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IOT Based Smart System To Monitor Patient Vitals In Real-Time For Communicable Diseases Like COVID-19

Aritra Dey, Biswamoy Pal
Student (MTech), JIS College of Engineering
Assistant Professor, JIS College of Engineering

Abstract

Due to the onset of COVID-19 pandemic, social isolation and quarantine have emerged as global essentials. IoT health monitoring systems prevent patients from meeting with medical professionals and making frequent doctor visits. However, medical staff must regularly monitor and observe the health of many people. The proposed work uses technology to make it easier for patients to get a diagnosis and treatment earlier. Using Internet of Things (IoT) technology, a smart health monitoring system is being developed that can monitor a person's temperature, heart rate, oxygen level, and blood pressure. This system is beneficial for villages and rural areas where nearby clinics can communicate with city hospitals about the health conditions of their patients. Nonetheless, in the event that any progressions happen in a patient's wellbeing in light of standard qualities, the IoT framework will caution the doctor or specialist in like manner. This health monitoring framework in light of IoT assists specialists to gather ongoing information easily. The system is able to regularly monitor the parameters thanks to the availability of high-speed internet. Additionally, the real-time data storage makes it possible to quickly retrieve previous measurements. Individual COVID-19 patients could be identified and treated earlier with the assistance of this system.

Keywords: IoT, Health monitoring, Sensor interfacing, Arduino, Android platform

Introduction

The COVID-19 pandemic's global spread has significantly altered and impacted individuals' daily lives. The health care systems of both developing and developed nations have been put under a lot of stress as a result of the sluggish production and delayed distribution of vaccines. The COVID-19 virus has significantly decreased the percentage of GDP in most nations. In this way, carrying back the Gross domestic product to a more elevated level is of prime worry as it relies on the recuperation of the populace too. Even though most of the country worked together to develop the vaccine, its deployment all the way through sanitization has helped the world economy recover quickly [1]. Additionally, as the most recent mutated Omicron virus [2] demonstrated, it is impossible to rule out the possibility of another wave being triggered by the removal of the restrictions. Therefore, the health authorities and departments are extremely concerned about the monitoring of COVID-19-infected and recovered patients in the wards. Therefore, the integration of sensor technology with the Internet of Things (IoT) and a machine learning algorithm for the processing of large amounts of patient data made possible the diagnosis and prevention of COVID-19 [3]. It was seen that in the colder time of year season, the disease pace of Coronavirus increments, as the circumstances for the endurance of SARS-CoV-2 infection is much positive [4]. Web of things is one of the arising advancements that is being consolidated in all aspects of human existence. The most widely recognized use of IOT is in the brilliant home, mechanized enterprises, schools, petroleum processing plants, climate observing frameworks, savvy urban areas and so on. Utilizing a smart health monitoring system based on the internet of things (IoT) can lessen the challenge posed by COVID-19. This could be worn like a smart watch or embedded in the COVID-19 patients' beds. Biomedical signs can give data about a singular's wellbeing, such a lot of data could be assembled, and essential deduction could be long of perception. Heart rate, SPO2, CO2, temperature, blood pressure, and other biomedical signals can be sensed to identify COVID-19. AI procedures could be conveyed to distinguish the Coronavirus patients out of a lot of information through estimating the wellbeing boundaries, putting away on the data storage with the assistance of IoT. The joining of AI with IoT will be worthwhile in numerous ways. The health authorities would be able to use IoT technology to separate patients who require immediate treatment from those who can be quarantined at home, preventing a huge patient bubble at hospitals and community health centres. The IoT-based smart health monitoring system might make hospitals use less oxygen. To keep track of where the recovered patient is, this system could also be integrated with a GPS chip. People in offices, hotels, and educational institutions are physically interacting now that the lockdown has begun in most countries, increasing the likelihood of COVID-19 infections and moving toward the third wave of the pandemic. Thus, in such a situation, information of the people is imparted to the wellbeing specialists, and the conceivable tainted people could be isolated speedily.

