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Original Article

An IoT-based Real-Time Remote Health Monitoring System

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Abstract *- Nowadays, most of the elder people get heart failure because they are not aware of their current heart rate when resting or doing some activities. Body temperature needs to be monitored remotely, even in rural areas, for diseases like COVID-19. IoT technology enables these facilities eliminating limitations of the current healthcare system. The aim of this paper is to develop a remote health monitoring system that can be made with locally available sensors with a view to make it affordable, easy and accessible to patients from rural areas. The proposed system is a real-time patient health monitoring system in which a patient's heart rate, peripheral oxygen saturation (SpO2) and body temperature can be monitored remotely, 24 hours in a day. This IoT-based remote viewing of the data enables a doctor or guardian to monitor a patient's health condition away from hospital grounds.*

Keywords *- Internet of Things (IoT), Health Monitoring, Pulse Oximeter and Heart rate Sensor, Temperature Sensor, NodeMCU.*

1. Introduction

Health monitoring is a major problem in today's world. As a result of a shortage of proper health monitoring, patients from different diseases suffer from serious health issues. Because of increasing work costs, medical institutions would compel to limit nursing staff for patients. Patients affected by infectious diseases like COVID-19 need to be monitored remotely due to its possibility of spreading among nurses also. Before inventing IoT, it needs 2-3 days to address an issue in a typical supply chain scenario for a satisfactory result. However, in IoT, it needs only minutes, seconds, or microseconds to take action. The high expectation and discharge of enormous data in the IoT environment indicate that the cost of data will reduce very soon. According to the WHO, 4.9 million people died from lung cancer, 2.6 million were overweight, 4.4 million for elevated cholesterol, and 7.1 million for high blood pressure [1]. Hypertension is a common disease that is mainly responsible for cardiac/stroke mortality of almost all chronic illnesses. But now, a limited number of remote HRV analysis systems is available for hypertension patient that enables doctors to track down the progression of the patient's health condition or critical issues in rural area [1]. These smart devices are also advantageous to health specialists to keep an eye on individually their patients. With tons of new healthcare technology startups, IoT is rapidly revolutionizing the healthcare industry. Here, we introduce a basic IoT-based healthcare monitoring system. Implementation of the nursing system will get a new dimension, and every patient can be monitored remotely. By this, based on procured data, immediate instruction can be given to the one who is in charge when the patient is in a critical situation. It may play a vital role in reducing labor costs, rather will be easy to assess from anywhere, anytime and will be helpful in taking an immediate decision. Thus, the nursing system will be digitalized. In the proposed model, patients can measure heart-beat rate, saturated peripheral oxygen level and body temperature by himself or herself, and that report is immediately sent to the doctors. Later that, those reports will be used to consult with doctors within a very short time. It also reduces the valuable time for both patients and doctors. They don't need to wait for the reports because sensors provide real-time data. The model is very effective for people in rural areas. IoT is served through Wireless Fidelity (Wi-Fi) technologies to send data or patient reports to the doctors with time and date. This proposed model can use any type of person, whether he or she is affected by a disease or not. So, they can check it on a regular basis because people pay more attention towards prevention and early recognition of disease.

2. Motivation

Developing countries like Bangladesh have a centralized tendency to use facilities in technology, livelihood, healthcare etc., sectors. Due to the lack of proper distribution of facilities throughout the country, people in rural areas lack of proper health treatment. They don't find the proper quality of treatment. Many people get treatment after the disease or fever gets too critical, considering the cost of treatment as well; many rural people cannot afford it. So, to make the first step of the treatment process easier, this paper is planned. A common man cannot afford the expensive daily check-up for his health. For this purpose, various systems which give easy

and assured caring units have been developed. This system reduces time with safely handled equipment. This contribution towards society will be very worthy because people can detect the abnormal practice of the body before getting into any serious disease. The person who is worried more about any other loved person can take care of and keep track of his health by sitting in any corner of the world with the help of IoT.

3. Literature Review

Naina Gupta et al. set forward an arrangement of IoT-based health monitoring systems that aims to settle the issue of time wastage during ambulatory services and in hospitals. They force to transfer the data via a GSM module connected through Bluetooth technology. Methodical health checks and monitoring of the different body parameters with the help of the different sensors attached to the body is the main focus of this work [2].

