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A Cloud-Based Body Area Sensor Network Mobile Healthcare System

Olutayo Boyinbode
Department of Computer Science, Federal University of Technology,
Akure, Nigeria

Abstract--- Body Area Sensor Network Mobile Healthcare System (BASNmHealth) is the use of sensors and actuators to monitor and improve patients' physical and mental conditions in a networked system. It encompasses the use of mobile telecommunication and multimedia technologies integrated within mobile and wireless health care delivery systems. BASNmHealth system deploys different sensors and actuators to monitor patients in his or her normal daily activities. This paper implements a Cloud-Based Body Area Sensor Network Mobile Healthcare System which achieved the following, (i) Early detection of infections; (ii)Continuous monitoring of health status of people; and (iii) Enhanced mobile scheduling between patients and healthcare professionals.

Keywords--- Cloud computing, Body Area Sensor Network, Mobile Health, Sensors, Healthcare

I. INTRODUCTION

The modern society is facing a major change in the aging society and requires convenient approach to the medical environment. As wireless communications are being developed and mobile environment is emerging, the interest for mobile health (mHealth) also gradually increases. However, mHealth infrastructure that reflects the condition of patients' health is insufficient. Health monitoring is an essential application of mobile sensor systems, especially for women, children and aged people. Recent advances in sensor techniques, wireless communication, power supply technologies and wearable sensor systems have enabled the creation of a new generation of constant health monitoring [3, 4, 7]**.** Similarly, the approach to precise processing of the context information is also insufficient. Various systems are being developed to check patient conditions and give them proper treatment from a remote place in real-time. In mHealth environment, there are large numbers of environmental sensors and actuators that are used to monitor and improve patients' physical and mental condition at the comfort of their homes. The move towards mHealth systems is also influenced by the growth in healthcare being fuelled by an ageing population and the increase in the rate of chronic diseases such as obesity, diabetes, cancer and chronic heart and lung diseases in the society. Healthcare professionals rely on the collected patient information to provide care, for the patient suffering from diabetes. MHealth system may be used to monitor blood glucose of the patient as the patient maintains his or her normal daily activities. These systems may be used to warn patients as well as healthcare professionals of the vital signs that a problem may occur and therefore help healthcare professionals to provide early diagnosis and prevent sudden death [12].

One of the main systems employed in mHealth is the Body Area Sensor Network (BASN). BASNs are considered to be an important means to relieve the pressure of insufficient medical resources in an aging era and are becoming a strategic direction of the mHealth research [4, 7, 11, 13]. At present, BASN is still at an early developing stage and facing a series of challenges, such as the existence of heterogeneous sensor protocols and "big data" computing and mining. BASN is defined as a wireless network, which is formed by sensors located on, and/or biosensors transplanted into the human body and a data collector (Sink) used for medical data collection in real time.

BASN can gather medical data, perform classified learning, and analyze data in real time, thus realizing an early medical warning. Being a network type of huge significance and demand, BASNs become a strategic direction of the mHealth research. Researchers show that, at present, there are 1 billion people worldwide with underweight and at least 0.3 billion people with a morbid obesity. As at now, i.e. 2017, the number of sub-health world population will reach 1.5 billion, and by 2020, the expense on chronic diseases will reach 10 thousand billion dollars. By 2025, the aging population will reach 1.2 billion and this is a giant challenge to the provision of sufficient medical resources [14]. BASN can solve the problem of shortage of both material and manpower resources in the medical sector effectively by classifying, learning, analyzing, and storing the patients' medical data and by providing the patients with early medical warnings, as a supplement to the traditional medical systems. The BASN mHealth systems are based on the Internet of Things (IoT) concept [6], whereby the medical treatment emphasizes the object management. This change of the concept urges the mobile medical technology to adapt "Things" in the mHealth systems which include doctors, patients, medical devices, and sensors.

