WSN Based Health Monitoring System for COVID-19 Patients

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Abstract The entire humankind is combating the COVID-19 pandemic since the onset of 2020. The increase in the cases has triggered an alarming situation all over the world. Doctors and hospital staff are working overtime in the COVID wards by putting their lives at risk. As the health line workers are in immediate contact with the patients, it causes a high risk of spreading the infection among them. To avoid immediate contact of the medical personnel with the patients, the work presented in this paper aims at devising wireless sensor network (WSN)-based COVID-19 patient health monitoring system, which is enabled with IoT and is useful in evaluating the patients, keeping a check on their vital/ health status without coming in contact with them, and eventually creating a feasible method of sending information related to the health of patients to the health staff. The doctors/nurses can keep an eye on the health stats and keep a check on the overall condition of the patients. In case hospital beds are not available, this system can also be used when the patient is home quarantined. The health personnel can take necessary action according to the parameters through mobile phone/desktop. The medical personnel may check these parameters through mobile phone or desktop and may take necessary action accordingly. Thus, the health monitoring system proposed in this paper helps monitor the data of patients remotely, and this decreases the need for contact between the health line workers and patients. This further lessens the possibility of infecting them.

Keywords Wireless sensor networks (WSN) · Internet of Things (IoT) · I2C communication · Wi-Fi

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1   Introduction

Since the very initial stage of corona virus disease 2019 (COVID-19), the cases have only surged. A lot of research regarding the diagnosis of COVID through artificial intelligence using different cough samples has been accomplished [1]. The virus is deadly and causes severe health problems as its after effect. It is difficult to lessen the spread as the symptoms are unable to be tracked on time and report. Despite the testing and trials of vaccination, the count of cases to decrease to a single digit will take some time. Hence, for areas which fall under containment zone and where the infection is spreading at a faster rate, therefore monitoring the patients remotely is advisable. Going by the advancements in technology, the WSN based patient health monitoring system fits correctly in this scenario [2]. These health monitoring models are widely used in the healthcare sector [3]. Health monitoring systems with IoT provide remote monitoring and early diagnosis [4]. One of the benefit would be to secure the load of being quarantined in the hospital (Fig. 1). And the patient can save himself from the hassle of going to the doctor and wait in a queue [5].

Despite continuous efforts from the medical personnel, it gets difficult to keep a track as the number of patients keeps on increasing every day. Thus, the solution of remote patient monitoring can be used. Remote patient monitoring also comes with many benefits like the patient can stay at their homes, while the health line workers can keep a check from distant location [6]. In the situation, this system comes as a first-hand solution to control its spread [7]. Real-time wireless health monitoring finds its applications in monitoring various kinds of health issues and diseases such as measuring blood pressure, body temperature [8], and cardiovascular diseases [9].

The objective of this paper is to design and implement the patient health monitoring system for the people struggling with COVID-19. It has sensors that will keep
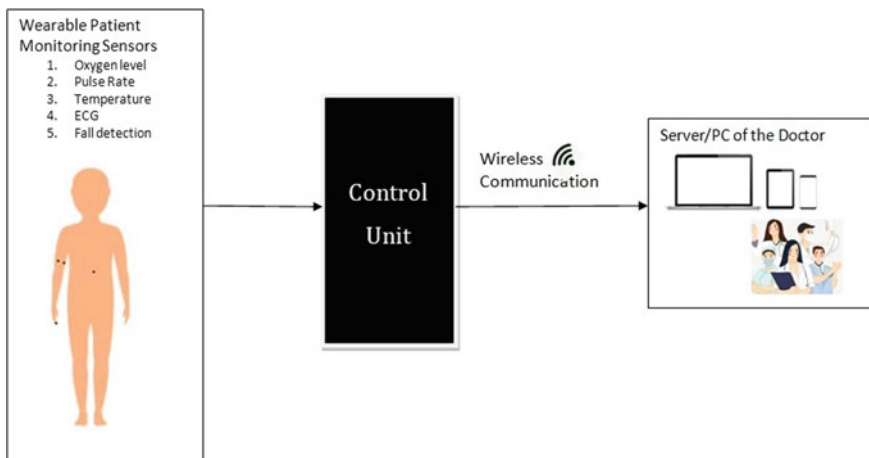