An automated health monitoring system that responds to or raises an alarm when the patient is in a critical situation is being developed. The data are analysed by an ESP8266 Node MCU microcontroller before being sent to doctors and concerned individuals via email and Twitter. Moreover, it likewise records and keeps up with the previous demonstrative data in regards to the patient wellbeing. The actual condition of the patient is communicated to medical professionals via an online portal, and the appropriate treatment can be implemented to cure the patient [5]. The smart patient health tracking system involves installing sensors for the patient's heart rate, temperature, and humidity in the room to monitor their condition. All of the values are sent to the doctor for evaluation after processing [6]. The gain of the signals from sensors like temperature, electroencephalogram, and heart rate readings is increased by passing them through an amplification and signal conditioning system. Data can be sent for storage and analysis by using any microcontroller, such as an Arduino [7]. The IoT-based framework is equipped for giving continuous data about the patient boundaries, as the web is an excellent correspondence channel, the security of the data is one of the difficult issues [8]. The wearable healthcare monitoring system could be used on a daily basis in the coming years thanks to the development of internet technologies like cloud computing, edge computing, and fog computing [9, 10]. A health monitoring system that can be used for physical rehabilitation and real-time tracking of disabled people is dependent on the measurement of biomedical signals with the various sensors [11]. When paired with wearable smart devices, portable biosensors can keep track of an individual's daily activities, aid in health management, and prevent life-threatening diseases from getting worse [12]. The individual health monitoring console (IHMC), through which the physician and team of specialists can easily access the biomedical data collected by sensors for purposes of evaluation and analysis, is another major obstacle in the development of a smart health monitoring system. Brahmni et al. created a similar IHMC. where patients' big data is managed by a cloud-based system in order to monitor and find pre-symptomatic COVID-19 [13]. Implementing the Internet of Things system with high levels of security and encryption to prevent data breaches is the main obstacle. The other major difficulties involved in storing the substantial amount of patient data in the cloud, where it could be retrieved with minimal delay. This system is novel because it can be installed on each patient's bed and share real-time patient data with doctors using a smart device that is connected to the internet. Additionally, this health monitoring system has the potential to be made into a wearable device that helps in the prevention of COVID-19 and other diseases.

Numerous analysts have done the work for the expectation of wellbeing utilizing savvy medical care IoT. Hamizah Anuar et.al. examined the improvement of wearable CBT (Center Internal heat level) sensor gadget in view of a solitary intensity motion idea. The sensor has been used in experiments on a variety of body parts, and the forehead provides the most accurate CBT estimation because the mean difference between the CBT sensor and the clinical thermometer is only about 0.05 °C [14]. Po-Wei Huang et.al. demonstrated the application of the Neural Network Regression-based algorithm to lengthen the 50-100 cm distance range. The programmed face following component requires the human face ought to be centred properly while estimating. The data and results can likewise be seen through Application and Web [15]. Rahman and others discussed the various kinds of smart health monitoring systems and the benefits and drawbacks of the technologies that are used in health care systems [16]. A wearable temperature measurement system that can be used in healthcare applications has been developed by Huang and his co-workers [17]. An exhaustive survey was finished by Albahri et al. on various IoT based innovation that could be used for telemedicine and medical care administrations for anticipation against different sicknesses [18]. A review was helped on a mission to screen understudies wellbeing through IoT based remote framework having a capacity of a continuous ready that can be shipped off guardians/watchmen [19]. A remote COVID-19 patient monitoring system that incorporates the measurement of vital body parameters like PPG, ECG, and temperature for identifying the patient's health status was developed by some researchers along a similar research path. Moreover, they likewise talk about the issues connected with security worries in IoT based savvy wellbeing frameworks [20]. Bassam and co. demonstrated the use of a wearable health monitoring system with a real-time location tracking feature and embedded GPS for COVID-19 patients. The entire system is connected to the Android interface via an API in order to monitor the health and recovery of the patient [21]. Paganelli et al. proposed a framework that is comparable. discussed various monitoring architectures for COVID-19 patients that may aid in the detection of the virus [22]. The application layer, the data distribution layer, and the data acquisition layer make up the majority of the proposed architecture. However, there are a few issues with the majority of IoT-based health systems, such as communication delays and latency. The fog computing and data mining algorithms can be used to find a solution to all of these issues [23]. A block encryption-based model could be used to secure data on the cloud because patient data security is one of the main concerns of the IOT-based smart health system [24]. Other parameters, such as gesture, facial expression, and body language, can be sensed to identify seizure or non-seizure epilepsy conditions, which can help a doctor decide on the patient's treatment through remote monitoring [25]. This is in addition to the common disease detection method of measuring vital body parameters. Bhatia et al. demonstrates how an IoT-based home system can be used to predict urinary infections like diabetes, cystitis, hepatitis, liver disease, and others [26]. Another review examines the advanced job of IoT in wellbeing checking of individual zeroing in on sickness the executives, patient experience, powerful therapy and job of 5G in correspondence [27]. The significance of machine learning in accurately assessing and managing cloud-based data for disease prediction is the subject of a Kondaka research group study. The IoT smart health system's errors can be reduced using deep learning techniques [28]. Li and his coworkers conducted a comprehensive survey to determine how well big data analytics and machine learning can address issues like cloud security, storage allocation, communication delays, and data retrieval. 29]. The IoT framework could be used for expectation of sedimentary way of behaving of individual utilizing AI strategies by evaluating the way of behaving, motions, wellbeing boundaries and so on [30]. An IoT/WSN based cloud framework was proposed by Onasanya et al. for location and therapy of disease patients zeroing in on the significant difficulties, for example, security and proficiency [31]. With the help of eight distinct learning algorithms, a second Internet of Things system was developed to identify potential COVID-19 patients [32]. This system helps to differentiate the symptoms of the common cold from those of COVID-19. The use of IoT systems to monitor patients in smart cities so that ambulances and other forms of assistance can reach patients' locations is the subject of a study [33]. Wan and co. developed a wearable Internet of Things health monitoring system with its own body area network, in which various sensors continuously measure and store parameters [34]. All the IoT innovation were either conveyed to medical clinic, or to home or wearable, so in every one of utilization region the framework experiences a portion of the worries. Uslu and co. discuss some of the things that must be taken into account when designing and implementing an automated IoT health monitoring system, such as the infrastructure of the IoT layer, intelligent computing, big data analytics, and network traffic [35]. When designing an IOT-based health monitoring system, a number of major issues arise, including the misuse of patient data, cases of cybercrime, data aggregation, and others. 36]. Following of Coronavirus cases is of prime significance which help the Govt. specialists to follow the patients and, in this manner, forestalling the further spread which would be conceivable with the help of IOT based global positioning framework [37]. Constant checking of Coronavirus patients with the assistance of large information on biomedical signs could cut down the transmission instances of Coronavirus [38].

