# ANALYSIS AND DEVELOPMENT OF IOT-BASED HEALTH MONITORING SYSTEMS

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**Abstract**

With increasing growth of new healthcare technology IoT is rapidly revolutionizing the healthcare industry. Nowadays there are lot of Internet of Things devices which is used to monitor the health over internet. By using these smart devices doctors and caretakers also taking advantages to keep an eye on the health conditions of the patients. In this work the proposed health monitoring of a patient using IoT based sensors which records the patient heartrate, blood oxygen using MAX30102 sensor, body temperature using LM35 sensor, room temperature and room humidity using DHT11 sensor and quality of air using MQ135. ESP32 Microcontroller board which controls these sensors sends these sensed values to the cloud and these sensed values can be viewed through the created website using various devices. The sensed values are also displayed in 16x2 i2c LCD display module. If the Heath condition is normal/abnormal it sends emergency message to the doctors/caretakers.

**Keywords:** Health, Internet of Things (IoT) Sensors; Analytics platform service; Digital automation platform

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## 1. Introduction

Internet of Things refers to connecting tangible objects to the internet, enabling them to recognize and communicating with other devices. The concept of IoT is acquiring information, communicating and monitoring our health through the smart devices. The patients get numerous benefits by these smart devices across the world. Data poses as one of the most crucial obstacles in healthcare, often originating from diverse sources. The difficulty lies in achieving interoperability to create applications that can leverage the data. The significance of the internet of things (IoT) system depends on the correct analysis and interpretation of the data generated. The real time data and analyzing the data to uncover patterns is some of the primary ways to help improving the patient outcomes by IoT based patient health monitoring. Therefore, transmitting the data to the cloud for analytics using appropriate tools and applications is vital. This approach generates valuable data that can facilitate informed decisions. Multiple benefits are expected from this device. Consequently, the healthcare industry is exploring such systems to enhance patient care. Monitoring the health conditions of the patients safely outside the hospitals by the doctors is possible by the IoT based devices. With rapid growth in technology industry like wireless technology, sensors, cybersecurity protocols that made possible for sensing the patients real time monitoring of the body conditions. Healthcare providers can access and share their patient data at the exact moment they need to do by using the cloud computing. By these improved medical technologies this innovation helps to reduce the cost, time spent in hospital, increasing the comfort and also manage to improve their own health. The health care providers to collect more data from the patient than before effectively by using the IoT based health devices. To develop software for uncovering the patterns and trends of the patient data can improve the treatment and diagnosis. Microcontroller that senses the real time data of a patient using sensors and will be sent to the cloud. After sending the sensor values to the cloud it will be send it to the webserver. Doctors, caretakers can view these sensed values in their created website and mobile app. By using the IFTTT Platform it can send SMS to the doctors and caretakers with emergency alert if the patient body condition is abnormal or critical. To explore wireless and wearable sensor - based monitoring systems and categorize the different types of sensors used in health monitoring and also to highlight the challenges and open issues related to healthcare security, privacy, and quality of service (QoS) [13]. The IoT works in tandem with other technologies such as Wireless Sensor Network (WSN), REST, and other protocols, including smart mobile devices, radio frequency data and these technologies work together to improve healthcare outcomes and provide more efficient and effective care for patients [14]. One major advantage of incorporating IoT into healthcare procedures is the significant reduction in the time taken to access a patient’s medical records. With IoT- based mobile health care systems, clinicians can access a patient’s data and medical history remotely, even before the patient reaches the hospital. This is especially useful in situations where medical institutions are overwhelmed with patients or when emergency medical care is required and there is a shortage of doctor health condition of a person or patient can be monitored by doctors and medical staff and provide timely medical care, even if they are not physically present. This technology helps to improve the efficiency of medical care and enables patients to receive timely and appropriate treatment, regardless of their location [12].

## 2. Materials and Methods

Related works

Monitoring or observance of the patient health using Internet of Things Temperature, Heart rate, Blood oxygen of a patient and parameters like Room Humidity, Room Temperature and toxicity level of environment control are additionally implemented.

This method will generate emergency alert once when they arise an abnormal condition in patient based on sensing of the real time different sensors and different modules for acting a function of unique variety [1]. Asthma health monitoring of patient is designed for monitoring the health condition of asthma patient where MAX 30102 is utilized to sense heart rate and oxygen saturation, while the DHT11 is used to monitor room humidity and temperature, air quality using MQ130, nostril temperature using LM35 controlled by an ESP8266 microcontroller. All these sensed data are sent to Firebase through Wi-Fi and doctors can view the sensed values using the created website and mobile application through any devices. Using this method patients can consult with the doctor and get a prescription through video calling feature. This system is designed in such a way that patients are freed from visiting the doctor by going to hospitals over and over again [2]. To visualize the patient health as to issue the major concerns of the health such as cardiovascular diseases and heart attacks. A Wi-Fi module enabled microcontroller ESP8266 and sensors that are wearable are measured and heart rate, blood oxygen, body temperature and ECG with reliable data of different health parameters are sensed and are uploaded to the cloud where application created will be more user friendly and helpful for the medical professionals where they can visualize or remotely access these data anywhere at any time from any location [3]. To monitor the health using Arduino uno microcontroller board along with MAX30102 heart rate sensor for sensing the heart rate, blood oxygen, 16x2 LCD Display module that displays the sensed values in the LCD Display, ESP8266 Wi-Fi module for sending these sensed values to the cloud. This Paper portrays predicting based on the patient sensed values in the real time data streams in the cloud for accurate predictions using various machine learning algorithms [4]. They address the three key factors for monitoring each individual health as the adaptation of technology acceptance in health care providers for the patients. First key factor that discuss about the adoption of Internet of Things based in-home remote monitoring is a major factor driving its growth. Second key factor that present the latest advances and key building blocks of IoT-based in-home monitoring are significant factors driving its growth. Third discuss about analyzing the potential of in -home health monitoring with IoT and offering recommendations for future development [5]. In this work proposes real time monitoring of an automated pain assessment system that utilizes facial expressions for analysis and bio potential monitoring of scalable Internet of Things system developed. Wireless sensor node is integrated into Internet of Things that can be utilized as wearable devices. A wearable device featuring a bio-sensing facial mask is proposed for monitoring a patient pain intensity along with facial surface electromyogram (SEMG) and up to 8 channels is sampled in the sensor node. The frequency range of the SEMG signal is sampled and transmitted to a cloud server. The created website and mobile application process and visualize real-time pain data collected from the wearable device used for monitoring [6]. By utilizing IoT technology, the researchers developed a system to monitor air quality and used LTE to transmit the collected data to a webserver. The various parameters such as VOC, CO, CO2, and humidity-temperature of air quality can be monitored. The webserver is integrated along with the cloud computing for analyzing the data and air quality can be monitored. The cloud that stores all the data from the webserver and further quality of air can be analyzed. [7]. In this work they proposed a system with Internet of Things and Machine Learning based system for managing and monitoring the physical and healthcare activities using smart wearable technology. This IoT- based framework is wireless, smart, and wearable, and utilizes fog computing to analyze health-related data as well as bodily movement data in real-time. Heart rate, electrocardiogram, breath rate can be determined using a 3D-acceleration. A module for gym activity recognition (GAR) has been developed to track the body's vital signs and movements during exercise in real-time. Health hazard alarming and identification is responsible by health zone module [8]. They designed the real time monitoring of human health due to the diseases suffered by the patients. By using wireless communication module and set of medical sensors is connected with the embedded ARM microcontroller. ARM microcontroller checks the health condition of the patient and to save the life of a patient by analyzing the scan. The proteus 8 professional software and through embedded C software [9]. PPG signals are used by pulse oximeters to measure the variation in blood volume in tissues. This is a non-invasive technique that involves using a light source and a detector. There are two types of PPG: transmittance and reflectance. In transmittance PPG, the light source is placed on one side of the tissue and the detector is placed on the other side to measure the variation in the tissue. However, this type of PPG can only be used in small volume organs such as ear lobes and fingers. On the other hand, reflectance PPG uses both the light source and detector on the same side of the tissue. The light source emits light into the tissue, and the detector measures the variation in the reflected light. Reflectance PPG can be used on any part of the body, making it a versatile option for pulse oximetry measurements. Wireless healthcare monitoring devices have been utilized with the intension of integrating them with artificial intelligence technology. The monitoring process involves the use of neural networks and a fuzzy system, which is supported by an increased number of sensor nodes for collecting diverse health information in a secure manner. The collected patient data is then transmitted through a GSM module to Azure IoT, where the raw data is transformed into a linguistic representation. A fuzzy-based inference system (FBIS), which has been trained with the help of a logic-based algorithm, is responsible for monitoring the patient's health condition in a more reliable and accurate manner. This system is designed to securely send the patient health status to medical experts, thereby enhancing the security and reliability of the patient's health data. [10].

