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Secure M-Health Patient Monitoring and Emergency Alert System Framework.

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ABSTRACT

Nowadays Mobile health care (M-health care) monitoring system has gained an attention based on latest developments in medical technology. The process of Healthcare monitoring system has been improved and readily accessible with the framework consists of wireless BSN's (body sensor networks) interfaced with M-Healthcare APP in smart phone device. Existing healthcare systems lacks in characteristics like vital sign monitoring of patients at anyplace, preserving their analyzed data from intruder, and providing immediate alert to caregiver in case of emergency. If the patient's data is hacked and modified then it results in high risks for patient and also lack of immediate alert may leads to death. In this proposed work a body sensor network is designed based on M-health patient monitoring framework (self health monitoring) and a health care APP is implemented in android based smart phone. If any abnormal state is detected then the framework alerts the patient and also the caregiver by raising an alarm and instantaneously an alert message is sent to the caregiver through the smart phone. Data security is achieved by pairing the patient's body sensor network with the smart phone using password protection mechanism. The main objective of this system is to monitor the high risk patients and to protect the patient's data from intruders at anytime and anywhere through android APP. Caregivers can get patient health analysis, medicine follow up reminder, daily notification alert of their medical data through this system framework.

Keywords: M-health care, body sensor network, Android mobile, Data security.

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INTRODUCTION

Health surveillance gradually plays a significant position in the day today life. Nowadays more people are affected with the chronic disease problem [1] however the conventional healthcare systems are mainly limited to hospitals and other preset locations, which are not always available for the patients. Mobile health care technology is essential if the patient needs to be constantly monitored their physiological information such as heart rate, body temperature, and blood glucose and respiration rate over a long period.

Advancement of the BSN technology makes it feasible to constantly observe physiological factors like electrocardiograph (ECG), Heart pulse rate, respiratory rate, blood oxygenation (SpO_2), body temperature, etc over a period of time [2]. BSN possess the features such as tiny, low power, wireless based health monitoring because of the improvement of precision based micro power amplifiers, MEMS technology, micro controllers and so on. BSN-microcontroller unit is equipped with wireless communication to transfer data to the remote device [3]. Key issues need to be addressed are reliable sensors to be used, reliable communication of vital sign data, accurate threshold values, secured patient's data.

In contrast with the monitor connected with the PC or PDA device, smart phone is lighter to hold, simpler to operate .Also it supports long range distance data communication possibilities and hence suitable to wide variety of applications. Smartphone posses characteristics like huge-capacity storage space, high speed processing, touch display; GPS based map-reading, high capacity battery, user-friendly human machine interface. Android based platform in smart phone allows installing new applications which makes android devices to be used more in mobile health field [4].

Mobile health monitoring system is developed in this work and it is capable of monitoring a patient's physiological information. It is for not only to calculate, examine and collect the different physiological parameters of the patient in real time but also alerts if the physiological parameters exceed the predefined health values. Also this abnormal information is communicated to the remote device (Android mobile) via SDP (Service discovery protocol) and AOA (Android open accessory) protocol [5].

MATERIALS AND METHODS

Mobile health monitoring system consists of two modules viz hardware module and software module. Sensor nodes interfaced with Arduino controller is the hardware module and an Android APP installed in smart phone is the software module. Sensor nodes are connected as a wearable device on patient's body that can sense periodic measure of respiration, blood sugar, glucose level in blood and heart rate in real time. Arduino UNO is used to acquire, accumulate, execute, broadcast vital sign data and alert automatically if normal value exceeds. Due to huge market split, low cost and openness features of Android platform, APP is designed on Android OS with Android SDK and NDK tool. Bluetooth wireless communication technology is used as a communication module between Arduino UNO controller and Android mobile. Proposed system comprises of two functionality Viz secure vital sign monitoring and emergency alert system.

System Framework and Description

The implementation of mobile health monitoring system components are integrated into a framework as shown in Fig 1.

Secure Vital Sign Monitoring

Vital sign monitoring mechanism is carried out with five layers Viz Sensor abstraction layer, Processing layer, Communication layer, Device layer and Application layer.

Sensor Abstraction Layer

Sensor layer includes biomedical sensor which is used as the sensing elements. It mainly senses the physiological data and sends the data to the processing layer. Biomedical sensors used in this system are Heart rate sensor, respiratory sensor and blood glucose sensor.