The following is how the research article is laid out: The related research on smart health monitoring systems is discussed in "Introduction." The "Methodology" contains the methodology and work flow for putting the prototype into action. "Design of System" discusses the design strategy for the various hardware components in "Details of System Components." The system's performance evaluation and the acquisition of patient data are discussed in "Result and Analysis." The last segment presents the end and cutting-edge examinations that can be carried out to make the IoT based savvy wellbeing framework a safe and productive one.

Methodology

The IoT-based health monitoring system is very efficient in comparison to the standard healthcare system. Because the sensors use electronic data signals, working with IoT is related to the embedded world. As a result, it becomes more difficult to achieve the required results and performances. In the beginning, the microcontroller, sensors, detectors, and other components are all connected together for synchronization. The sensors and finders recognize the signs in simple structure, which should be additionally changed over into computerized structure. The inbuilt simple to advanced change is performed through the microcontroller to get information in legitimate computerized design. The data are sent to a microcontroller called Arduino. Nowadays, the Internet of Things makes the most use of the Arduino. After the change of information, stockpiling of information is performed. The information is being shipped off for real-time data storage.

The circuit diagram of the proposed work is shown in Fig. 1.

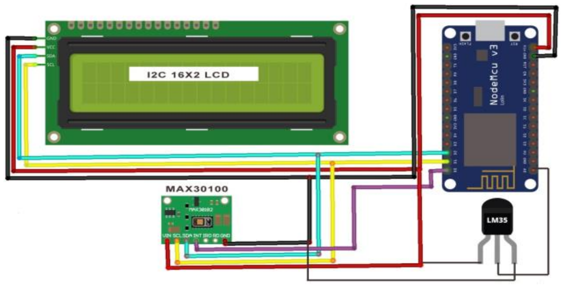

Fig. 1

Circuit diagram of proposed IOT smart health system

Figure 2 shows the flowchart of the steps performed in the whole process. It shows the order of the workflow and steps in the sequential order, including the initialization, setting up of protocols successfully, reading sensor values accurately, sending measure values to display monitor and android application to store sensor data.