Even with the availability of effective, convenient and affordable health services in our society, the mortality is still at alarming rate because of the people negligence in visiting healthcare professionals, healthcare centre and also as a result of self-medication[12]. This research work will enable patients to have easy access to healthcare professionals and also medical professional can easily communicate, monitor, and manage the health status of their patients remotely. In a nutshell, the research work is motivated by the followings: Lack of adequate health facilities in personnel and medical equipment. Records have it that Sub-Saharan Africa countries have averages of 1.15 health workers for every 1,000 of its citizens [14]; there are limited financial resources available to support healthcare infrastructure and health information system. Shortage of nurses and midwives means that over two-thirds of women in Africa have no contact with health personnel following childbirth. Therefore, Africa accounts for more than half of the world's maternal and child deaths. With the advent of BASNmHealth system, the access to medical health care will improve.

II. CLOUD BASED BASN MOBILE HEALTH

BASN Mobile healthcare is an area of technology that uses a large number of sensors and actuators to monitor and improve patients' health conditions in a networked system [12]. Mhealth broadly encompasses the use of mobile telecommunication and multimedia technologies as they are integrated within increasingly mobile and wireless health care delivery systems. It has been found that with the advent of mHealth; the cost savings were especially prevalent in the chronic disease areas of congestive heart failure, pulmonary disease, diabetes, and skin ulcers. With around the clock monitoring and electronic data transition to care-givers, remote devices speed up the treatment of patients requiring medical intervention. Rather than having to wait for a patient to discover there is a problem, monitors identify deteriorating conditions in real time, and alert physicians. The mHealth field has emerged as a sub-segment of eHealth, the use of information and communication technology (ICT), such as computers, mobile phones, communications satellite, patient monitors, etc., for health services and information. mHealth applications include the use of mobile devices in collecting community and clinical health data, delivery of healthcare information to practitioners, researchers, and patients, real-time monitoring of patient vital signs, and direct provision of care (via mobile telemedicine).

The main motivation behind the development of the mHealth field arose due to recent rapid rise in mobile phone penetration in healthcare workforce. Cloud computing involves deploying groups of remote servers and software networks that allow centralized data storage and online access to computer services or resources. Cloud computing focuses on maximizing the effectiveness of the shared resources with easy access via web-based applications; with cloud computing, multiple users can access a single server to retrieve and update their data without purchasing licenses for different applications. Cloud based Mobile Healthcare system stands to benefit from some characteristics exhibited by Cloud computing: Cost reductions claimed by cloud providers. A public-cloud delivery model converts capital expenditure to operational expenditure, device and location independence enable users to access systems using a web browser regardless of their location or what device they use (e.g., PC, mobile phone), maintenance of cloud computing applications is easier, because they do not need to be installed on each user's computer and can be accessed from different places and performance is monitored, consistent and loosely coupled architectures are constructed using web services as the system interface.

III. RELATED WORKS

Aart Van Halteren, et al [1] of the University of Twente, the Netherlands and Ericsson GmbH, Germany developed a MobiHealth project of customizable vital signs monitoring system based on a body area network (BAN) and a mobile health (mobiHealth) service platform which utilized public wireless networks. The developed system allows the incorporation of diverse medical sensors via wireless connections, and the live transmission of the measured vital signs over public wireless networks to healthcare providers. The mobiHealth focused on service test of the network infrastructure (public wireless networks) for the suitability of mobile healthcare applications. Their results documented the feasibility of using the system, which comprises of the mobiHealth and its infrastructures, and also demonstrated logistical problems associated with use of the BANs and the infrastructure for transmitting mobile healthcare data.

Rohit Chaudhri, et al [2] developed a high level framework that allows customization and flexibility of applications that interface with medical external sensors through a typical Android sensing application that enable code reuse and lower application development barriers. Rohit Chaudhri, et al [2] of the University of Washington, Seattle, WA USA, described through the ODK Sensors, the framework designed to simplify the process of integrating sensors into mobile data collection tasks for both programmers and data collectors. They described in details the mobile platforms such as smartphones, tablets through which external sensors can connect to the platforms over wired (USB) and wireless (Bluetooth) channels. Their main goal was the provision of a high level framework, which allows customization and flexibility of applications that interface with external sensors therefore support a variety of information services that rely on sensor data.

