Simulation of a Real-time Mobile Health Monitoring System Model for Hypertensive Patient in Rural Nigeria

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ABSTRACT

Abstract
This work presents the reports of a simulated model for a real-time mobile health monitoring system for hypertensive patients in order to provide efficient health services to the patients in their various locations even rural areas. The untimely death of many people suffering from hypertension had been most of the time as a result of untimely medical attention received by people at the peak of their suffering. The use of mobile medical monitoring system is therefore inevitable in order to address the problem of limited medical facilities in most of the remote areas and semi-urban part of Nigeria. The model was designed using unified modelling language. JAVA (standard edition) was used to develop and simulate the model while MYSQL was used as the back end. The medical data of the hypertensive patients were routed from the mobile sensor implanted on the patients via the General Packet Radio Service (GPRS) of a local GSM Network to the Patient Record Database which was hosted online to provide all the possible itineraries for its accessibility by the Medical Specialist from any location in the world for proper monitoring and follow-up. A consultant cardiologist interpretation was used as threshold reference points in order to evaluate the system using Heart rate, Systolic and Diastolic blood pressure as its performance metrics. In conclusion, the result showed that the model using GPRS-enabled real-time system is feasible and implementable to monitor the health status of hypertensive patients in rural and semi-urban areas of Nigeria.

Keywords: Hypertension, Wireless Medical Body Sensors, GPRS, UML

1. INTRODUCTION

Digital technology advances in wireless networking, micro-fabrication, and integration of physical sensors, embedded microcontrollers and radio interfaces on a single chip, promise a new generation of wireless sensors (Otis and Rabaey, 2003; Raskovic et al., 2004). The impact of digital technology in medicine particularly when combined with communications is growing rapidly. Recent technological advances in sensors, low-power integrated circuits, and wireless communications have enabled the design of low cost, miniature, light weight, and intelligent sensors (Milenkovic et al., 2006).

The mobile health monitoring system consists of medical body sensors, communication and storage devices. These are responsible for the conversion and transmission of the patient physiological data to the appropriate quarters. A sensor is a device that converts a physical phenomenon into an electrical signal. As such, sensors represent part of the interface between the physical world and the world of electrical devices, such as computers. (Tom, 2005).

Typically a sensor is composed of components that sense the environment, process the data, and communicate with other sensors/computers. A sensor responds to a physical signal stimulus, such as heat, light, sound, or pressure, and produces a measurable electrical signal (Iyengar et al., 2011). The ideal wireless sensor is networked and scalable, consumes very little power, is smart and software programmable, capable of fast data acquisition, reliable and accurate over the long term, costs little to purchase and install, and requires no real maintenance. Selecting the optimum sensors and wireless communications link requires knowledge of the application and problem definition (Lewis, 2004).

Medical sensors can be designed for implantation or integration into clothing, they can also be implanted like tiny patches on body surface (Giovanni and Sandro, 2013), and they can be fixed into shoes. Sensors process raw information continually, store them locally and then send the processed event notifications to the server.
1.1 Hypertension
According to the Seventh report of the [8] hypertension was defined as a Systolic Blood Pressure (SBP) of 140 mmHg or greater and/or Diastolic Blood Pressure (DBP) of 90mmHg or greater. The classification addresses the issue of severity and increased risk by defining two stages of hypertension, which ranged from Stage1 (SBP 140-159mmHg and/or DBP 90-99mmHg) to Stage2 (SBP≥ 160mmHg and/or DBP≥100mmHg).
Hypertension may be Essential (Primary) or Secondary to other conditions of the body. The commonest type (about 90-95%) is Essential Hypertension. Secondary Hypertension may be due to a disease of the kidneys, endocrine system (pituitary, thyroid, adrenal glands etc.) or it may be associated with toxemia of pregnancy, or ingestion of drugs or lesions in the brain (Mabadeje, 2002).

According to Bloomfield et al. (2006), Hypertension is more common in some ethnic groups, particularly Black Americans and Japanese, and approximately 40-60% is explained by genetic factors. Important environmental factors include a high salt intake, heavy consumption of alcohol, obesity (Adedoyin et al, 2008), lack of exercise and impaired intrauterine growth. There is very little evidence that 'stress' causes hypertension. According to a recent research by Adedoyin et al, (2008) on the prevalence and pattern of hypertension in a semi urban community in Nigeria the total prevalence estimate of hypertension based on 140/90-mmHg definition was 36.6% with a male-to-female distribution of 15.54 and 20.03%, respectively.

2. RELATED WORKS
According to Milenkovic et al., (2006), Wearable Wireless Body/Personal Area Network (WWBAN) is a pivotal part of multi-tier telemedicine system architecture. The work divided the architecture into three major tiers. Tier1 encompasses a number of wireless medical sensor nodes that are integrated into a WWBAN. Each sensor node senses, sample, and process one or more physiological signals. Tier 2 encompasses the Personal Server (PS) application running on a Personal Digital Assistant (PDA), a cell phone, or a home personal computer. Tier 3 encompasses the transportation of the patients with ambulance. The work gave general background information on various gadgets that can be used in telemedicine systems the major drawback is that it does not provide detail information on the communication technologies on which the system will work.

Also, Piette et al, (2012) developed hypertension management system using mobile technology and home blood pressure monitoring; the web based server monitoring system places weekly automated monitoring and behavioural change telephone calls on individual patients to monitor and provide hypertension information and usual healthcare to them. The use of this system results in fewer depressive symptoms, fewer medication problems, better general health and greater satisfaction with care for the hypertensive patients.