In [3], a low-cost IoT system for multi-patient ECG's monitoring is introduced. The authors introduced a prototype that is bound to work only on the transmission of Electrocardiographic signals through ZigBee wirelessly. By connecting different sensors to various nodes in the body, they accumulated a series of data which is in analogue form and made a web application for displaying the corresponding readings according to the patients. Their application is restricted to 20 users only, and the data comprises various bandwidth issue which causes errors in the proposed result.

Melisa Pereira and N. Kamath have analysed A novel IoT-based health monitoring system using LPC2129"[4] in which they sought to resolve the difficulty of wireless data transmission. Their principal elements are body fat level in percentage and heart rate. In the suggested solution, they adopted an Arm 7 processor that works on data transmission via wifi. The entire system appears to be confined due to the adoption of such technology that doesn't sustain considered long-range communication.

Tati Erlina et al. [5] made a system that is focused on solving the issue of monitoring comatose patients' physiological condition by monitoring heart-beat, respiratory rate and eyelids status. This total system is made to send the data to Android App on the mobile phone on which the application is made to show different readings measured. But the solution failed to hold the security of the system and put important data at risk.

In [6], Ashwini Gatte et al. proposed an IoT-based fitness tracking system for aged persons in which he used different parameters of body glucose, blood pressure, heart-beat rate as well activity monitoring etc., with the approach of Raspberry Pi. They also used ECG (Electrocardiogram) sensors for the heart-beat and other diseases and also proposed different IoT-based protocols which can be used in this type of system.

Niket Patil et al. worked on the fitness monitoring and apprehending system for soldiers using IoT [7]. They proposed the monitoring system using the sensors like LM35, Pulse Rate Sensor and Oxygen spotter sensing system, and for tracking purposes, they used GPS SIM28M, which is very precise in tracking the location of a soldier. This whole system is connected to the internet using Node MCU ESP 8266 Wi-Fi module, and it also comprises a panic button to get help in an emergency. And the whole system is low-cost, and sensors are connected with Arduino Uno (ATMega 328p) as the MCU Board.

In [8], An IoT-based patient monitoring system using Raspberry Pi along with sensors that track the Patient's Body temperature, heart-beat rate, body movement and Respiration Rate is introduced. Here IR transmitter and receiver are utilised to monitor the heart-beat rate. The transformer, specifically the step-down transformer, is adopted to bring the input voltage of 230 V to convert into 9 V and 5 V, and here, SMPS Switched Mode Power Supply is also used as every sensor has distinctive input.

Chowdhary et al. proposed an efficient health monitoring system with a GSM module connected to a Raspberry Pi in an assembly of different health monitoring sensors. This system focused on the direct transfer of health data in the form of direct messages on the phone of the doctor. They aimed to make it portable and hence decrease the load in the hospitals for patient monitoring. They obtained a speed of 20 seconds per reading for refreshing the updated value and storing the data in the system [9].

Nubenthan and Ravichelvan [10] developed a wireless continuous patient monitoring system for Dengue using a wireless interface for WBAN using IEEE 802.15.4j and IEEE 802.15.6 standards. They separated the hardware and used Wi-Mon software to collect the data from different sensors. This information provides the idea of patient seriousness in any disease like Dengue. Collection of vital information such as body temperature, pulse rate, ECG, oxygen saturation and blood pressure are used as a base material to monitor health with the accuracy of Wi-Mon software.

In [11], Khan et al. worked on a healthcare monitoring system with a combination of Arduino Uno and Raspberry Pi. They collected all the data with Arduino from all the sensors and then used a raspberry pi to shoot a video. Using a local server, they created a hub of reading that was updated every 2 minutes. This system was proposed to resolve the issues for aged groups and patients who do not regularly visit the doctor.

Uddin et al. proposed a real-time patient tracking system that can be supportive in ICU. This system configures all the data with the help of body sensors in support of Arduino Uno and transfers it to an application. This app helps monitor various parameters in a specific range and connectivity. With

the help of IoT Cloud and IoT protocols, they offered a varying range of transmission of data to the developed app [12].

An IoT-based patient health monitoring system using a wearable biomedical device is proposed by Zia Uddin Ahmed et al. [13]. In this system, sensors are connected to the microcontroller along with a GSM module for sending information to the user or their family in an emergency.

This system comprises so many hardware devices which are directly connected to the body of the patient. And this data is distributed in multiple sectors, and this allows the user to take data from multiple locations.