Joseph Kee-Yin Ng [8] a Senior Member of IEEE addressed how mobile and wireless technologies can play a role in mobile healthcare systems. The research work dealt with the background information and the differences between traditional computing, location-aware computing and mobile computing. The meaning of ubiquitous healthcare using a network centric approach which invariably presented a prototype environment for building systems and applications related to ubiquitous healthcare systems. Joseph Kee-Yin Ng used mobile phones, off the shelf components and existing technologies in ubiquitous computing (i.e., wireless and mobile positioning technology, data acquisition from sensor and ad hoc networks) and data management (i.e., data capturing, data storage and retrieval, data/signal processing) to build middleware, APIs and tools for the development of systems and applications for ubiquitous healthcare systems.

Zhanlin Ji, et al [5] of University of Limerick, Limerick, Ireland, described a mobile healthcare system based on the ISO/IEEE 11073 personal health data (PHD) standards (X73) and cloud computing techniques. They outlined a number of design issues associated with the system implementation which includes a middleware on the user side, provision of a plug-and-play environment for heterogeneous wireless sensors. They described the mobile terminals which utilized different communication protocols and how distribution of medical "big data" processing subsystem in the cloud can be achieved.

IV. THE BASN-BASED MOBILE HEALTHCARE SYSTEM ARCHITECTURE

The BASNmHealth systems are based on the Internet of Things concept, whereby the medical treatment emphasizes the object management. This concept urges the mobile medical technology to adapt. "Things" in the mHealth systems include doctors, patients, medical devices, and sensors [6]. The focus of this research work is on the development of a cloud-based mHealth system, consisting of a healthcare middleware in the BASN domain and a distributed data processing system. The system contains three tiers as follows [5] figure 1:

1. Wearable Body Area Sensor Network (WBASN)
2. Automated Intelligent Central Node (AICN) or Sink
3. Cloud-based Central Server (CICS)

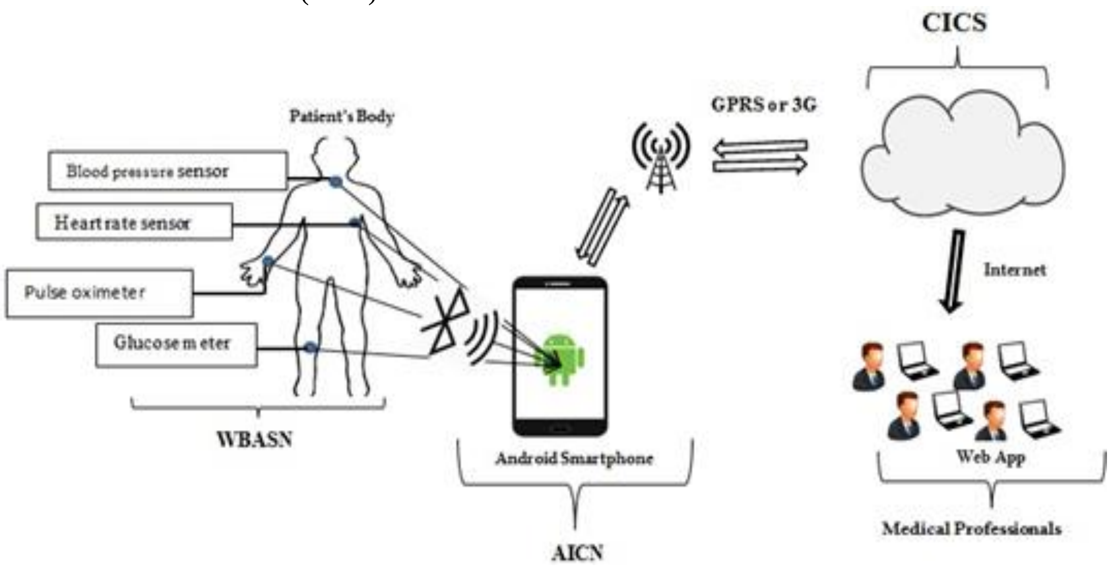

Fig. 1 The BASN-based Mobile Healthcare System Architecture

A. Wearable Body Area Sensor Network (WBASN)

WBASN consist of two open source electronics boards, the Arduino Leonardo and Arduino wireless Yun shield and three medical sensors put and adapted to the body of patient; the sensors gather their appropriate data and transmit that information to the second tier components (AICN) via wireless hotspot communication protocol. The wireless medical sensors include heart rate sensor, temperature sensor and Galvanic Skin Response (GSR) sensor and they operate in a plug-and-play manner. These medical sensors use hotspot wireless protocol for communication with the based middleware (Sink) Android smart phone.