Proposed method

The main purpose of this paper is to monitor the real time health condition using IoT based devices. The various parameters such as heart rate, blood oxygen, body temperature, room humidity, room temperature and air quality is sensed by various sensors and these sensed values are controlled by microcontroller and by using the Wi-Fi module these sensed values is send to the cloud and doctors/caretakers can view these sensed values through our created website and mobile application and an emergency alert SMS is sent to doctors and caretakers if the health condition of the patient is abnormal/critical.

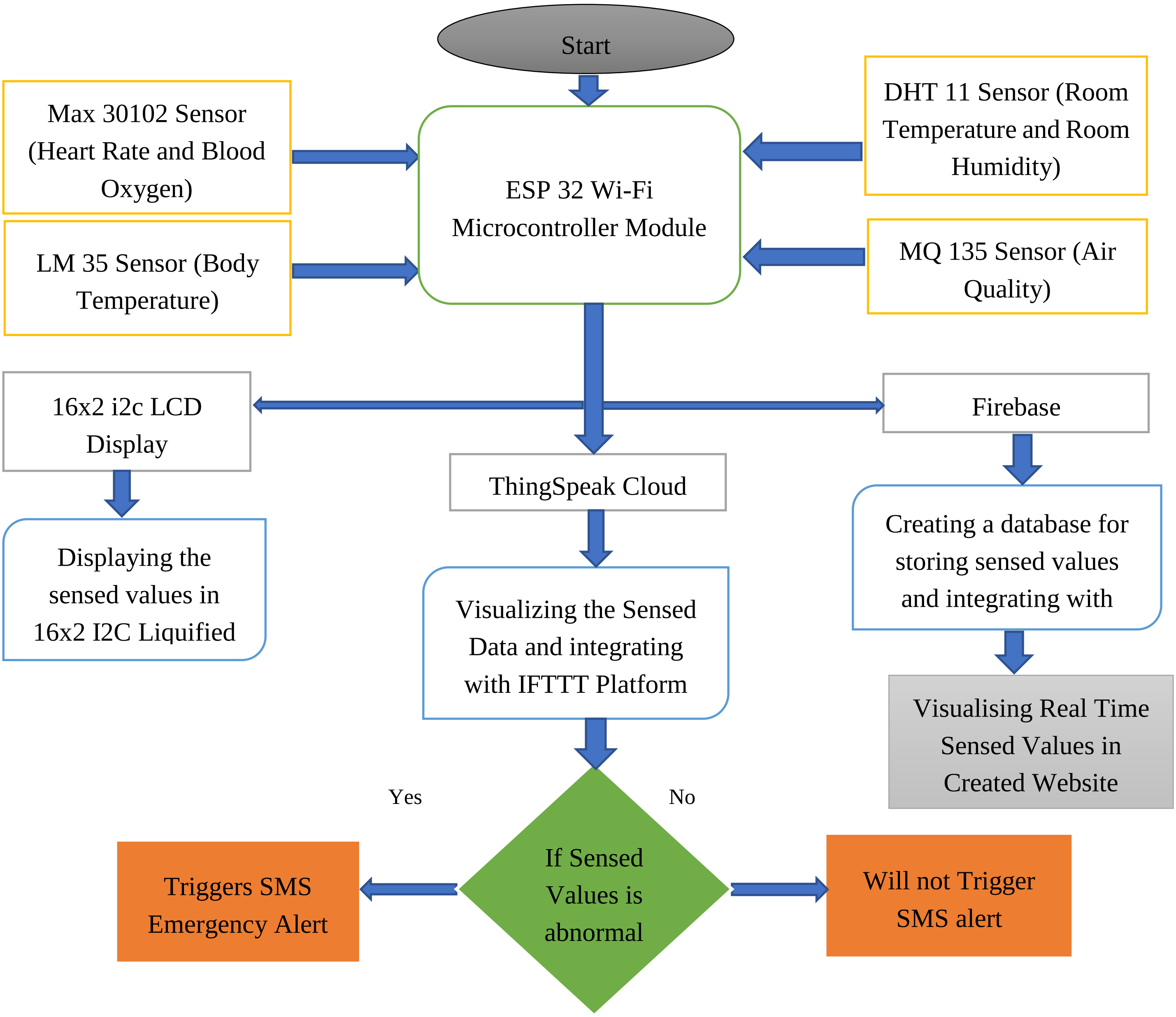


Figure 1. Flow chart of our proposed IoT Health Monitoring System

The Proposed flow chart diagram of the Internet of Things based health monitoring system is explained in Figure 1. The various sensors include MAX 30102, LM 35, DHT 11, MQ 135 Sensors. The real time database is created in the firebase and it is integrated with the created website. The ThingSpeak is integrated along with IFTTT by creating Thing HTTP and react in ThingSpeak and creating different applets in If this then that platform if the sensed values is set to a particular condition and if it satisfies then the react triggers the applet in IFTTT and the SMS messages is sent to the registered mobile number. Figure 1 shows the flow diagram of our proposed model. During the prototype phase, each sensor node is individually connected to the cloud to ensure continuous and uninterrupted data flow. The sensor data is sent directly to the cloud, where Smart Ambient Behavior System (SABOS) employs ThingSpeak, an IoT analytics platform, and MATLAB for data analysis. SABOS also integrates the if this then that (IFTTT) service, which enables it to respond to unexpected behavior data and adjust environmental conditions accordingly. IFTTT as a free web service that uses a REST-based API server-style architecture to facilitate application programming interface using HTTP requests to access and utilize data. With IFTTT, SABOS can create conditional statements called applets that are triggered by changes that occur within other web services, such as ThingSpeak. By leveraging this technology, SABOS can effectively monitor and analyze behavior and proactively optimize environmental conditions to achieve optimal outcomes [16].

