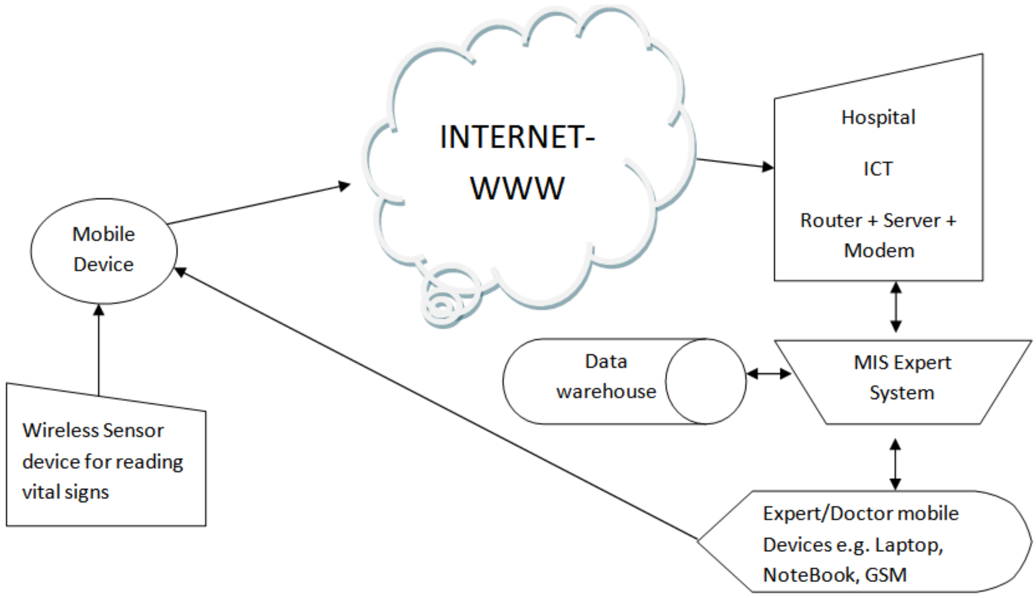


Figure 3. system architecture of Intelligent Remote Blood Pressure Monitoring Information System