Fig. 1 Proposed system

track of the vital stats, thereby reducing the cost of visiting the doctor [10]. The nodes empower the network which is acquired over a wide area and process it which is further transmitted to ESP32. In case, the parameters fall out of the range described the buzzer rings. One main parameter to keep a check on the person's health is the heart rate of the patient [11, 12]. The common symptoms of COVID-19 include low oxygen level, high temperature, and high heart rate, and in some cases, the patient may lose balance. WSN (a self-configured) is wireless network responsible for gathering, processing, and distributing data to the sink where data is gathered in the database storage center. This database storage center acts as a medium among the network and the users [13, 14]

Recent literature survey and advancements in innovation have made it simpler to gather information anywhere, be it in the home, industry, and across urban communities [15, 16]. As this information is gathered and deciphered, the information would now be easily accessible. These steps are making what is known as the Internet of Things (IoT), the Internet of Everything, it is used to be known as Machine to Machine (M2M) correspondence [17]. Earlier GSM modules and Bluetooth devices were being incorporated to monitor the patient's health status. The current circumstance is advancing quickly with the making of low power WSNs [18]. Presently, the gathered information can be given to individuals who need it. Systems for health monitoring based on IOT are effectively put to use for various diseases [19–24].

2 Methodology

2.1 Proposed System

The main goal is to design and implement a wireless sensor network-based patient health tracking device for COVID-19 positive patients. Sensors are placed on the patient's body (arm/chest) suffering from COVID-19 or any other communicable disease to sense heart rate, oxygen level, and core body temperature of the virus contained patient and of the environment. Two sensors are placed on the arm to analyze heart rate and vibrations, and for fall detection. Along with four sensors, an emergency button is provided for notifying the health staff. The sensors are further interfaced to a control unit that calculates the values; the data is eventually then transmitted to the cloud server. The data can then be accessed by the medical staff or doctor at any other distant location. Therefore, based on the parameters (heart rate value, oxygen level, body and room temperature, the electrical activity of heart contraction and fall detection vibration), the doctor can analyze the virus-contained patient and therefore suitable measures could be taken.

2.2 Sensor

- Pulse oximeter measures the value of heart rate of a person along with oxygen level. The oxygen level is measured by sending the infrared light into capillaries in the finger, earlobe, or toe and detects the amount of light reflected off the gases. Pulses are digitally detected by the microcontroller to give the suitable outcome, explained with the formula:

$$\text{Beats per minute} = 60 * f, \text{ where f is the pulse frequency}$$

- Temperature sensor is connected to the microcontroller via analog pin and through which the signal is transformed in digital value using ADC. This digital data gets converted into the actual temperature value in degree Fahrenheit using the equation:

$$\text{Temperature (F)} = [\text{temperature value} * 9 / 5 + 32]$$

- Electrocardiogram (ECG) sensor is used to determine the electrical waves of the heart to diagnose different heart conditions.
- Knock sensor measures the fall detection of any patient due to breathlessness. The sensor gives the value "0" when no fall is detected and gives the value "1" when the falling of a person is detected.
- Emergency Button allows the patient to notify the doctor or the medical staff incase he/she feels unwell.

2.3 Protocol Used

I2C communication inter-integrated circuit is a serial communication protocol, transmitting data bit by bit through a primary wire. As the data packets are to be transmitted after a particular duration, clock signal shared among the master as well as the slave is considered for synchronization of output of bits to sampling of bits.

Wi-Fi -the microcontroller implements Wi-Fi Direct specification and TCP/IP full 802.11 b/g/n/e/i WLAN MAC protocol. When used in station (client) mode, the processor can communicate with most Wi-Fi routers for easy access. Wi-Fi Direct is easier to setup, has high data transfer speed, and has advanced system interconnections.

Experimental Setup.