Hardware Design

The circuit diagram presented in Figure 2 showcases the hardware design implemented in Proteus software. The design consists of a microcontroller and several sensors and interconnected to perform a particular function. This software enables the designer to create a virtual prototype of the hardware design, simulate its behavior, and test its performance before producing a physical prototype. By doing so, the designer can detect and rectify any potential issues in the design, thus minimizing the risk of failure during implementation [25]. The circuit presented provides a concise overview of the pin configurations required for the interfacing several sensors and modules with the ESP 32 microcontroller board. The MAX 30102 intended for pulse oximetry and heart-rate monitoring, necessitates a 5v power supply connected to its VCC pin. The SCL and SDA pins are employed for I2C communication and must be connected to GPIO22 and GPIO21, respectively. The GND pin must be connected to ground to complete the circuit. For Temperature measurements, the LM35 temperature sensor requires its VOUT pin to be connected to GPIO35, while its VCC pin must be connected to a Vin pin for power input. Ground must be connected to the GND pin. The MQ-135, sensor used to measure air quality, necessitates its AOUT pin connected to GPIO32 to receive an analog signal. Its VCC and GND pins should be connected to VIN and ground, respectively. The DHT11 sensor, used for humidity and temperature measurements, requires its VCC pin to be connected to VIN for power input, with its data pin connected to D4 (a GPIO pin), and the GND pin connected to ground. Finally, for display purposes, the I2C LCD module requires the GND pin to be connected to ground, with the VCC pin connected to Vin for power input. The SDA and SCL pins must be connected to GPIO21 and GPIO22, respectively, for I2C communication. Each sensor is connected with a microcontroller ESP32 Wi-Fi module which controls these sensors and making a connection with IP. AC Power supply is used by the connecting components for supplying electrical energy. Sensors that sense values from the human body and surrounding environment and these sensed values are send to the cloud using microcontroller and these sensed values are also displayed in the 16x2 LCD display. The microcontroller that sends the measured values to the firebase and ThingSpeak cloud. Proper configuration of these sensors and modules to the ESP32 microcontroller board provides an excellent platform to design and implement Internet of Things based various applications like IoT based Real Time Health Monitoring with precision and efficiency.

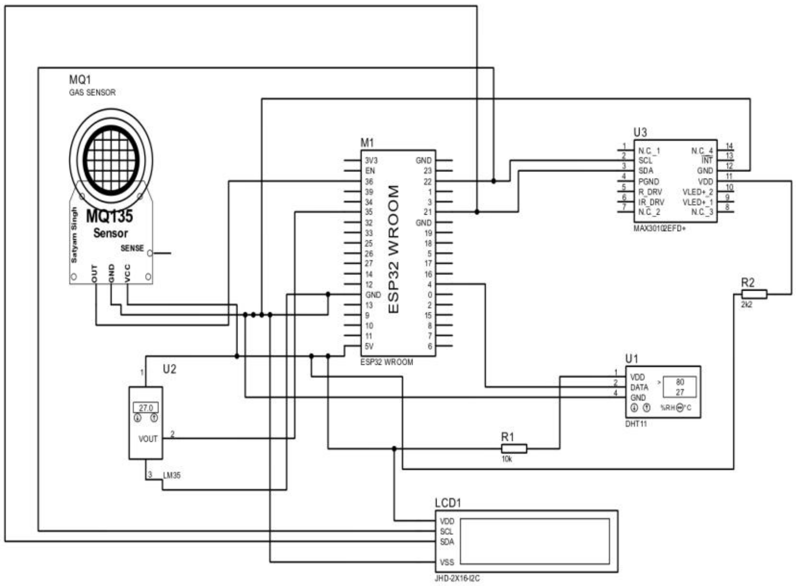


Figure 2. Circuit Diagram of our proposed IoT Health Monitoring System

Description of Hardware Components

The various hardware components that we used is explained briefly as follows. ESP 32 Microcontroller as shown in Figure 3a is a dual Wi-Fi and Bluetooth support, as well as full TCP/IP support for complete internet connectivity. It has the ability to function either as a standalone system or as a peripheral device to a host MCU, which can reduce the communication stack overhead on the primary application processor. MAX 30102 Sensor as shown in Figure 3b of internal LEDs, photodetectors, optical elements, and low-noise electronics with ambient light rejection, as a biosensor module it combines pulse oximetry and heart rate monitoring functionalities. This sensor is designed to measure pulse oximetry (SpO2) and heart rate (BPM) signals using two LEDs (one infrared and one red), optimized optics, a photodetector, and low-noise analog signal processing. By detecting the amount of light reflected back to the photodetector using a single LED at a time, the device accurately calculates blood oxygen levels and heart rate. The MAX 30102 sensor utilizes a sophisticated algorithm based on photoplethysmography (PPG) to measure the heart rate and oxygen saturation level. This algorithm involves filtering, signal processing, and peak detection techniques. The filter eliminates any noise or interference in the signal, while the signal processing identifies features in the PPG waveform. The peak detection then calculates the time between peaks and valleys to determine the heart rate. Meanwhile, the oxygen saturation level is derived from the ratio of absorption at the red and infrared wavelengths, which varies based on the amount of oxygen in the blood. Although, the sensor does not have a direct formula for its readings, it provides accurate measurements using its complex algorithm. The MAX 30102 technical specifications include with a module has 8 pins for connectivity, including a Vin power pin that can connect to a microcontroller's 3.3V or 5V output, and I2C clock and data pins (SCL and SDA). The sensor emits red light at a wavelength range of 660nm and infrared light at a wavelength range of 880nm, allowing it to penetrate the skin and measure blood oxygen levels accurately. It can operate over a wide temperature range of -40 degree Celsius to 85 Degree Celsius, which makes it suitable for use in different environments. During measurements, the MAX 30102 Sensor draws a current of 600 microamps, while in standby mode, it only draws 0.7 microamps. This low power consumption makes it an ideal choice or battery-powered devices, and it does not put a significant burden on the power supply. The INT pin generates an interrupt for each pulse and can be programmed accordingly, while the IRD pin has an LED driver for SpO2 and heart rate measurements. The RD pin controls the red LED, and the GND pin serves as the ground connection. The MAX30102 can be fully customized through software registers, and its digital output data can be stored in a 32-deep FIFO buffer within the integrated circuit. This FIFO feature allows the device to be connected to a microcontroller or processor on a shared bus, where data can be saved and retrieved intermittently, without requiring continuous communication with the MAX30102's registers and this device compact size and superior performance as this sensor's precise wavelength ranges and low power consumption make it an popular choice for a variety of applications, including fitness trackers, wearable technology and medical devices. By utilizing the same two wavelengths of light (red and infrared) to identify changes in blood volume that occur with each heartbeat, the pulse oximeter can calculate heart rate by measuring the time interval between each peak in the infrared signal. This time interval is then converted to beats per minute (BPM) using a simple formula.

Heart rate (BPM) = 60/time interval between peaks in seconds (1)

Most pulse oximeters will also display the waveform of the infrared signal, which can be used to visually confirm the accuracy of the heart rate measurement. It is crucial to note that pulse oximeters may not be reliable in all situations and that some medical conditions may affect the accuracy of the measurement.

As with any medical device, its crucial to follow the manufacturer's instructions and consult with a healthcare professional if you have any questions or concerns. Furthermore, SpO2 is a non-invasive measurement of the percentage of hemoglobin in the blood that is saturated with oxygen, and it can be calculated using a pulse oximeter that shines two different wavelengths of light through a thin part of the body, such as a finger or earlobe. The absorption of light at each wavelength corresponds to the levels of oxygenated and deoxygenated hemoglobin present in the blood. The SpO2 formula is based on the ratio of red and infrared light absorbed by the blood and is calculated using a specific formula that incorporates the values of RED, RED average, IR, and IR average. By deriving the ratio R from these values, the SpO2 can be determined using an empirical formula that is based on the saturation of hemoglobin with oxygen.