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Monitoring heart rate

Monitoring module of heart rate sensor is explained in Fig 2. Photoplethysmography is a technique used to detect the changes in blood volume in the marginal parts of the body like the fingertip. Pleth is a device that detects the signal [7]. The light point from the led of the Pleth is observed by one side of vascular tissue of the body (fingertip) and it is detected at other side using Light sensitive detector (LSD). The flow of blood volume is controlled by heart rate pulse. When the light passes through the vascular tissue, its intensity varies as the volume of the blood varies and hence the detected signal pulse is equal to the heart rate pulse. Table1 shows the predefined heart rates for different ages.

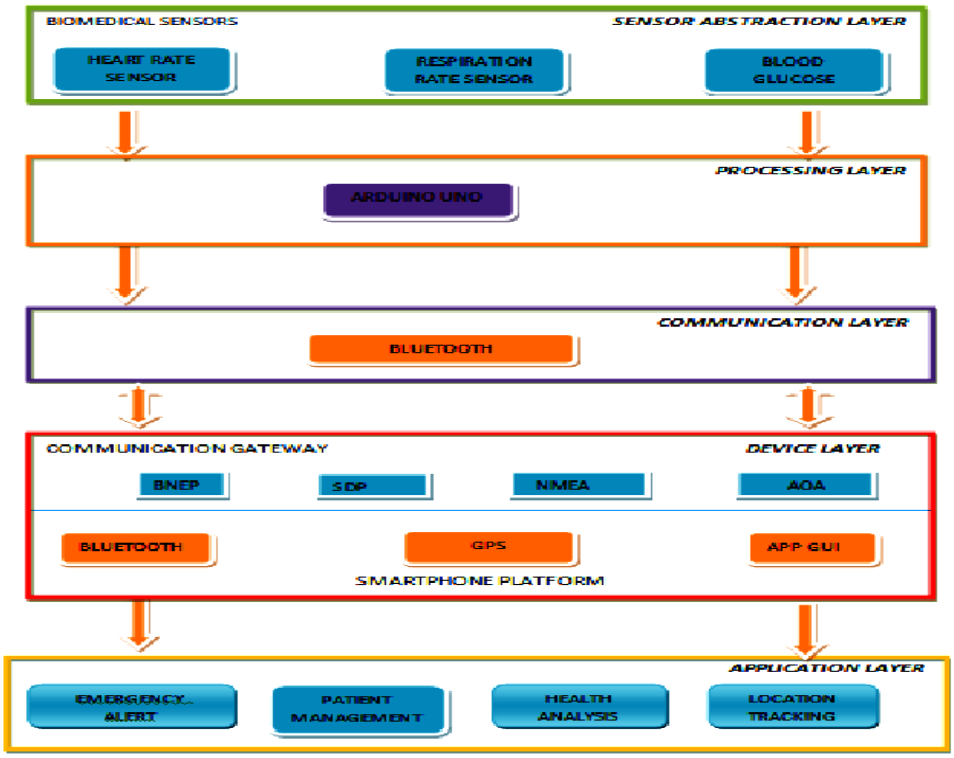

Figure 1: System framework

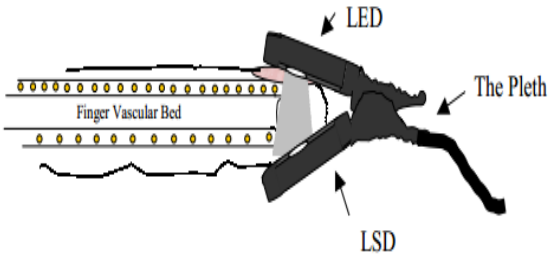

Figure 2: Heart rate sensor

Age	Average Heart Rate (beats per minute)
Newborn	140
7 years	85 – 90
14 years	80 – 85
Adult	70 – 80

Table 1: Normal heart rates

Tachycardia and *Bradycardia* are the medical terms indicates abnormal heart rates

- If the heart is beating too fast at rest state means *Tachycardia* (frequently above 100 beats a minute)
- If the heart rate beats too slow means *Bradycardia* (frequently below 60 beats a minute).

Abnormal heart rate calculation formula:

Abnormal level = 1 minute real time heart beat value - Predefined heart rate

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Monitoring respiration rate

Respiration rate is defined as number of times a human being breaths per minute. The number of breaths for each minute is calculated by analyzing how many times over a period the chest rises. Normal respiration rates for an adult human being should vary from 12 to 16 breaths for each minute at rest. Face mask type vital signs shown in fig 3 consists of a detector, analyzer, transmitter and display. Abnormal rates will rise by means of some symptoms like illness, fever and other medical conditions. While monitoring respiration condition for a patient it is significant to check whether a human being has *dyspnea (*trouble in breathing) symptom [7]. *Agonal respiration* is the medical term that indicates abnormal pattern of breathing.