4. Working Methodology

The Working flow diagram of the real-time IoT-based health monitoring system is shown in Fig. 1. The system consists of three major embedded electronics: Pulse Oximeter and Heart Rate Sensor, Temperature Sensor and NodeMCU.

A 5V adapter is connected as a source supplier for the transmission of instructions from the PC to NodeMCU. The patient will touch the Pulse Oximeter and Heart Rate Sensor, and then the sensor's ray will count the beat from blood flow. Touching the temperature sensor will measure the body temperature. The results will then be uploaded via ESP8266, which is integrated into the NodeMCU module, and we can access the data from a mobile-based web server that acts as an IoT cloud.

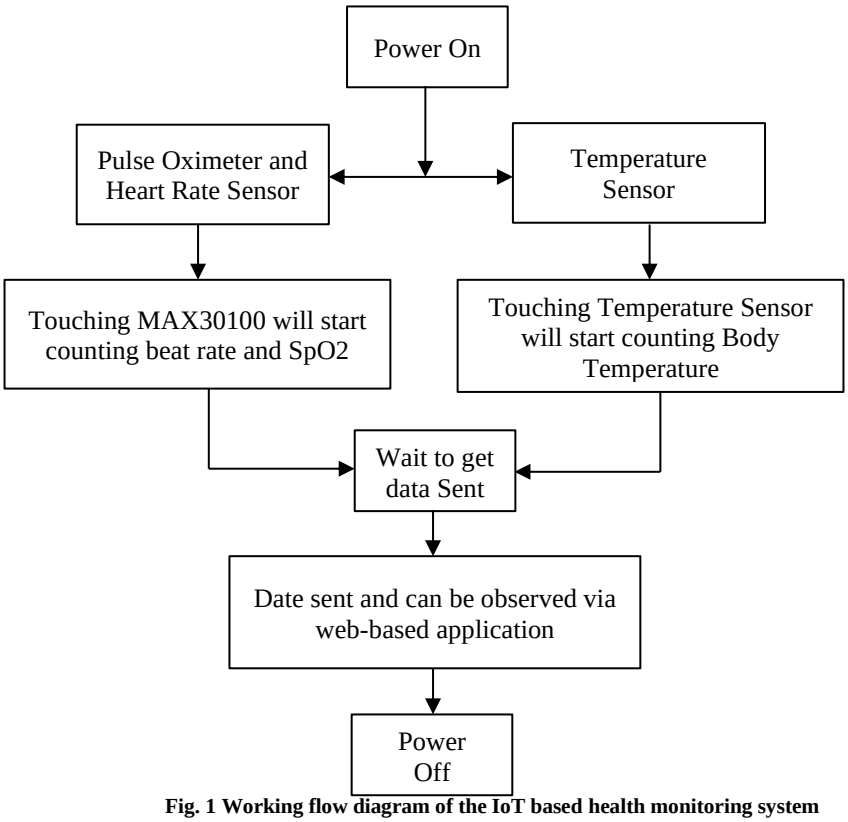

Fig. 1 Working flow diagram of the IoT based health monitoring system

4.1. System Model

The proposed health monitoring system model using IoT is shown in Fig. 2. Our paper is comprised of both hardware and software. In the hardware part, heart-beat, SpO2 and Temperature sensors are used. When the heart-beat, SpO2 and temperature are measured, the Wi-Fi module helps to upload it in a mobile APP-based Web server.

Fig. 2 IoT-based health monitoring system model

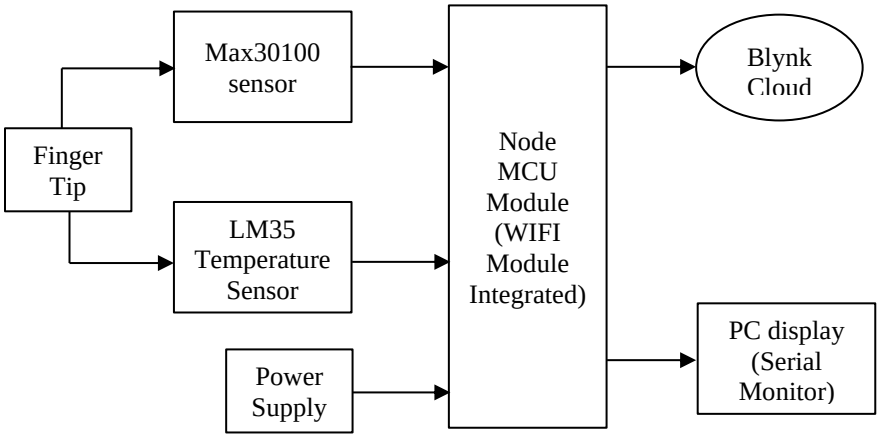

Fig. 3 Block diagram of the hardware implementation of the IoT based health monitoring system