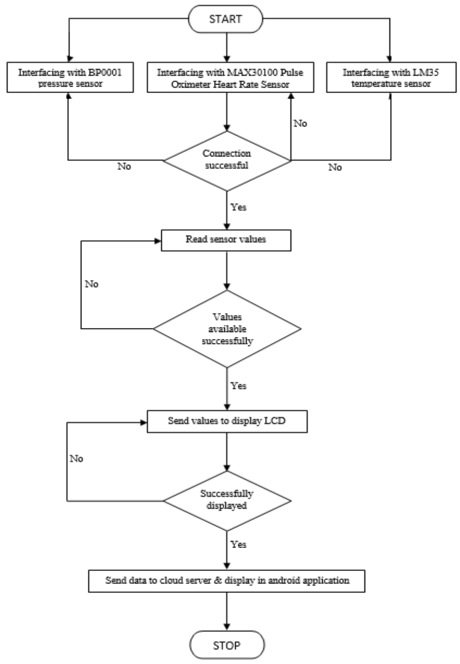

Fig. 2

Flow chart of IOT smart health system

Details of System Components

This section deals with the hardware components that are necessary for the prototype's development such as the oximeter, temperature sensor, blood pressure sensor, and microcontroller with built-in ADC. The Corona virus infection initially enters through the nostrils and mouth thereby moving towards the breath arrangement of human. Owing to high blood pressure found in COVID-19 patients, one of the most important parameters in detecting COVID-19 is measuring the blood pressure. In order to track and identify potential COVID-19 infection, COVID patients must have their temperature and oxygen level monitored. Since it was discovered that COVID-infected individuals had drastically reduced oxygen levels, it is measured using an oximeter. The microcontroller (Arduino IDE) is to be interfaced with all of the sensors in order to display the data, record it and process further.

NodeMCU

NodeMCU is an open-source firmware and development kit that helps you to prototype or build IoT products. It includes firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The firmware uses the Lua scripting language. It is based on the eLua project and built on the Espressif Non-OS SDK for ESP8266. The schematic diagram of NodeMCU is shown in Fig 3.

Fig. 3

NodeMCU ESP8266

Blood Pressure Sensor

The BP sensor is wrapped around the arm and it gives three different values or data to the microcontroller. In these values, first one is systolic, second is diastolic and third value is pulse rate and are fed to the Arduino IDE. Sensor BP0001 is board mount blood-pressure sensor which is used for this research work, having pressure range of 0–300 mg and an accuracy of about ± 1%. The schematic of BP sensor is shown in Fig. 4.

Fig. 4

Blood-pressure sensor BP0001

Temperature Sensor

In this project, an LM35 analogue temperature sensor (figure 5) is used to measure body temperature. This sensor is able to read temperatures from −55° to +150°C and has a 0.5°C tolerance. This sensor is put under the body arm and is connected to the analogue input of the NODEMCU as it is shown in circuit. The sensor imports the analogue data and it converts to a digital value using an internal analogue to digital (A/D). Then the digital value is converted to a Celsius temperature. Afterward, this temperature is transmitted to the NODEMCU to be sent to the Server using an ESP8266 WI-FI chip included in the NODEMCU module.

The schematic of sensor LM35 is shown in Fig. 5.

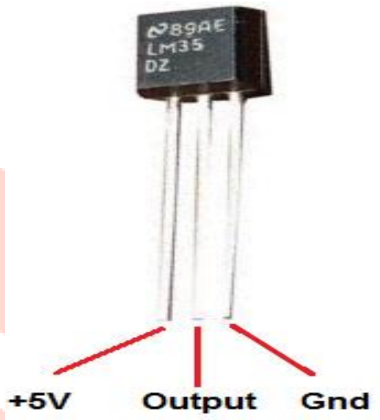

Fig. 5

LM35 analogue temperature sensor

Pulse Oximeter

The MAX30100 is an integrated pulse oximetry and heart-rate monitor sensor solution. It combines two LEDs, a photo detector, optimized optics, and low-noise analogue signal processing to detect pulse oximetry and heart-rate signals.

The MAX30100 operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times. Pin diagram and schematic of the sensor MAX30100 are shown in Fig. 7.