The mobile phone of the patient serves as a gateway to the middleware sink. A software agent, (myHealth app) operating on the phone, periodically collects data from the sensors and sends the user record to the Cloud-based Central Server (CICS) which is a web based application using 3G network. The message contains medical parameters' values, the user's location, medical device's information, and other useful information.

The Wearable Body Area Sensor Network, which is the hardware part, consists of Arduino Leonardo, Arduino Yun Shield, and three medical sensors. The Arduino devices enable wireless communication between sensors and AICN, power supply to the sensor and transfer of data by the sensors. The sensing module plays the essential role in acquiring data from users by using different types of sensors or sensing elements.

B. Automated Intelligent Central Node (AICN) or Sink

AICN is responsible for collecting and processing the data generated by the WBASN sensor nodes, the Cloud-based Mobile Healthcare System uses smartphone with Android operating system as the automatic intelligent central node (AICN). The communication between Cloud-based Central Server (CICS) and Automatic Intelligent Central Node (AICN) is via 3G internet connection. Considering the constant increase in processing power, allowing for sophisticated real-time data processing, smartphone is a great choice as a central node and body gateway component. Other advantage is that smartphone is often pre-integrated with sensors; such as accelerometer to determine mobility and global positioning system (GPS) for location, which makes them attractive for a fully integrated wearable mobility monitoring system.

C. Cloud-Based Central Server (CICS)

Cloud-Based Central Server (CICS) receives sensors data from all the AICN. Once the data is uploaded to the server through the GPRS or 3G network, it is stored in user/patient's database to which are then analyzed. Among other things the data will contain: medical parameters' values (user health status) the user's location (via device accelerometer) medical device's information and other useful information. This analysis is performed autonomously, without human's intervention, comparing the patient's vitals against pre-existing knowledge of his/her condition as well as any recommendations prescribed by the patient's doctor or healthcare professional.

After processing the information, medical professionals can identify the real time positions and health status of the patient through a web application from the cloud server. Once an abnormal or defect situation is detected, an alert signal is sent in text format to give the medical professional an idea of the patient's health status and to alert him/her of the patient's current location in the case of an emergency. The medical professionals then take it up from the alert and send appropriate message to the patients based on his/her status report.

The medical care contents will be personalized and customized to best suit each mobile phone and patient. Different patients will definitely receive different medical-care advices and statements based on their personal profiles and current medical condition.

V. MYHEALTH APP DEVELOPMENT PROCESSES

An Android app is a software application developed for use on devices powered by Google's Android platform. Because the Android platform is built for mobile devices, a typical Android app is designed for a smartphone or a tablet PC running on the Android OS.

Novice developers who simply want to play around with Android programming can make use of the App Inventor. Using this online application, a user can construct an Android app as if putting together pieces of a puzzle. The Android platform supports three broad categories of sensors: motion sensors, environmental sensors, and position sensors

Android allows application developers to obtain the raw data from these sensors in order to be able to then use it in the application. Therefore, one can access the sensors available on the device and acquire raw sensor data by using the Android sensor framework. This sensor framework provides several classes and interfaces that help you perform a wide variety of sensor-related tasks.

The Android app developed is responsible for data collection and represent automatic intelligent central node (AICN) called myHealth App. The myHealth App was developed using Java programming language with the aid of tools included in Android studio like Android SDK, Java SDK etc. The Android SDK tools compile the code, along with the data and resource file into an APK format. The APK file contains all the contents of the application and this is installed on the smartphones.