4.2. Hardware Implementation

To run the system, first, we need to connect the NodeMCU module to the power supply, as it is the main control unit. On the input side, we have Pulse Oximeter and heart-beat sensor (Max30100) and temperature sensor. Moreover, the WiFi module integrated into NodeMCU Module helps to send data to the cloud, and when the data gets uploaded, we can check the output in the cloud application on the smartphone. First of all, a finger is placed in the Pulse Oximeter and heart-beat sensor and in the temperature sensor. After that, if the connection is built up, it shows the result in the serial monitor. And then, it sends data to the Blynk cloud to monitor from far. This is all about the block diagram in Fig. 3, which shows the entire process of hardware.

5. Practical Circuit Connection

Figure 5 shows the practical circuit of the proposed IoT-based health monitoring system. The precision of the system depends on the sound design of the circuit and the proper arrangement of the circuit elements. The performance of every circuit stage depends on the performance of the previous stage. So, each and every stage of designing must be meaningful.

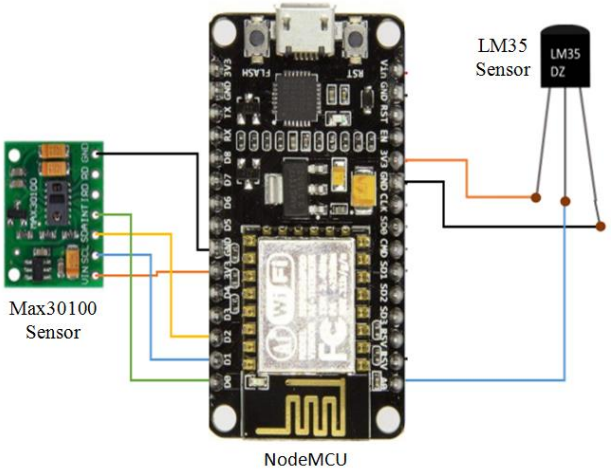

Fig. 4 Circuit diagram of the IoT-based health monitoring system

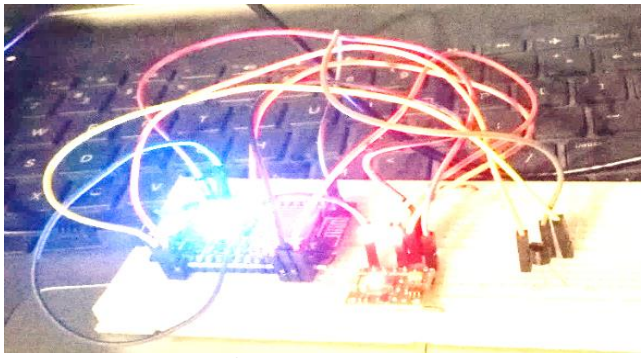

Fig. 5 Practical circuit of the proposed IoT-based health monitoring system

Sensors are connected to the NodeMCU module. Instructions are uploaded to this microcontroller via the Arduino IDE software tool. Now, as power is ON, the system is ready to measure heart rate, saturated oxygen and body temperature. The Wi-Fi module integrated with NodeMCU will send this value to Blynk to monitor remotely.

6. Results and Discussion

The proposed patient health monitoring system based on IoT worked successfully when implemented on a practical circuit. Heart Rate, peripheral oxygen saturation (SpO2) and Body temperature were sent to the web server from the circuitry. This part is presented below under three different health conditions: normal condition, fever condition and scared condition.

6.1. Normal Condition

During normal conditions, all the health parameters fall in the normal range: normal pulse rate of 60-100 beats per minute (bpm), normal SpO2 95-100% and normal body temperature of 97-99˚F for a healthy adult. Thus, we can see the parameters in the web-based server in the normal range. Figures 6 to 9 show the results of the health parameters under normal conditions. The values of health parameters recorded at a particular instant are shown in Gauge form in Fig. 6. The

live results of the pulse rate, SPO2 and body temperature against time are presented respectively in Figures 7, 8 and 9. Slight misalignment of results from the normal range may occur due to analog measurement of sensors and the high sensitivity of the sensor.