Temperature sensor, ECG, pulse oximeter sensors, knock sensor, and emergency button are monitored and displayed on the screen. The values are stored on cloud database. Range of heart rate is determined as in Table 1. The real-time value curve for heart rate in Fig. 2 is as given:

Table 1 Range for heart rate

Heart rate	State
60BPM–100BPM	Normal
<60BPM	Low
>100BPM	High

Fig. 2 Real-time curve for heart rate
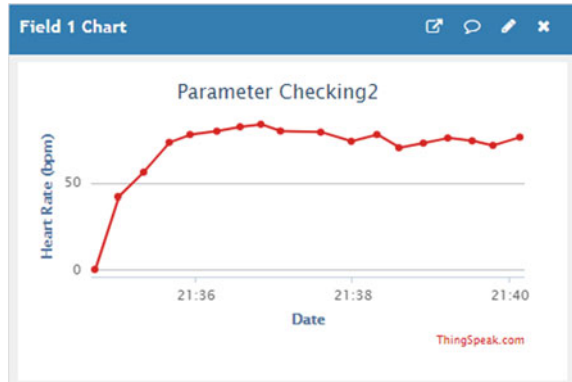
$$\text{Normal} = \left\{ \begin{array}{l} 1 \text{ (Healthy), } 60\text{BPM} <= x <= 100\text{BPM} \\ 0 \text{(Unhealthy), } x > 100\text{BPM and } x < 60\text{BPM} \end{array} \right\}$$

$$\text{Low} = \left\{ \begin{array}{l} 1 \text{ (Healthy), } x > 60\text{BPM} \\ 0 \text{ (Unhealthy), } x < 60\text{BPM} \end{array} \right\}$$

$$\text{High} = \left\{ \begin{array}{l} 1 \text{ (Healthy), } x < 100\text{BPM} \\ 0 \text{ (Unhealthy), } x > 100\text{BPM} \end{array} \right\}$$

For oxygen level of the patient, different range is considered and recorded as in Table 2. The real-time value curve for oxygen level in Fig. 3 is as given:
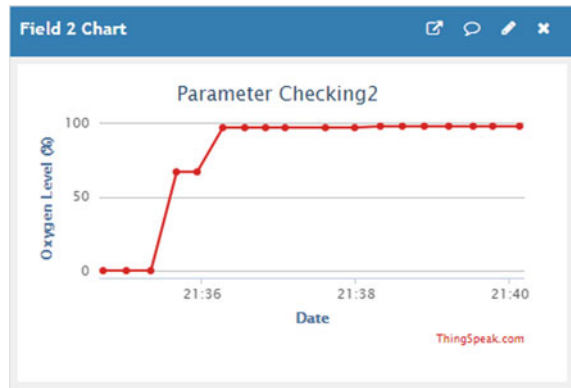
$$\text{Normal} = \left\{ \begin{array}{l} 1 \text{ (Healthy), } 95\% <= x <= 100\% \\ 0 \text{(Unhealthy), } x > 100\% \text{ and } x < 95\% \end{array} \right\}$$

$$\text{Low} = \left\{ \begin{array}{l} 1 \text{ (Healthy), } x > 95\% \\ 0 \text{ (Unhealthy), } x < 95\% \end{array} \right\}$$

Table 2 Range for oxygen level

Oxygen level	State
95–100%	Normal
<95%	Low
>100%	High

Fig. 3 Real-time curve for oxygen level

$$\text{High} = \begin{cases} 1 \text{ (Healthy), x} < 100\% \\ 0 \text{ (Unhealthy), x} > 100\% \end{cases}$$

Similarly, to determine body temperature, different range of body and room temperature values is also considered as in Table 3. The real-time value curve for body and room temperature in Figs. 4 and 5 is as given:

$$\text{Normal} = \begin{cases} 1 \text{ (Healthy), } 97°F <= x <= 99°F \\ 0 \text{(Unhealthy), x} > 99°F \text{ and x} < 97°F \end{cases}$$