The major setback of this system is that the measured data are not transmitted and also the blood pressure monitoring is home-based. This problem can be addressed by adapting the solutions of the mobile health monitoring system model based on GPRS technology that is widely deployed or common in most environments.

2.1 Requirements for Wireless Medical Sensors
Wireless medical sensors should satisfy the main requirements such as wearability, reliability, security, and interoperability. (Milenkovic et.al, 2005).

i. Wearability: It requires that the wireless medical sensors should be lightweight and small.

ii. Reliable communication: One approach to improve reliability is to move beyond telemetry by performing on-sensor signal processing.

iii. Security: A relatively small number of nodes in a typical WWBAN and short communication ranges make key establishment, authentication, and data integrity achievable.

iv. Interoperability: Wireless medical sensors should allow users to easily assemble a robust WWBAN depending on the user's state of health.

3. DESCRIPTION OF THE SYSTEM MODEL
The model was developed using a 3-tier architectural model. Each tier referred to as model entities are as described in the following sections:

3.1 Medical Body Sensor
According to Bolaji (2012), various kinds of medical body sensors are adaptable for use in remote healthcare systems; ranging from wearable body sensors which can be in form of vest or hand-worn materials to implantable body sensors for pressure and other health signal measurements. The recent development in microelectronics and wireless technology makes it easier to develop network based wireless medical sensors. Medical sensor makes it easier for medical personnel to provide adequate follow-up and monitoring of patients based on the acquisition of their physiological data by the sensor attached to their bodies. The use of medical body sensor also reduces the risk and the cost involved in travelling to meet the cardiologist for check-up, prescription and treatment. The architecture for the real-time mobile health monitoring system is as shown in Figure 1.
3.2 Patient Mobile Communication System
The patient data flow starts from the medical sensor which acquires, buffer and transmits the hypertensive patient physiological/clinical data in real-time or at interval (based on predefined settings) via Bluetooth to the mobile phone of the patient. The data includes the patient’s identity number, which is unique to each patient, the bio-data of the patient and the medical history of the patient. The data is then buffered on the patient mobile phone which serves as the gateway for the onward transmission to the Internet.

The onward transmission may be earlier than the specified time if the phone which is configured to detect critical physiological readings based on preset threshold values encounters such. In this model, the wireless bearer is GPRS mobile packet data network, the Gateway GPRS Support Node (GGSN) acts as the interface between the GPRS mobile network and the Internet (Pashtan, 2005). The patient phone can be any mobile phone with Bluetooth and GPRS enabled facilities to aid transmission of digitized physiological/clinical data being received from the medical body sensor. The mobile phone type adopted for this model is Nokia 6680 which is a GPRS enabled smart phone, it uses the Symbian Operating System. The model uses the existing GSM network to transmit and receive TCP/IP based data to and from GPRS mobile devices. Private IP addresses are typically and dynamically assigned within the network to mobile devices. GPRS supports fast transfer of data, voice and video over the Internet.

3.3 Health Information Web Server and Database Module
This part of the system is hosted online and communicates with the mobile device using the GPRS connection of the mobile phone network provider. It handles all data submission and data requests on the system network. This section consists of: Proxy Server (Load balancer), Domain Naming System (DNS), Web/Application Servers, Database Management Server, Database Servers. MySQL Database was used for this model because it can handle very light weight database requirements of small enterprises as well as large data requirements of very large businesses.

The data received at the server would be made available to the health care provider’s network, through the personal computer (PC), laptop, or Personal Digital Assistant (PDA), smartphones or any other mobile device that can access the Internet. By using an appropriate password, the patient’s physician can log on to access patient’s record in the database or initiate real-time monitoring of the patient physiological data from any location in the world where Internet is accessible.

3.4 Discussion on the Designed Model
The model was designed with Universal Modeling Language (UML). UML’s representation supersedes the flowchart because it makes provision for many different viewpoints on a system. Three UML type diagrams that were used are: the activity, sequence, and use case diagrams. The sequence diagram describes how the objects in the system interact over time. The actions in chronological order are as shown in Figure 2. The activity diagram shown in Figure 3 depicts the sequential flow of activities of the use case; it was used to model actions that will be performed when an operation is being executed as well as the results of those actions. The use case diagram is the description of the system’s behaviour from a user’s viewpoint. This diagram is a valuable aid during the analysis as developing use cases helps to understand requirements. The use case diagram is shown in Figure 4.
The simulation of each of the model entities in the system were carried out using the Java high level language implementation for mobile phones-Java Micro Edition (Java ME) and its implementation for enterprise solutions-Java Enterprise Edition (Java EE). Random number was generated to represent the transmitted patient data from the mobile medical sensors. The monitored data are the: Heart Rate, Systolic Blood Pressure and Diastolic Blood Pressure. The resulting interfaces and graphs from the simulation are as shown in Figures 5, 6 and 7.
5. CONCLUSION

This paper presented a developed and simulated model for a health monitoring system for hypertensive patients in remote areas using body sensors and mobile devices that have a connection to the Internet through the GPRS network, health information system and medical specialist. To achieve this, the various existing models were appraised. At the end of the review and having taken into consideration the peculiarities of mobile devices with their limited resources, the new model was presented for hypertensive patient. This work has thus made it possible to provide a working solution to the problem of distance in health care provision for people living in rural locations away from Medical Specialist. Furthermore, the work if properly optimized is a viable option for mobile healthcare provision for patients with hypertension that require frequent monitoring to reduce the incidence sudden heart failure and avoidable health disaster. Future research work on this could be done around the issue of sensor power consumption, medical information routing protocol, security, and interoperability with different body area sensor networks.
REFERENCES