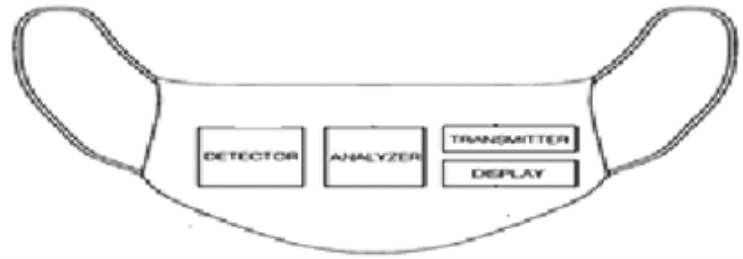

Figure 3: Respiration sensor

Abnormal level = real time respiration rate – predefined breath rate

Monitoring blood glucose level: A sample of blood is acquired by stabbing the finger with a biosensor needle (disposable) and it is dropped into an electrode strip. The blood glucose level is measured by placing the strip into a digital monitor sensor board [7]. Though, the finger stabbing method is little painful to the patient, it provides better accuracy and reliability than other methods. *Hyperglycemia* is the medical term indicates abnormal glucose level. Table 2 shows the predefined blood glucose levels

LEVEL	RANGE(mg/DL)
ABNORMAL LEVEL	215 to 380
GOOD LEVEL	158 to 100
EXCELLENT LEVEL	50 to 115

Table 2: Blood glucose level

Processing Layer

The processing layer uses Arduino UNO controller board to process the sensed information. Sensed data received from the sensing layer is transferred to the Arduino UNO controller through analog input pins. In built ADC will convert the sensed analog data values into digital data. Controller starts analyzing the sensed patient data by comparing with predefined health data and decides whether any abnormality occurs. Arduino UNO is a ATmega328 chip based microcontroller board contains 14 digital IO pins ,6 analog input pins, reset button ,16 MHz ceramic resonator, power jack and USB connector port. Both power jack and USB connector provides power supply to the Arduino board. In this work USB connector is used as power supply and it is also used for transmitting data.

Communication Layer

Communication layer uses Bluetooth module HC-06 for wireless data communications. It provides a serial communication between the Android phone and an Arduino UNO controller. Through UART cable the processed data is transferred from Arduino to HC-06 Bluetooth module. Bluetooth devices work at unlicensed industry scientific medical (ISM) band which is about 2.40–2.48 GHz approximately. 2.45GHz is split into 79 channels with 1 Mbps data rate and bluetooth module works with a low-power option. Serial Port Profile (SPP) is used to interchange data with Android device. SPP allows bluetooth to create connections with another

device using peer to peer (p2p) connection. It only transmits the data to the device which is paired already using password protection mechanism. The syntax which is used to create a bluetooth socket and allows transferring data between bluetooth and android serially is shown below.

```
Tmp=device.create Rfcomm socket to service record (My_UUID)
```

Device Layer

Device layer comprises of two modules viz. smart phone platform and communication Gateway. In the smart phone platform an android APP is created using Android studio. App performs many functions like receiving the measured physiological sensor data from Bluetooth module, storing the data in the smart phone with built-in database SQlite functions and finding the current location with built-in GPS feature based on National Marine Electronics Association (NMEA) protocol. The communication gateway comprises of four protocols viz BNEP, NMEA, AOA and SDP. Bluetooth network encapsulation protocol (BNEP) is used for distributing network packets from bluetooth module to the smart phone through L2CAP layer in the bluetooth protocol stack. Service Discovery protocol (SDP) allows the bluetooth module to determine the facilities of the device which is going to pair. While connecting a smart phone to a HC 06 Bluetooth module, SDP first determines which Bluetooth profiles are carried by the module and connect each of them using protocol multiplexer settings. Universally Unique Identifier (UUID) is used to identify each device. Android open accessory (AOA) protocol uses appropriate android inbuilt accessories to communicate with bluetooth layer and in turn Arduino. It supports both point to point and multipoint communication. Smart phone in built GPS uses NMEA protocol to find the location point through latitude and longitude.

Application Layer

Application layer posses applications like patient management, emergency notification alert, health analysis and location tracking with the help of monitored real time vital sign data.