R = (square root of (RED / RED average)) / (square root of (IR / IR average)) (2)

SpO2 = -23.3 * (R - 0.4) + 100 (3)

This SpO2 formula is used to calculate the percentage of hemoglobin that is saturated with oxygen based on the value of R, which is the ratio of red and infrared light absorbed by the blood. The constant value of 0.4 in the formula represents the baseline of R for fully oxygenated blood, while in the value of -23.3 is derived from empirical measurements. The formula has been shown to provide accurate estimates of SpO2 in clinical settings.

DHT 11 Sensor as shown in Figure 3c is a digital temperature and humidity sensor that employs a capacitive humidity sensor and a thermistor to measure the surrounding air, providing a digital signal output for further use. The DHT11 sensor is frequently used to measure temperature and humidity. It's simple to connect with other microcontrollers and includes a dedicated 8-bit microcontroller for transmitting temperature and human readings as serial data. The DHT sensor's technical specification includes it is capable of measuring temperature from 0 to 50 degree Celsius and humidity levels from 20% to 90% with an accuracy of plus or minus 1% and plus or minus 10 Degree Celsius, respectively and for further analysis of the sensor. The sensor requires a supply voltage between 3.5 and 5.5 volts to operate, and its working current is 0.3 milliamperes during measurement and 60 microamps in standby mode. This sensor transmits data in a digital format, which makes it easy to integrate into a range of systems and devices. The temperature and humidity measurements are each encoded as 16-bit values, ensuring high precision and accuracy. The sensor's compact size and low power consumption make it an ideal choice for battery-powered devices and applications where space is limited. Overall, the DHT11 Sensor is a reliable and versatile device that provides accurate temperature and humidity measurements in a range of environments. Its precise measurements, digital data transmission, and low power consumption make it a popular choice for a variety of applications, including weather stations, HVAC systems, and environmental monitoring

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3a.

3b.

3c.

3d.

3e.

3f.

Figure 3. Hardware Components of our proposed IoT Health Monitoring System

$$RH=(P_w/P_s)x100\% \quad (4)$$

The equation provided is commonly used to calculate relative humidity (RH) based on the ratio of the partial pressure of water vapor (Pw) to the saturation vapor pressure (Ps) at a given temperature and pressure. Relative humidity is a measure of the amount of moisture in the air compared to the maximum amount of moisture that the air can hold at a specific temperature and pressure. It is expressed as a percentage, with 100% representing complete saturation or the maximum amount of moisture that the air can hold at a given temperature and pressure.

The equation states the relative humidity is calculated by dividing the partial pressure of water vapor (Pw) by the saturation vapor pressure (Ps) and multiplying the result by 100%. Partial pressure is the pressure exerted by a component gas in a mixture of gases, and saturation vapor pressure that water vapor can exert in the air at a specific temperature and pressure. By using this equation, we can calculate the relative humidity of a given air sample by measuring the partial pressure of water vapor and the saturation vapor pressure at a specific temperature and pressure. This calculation is important in a wide range of applications, including weather forecasting, indoor air quality monitoring, and industrial processes. LM 35 Sensor as shown in Figure 3d is an integrated precision circuity that delivers a voltage output directly proportional to the Celsius temperature. It doesn't require external calibration and has a sensitivity of 10 millivolts per degree Celsius. As the temperature rises, the output voltage of the LM-35 also increases. The LM35 sensor outputs the voltage in linearly proportion to the Celsius temperature. To calculate Temperature of a body we can measure the voltage on the LM35's OUT pin and the output scale factor of the LM35 is 10 mV/$^0$C. LM35 temperature sensor has three pins. VCC pin is connected to the 5V of VCC. The GND pin is connected to the GND (0V). The OUT pin outputs the voltage in proportion to the temperature value. The widely accepted formula for computing temperature from the output voltage is given by:

Temperature (in Celsius) = (VOUT – 0.5) x 100 (5)

Here, VOUT signifies the output voltage of the LM35 sensor in volts, while 0.5 represents the voltage at 0 degree Celsius. The output voltage increases by 10mV for each Celsius degree in temperature.

Furthermore, the LM35 sensor also facilitates temperature readings in Fahrenheit via the formula:

Temperature (in Fahrenheit) = (Temperature in Celsius x 1.8) + 32 (6)

Where 1.8 is the conversion factor from Celsius to Fahrenheit and 32 is the offset value needed to convert Celsius to Fahrenheit. To measure the temperature sensor's ADC output

ADC Val = analog Read (PIN_LM35) (7)

To calculate the millivolt voltage from the ADC value of the temperature sensor

ADC VREF mV = (Millivolts * ADC RESOLUTION) / ADC Val (8)

To determine the temperature in Celsius based on a voltage reading

Celsius temp = ADC VREF mV / 10 (9

To change a temperature from Celsius to Fahrenheit, a conversion formula is needed

Fahrenheit temp = Celsius temp * 9 / 5 + 32 (10)

It is noteworthy that the LM35 sensor provides temperature values directly in Celsius, which enhances its suitability for a broad range of temperature sensing applications. MQ 135 Sensor as shown in Figure 3e is Capable of detecting harmful substances such as smoke and benzene, making it suitable for a variety of applications including air quality monitoring, detecting noxious fumes, and identifying pollution in homes, industries, and portable settings. By measuring the concentration of NH3, NOx, alcohol, benzene, smoke and CO2 in the air, this versatile sensor can assist in identifying potential dangers and promoting a safer environment. In a Microcontroller-based setup, the calibration process for the MQ-135 gas sensor involves first obtaining the baseline resistance value (Ro) of the sensor in clean air, which is achieved by measuring the output voltage and using ohm's law to calculate the corresponding resistance. Subsequently, the sensor resistance (Rs) can be determined for a given gas concentration using the below mentioned formula.

Rs = ((VCC / VRL)-1) x RL (11)

Here VCC is the supply voltage, VRL is the voltage across the load resistor, and RL is the load resistor value. The calculated Rs value can then be compared to the Ro value to determine the gas concentration using a calibration curve specific to the gas being detected. The 16x2 i2c LCD display as shown in Figure 3f equipped with an I2C Interface and can show 16x2 characters on 2 lines. The display consists of a 5x7 pixel matrix for each character, allowing for a total of 224 different characters and symbols to be displayed. The LCD also features two separate registers, one for commands and one for data, to allow for easy control of the display output. Creating custom characters on LCD is a straightforward process that involves understanding the CG-RAM of the LCD and the LCD controller chip. Once you have designed your custom character and stored it in the CG-RAM, it can be displaced on the LCD screen just like any other character. AC Power Source deliver and distribute electricity over long distances to power microcontrollers like the Arduino, ESP Wi-Fi Module, and Raspberry Pi through electrical grid systems. An AC power supply is a specific type of power supply designed to provide alternating current power to a load. The incoming power may be in either AC or DC form. In many cases, the power provided by wall outlets and other power storage devices may not be compatible with the power required by the load. In order to solve this issue, AC power supplies transform and adjust the AC power from the electrical source to the voltage, current, and frequency that are needed by the device. This is achieved through voltage stepping (either up or down) and filtering, which results in a controlled and accurate supply of electrical power to the device. The main AC power supply operates at around 230 volts for the UK mains supply, and its frequency is set at 50 Hz. This means the current changes direction 50 times per second, allowing for the safe and efficient distribution of electrical energy.