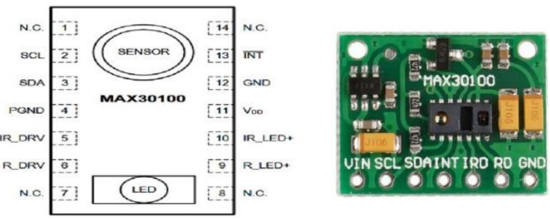

Fig. 7

Pin diagram of MAX30100 Pulse Oximeter Heart Rate Sensor Module

Data Storage and Display

A 2 Inch LCD Display Module is utilized in developed prototype smart health monitoring system. The LCD display Module is in-plane switching screen (IPS), having a 240 × 320 resolution. It has an inbuilt embedded controller and, communication is carried out by SPI interface. The SPI interface requires minimum GPIO pins for controlling its functionality. Figure 8 shows the schematic of LCD display.

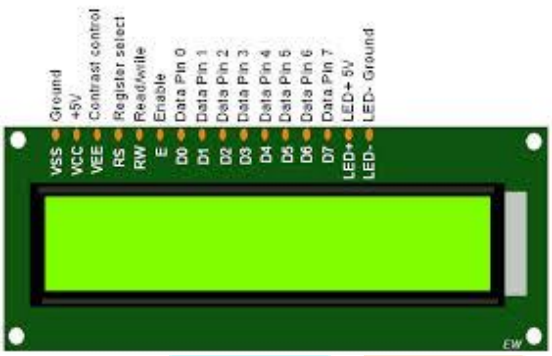

Fig. 8
Schematic of LCD display

Design of System

The three main steps that make up the entire workflow are: information catching, information handling followed by information capacity, and showing patients' boundaries on the screen. Information catching is the main step as the accuracy and precision of estimation framework rely exclusively upon this step. In information catching, the sensors to be utilized are associated with microcontroller for example Arduino IDE. The sensor yields are associated with the GPIO pins of Arduino IDE, which have been chosen. The Arduino IDE's Rx pin is connected to the BP sensor's Tx output pin. In the wake of making the equipment associations, the power supply of + 5 V is given to the microcontroller and to the sensors. The Arduino IDE module and various sensors are powered by the SMPS-based power supply. The most extreme power utilization of entire framework is 7-8W as Arduino could be designed in power saving mode when no information transmission is occurring with Wi-Fi. The IC-based sensors used for measurement and data acquisition all require a low load current value. The effectiveness of force SMPS used to drive up every one of the gadgets is moderately high (80-85%), a portion of the proficiency is lost in heat scattering. With various biomedical sensors for each patient, the developed system could be scalable to optimally monitor five patients simultaneously.

The microcontroller, or Arduino IDE, is initially connected to the sensors that will be used. The GPIO pins of the Arduino IDE that have been selected and set up as input are connected to the sensor outputs. The Arduino IDE's Rx pin is connected to the BP sensor's Tx output pin. The microcontroller and the sensors receive a +5 V power supply after precise hardware connections have been made. The LM35 analogue temperature sensor is put close to the human body and it distinguishes the temperature of patient. The microcontroller receives three distinct values or data from the BP sensor and the pulse oximeter, which is encircled around the arm. These values are - systolic, diastolic, beat rate and O2 stats; which are fed to the Arduino IDE for processing.

The outputs of the sensor values captured by Arduino IDE are now sent to the display monitor to view the corresponding values. The required information is displayed on the screen and at the same time is stored on the android application for maintaining further records. In this way, the required information is displayed on screen and at the same time is stored in real-time which can be retrieved by the doctors for future analysis. The data can also be easily assessed by other users and researchers.

Result and Analysis

The planned model is tried on various patients or subjects to get the presentation of wellbeing observing framework. The heart rate, body temperature, blood pressure, and SPO2 were all measured for performance analysis. The adequacy of the framework can be assessed by contrasting the estimation information and business sensors accessible.

The comparison of measured heart rate data with the commercial sensor is shown in Table 1. It was discovered that the relative error was between 0.00% and 2.74%. The relationship between the relative error and the number of subjects is depicted in Figure 9. The patient's internal heat level was estimated with LM35 sensor and was compared to a commercial contact thermometer shown in Table 2. The maximum relative error was processed as 2.90%. These readings rely on environmental conditions like dampness as well as the exact arrangement of the sensor. The relationship between the temperature measurement's relative error and the number of subjects is depicted in Figure 10. The developed system is used to take the blood pressure, and the results are shown in Table 3. The developed system has measured the oxygen level in COVID-

19 patients using a separate SPO2 sensor (Table 4). The O2 measurement system's high accuracy was demonstrated by the fact that the maximum relative error was found to be 1.04%. The plot between the relative error and the number of subjects is shown in Figure 11.

