Internet of Things Based Patient Health Monitoring System Using Wearable Biomedical Device

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Abstract— ***Enhanced and intelligent healthcare system is a symbol of developed and prosperous nation. Internet of Things (IoT) has abounded the digital healthcare system by providing remote monitoring of patients' health condition and allowing doctors to have access to those information. This paper proposes an IoT based automated and intelligent system that automatically senses patients' health condition, stores and displays those data over internet and informs doctor about critical conditions. This paper focuses on making the system affordable and user friendly for the mass people. This system will help the doctors always to be up to date about patients' health condition. The proposed system will alert both doctor and family member of the patient about any kind of injury in case of emergency situation. Thus, percentage of saving lives will increase and due to remote monitoring, a doctor will be able to provide medical service and advice to increased number of people than before.***

Keywords: Internet of Things (IoT), remote monitoring, raspberry pi, medical database, health assistant.

I. INTRODUCTION

Internet of Things IoT has brought revolutionary change in information and communication technologies. Internet of Things (IoT) gives the access to vast data and it allows devices embedded with sensors and actuators to communicate and share information among them. Physical devices and systems embedded with different sensors, software and actuators are connected with each other and exchange information and data through internet. Objects are being sensed and controlled across the internet remotely. IoT creates huge opportunities as physical world is integrated into computer based systems. This integration results in reduced human participation, improved efficiency along with economic benefit and accuracy [1].

Keeping a patient at close observation and monitoring critical signs such as heart rate, blood pressure and body temperature etc. is a major significant phenomenon in the healthcare monitoring systems. Majority of the monitoring devices are available at critical or intensive care units and operating rooms. These devices show measured values at the adjacent display only. It is quite possible that doctor has not been alerted at emergency situation when patient's condition comes down at a critical stage in spite of 24 hours close observations. Also, after getting discharged from hospital and taken to home, a patient needs to be kept at close observation and report any health injury to doctor too.

Reason behind not sharing these data remotely with specialized doctors and family members immediately is that the technology that combines all these features is not affordable and accessible by mass people in developing countries while the technology is available and developed already. All the thing required is implementing the technology and IoT is the best solution so far to make it possible [2].

Using IoT as the technology combining doctor and patient, it is also possible to keep a record of the patient's health status. This will help the doctor to understand that patient more accurately.

The arrangement of the paper is as follows, introduction is included in the section 1. In section 2, IoT in healthcare related significant previous works is discussed. The proposed system is described in section 3 that includes design methodology, block diagram and system architecture. In section 4 equipment used in the system is descried. Section 5 contains the performance measurements and finally section 6 is the conclusion.

II. RELATED WORKS

This paper aims for a combined approach to develop an appropriate healthcare system beneficiary and useful for both patients as well as doctors. The main focus of this work was on low cost, compact design, less complicated, portable and user friendly. There are a lot of healthcare monitoring systems available having different drawbacks like low power saving, bulky, wired setup, slow response etc.

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Wearable wireless system is very helpful to overcome these drawbacks. Some significant and related works have been focused in the literature.

In [3] author Highlighted the opportunities and challenges for IoT in realizing this vision of the future of health care. He proposed that multiple physiological measurements can readily be incorporated with wearable sensors and this enables stocking of data having much accurate sampling rate over much longer time scales.

In [4] author proposed a system where different sensors are being connected to the transmitter board of Arduino Fio where module of xbee is also connected. An Arduino is connected to patient side computer that receives the sensed values wirelessly. LabVIEW reads all these values. LabVIEW is connected with internet and it generates an URL that is accessible from any computer.

In [5] author proposed a system where all of the sensors will be directly connected with the Raspberry Pi which will then display the calculated outputs, ring alarm in case of any hazards, alert through Email and SMS and also keep a cloud display and database for further use of those data. This system has an interesting feature that the prescribed medications' names and dosage units will be displayed.

In [6] author compared between different existing system used for IoT and choose GSM-GPRS system for transmission of data and RFID for checking human activity.

In [7] author proposed a system that uses Atmega328P microcontroller for sensing the data and ESP8266 Wi-Fi module to transmit data over internet. The Wi-Fi module has storing and processing capacity, so it is very easy to be connected with.