Data Security

The monitored vital sign data is transmitted to android mobile app through bluetooth gateway. During bluetooth transmission and submission of the data to the caregiver through the cellular network secure transmission of private medical data needs to be protected. Security is mandatory because intruders can potentially attack the data and change the vital sign data. This results in misinterpretation of the vital sign data and may create a false alarm and also fails to identify the critical situations of patients. Data security is achieved by pairing the patient's body sensor network with the smart phone using password protection mechanism. Pairing must be done before transmitting data from HC-06 bluetooth module to smart phone. To pair, the bluetooth options are checked whether android mobile is discoverable or not to nearby device (visible or hidden). Once it is discoverable, HC-06 bluetooth module on the smart phone is searched and selected. 4 to 8 digit pass code is entered in smart phone to get paired with HC-06 module. Once devices are paired HC-06 bluetooth module will send the data and smart phone will receive the data.

Emergency Alert Communication

Emergency alert mechanism checks for any sudden abnormal change in patient body based on comparing the predefined health data with real time biological data (i.e. heartbeat, respiratory, blood pressure). It is implemented in the Arduino UNO controller to alert the caregiver about patient condition. The main objective of this mechanism is to provide an alert message immediately to caregiver if any abnormal change occurs in patient body. Alert is provided by raising an alarm and an alert message is sent to the caregiver's smart phone through the bluetooth gateway. If there is no abnormality it continues monitoring the real time data obtained from sensors.

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Pseudocode of proposed work

Initialize biological sensors;
Initialize predefined sensor value;
Initialize smart phone APP;
Sense the vital sign data from sensor;
Store real time vital sign data and predefined data as variables R & y (i);
Interface biological sensor with Arduino;
Detect the risk state with R and Y values;
REPEAT (every per minute)
{
If(y > R or y < R) ABNORMAL
Then
Alert the caregiver, Call Alarm message procedure;
End if;
If (y =R) NORMAL
Then
Go to sense the vital sign;
End if;
}
Alarm message procedure:
Abnormal data transmission from Arduino UNO to bluetooth module;
Broadcast the same to the Smartphone APP from bluetooth module using SDP and BNEP protocol;
End;

Figure 4: Pseudo code of proposed work.

PROPOSED METHODOLOGY

Proposed Mobile Healthcare (m-health care) monitoring system consists of two major modules Patient part (Transmission unit), and caregiver part (Receiving unit).

Patient part

Patient part comprises of biomedical sensors, Arduino UNO and bluetooth module. Acquired bio signals from the sensors attached on the patient body are analog values. In built ADC in Arduino UNO will convert the sensed analog value into digital value because Arduino UNO can process only digital data. Abnormal values obtained are transferred to caregiver side using HC-06 bluetooth module gateway.

Caregiver part

A health care APP is implemented in android based smart phone to monitor the biological values in real-time. If any abnormal state is detected then the APP alerts the patient and also the caregiver through the smart phone APP. Pairing must be done before transmitting data from HC-06 bluetooth module to smart phone.

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RESULTS AND DISCUSSION

Hardware setup of proposed work is shown in fig5.

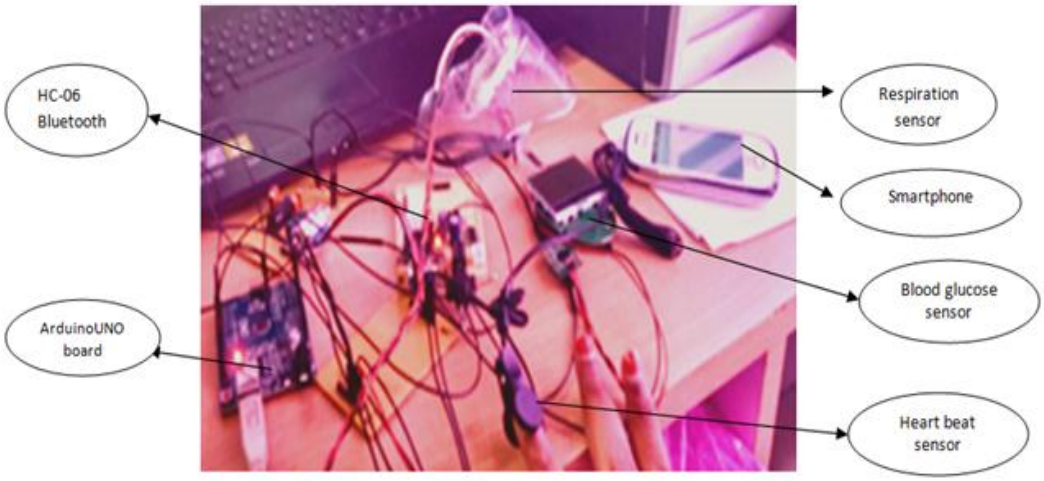

Figure 5: Hardware setup of proposed work

Iinterfacing of biomedical sensor with Arduino UNO

Input pin of biological sensors are connected to Analog pins of Arduino UNO .