Table 3 Range for body temperature

Body temperature	State
97–99°F	Normal
<97°F	Low
>99°F	High

Fig. 4 Real-time curve for body temp
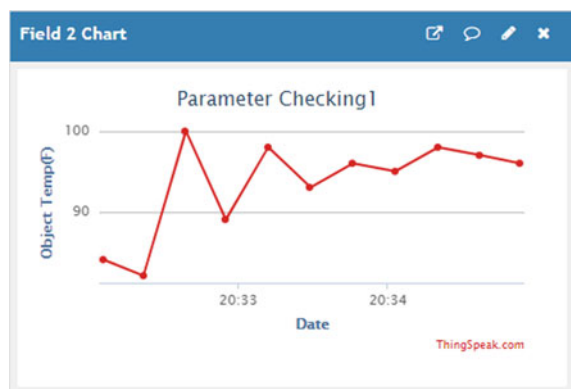
Fig. 5 Real-time curve for room temp
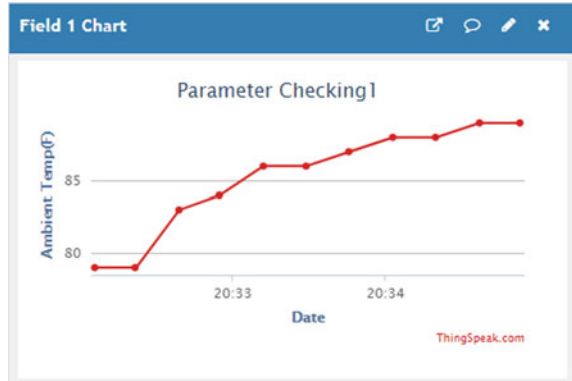
Table 4 Condition for fall detection

Fall detection	State
No fall detected	0
Patient fall detected	1

$$\text{Low} = \begin{cases} 1 \text{ (Healthy), } x > 97°F \\ 0 \text{ (Unhealthy), } x < 97°F \end{cases}$$

$$\text{High} = \begin{cases} 1 \text{ (Healthy), } x < 99°F \\ 0 \text{ (Unhealthy), } x > 99°F \end{cases}$$

For fall detection, the range lies between "0" and "1," which determines the falling of the patient. Value "0" states that no fall is detected and value "1" states that patient fall is detected as in Table 4. The real-time value curve for fall detection in Fig. 6 is as given:

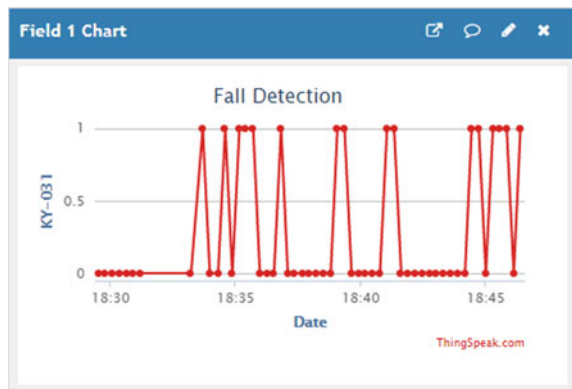**Fig. 6** Real-time curve for fall detection

Fig. 7 Real-time curve for ECG-1

$$\text{Healthy} = \{0, \text{ No fall detected}$$
$$\text{Unhealthy} = \{1, \text{ Patient fall detected}$$

For electrocardiogram (ECG), values are determined by the electrical activity of the patient's heart at rest via electrical leads. Information like rhythm, heart rate, etc., are assessed, and P wave, QRS complex, and T waves are analyzed to detect any abnormality.

Analyzing the different range values for all parameters, the outcome for patient's health status is diagnosed in Figs. 7 and 8 which is as follows: Healthy, unwell, urgent checkup, low fever, and high fever as given in Tables 5 and 6.

Fig. 8 Real-time curve for ECG-2

Table 5 Rules for analyzing health status

Heart rate	Oxygen level	Body and room temperature		
		Low	Normal	High
Low	Low	Urgent checkup	Unwell	Urgent checkup
Normal	Normal	Low fever	Healthy	High fever
High	High	Urgent checkup	Unwell	Urgent checkup

Table 6 Rules for analyzing health status

Fall detection (State)	Outcome
Patient fall detected	Urgent checkup
No fall detected	Healthy

The analysis of the COVID-19 positive patient's health status for all vital parameters can be summarized by considering the cases from Tables 5 and 6, and their health status can be determined by the doctor/medical staff. Cases are as follows:

1. If the output for heart rate/oxygen level along with patient temperature is (Low & Low) or (Low & High) or (High & Low) or (High & High), then the patient requires immediate medical attention.
2. If the output for heart rate/oxygen level along with patient temperature is (Low & Normal) or (High & Normal), then routine checkup is required.
3. If the output for heart rate/oxygen level and body temperature is (Normal & Low) or (Normal & High), then the patient is having low or high fever.
4. If the output for heart rate/oxygen level and body temperature is (Normal & Normal), then the patient is healthy.
5. If the patient fall is detected due to breathlessness, then an urgent medical checkup is required; otherwise, no fall is detected and the patient is healthy.