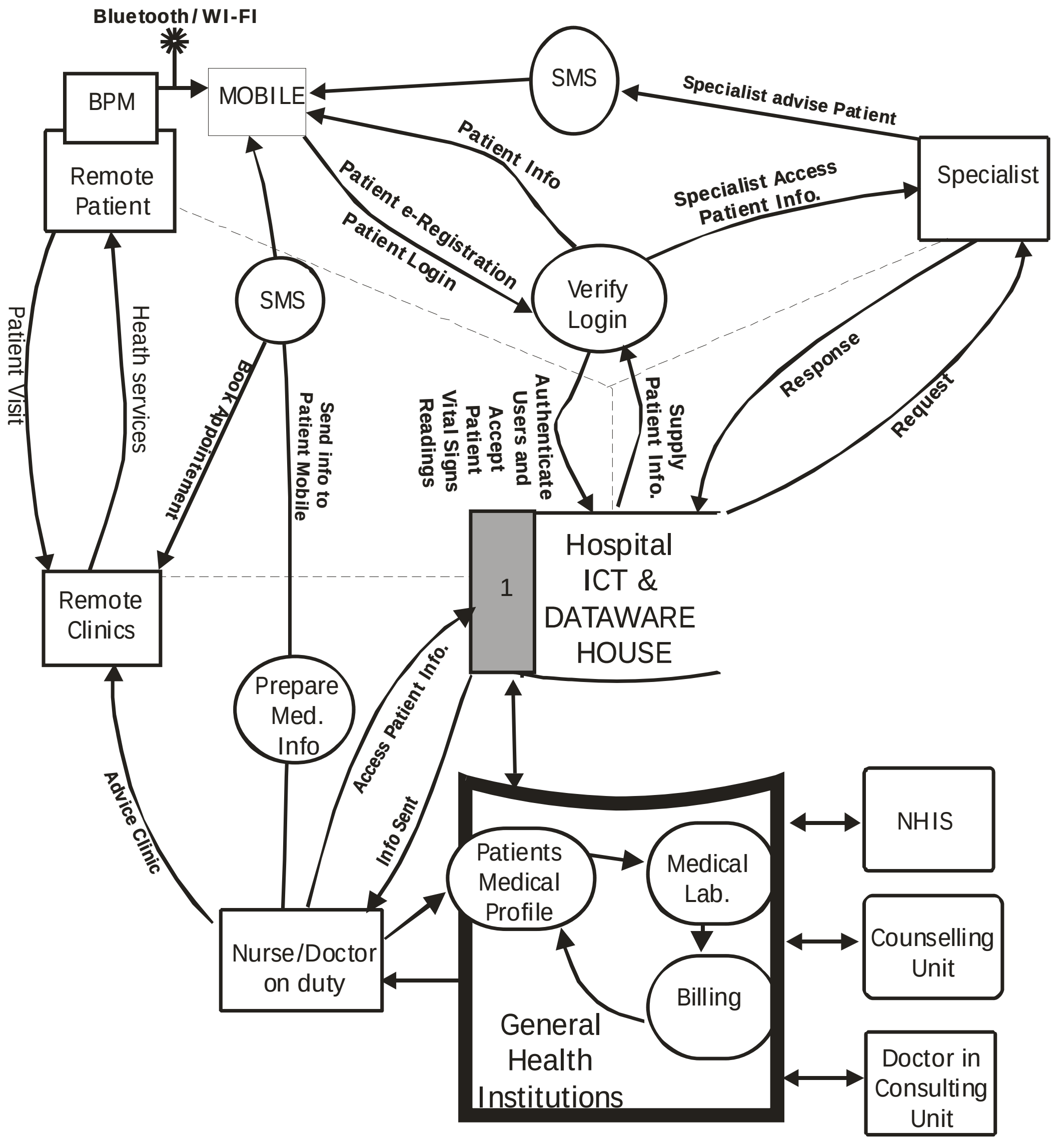


Figure 4. Data Flow Diagram of Intelligent Remote Blood Pressure Monitoring Information System

5. System Implementation and Deployments

The intelligent remote blood pressure monitory system consists of two subsystems: Hospital Server Application (HSA) and Remote User Application (RUA) application.

Both application were implemented using JAVA Software Development kit (SDK) 7.0 and Netbean 7.0 was the Integrated Data Environment (IDE) used for the development of the server and remote application. The Hospital server application was deployed and tested on HP Compag 500B computer system with windows 7 operating system and WAMP 2.0 server installed and configured for proper functionality.

The Remote User Application (RUA) is a java achive file (jar) that runs in various java enabled mobile devices. For the purpose of this work, a mobile phone simulator was firat used to execute the jar file and all vital signs from the simulator were sent to the hospital server application database. Later a Nokia 5300 phone was used to run the application and connections was established to the server via either Bluetooth connection.

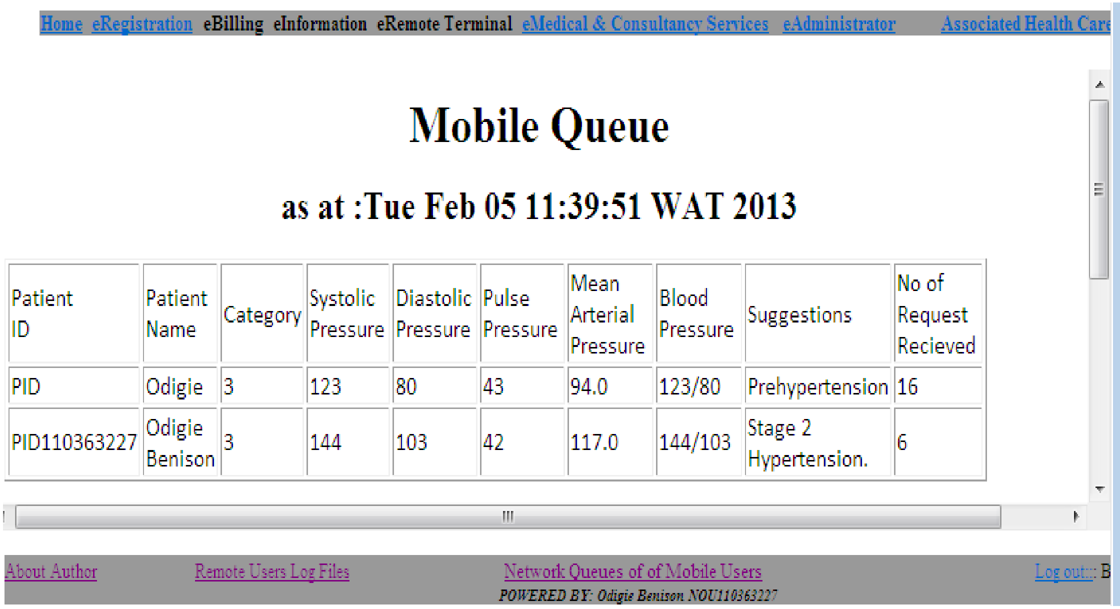
The minimum hardware configuration for HSA to run is a Pentium IV system with 512MB RAM and 250GH hard disk running windows XP or later version.