Interfacing of Bluetooth module HC-06 with Aurdino UNO

Bluetooth module acts as a Communiction gateway between Arduino and Android phone. Data processing is done using CSR processing chip in the HC-06 bluetooth module. Tx pin in Arduino UNO wiil transmit the data to the bluetooth module and Rx pin in Bluetooth module will receive the data from Arduino. Bluetooth module will wirelessly transfer the patient abnormal data to the Smartphone App.

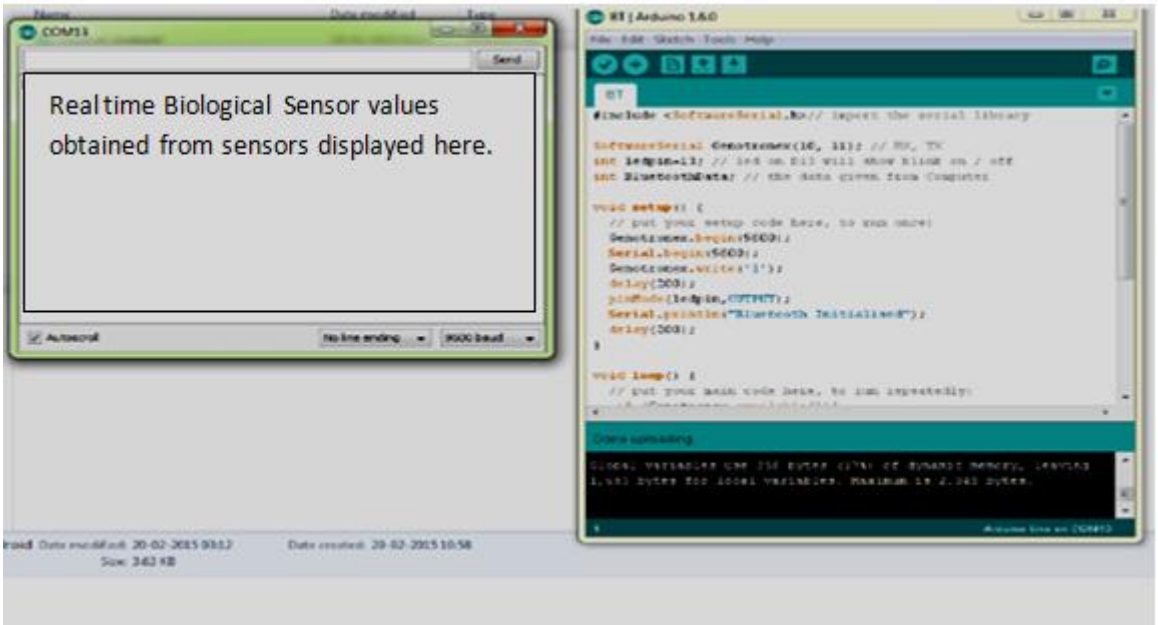

Figure 6: code compilation in Arduino IDE

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Embedded code runs on Arduino IDE compiler tool is shown in fig 6. The obtained real time sensor values are displayed in the serial monitor of Arduino IDE.

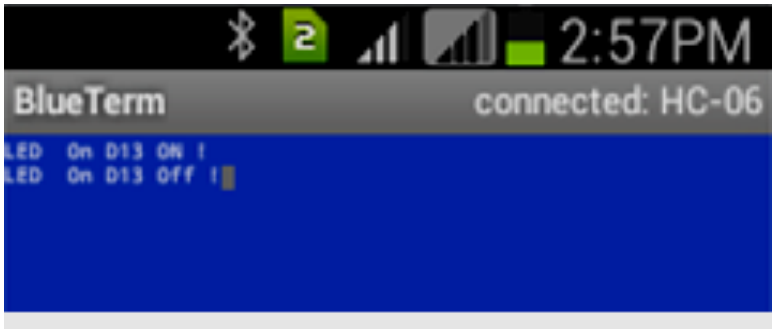

Figure 7: Communication establishment.