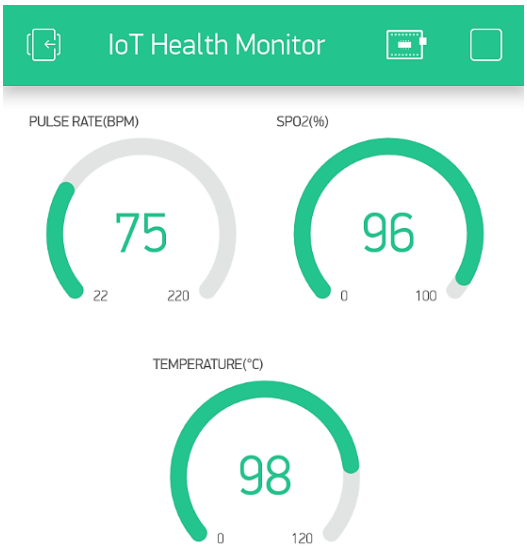

Fig. 6 Health parameters shown in gauge form under normal conditions

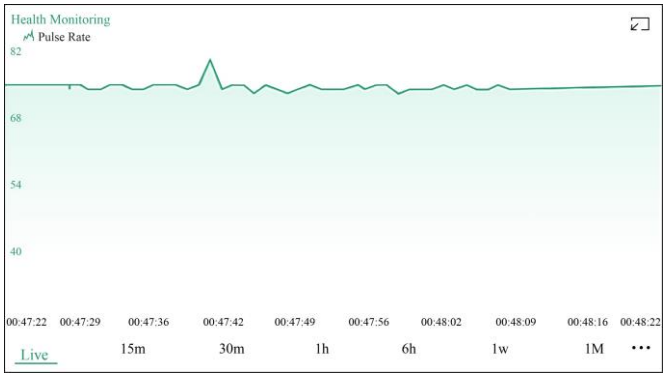

Fig. 7 Graph of pulse rate under normal condition

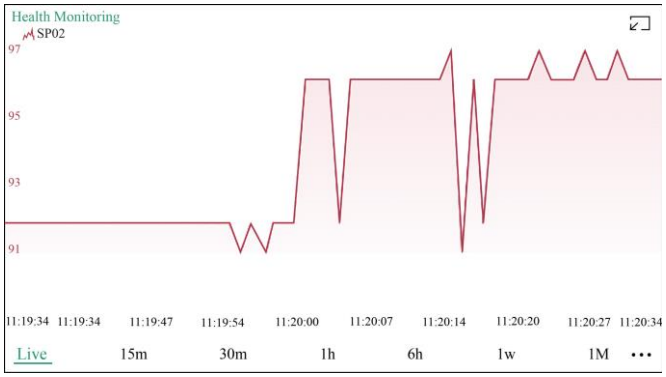

Fig. 8 Graph of SpO2 under normal condition

Fig. 9 Graph of body temperature under normal conditions

6.2. Fever Condition

Figures 10 to 13 show the health parameters when the patient suffers some fever. As fever is related to an increase in body temperature thus, in the figure, body temperature is greater (105.4 ºC). Heart rate increases a little with body temperature; thus, SpO2 decrease a little. But both heart rate and SpO2 fall in the normal range.

Fig. 10 Sensor parameters shown in Gauge form under fever conditions.