In [8] a system is being proposed by the author that measures patient's body temperature and heart rate and uses IoT features. This system supports displaying gathered data through mobile application. Wi-Fi module is used to transmit data to internet and using Bluetooth technology, data is being displayed at mobile application.

In [9] author proposed a system to measure heart rate and body fat using LPC 2129 ARM Processor Development Board. Wi-Fi technology was used to send data to web server and those data were displayed using a web page.

In [10] author discussed about all of the available architectures for IoT network. Also, author compared between different technologies for sensing different human body parameters side by side and also he makes comparison between data transmission and receiving technologies according to the size and requirement of the data.

It is a complete survey indeed and very much helpful for understanding IoT networks and their operations.

III. SYSTEM DESCRIPTION

A. *System Structure*

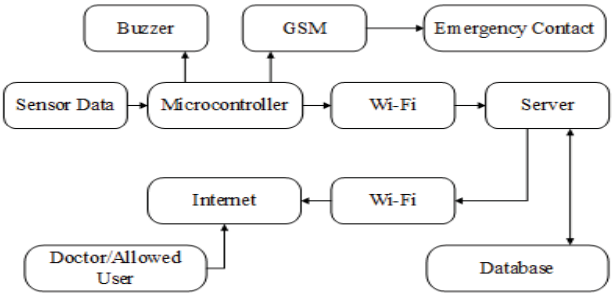

Fig. 1. Block diagram of the system.

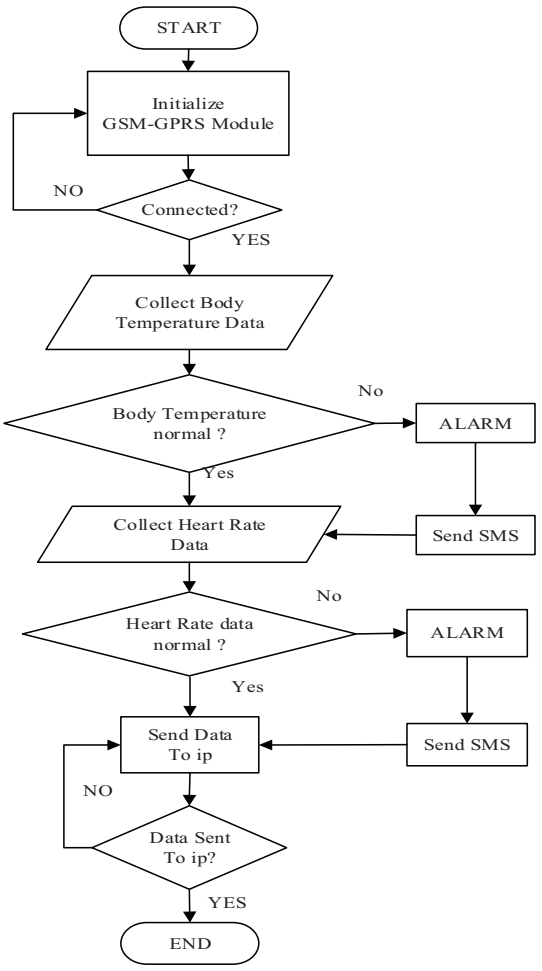

Fig. 2. Flow chart of the system

The system consists of two different sides where one is web application side consisting of web pages including database and another is the patient side which consists wearable sensor. Figure 01 and figure 02 depict the total block diagram and flow chart of the system and figure 03 illustrates circuit diagram of our wearable sensor.