A. Development Phases Of myHealth Web Application

MyHealth web application implements five major activities classes and each activity class has its own corresponding layout file stored in the application resources with specific purpose action. The activities run underground while the overall results are display through the web page.

i. Doctor Login Function: Once the page loads, it is required that doctor or any other healthcare professionals must login to access the patient's records. Page_Load(object sender, EventArgs) handler: load up the web page.

Class Login: System.Web.UI.Page handler: allows doctor to login to access the patients' records.

ii. Insert Record Function**:** Immediately the sensors data are sent to the cloud server, the web application insert each data into a corresponding patient's account.

InsertPatientTemperature(string temperature, string number, string date) handler: inserts patient's temperature readings together with his/her phone number, brand of mobile phone, date and time.

InsertPatientHeart(string heart_rate, string number, string date) handler: inserts patient's heart rate readings together with his/her phone number, brand of mobile phone, date and time.

InsertPatientgsr(string gsr, string number, string date) handler: inserts patient's GSR readings together with his/her phone number, brand of mobile phone, date and time.

iii. Get Total Record Function**:** The purpose of myHealth web application is to allow the healthcare professionals to access the patients' records and make medical recommendations based on the records. To achieve this, lowest, average and highest reading must be set. This handler gets the total records of each patient.

getTotalRecord(string tableName) handler: this handler get the total records of each patient to ease decision making.

getHighestValues(string tableName, string column) handler: get the total highest records of each reading (temperature, heart rate and gsr) and store it on patient table.

getAverageValues(string tableName, string column) handler: get the total average records of each reading (temperature, heart rate and gsr) and store it on patient table.

getLowestValues(string tableName, string column) handler: get the total lowest records of each reading (temperature, heart rate and gsr) and store it on patient table.

iv. Compare Patient Record Class: As new readings are saved in the database, total records are calculated and compare with the default data. If much changes in readings are noticed as a result of abnormal medical situation of the patient, then alert are sent.

ComparePatientTemperature(string temperature, string number, string date) handler: compare the temperature records of each patient

ComparePatientHeart(string heart_rate, string number, string date) handler: compare the heart rate records of each patient

ComparePatientgsr(string gsr, string number, string date) handler: compare the GSR records of each patient

v. Send Alert Function**:** this is subject to the compare patient's records activity. If abnormality is detected from the records, send alert activity take charge. The alert is a SMS text alert which will include name of the patient and corresponding recommendations. Most often than none, the alert is to visit the hospital as soon as possible.
SendAlert (string number, string date) handler: send .txt alert to the patient

VI. SYSTEM IMPLEMENTATION

The conceptual framework of BASNmHealth was built and myHealth smartphone app was fully developed and tested on various volunteers' smart mobile devices. Volunteers were chosen to take part in the test field for the project. The main goal was to collect the medical data of the volunteers, using their smart phones as AICN. MyHealth App was developed based on android version 4.2, thus making it easy for volunteers to install it on their smart mobile devices, because any phone with android version 4.2 and above can easily install it on their devices. Implementation started with myHealth App installation on volunteer's device running Android OS.

A. Interface Design (myHealth App)

The user interface of myHealth App was designed to be user friendly. The main activity page has several buttons with graphical image for each button, and each button is for different activity, that shows value of the parameters the app is measuring, which makes the application easy to use and understand.

B. Main Home Page

As shown below, main home page allows user to register as the user by entering his/her name, age, marital status, and phone number. It displays a layout which has a drop down menu having several buttons, each corresponding to a feature of the application.

Fig. 2 myHealth Main Home Page

C. Home Page

In the subsequent use of the app, the home page displays the name and the phone number of the user and his/her current medical reading.

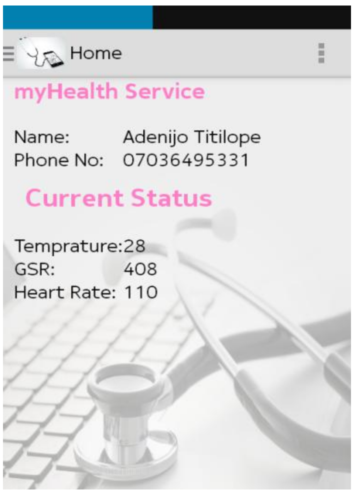

Fig. 3 myHealth Home Page

D. Profile Page

Profile page displays the profile of the user.