Software Design

Real-time data from a database can be received by the Firebase system. The Firebase system can send all the sensed values to a mobile application and a website. These values can be viewed on the website by doctors, patients, and caretakers. The ThingSpeak cloud enables aggregation, visualization, and analysis of live data streams, as well as display of all sensed values. This cloud can be integrated with the IFTTT Platform. The website is designed using HTML, CSS, JavaScript and features a user sign-in option. Once verified by the admin, users can access the application and their information is stored in the cloud. A detailed description of the website design is provided. The Website was constructed using an assortment of web technologies, such as HTML, CSS, Bootstrap, jQuery, and JavaScript. HTML, also referred to as hypertext markup language, is utilized to format and display online content as web pages, which often contain hypertext links to other pages. CSS, or Cascading Style Sheets, is utilized to design and organize web pages, allowing users to personalize design features such as font, color, size and spacing. Interactive and dynamic content for web applications and browsers is produced using JavaScript, a scripting language.

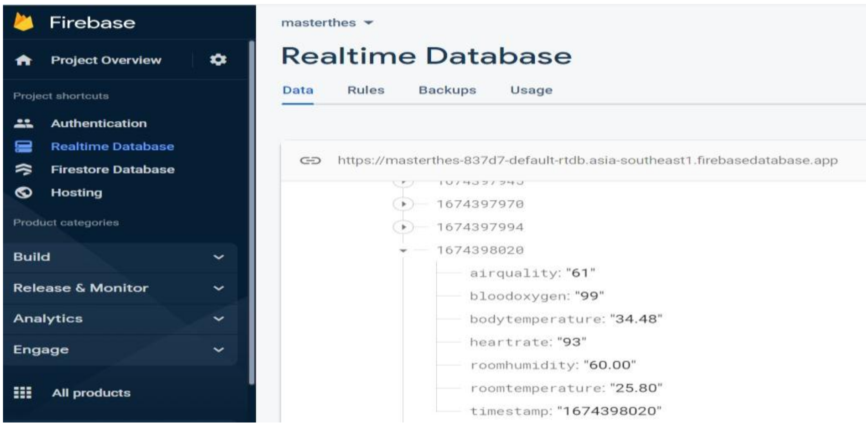


Figure 4. Real Time Database created in Firebas

By leveraging Firebase hosting, the web application is served over a global CDN and equipped with a secure SSL certificate. This allows access to our web application from anywhere via the Firebase-generated domain name. As shown in Figure 4. Real-time sensor readings are stored in Firebase's database and the database is protected with a set of rules. Figure 5 as shown below is the login page of our created website application for securing the patient or person's personal health data information from unauthorized users.


Figure 5. Login page of the created health monitoring website

IFTTT, an abbreviation for If This Then That, is a free online tool that allows users to automate web -based activities and improve productivity. IFTTT integrates with various developer devices, services, and applications to create customized applets for automation purposes. As shown in Figure 6. Applets are created with Triggering event. If a person's physical condition becomes abnormal or critical, IFTTT triggers the applet that automatically sends emergency alarm SMS messages to doctors and caretakers, enabling them to respond promptly to the patient.

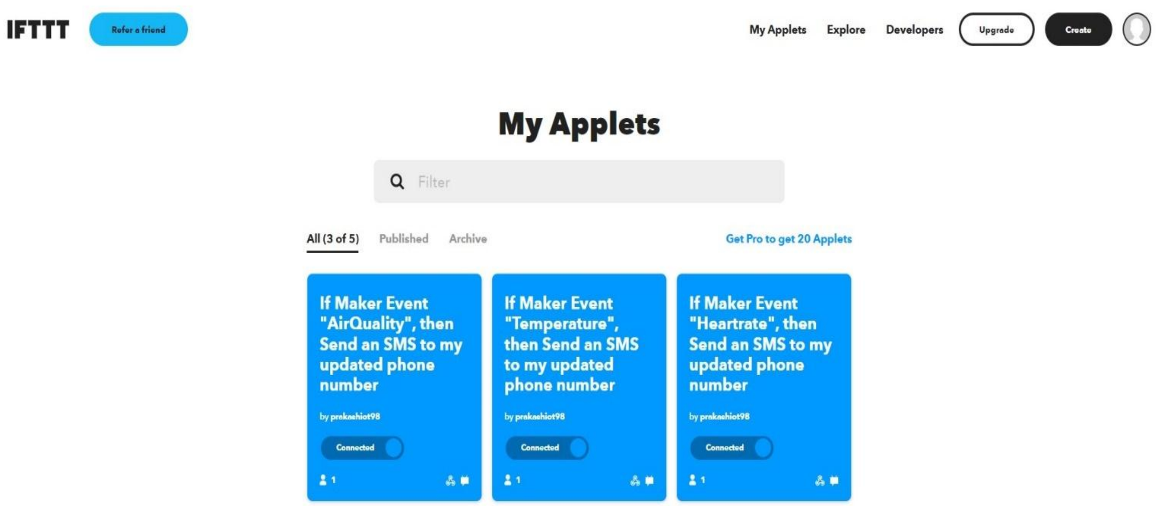


Figure 6. Created Applet in IFTTT for Triggering the SMS

## 3. Results

This paper discusses about the Design and Development of IoT based health monitoring system that utilizes various sensors to measure a person or patient's heart rate, blood oxygen, body temperature, room humidity, room temperature, and air quality. Though testing, we found that our proposed system allows for real-time monitoring of a person's body health. The Heart rate and Blood Oxygen sensed by MAX30102 sensor, DHT-11 that senses Room Temperature and Room Humidity, LM35 that senses the body temperature along with MQ135 that senses the surrounding air quality level and all these data are processed in ESP 32 Wi-Fi module and it is also interfaced along with 16X2 LCD module which displays our sensed values in the Liquid Crystal Display.

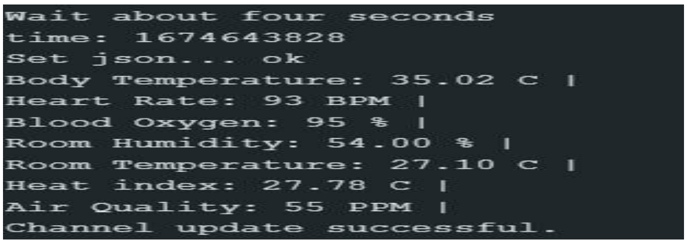


Figure 7. Displaying sensed values in the Arduino ide serial monitor

The Arduino ide serial monitor display with a baud rate of 115200 as shown in Figure 7. describes the measured values of our body's health condition. Baud rate is a measure of how many signal changes per second occur when data is transmitted through a medium. A higher baud rate indicates faster data transfer during transmission and reception. After the various sensors senses the heart rate, blood oxygen, body temperature, room humidity, room temperature and air quality and microcontroller that controls the sensors can display the sensed values in the 16x2 i2c LCD Display. When a person is sensed by the sensors there sensed values are displayed in the real time as Figure 16. shows the sensed value of a person's heart rate as 93 BPM. Similarly, as shown in Figure 8. all the sensed value are displayed in LCD Display module withbody temperature as 35.02 celsius, heart rate as 93 beats per minute (bpm), blood oxygen as 95%, room humidity as 54%, room temperature as 27.10 degree celsius and air quality as 55 parts per million (ppm