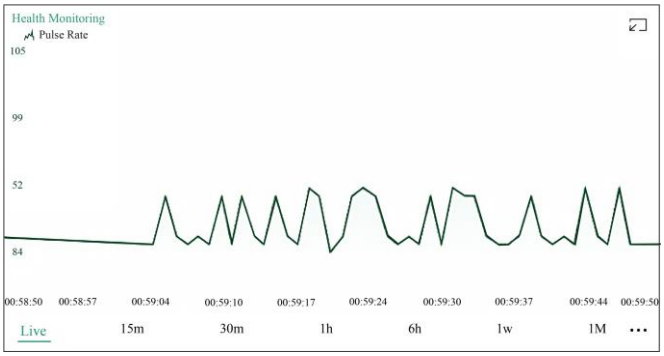

Fig. 11 Graph of pulse rate under fever condition

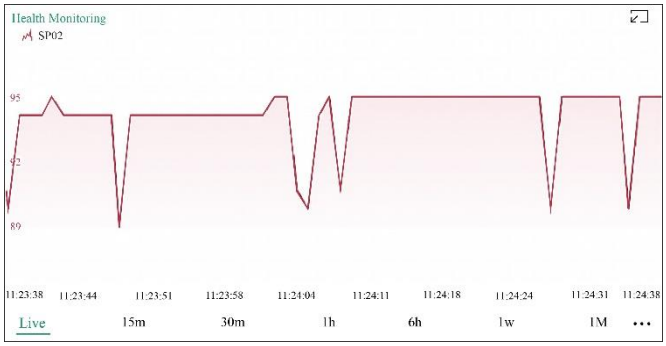

Fig. 12 Graph of SpO2 under fever condition

Fig. 13 Graph of body temperature under fever condition

6.3. Scared Condition

When someone gets scared, their pulse rate gets increased. Thus, the oxygen saturation level gets decreases, and the temperature gets increases a little bit more than usual condition. The abnormal increase in the graph is due to an instant increase in heart rate when someone gets scared. Figures 14 to 17 show the results. Note that there is an inversely proportional relationship between pulse rate and SpO2 and a proportional relationship between pulse rate and body temperature.

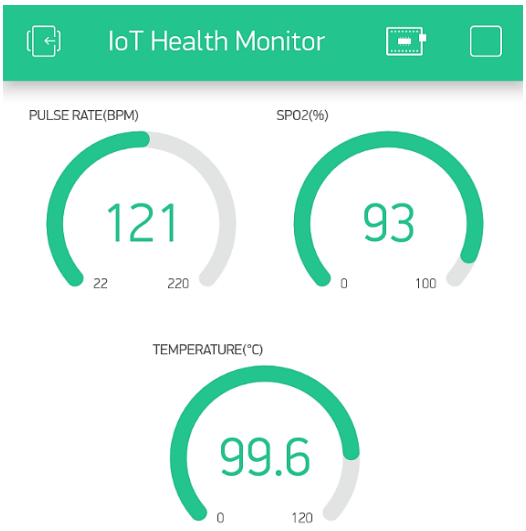

Fig. 14 Sensor parameters shown in Gauge form under the scared condition

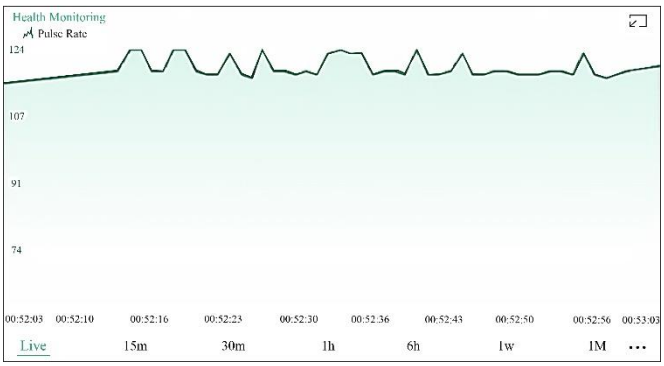

Fig. 15 Graph of pulse rate under the scared condition

Fig. 16 Graph of SpO2 under the scared condition

Fig. 17 Graph of body temperature under the scared condition

7. Conclusion and Future Work

In this paper, we have successfully developed an IoT-based real-time health monitoring system using locally available sensors that gives an opportunity to monitor patients continuously by using the web and app service. By using the proposed system, a patient's heart rate, peripheral oxygen saturation (SpO2), and body temperature can be monitored remotely, 24 hours in a day. Data has been presented and discussed under the normal, fever and scared health conditions. This IoT-based remote viewing of the data enables a doctor or guardian to monitor a patient's health condition away from hospital grounds and reduces healthcare costs, especially for people in rural areas people.

In the present work, we just have included two necessary sensors that give three health readings. In future, there is a scope for adding several developed sensors like ECG sensor, blood pressure sensor, blood glucose sensor, accelerometer, room temperature and humidity sensor, body movement/position sensor, vibration sensor, toxic gas sensor, CO/CO2 and much more newly developed sensors that will represent the system a complete package for health monitoring overall unusual health conditions. In future, we will add a web camera for constant monitoring of the patients in real-time and will develop our own website and enable secure login for every single patient. Also, we will try to develop a mobile-based application of our own that will add an emergency alert SMS option to nearby hospitals so that ambulances come as soon as possible. Also, SMS can be sent to the close one of the patients, and we can set up an arrangement that will enable doctors to give real-time prescriptions to the patients online according to the real-time reports.

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