3   Result and Discussion

The pulse oximeter sensor, along with body temperature sensor, knock sensor (fall detection), ECG module, and emergency button is interfaced with the microcontroller. The complete prototype model can be seen in Figs. 9 and 10 where calculated data is displayed on the screen and visible to the doctor/medical staff observing the patient.

The readings measured are transferred to cloud center where the data is stored and accessed by the authorized user. The recorded data is displayed on the screen and the application as shown in Fig. 11.

The output from Fig. 11 signifies that there was some delay initially for the data received, but eventually it got stable just after few minutes, and an approximate real-time reading of **heart rate = 72.83 bpm** and **oxygen level = 98%** is observed for both parameters of sensor.

The output from Fig. 12 signifies that there was some delay initially, but eventually

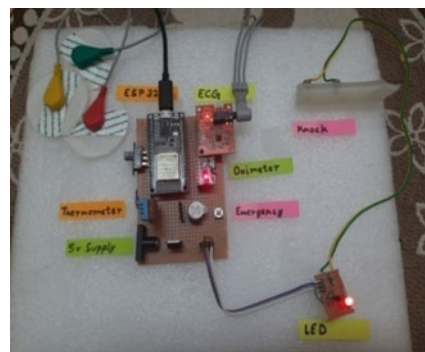**Fig. 9** System prototype—internal structure
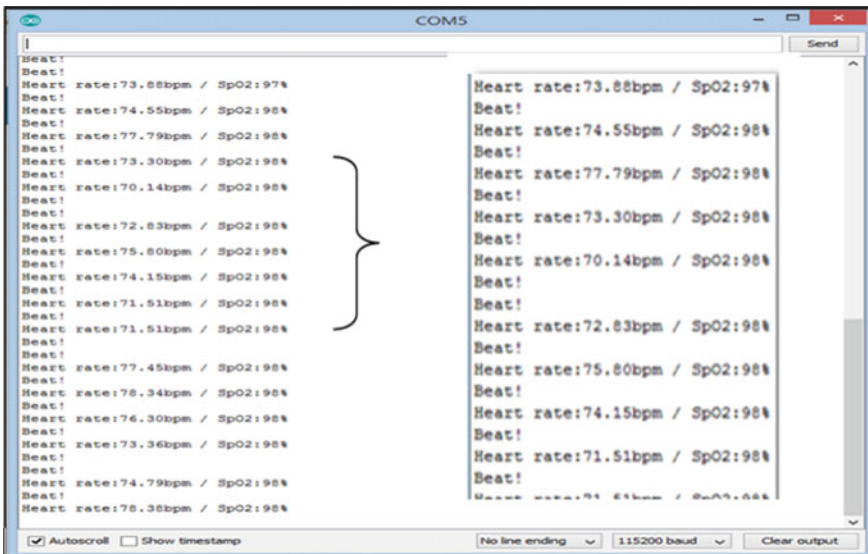
Fig. 10 System prototype

Fig. 11 Output on monitor for pulse oximeter

it got stable just after few minutes, and an approximate real-time reading of **ambient temperature = 89F** and **object temperature = 98F** is recorded for both parameters of the sensor.