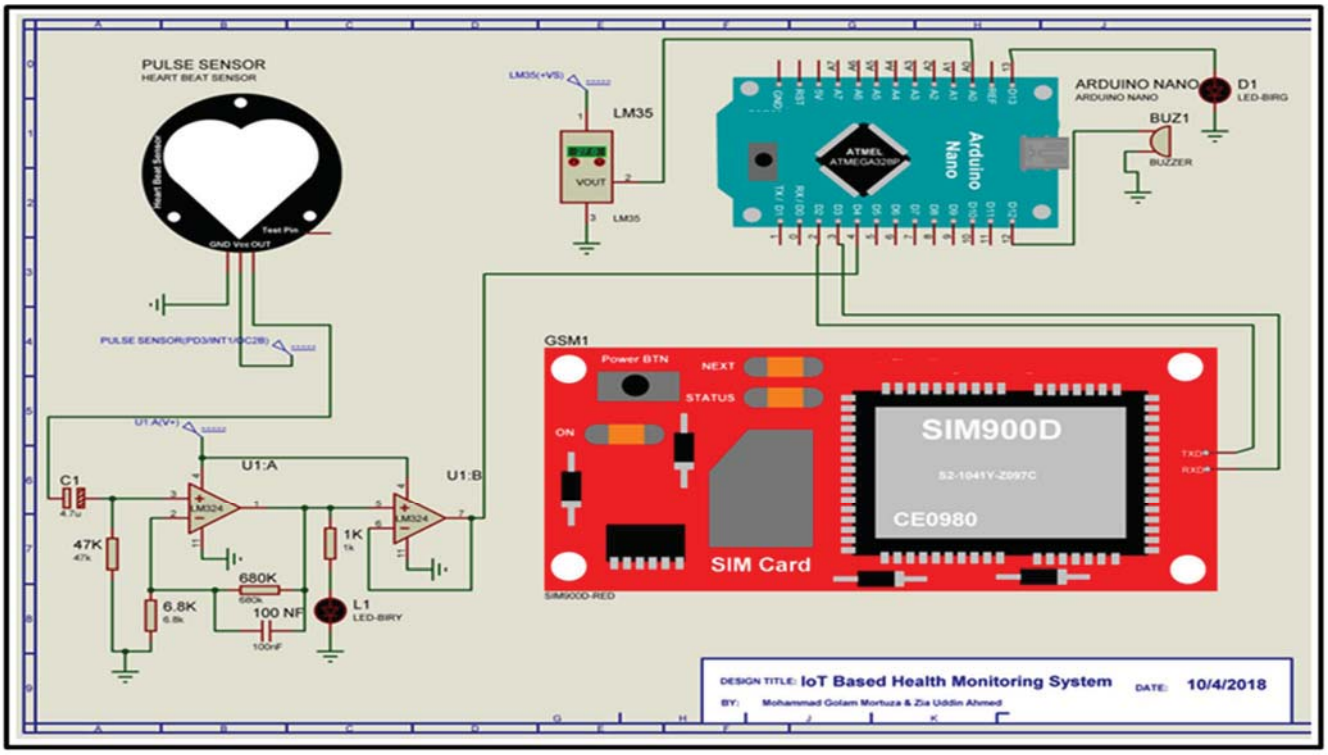

Fig. 3. Circuit simulation of the system.

B. *Web Server*

The server is formed using Flask which is a Python-based micro web framework and server. Despite the word micro, Flask support extensions that can add multiple features and all of them are free of cost. Flask provides simplicity and flexibility by implementing a bare-minimum web server [11]. The Web server is running on Raspberry Pi 3 Model b and accessible using a public IP address. The Raspberry Pi is a low cost, credit-card sized computer, can be portable and also can handle multiple tasks [12].

The webpages are created with HTML, CSS, and JavaScript and for the database, SQLite has been used. Flask integrated with SQLite database, to store patient's health conditions that can be used later. Webserver provides an authentication for doctors and patients. Doctors are able to see multiple patients' data at a time and able to check the whole condition of an individual patient from anywhere using the internet. Patients are also capable to log in and see there real-time data as well as previous data. Patients can upload their medical reports for future use and for doctors to view their conditions and prescribe accordingly.

Data acquired from the patient's sensor is taken by a unique API for security purpose. Taken data is displayed in a table manner and also with the help of Google Chart API, a graphical form is on the website including individual date-time. The critical level also pointed out in websites.