Bidirectional communication is established between Arduino UNO and Smart phone. Fig 7 depicts the snapshot of smartphone during communiication establishment. Led in Arduino UNO board turns ON while pressing key 1 in Smartphone and turns OFF while pressing key 0.

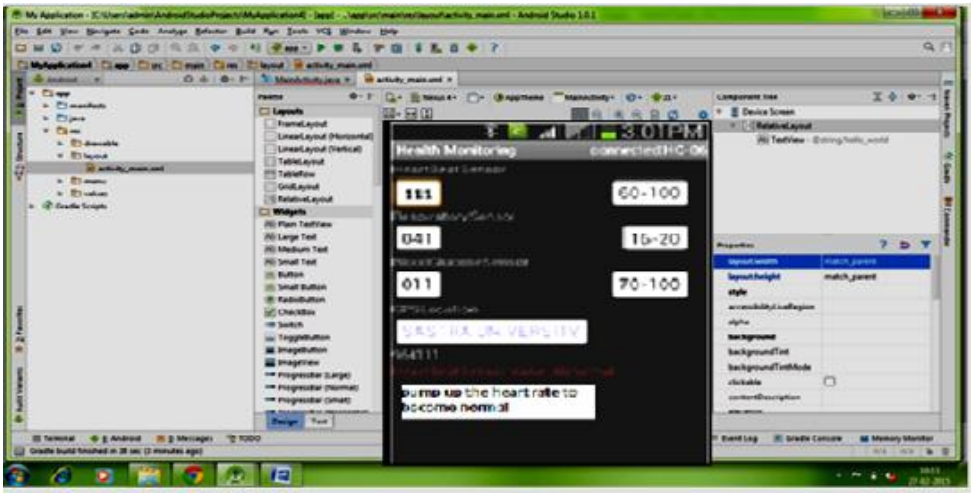

Figure 8: Android code compilation in Android studio tool

Fig 8 shows the Android code compiling in Android studio. The android application is developed in Android studio using SDK and NDK tool. Generated application file (.apk file) is compatible with all the versions of android operating system. Install the .apk file of health monitoring application in Smartphone using AOA protocol.

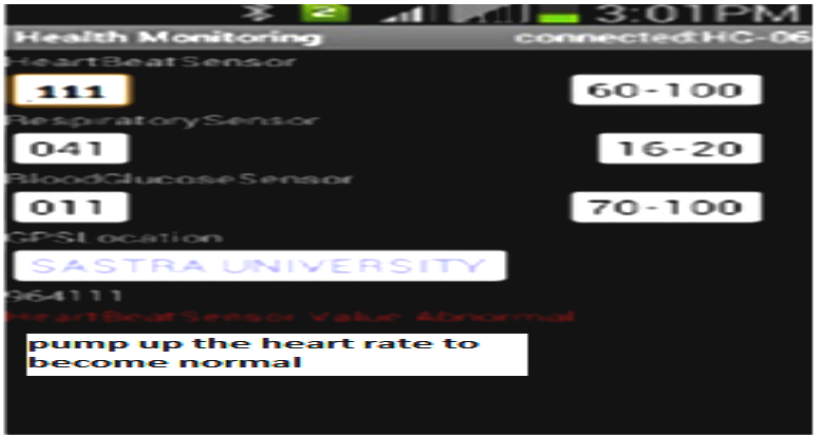

Figure 9: Health monitoring Android application

Figure 9 shows Android mobile health monitoring application working in a Smartphone. Caregiver can get the health condition of patients through this Smartphone APP.

CONCLUSION AND FUTURE ENHANCEMENT

Wireless M-health care system framework is proposed here .It comprises of smart mobile device and biological sensors that can provide immediate and continuous detection of various physiological data of the human and embed vital signs to hardware modules. In traditional healthcare, lot of communication time causes an emergency and time-critical medical treatment being delayed. Proposed framework is considered as an intelligent medical communication framework that contains features like accurate data, real-time monitoring and it can also used for multi-user physiological status monitoring alarm system. It offers quicker and more convenient medical emergency notification mechanism that allows non professional caregivers to make correct clinical judgments and to give patient first aid treatments. Communication Gateway in the communication layer is open interface and flexible to add further communication modules like zigbee for long distance communication. This work can be enhanced to store the sensed data in a remote server through Wi-Fi.

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