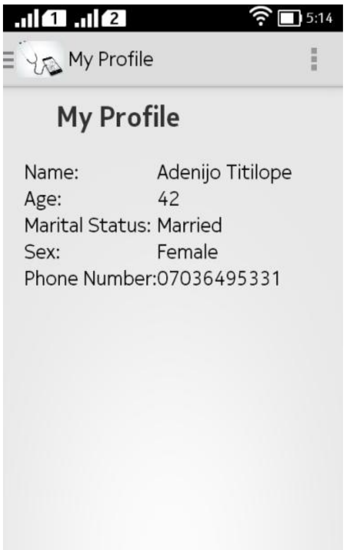

Fig. 4 myHealth Profile Page

E. Take Reading Page

This page shows the connectivity to the Arduino device (WBASN), shows options of reading to take, how the reading are taken and when the readings are successfully saved.

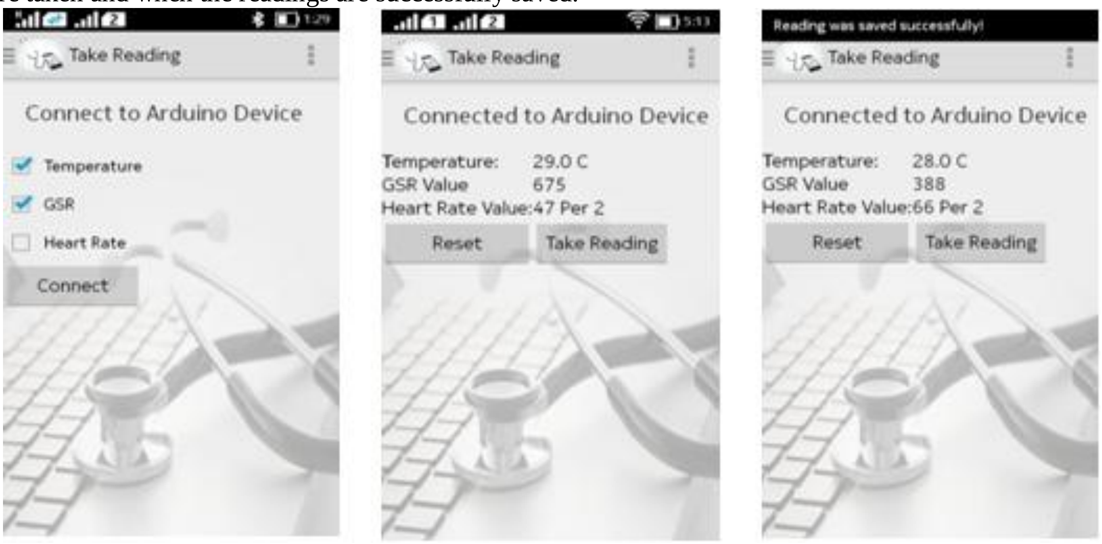

Fig. 5 myHealth Take Reading Page

F. My Health Status Page

This page displays the current status of the user by displaying the current readings, last readings and calculate the average report of each reading.

Fig. 6 My Health Status Page

G. Analyze Page

The analyze page shows the total data recorded by the device, the average data, details of the devices, date and time.