C. *Wearable Device*

Arduino microcontroller is used for wearable device part. Here we used two sensors, one for body temperature and another for reading heart rate. Two sensors taking multiple data to take the best possible measurement. Piezo sensor is used for heart rate measurement and a good thing is which can be used as a patch. Piezo sensor data is in analog form and which is amplified and converted to a digital signal for the microcontroller to process. And LM35 is giving continuous body temperature of the patient. Temp sensor is placed below the device for best results as it is in direct contact with the patient. Arduino fetches the data from the sensors and sends it to the server by SIM 900D GSM module every 10 min. In a time of the critical situation, Arduino sends SMS through GSM SIM900D to emergency contact and also give an alarm signal. Fig 03 illuminates the whole progression.

IV. Equipment Details

A. *Hardware Module Description*

In this paper different instruments and technologies have been used for achieving the better output within the desired architecture. Sensors and modules are discussed below:

a) Arduino Nano

Arduino Nano is a very small development board which supports ATmega328 microcontroller. It has vast technical features. Nano has 14 digital I/O pins among which PWM output is provided by 6 pins.

It has 8 analog input pins. It also has 32 KB of flash memory, 2 KB of SRAM and 1 KB of EEPROM. Nano's clock speed is 16 MHz. Besides, it has an operating voltage of 5 V at logic level and recommended input voltage is 7-12 V. [13]

b) Raspberry Pi

In this paper, raspberry pi 3 model b as a server and database. This is a small computer with 1.4 GHz quad-core processor (64-bit), wireless LAN(dual-band), Bluetooth 4.2/BLE, Ethernet(faster than previous) and Power Over Ethernet support(with separate PoE HAT). Moreover, it has

1 GB ram, 40 extended GPIO pins, 4 USB 2.0 ports 4 pole stereo output port. [14]

c) LM35 Temperature Sensor

It is a temperature sensing device that senses temperature and gives a voltage output linearly proportional to the celcius (centigrade) temparature. It has a range of -55° to 150° and it's scale factor is 10 mV/°C. [16]

d) GSM SIM900D

SIM900a module is a breakout board with Quad-band(850/900/1800/1900 MHz)/Dual-band(900/1900 MHz) GSM/GPRS module.It communicates with controller through AT commands. It consumes very low power, at sleep mode it consumes 1.5 A current. It operates soundly at -40°C to +85°C temperature. Module [17]

e) Piezoelectric Sensor

Piezo electric sensor is a device which converts pressure, temperature or force to electrical charge. Piezo is a Greek word that means 'press' [18]. The change is electrical charge across the sensor due to blood flow in artery and veins is being calculated by microcontroller to determine human heart rate. [18]

V. Performance Measurements

First of all our wearable device containing both heart rate and temperature sensors are being attached with patient's body. After the setup of the device in patient's body, the microcontroller will begin to measure the data and it will send the final data to the server. Fig 04 shows the implemented wearable device in patient's hand.

Fig. 4. Wearable device at patient's hand

Figure 05 illustrates the login page for doctor and patients. Both doctor and patients have individual username and password for login. Only doctors are able to see all the patients they are assigned to.

Fig. 5. Authentication page

Figure 06 shows displaying of multiple patients real-time data to an authorized and specialized doctor. By clicking on the patient id doctors will able to see the whole data described in figure 06

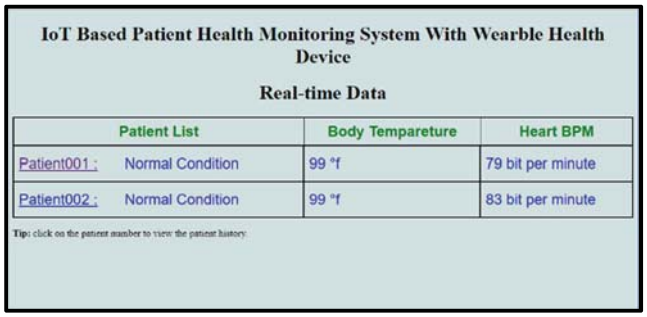

Fig. 6. Multiple Patients real-time data (Doctors view)

Figure 07 shows the all-time data of a single patient in a table manner. At the bottom an option for both doctors and patients is given to upload their ECG/Blood Group or any kinds of laboratory reports for better analysis of patient's conditions.