The minimum hardware configuration for RUA to run is any portable mobile device with appropriate Bluetooth connections and device must be java enable.

6. System Testing and Report generation

6.1. MIS Expert System Interface

The reports of various blood pressure readings for medical experts to view and make decisions were depicted in Figure 5a and 5b. As shown in the report, the mean of a various BP (Systolic and Diastolic) readings for patients are shown (see Figure 5a). Suggestion based on BP reading was also given. A patient BP reading was reported in a line chart for remote medical experts to view and provide just-in-time action plan(s) for patient with complicated cases (see Figure 5b).



Patient ID	Patient Name	Category	Systolic Pressure	Diastolic Pressure	Pulse Pressure	Mean Arterial Pressure	Blood Pressure	Suggestions	No of Request Recieved
PID	Odigie	3	123	80	43	94.0	123/80	Prehypertension	16
PID110363227	Odigie Benison	3	144	103	42	117.0	144/103	Stage 2 Hypertension.	6

Figure 5a. Mean BP values of remote users vital signs collected overtime

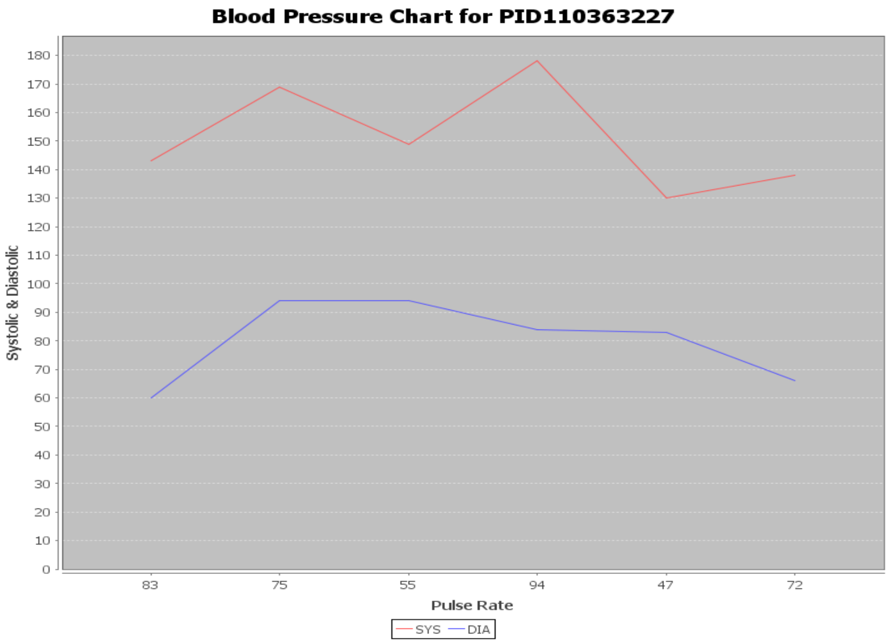


Figure 5b. Line graph showing Patient BP readings.