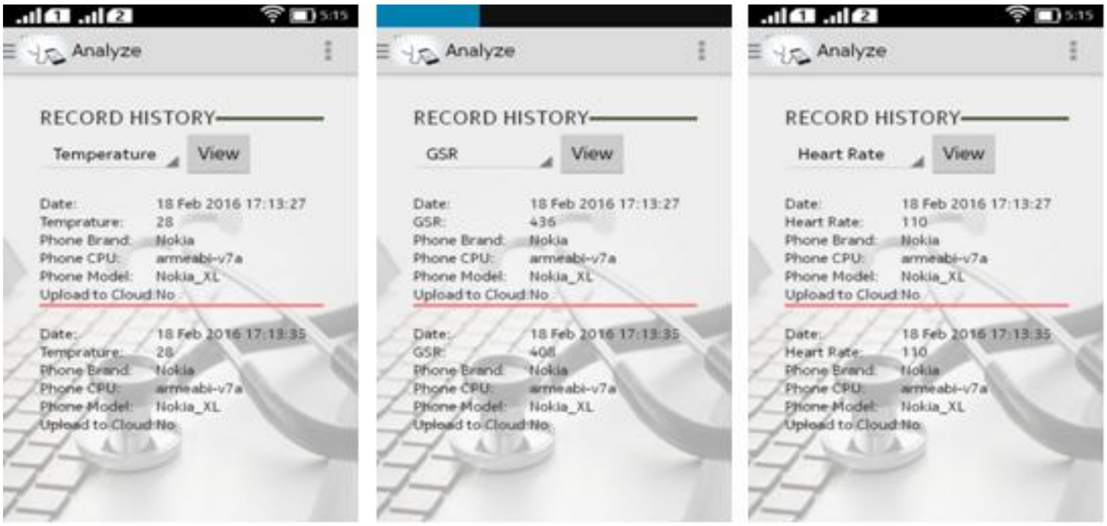

Fig. 7 myHealth Analyse Page

H. Send SMS Activity

This page displays how user can manually send SMS to the healthcare professionals in case of internet connection failure.

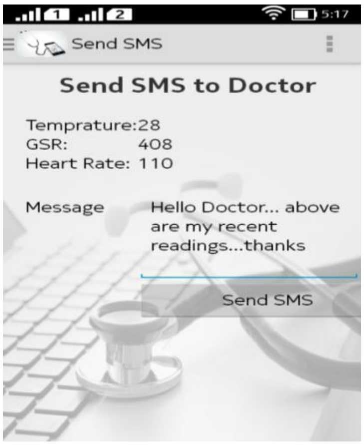

Fig. 8 myHealth Send SMS Page

I. Web Design (myHealth Web Application)

The web application was designed to be user friendly. The index page shows the dashboard that displays the total number of patients, temperature history, GSR history and heart rate history. Figure 9 shows the index page of the web application.

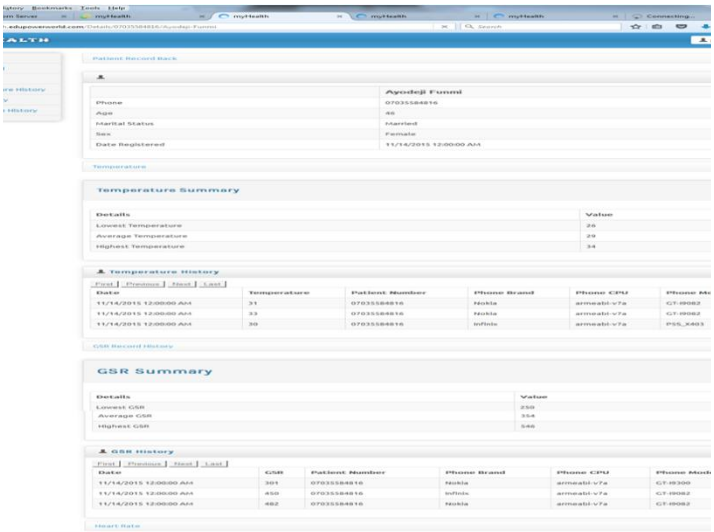

Fig. 9 Index page of the web application

VII. CONCLUSION

BASNmHealth is the use of sensors and actuators to monitor and improve patients' physical and mental conditions in a networked system. It encompasses the use of mobile telecommunication and multimedia technologies integrated within mobile and wireless health care delivery systems. BASNmHealth system is used to monitor the health of the patients in lifelong medication. This research developed a cloud-based BASN mobile healthcare system application, consisting of a healthcare middleware in the BASN, which improved the early diagnosis of chronic diseases and medical appointment with clinicians via mobile devices.

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