From Fig. 13, reading was noted from the knock sensor which signifies the falling detection of any patient due to breathlessness. It is observed that the sensor gives the value **"0"** when no fall is detected and gives the value **"1"** when the falling of a person is detected. The vital parameters of the patient displayed on (Internet of Things) IoT application are shown below in Fig. 14.
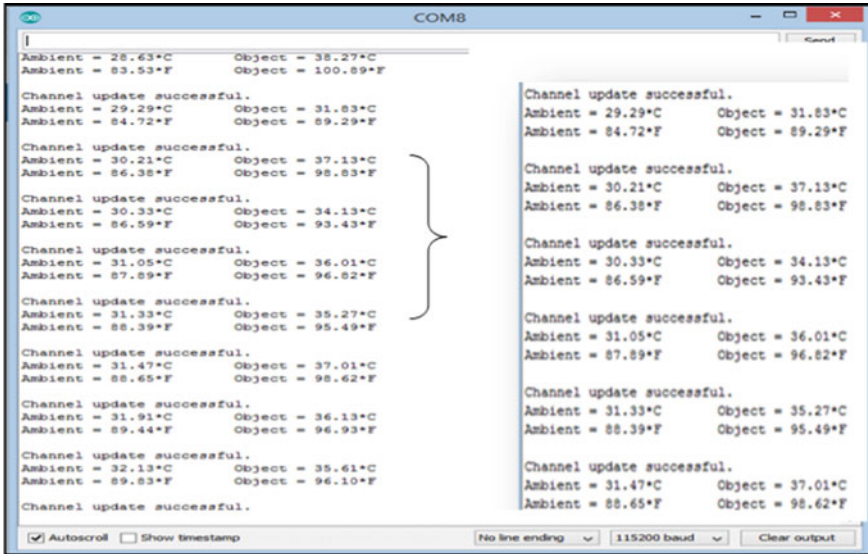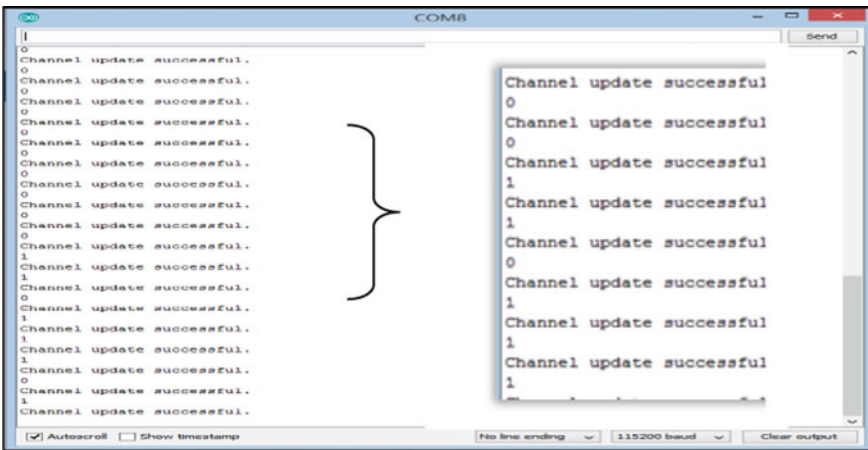
Fig. 12 Output on monitor for body and room temp

Fig. 13 Output on monitor for fall detection

4 Conclusion and Future Scope

To avoid coming directly in contact with the patients during the situation of the COVID-19 pandemic, a wireless sensor network (WSN)-based COVID-19 patient health monitoring system has been designed in this paper. Therefore, creating a health
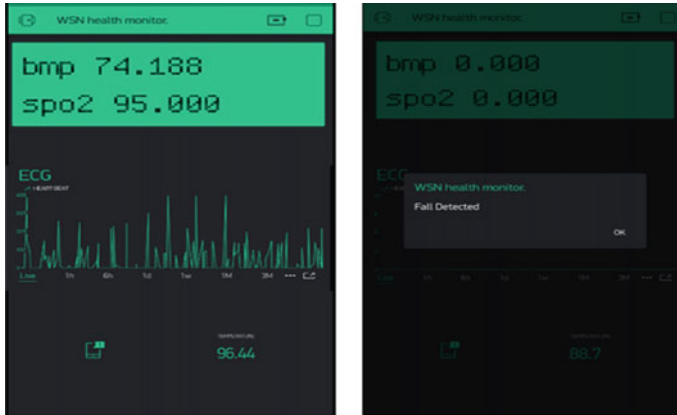
Fig. 14 Sensor value displayed on IoT application

monitoring system which transmits real-time data of the patients from a particular location to a targeted point contributes to the reduction in cases.

The existing WSN based health status monitoring systems majorly comprises of specific sensors which are required for a particular use. Some basic additional implementations has been done including reduction in the size of the hardware, addition of sensors, implementation of low power wireless networks, and making the model wearable.

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