6.2. User Interface Design

The Remote User application (RUA) is a JAVA ARchieve file (jar) file that is executed in a non PC terminal (mobile device). It captures patient vital signs and sends it to the remote server. The RUA can be downloaded and installed in mobile device. It is configured to capture or read and send the blood pressure readings from the wireless sensor. The screen shots depicted in Figure 6 describe the RUA application in a simulated Phone.

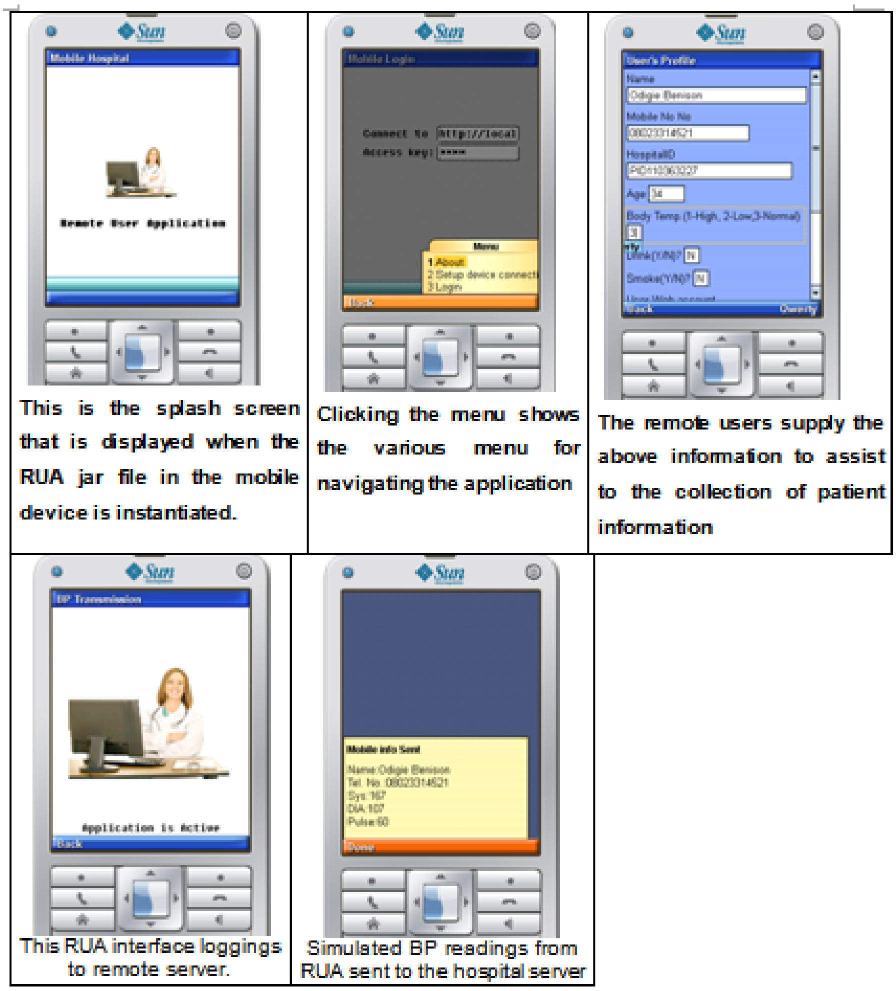


Figure 6. Interfaces of RUA application

7. Conclusion

This work has practically demonstrated the feasibility of designing an Intelligent Remote Blood Pressure Monitoring system for effective transmission of vital signs of patient via wireless telemedicine devices and has acted intelligently to convey useful decision data to healthcare providers such that will help facilitate the treatments of patient with severe health problems. The gains of this system are numerous and include continuous monitoring of patients remotely, easy accessibility, low cost and instant short SMS alerts messages and health tips on proper health styles to patients irrespective of their locations from the health care institutions. It also provides useful data that helps health policy makers at the state and national levels of government to put appropriate legislatures and funding towards improving the healthcare system. Although the system was simulated, it is hoped that future studies will design a wearable wireless sensor that can synchronously transmit appropriate signals from both PC terminal, non PC terminal (mobile devices) and satellite TV devices with internet support for various categories of users to connect to the hospital server.

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