Table 1

Comparison of data values measured by Heart rate sensor and commercial sensor

Number of samples	Actual bpm	Observed bpm	Relative error (%ϵr)
D1	68	69	1.47
D2	69	70	1.45
D3	70	70	0.00
D4	71	72	1.41
D5	70	71	2.74

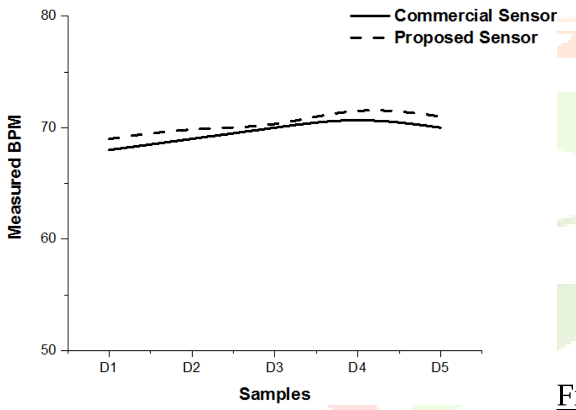

Fig. 8

Relative error vs. number of subjects in Heart rate sensor

Table 2

Body temperature collected with LM35 temperature sensor and its comparison with commercial contact thermometer

Number of samples	Actual body temperature	Body temperature observed	Relative error (%ϵr)
D1	34 °C	35 °C	2.90
D2	34 °C	34 °C	0.00
D3	35 °C	36 °C	2.85
D4	35 °C	35 °C	0.00
D5	36 °C	35 °C	2.78

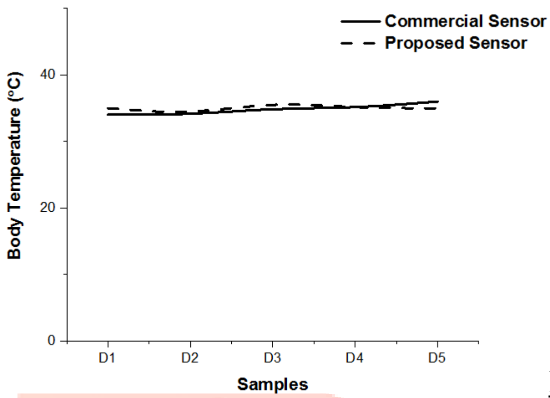

Fig. 9

Relative error vs. Number of subjects in BP measurement

Table 3

Blood Pressure data collected with the developed IOT system

Number of samples	Systolic	Diastolic
D1	110	61
D2	115	74
D3	121	86
D4	123	72
D5	120	80
D6	141	90

Table 4

Comparison of developed SPO2 system with commercial oximeter

Number of samples	Actual SPO2 (in %)	Observed SPO2 (in %)	Relative error (%ϵr)
D1	98	98	0.00
D2	96	97	1.04
D3	97	97	0.00
D4	98	99	1.02
D5	97	98	1.03