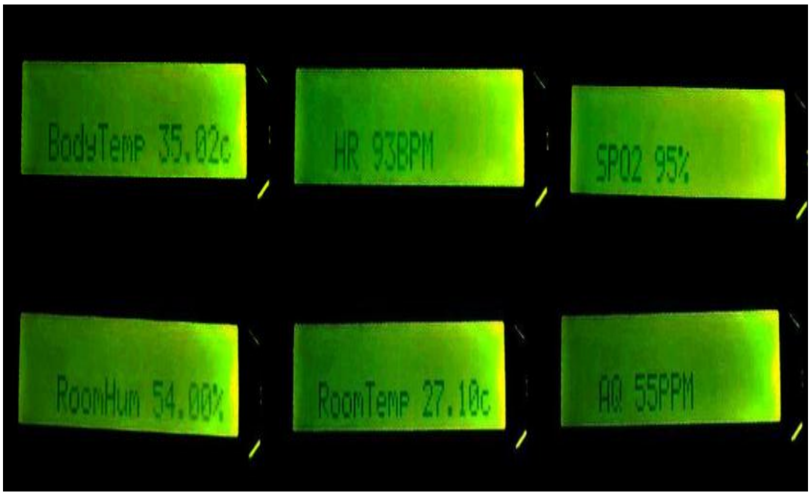


Figure 8. Sensed Values Displayed in LCD Display

The sensed data are sent to the ThingSpeak cloud by ESP module which visualizes our sensed data and it integrated along with IFTTT platform that sends an emergency SMS alert when the patient health condition is critical to ourselves/doctors/caretakers so that necessary precautions can be taken for our health as soon as possible. These sensed values are also sent to the created website by firebase database that stores our real time sensed values. We can able to further monitor the real time sensed values automatically for every time when the sensor senses the values. We can further able to delay the displaying sensed values according to our wish by changing it in the arduino ide code.

Table 1: Average range of Sensor Values

| **Measurement** | **Average normal range** |
|---|---|
| Heart Rate | 60-100 BPM (18 and over)<br>70-100 BPM (6-15) |
| Blood Oxygen | 95 – 100 % |
| Body Temperature | 30-40$^{0}$ C |
| Room Humidity | 30-70% |
| Room Temperature | 15-30 |
| Air Quality | 0-50: This Air Quality range indicates a high level of purity and is not hazardous to health.<br>51-100: This Air Quality range suggests a moderate level of pollution, which is acceptable but may cause some discomfort for certain individuals.<br>101-150: This Air Quality range may be detrimental to individuals with sensitivity to airborne pollutants<br>151-200: This Air Quality range can cause difficulty breathing and other negative health effects in some individuals.<br>201-300: This Air Quality range is considered to be of emergency status and may pose a health risk to the general population.<br>301-500: This Air Quality range is highly hazardous and can cause serious health problems, including respiratory diseases and other respiratory issues. |

Measurements involves the act of ascertaining the numerical value of something. Across various disciplines including science, engineering, and medicine, accurate measurements are necessary to derive meaningful and reliable outcomes. An average normal range refers to the spectrum of values that a particular physiological or biological feature is anticipated to be presented within during standard conditions. Typically, this range is established through the examination of the parameter in a sizeable group of healthy individuals, with the mean and standard deviation being calculated. The Normal or Average range of sensed values is discussed briefly in Table 1. If the sensed values are above or below this mentioned average range it is considered as abnormal condition and necessary steps should be taken by the doctors, caretakers or ourselves by maintaining with a normal sensed value accordingly. This would be helpful for those who needs to maintain good health condition with their sensed values and helps to improve the health condition of an individual person who are connected with these sensors.

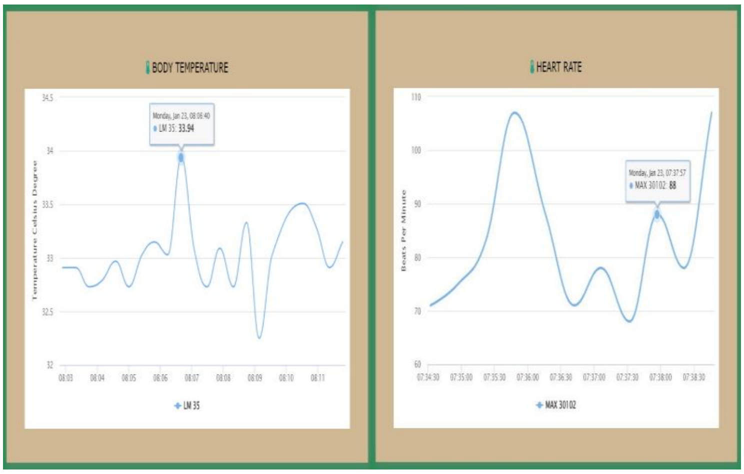


Figure 9. Graphical representation of the sensed values through our created website

The visual representation of the Body Temperature and Heart Rate values as shown in Figure 9. that were sensed by our system. This allows for easy monitoring and analysis of the data, providing a visual representation of the changes in these health indicators over time. In the above graph we can able to visualize that body temperature of one particular point shows us that it sensed 33.94 degree Celsius and at the same we can able to visualize the heartrate is sensed as 88 beats per minute with respect to date and time. The real time health monitoring of our sensedvalues in the created website in a numerical format representation is shown as in Figure 10. It describes the sensedvalues of the person's body temperature as 33.70 degree celsius, heart rate as 75 beats per minute, blood oxygen(SpO2) as 99%, Room temperature as 26.20 degree celsius, Room humidity as 68% and Air quality as 65 PPM.

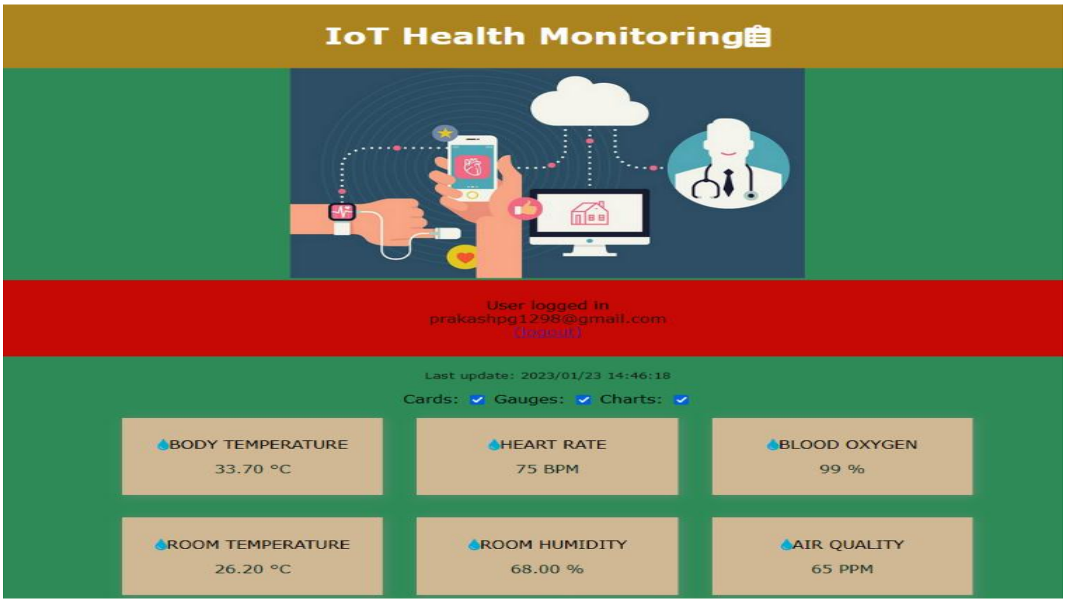


Figure 10. Displaying the real time sensed values in the created website

The tabular representation of some of the sensed values in the created website as shown in Table 2 consits of updated time with date, month and year, Body Temperature, Heart Rate, Blood Oxygen, Room Humidity , Room Temperature and Air Quality.