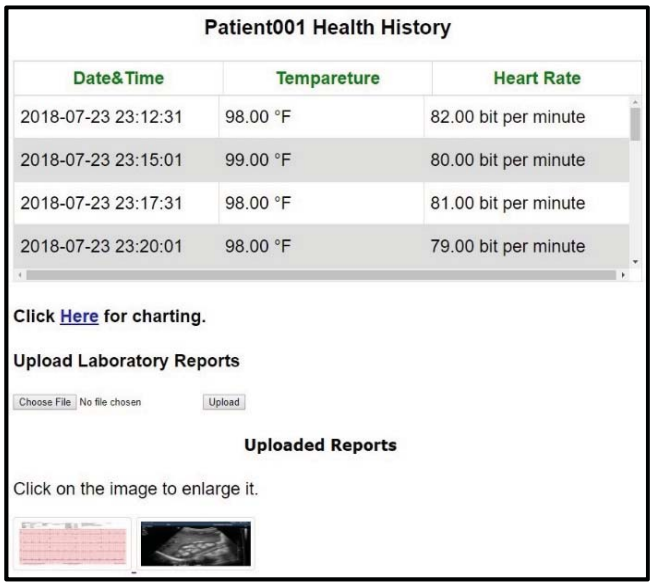

Fig. 7. Individual Patient health history and reports

Figure 08 clarifies temperature and bpm including their time and data using graphical form. Figure 9 shows the alert message sent to patient's emergency contact number to minimize patient's health risk. At the same time buzzer also gives a sound signal to a nearby person to help the patient.

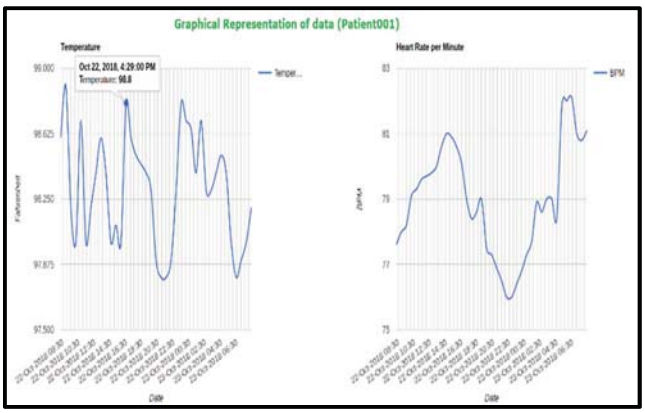

Fig. 8. Graphical representation of patient's health data

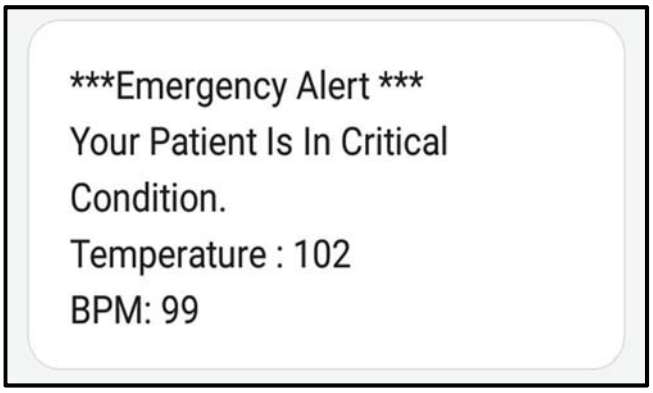

Fig. 9. Emergency alert through SMS

VI. Conclusion

Our designed system provides low power consumption, simple architecture and cost-effective. Using this system, the problem of insufficient doctors can be solved perfectly. The emergency alert system minimizes patient's health risks. The database gives doctors the opportunity to make decision observing previous medical data. This system is going to help minimize time wastage in a critical health situation. The system is accessible from everywhere by means of the internet. But still, there is some future development in our system to use the idea more fluently. Our heart rate sensor need to be update as it is still unstable when patients are moving. For example, Blood pressure, EEG, ECG, etc. can be implemented in the system. More sensors mean more data for doctors to identify diseases. For data security, advanced database security can be implemented. For a rural area, a video conference system can be included in the system which will give some extra benefit to prescribing medicine without traveling to distance.

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