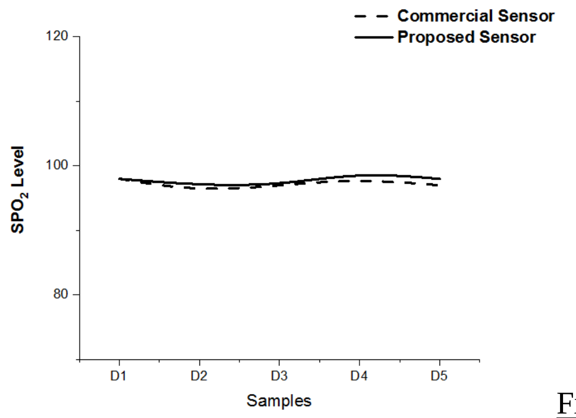

Fig. 10
Relative error vs number of subjects in SPO2 measurement

Figure 11 depicts the developed IOT health system, which includes BP monitoring and the connection of various sensors to the microcontroller. Figure 12 depicts snapshot of the Android application displaying the patient's data. The model of the smart health monitoring system can be put and installed near the bed of the Coronavirus patient. The real-time measured data are collected, stored and deployed to cloud by means of the android application. The data pertaining to a specific patient can be accessed by physicians or doctors from the cloud servers. The nurse and doctors will be given a link to an online access point for monitoring purposes. Any computer with an internet connection, smart tablet, or smartphone could open this link. Every patient is related to unique ID number which is created when a patient is conceded for observation and treatment. When all patient parameters are below the limit, i.e., no indicative symptoms are present, a COVID-19 patient can be removed from the COVID ward. A system of this kind would make it easier for doctors to decide how to treat COVID-19 patients. The impediment of this framework is that similar arrangement of sensors is to be utilized for estimation purposes. Security is another major drawback of this system, as data spoofing is possible. In order to make the system as a whole extremely secure, a separate cloud equipped with encryption-based technology may be required. Before being shared with any doctor, the data would be encrypted. The patient's prescription could be linked to the patient's country identification number or health card digital ID in a future upgrade. For individual patient checking, separate sets of biomedical sensors are to be sent to individual Coronavirus patient's bed. The additional benefit of this framework is that this framework can be even sent to non-Coronavirus patient treatment, and the expense of this framework is moderately low. This brilliant framework can diminish the weight on the clinics and doctors, which eventually helps in the early recognition and treatment of Coronavirus illness. This created framework would be valuable to a huge society as individuals from low-pay segments are predominantly reliant upon the public authority emergency clinics and enormous number of these frameworks because of its minimal expense, could be sent no sweat and could help the patients.

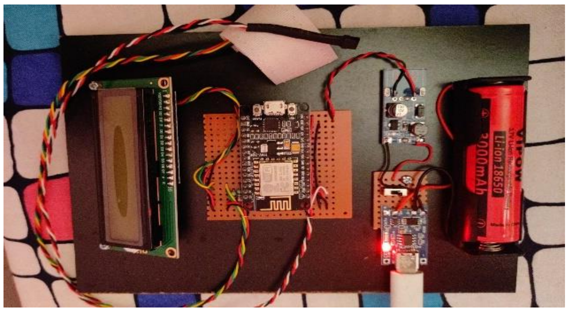

Fig. 11
Image of developed prototype of smart IOT health monitoring system

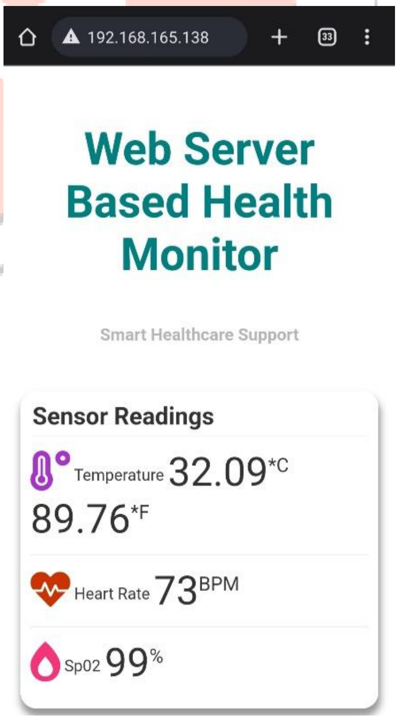

Fig. 12
Screenshot of the android application developed for real-time data monitoring

Conclusion

The developed smart health monitoring system makes it easier for doctors to identify each patient's information by simply displaying it on a display monitor at their location. Doctors are able to differentiate the patient's data based on the patient's prior logged values and present ones. Alongside data storage, the Internet of Things likewise gives valuable opportunities to add further developed highlights or advantages and more biomedical sensors to this framework. As a result, IoT technology makes this monitoring system more adaptable and future-ready. By monitoring a patient's vital stats such as body temperature, heart rate, oxygen level, and blood pressure in this proposed work, we have utilized technology to simplify diagnosis and treatment. Therefore, utilizing the newly developed IOT smart health monitoring system, contactless tracing and treatment of COVID-19 patients are very much within reach. Securing the data of the patients and making the data available to the physician within the allotted time with less delay are the primary difficulties of this developed prototype. Encrypting data, which would protect it from a security breach, is one method. Using the edge computing method, secured on-demand patient data would be made available for analysis. The use of cryptic keys and machine learning algorithms along with unique IDs would make it easier for hospitals and health services to identify potential COVID-19 patients from a large amount of data.

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