Table 2: Tabular Representation of the sensed values in the created website

| Time | Body Temp (°C) | HR (BPM) | SPO2 (%) | Room Temp (°C) | Room Hum (%) | Air Quality (PPM) |
|---|---|---|---|---|---|---|
| 2023/01/22 20:09:49 | 34.72 | 71 | 98 | 25.80 | 60.00 | 60 |
| 2023/01/22 20:09:24 | 34.78 | 88 | 98 | 25.80 | 60.00 | 61 |
| 2023/01/22 20:09:00 | 34.60 | 78 | 97 | 25.80 | 60.00 | 59 |
| 2023/01/22 20:08:35 | 34.36 | 83 | 100 | 25.80 | 60.00 | 60 |
| 2023/01/22 20:08:11 | 34.66 | 65 | 98 | 25.80 | 60.00 | 61 |
| 2023/01/22 20:07:46 | 34.66 | 107 | 100 | 25.80 | 60.00 | 60 |
| 2023/01/22 20:07:21 | 34.84 | 83 | 100 | 25.80 | 60.00 | 61 |
| 2023/01/22 20:02:01 | 34.18 | 83 | 87 | 25.80 | 60.00 | 61 |
| 2023/01/22 20:01:36 | 34.24 | 78 | 92 | 25.80 | 60.00 | 61 |
| 2023/01/22 20:01:12 | 34.60 | 75 | 99 | 25.80 | 60.00 | 63 |
| 2023/01/22 19:18:30 | 32.73 | 81 | 99 | 26.70 | 60.00 | 56 |
| 2023/01/22 19:18:05 | 33.82 | 82 | 99 | 26.70 | 66.00 | 62 |
| 2023/01/22 19:17:41 | 33.76 | 82 | 99 | 26.20 | 76.00 | 62 |
| 2023/01/22 19:17:16 | 33.94 | 78 | 100 | 25.80 | 59.00 | 62 |
| 2023/01/22 19:16:50 | 33.88 | 78 | 99 | 25.80 | 59.00 | 60 |
| 2023/01/22 19:16:25 | 33.94 | 78 | 99 | 25.80 | 60.00 | 60 |
| 2023/01/22 16:23:34 | 32.67 | 100 | 100 | 26.70 | 70.00 | 56 |
| 2023/01/22 16:23:10 | 32.61 | 88 | 99 | 26.70 | 71.00 | 57 |
| 2023/01/22 16:22:45 | 32.61 | 83 | 100 | 26.70 | 71.00 | 55 |

For every 24 seconds gap the sensed values is updated in the tabular column in the website. It will be more useful and easy for the users to monitor the real time data of the persons or patients in more efficient way. ThingSpeak offers a range of features, including the ability to schedule events, use RESTful and MQTT APIs, collect data in private channels, and share data in public channels. In addition, the platform provides powerful MATLAB analytics and visualizations to help you make sense of your data. ThingSpeak collects data from sensors or actuators, processes and displays it, and can trigger actions based on the data. It has been utilized in various IoT projects. To gain access to the website, a new account was created and a channel was set up with six fields: Displaying Body Temperature, Heart rate, Blood oxygen, Room temperature, Room humidity and Air Quality. An API key unique to the channel was provided, which was then incorporated into the code using the Arduino IDE and uploaded to the Node MCU microcontroller board. temperature as 25.8 degree Celsius and air quality as 59 parts per million with respect to day, date, time, year and location. ThingSpeak provides a login forum for security purposes, with the username and password only known to the patient, medical professional or caretakers administering their care, which enables them to view the patient's data (readings) while safeguarding their medical information against hacking and leaks [17]. Figure 20 represents the displaying of sensed values in ThingSpeak and we can able to visualize the sensed values in graphical representation as body temperature as 35.68 degree Celsius, heart rate as 78 beats per minute, blood oxygen as 99%, room humidity as 71%, room temperature as 25.8 degree Celsius, and air quality as 59 PPM. To visualize the changes in the sensed values, graph according to changes in values with x axis as date and y axis as different values sensed with respect to time and date as shown in Figure 11.

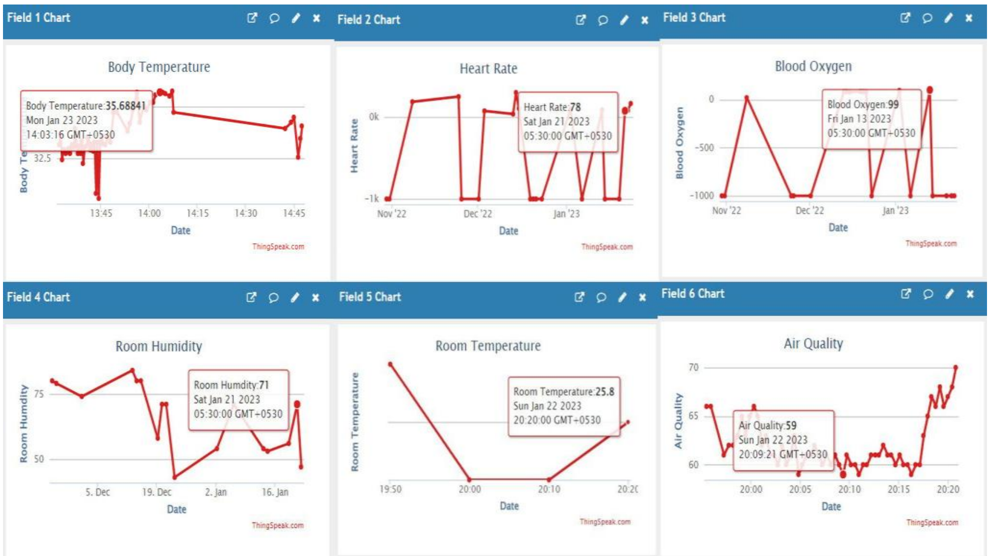


Figure 11. Displaying the sensed values in ThingSpeak Platform

Table 2*:* The Real time data collected from ThingSpeak cloud and exported to an Excel Sheet for further analysis

| **SL** | **Heart Rate in BPM** | **Blood Oxygen (SPO2) %** | **Body Temperature in degree C** | **Room Humidity in %** | **Room Temperaturein degree C** | **Air Quality (CO2)** |
|---|---|---|---|---|---|---|
| 1 | 80 | 99 | 36.32 | 58 | 29.6 | 58 |
| 2 | 78 | 96 | 38.15 | 57 | 29.4 | 57 |
| 3 | 76 | 98 | 33.65 | 56 | 29.6 | 56 |
| 4 | 82 | 96 | 39.26 | 58 | 29.8 | 58 |
| 5 | 84 | 98 | 35.08 | 59 | 28.4 | 59 |
| 6 | 92 | 95 | 32.22 | 59 | 29.8 | 59 |
| 7 | 76 | 97 | 39.43 | 59 | 29.6 | 59 |
| 8 | 86 | 99 | 37.65 | 59 | 29.8 | 59 |
| 9 | 94 | 96 | 34.22 | 59 | 29.4 | 59 |
| 10 | 73 | 99 | 32.13 | 59 | 28.3 | 59 |
| 11 | 84 | 96 | 30.12 | 60 | 28.4 | 60 |
| 12 | 89 | 99 | 38.18 | 68 | 28.6 | 68 |
| 13 | 78 | 96 | 36.12 | 60 | 28.6 | 60 |
| 14 | 94 | 92 | 35.16 | 60 | 28.4 | 60 |
| 15 | 81 | 97 | 34.15 | 61 | 28.8 | 61 |
| 16 | 76 | 100 | 32.18 | 61 | 28.4 | 61 |
| 17 | 82 | 100 | 32.88 | 61 | 28.6 | 61 |
| 18 | 93 | 97 | 32.65 | 69 | 28.4 | 69 |
| 19 | 81 | 96 | 39.12 | 61 | 28.2 | 61 |
| 20 | 107 | 99 | 38.08 | 61 | 27.4 | 61 |
| 21 | 85 | 96 | 37.14 | 67 | 27.2 | 67 |
| 22 | 89 | 100 | 36.07 | 61 | 26.6 | 61 |
| 23 | 82 | 99 | 36.28 | 69 | 27.2 | 64 |
| 24 | 103 | 96 | 35.35 | 72 | 26.0 | 62 |
| 25 | 96 | 99 | 35.98 | 76 | 25.8 | 62 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 26 | 81 | 100 | 33.15 | 78 | 26.0 | 62 |
| 27 | 84 | 98 | 32.22 | 82 | 26.2 | 66 |
| 28 | 71 | 99 | 32.36 | 76 | 25.4 | 62 |
| 29 | 92 | 96 | 31.58 | 72 | 24.2 | 63 |
| 30 | 88 | 99 | 32.45 | 68 | 25.6 | 65 |

In ThingSpeak, the access to an IoT analytics platform that enables us to consolidate, display, and examine real-time data streams in the cloud. Our devices can transmit data to ThingSpeak, and immediately create visualizations of this data and even set up alerts. Thing Speak is a time-series database. Each channel can include up to eight data fields With ThingSpeak, we have the capability to:

a. Gather - Securely transfer sensor data to the cloud.
b. Analyze - Use MATLAB to interpret and visualize the data.
c. React - Trigger a response based on the data collected.

To export the data from our ThingSpeak channel to a CSV file by selecting My channels under Channels and select the data that needs to be exported / imported and the above Table 2. describes the sensed values that is derived from the ThingSpeak platform and we can able to download the exported csv file for various purposes such as data analytics and machine learning process if needed. The SMS alert messages as shown in Figure 12. represents body temperature as 39.01 degree Celsius, Heart rate as 107 beats per minute, blood oxygen as 92%, room humidity as 76%, abnormal surrounding temperature, air quality as 67 ppm.

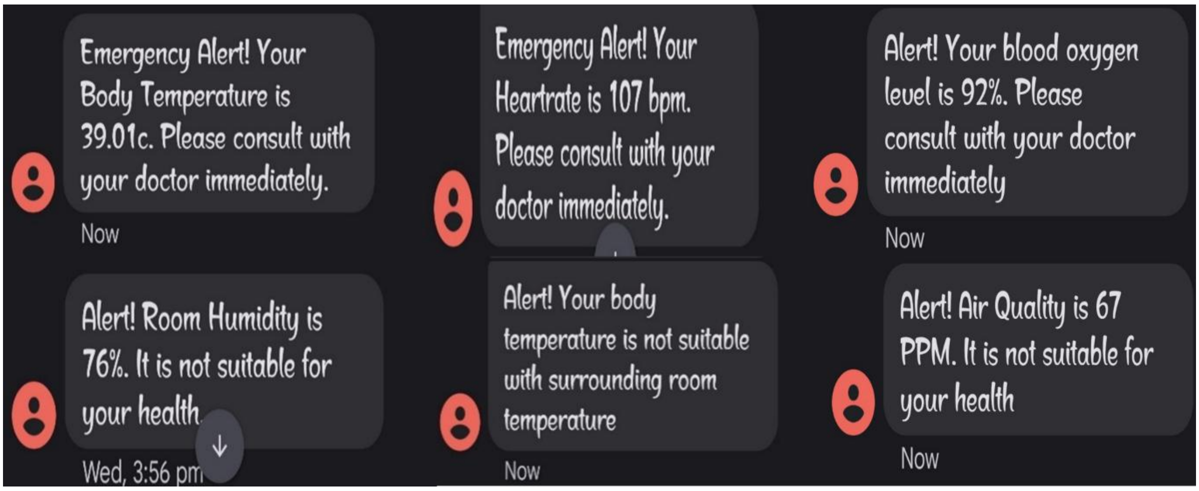


Figure 12. SMS Alert Messages Triggered by IFTTT

When the sensed values are set to a particular value for Triggering in ThingSpeak React and Things HTTP using IFTTT URL and when it reaches the trigger value then an applet created using IFTTT will send alert messages via SMS to the registered mobile number. This will be useful for doctors, caretakers as well as individuals for those monitoring the real time health condition.

## 4. Discussion

The proposed system will monitor the real time health status of a person by using various sensors such as MAX30102 sensor senses the heart rate and blood oxygen, LM35 sensor senses the body temperature, DHT11 sensor senses the room temperature and room humidity along with MQ135 sensor senses the air quality of our surrounding environment. It is portable due to its minimal in size and very reliable to use. It costs very minimum for our proposed system. As a result, the system we proposed is implemented efficiently for real-time health monitoring for the critical body condition patients or persons so that doctors, nurses and caretaker can have alert in taking care of their patients by using SMS emergency alert. We can able to send these real time sensed data to the cloud and monitor the sensed data through the ThingSpeak cloud platform efficiently. The sensed values will be displayed in the 16x2 LCD display that is interfaced with ESP-32 microcontroller Wi-Fi module if there was any internet connection issue occurred. We can also view these sensed values through our created website by using any devices such as laptops, mobile phones and remote access to the system by specialized medical professionals will minimize exposure time, enabling immediate action to be taken. The access to the created website will only authorized by the users who have been authenticated with a valid username and password. Our system can effectively transmit data from the sensor nodes to the cloud servers and end-users but the security model is limited and not designed for wide networks. The COVID pandemic has altered the way of living, as people are more time-constrained. This virtual real time health monitoring would allow individuals to avoid visiting medical facilities with high footfall, reduce direct contact with others, and maintain a safer and more comfortable experience. Therefore, this study offers a promising solution to the problems discussed earlier in the paper. The proposed system makes use of four sensors to track heart rate, blood oxygen, body temperature, room temperature, room humidity, and air quality. Nevertheless, the system can be expanded with more sensors with more sensors to measure blood pressure, ECG, and blood glucose levels in the future. The proposed model can be further improvised with reducing energy consumption by implementing deep sleep features in the future and also improving the security model of the prototype systems. Additionally, machine learning algorithms and data analytics methods can be employed to predict diverse health information, such as the risk of a person experiencing a heart attack, stroke, or cardiovascular diseases, and to classify whether a patient's health condition is within the normal range or outside it. In this paper, the current and future states of real time health monitoring system that rely on Internet of Things, including their requirements, challenges, recommendations, and directions for future research.

**Supplementary Materials:** The following are available online at www.forexjournal.co.in/download/sup.pdf, Figure S1: title, Table S1: title, Video S1: title.

**Author Contributions:** The author Prakash contribute in validation, software of the paper. The author jaffino contribute in writing—original draft preparation, Conceptualization of the paper.

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**Conflicts of Interest:** The authors declare no conflict of interest

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