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## IoT Framework for Real-Time Health Monitoring- Fingertip Sensor-Based

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### Abstract

The continuous increase in the global population and the occurrence of chronic diseases has resulted in an increase in the number of patients visiting hospitals and healthcare facilities thereby increasing the complexity of health needs. Thus, the traditional approach of attending to patients which is based on hospital and healthcare facility visits can be tedious considering the doctor-to-patient ratio in many developing nations. Therefore, the advancement in technology can be utilised in the manufacture of gadgets that are capable of monitoring patient's health remotely using the Internet of Things (IoT). These gadgets generate vital indicators that may be viewed remotely through web connectivity and enable the acquisition of data in real time. The system presented in this paper makes use of fingertip sensors to track heart rate, blood oxygen levels (SpO<sub>2</sub>), and temperature of the patients. The system uses a microcontroller (ESP8266) which collects all data from the sensor and transmits them wirelessly to a cloud-based platform (Ubidot) for easy access and analysis. The results obtained from the temperature readings of a patient when compared against a standard thermometer reading indicated the smallest deviation of 0.45% and the largest deviation of 1.29%. This indicates a relatively high accuracy and reliability of the system. Notably, in this study, some of the SpO<sub>2</sub> samples showed a result below the normal criteria (usually > 95%), which suggests a probable respiratory difficulty. The system provides affordable and user-friendly data visualization thus enabling medical professionals to monitor patients in real-time, reducing response times for critical conditions, and supporting preventive care.

**Keywords:** Cloud Computing; Fingertip sensor; Internet of Things (IoT); Real-time monitoring;

### 1. Introduction

The global increase in population and the frequent outbreak of infectious diseases are responsible for a significant rise in the number of patients who visit hospitals and healthcare facilities, thereby increasing the complexity of health needs and making healthcare inaccessible to many people, despite the government efforts to develop the sector and make it accessible (Josiah et al., 2025), 2024; (Shah, 2024). Additionally, the low doctor-to-patient ratio in many developing nations increases the death rate. In government hospitals, one doctor treats about 11,000 patients, despite the World Health Organization's (WHO) recommended optimal ratio of 1:1000 (Pandey et al., 2019). This has posed many challenges for elderly people requiring continued

care and prompt response, considering the limited available resources (Alsayaydeh et al., 2023). There are also occasions when doctors must take a little break, even when patients are closely monitored, particularly those who require 24-hour care. During this time, the patient's condition may worsen and an emergency may arise. By the time the doctor returns to treat the patient, it may be too late, and the patient may have been lost as a result of the treatment delay. (Shah, 2024). Furthermore, traditional paper-based recording systems are used in many hospitals thereby the tendency to lose patients' records increases. In addition to compromising patient care, these problems may result in a loss of time and money (Alsayaydeh et al., 2023).

Considering the above-identified problems, there is a for an affordable healthcare system that can effectively provide a wide range of medical services such as real-time remote monitoring, and instant check-ups for patients to maintain optimal health. Thus, an Internet of Things (IoT)--based patient health monitoring system can completely transform healthcare (Alsayaydeh et al., 2023). Therefore, a system that continuously monitors the patient's condition and alerts the doctor of any changes is necessary (Shah, 2024).

The term "Internet of Things (IoT)" which is a result of advanced research on information and communications technology has given birth to innovative applications such as smart cities and smart homes and has also transformed education, healthcare, transportation, and defense operations. It also has the potential to improve the quality of life of the people especially those living in urban areas (Abdulmalek et al., 2022). In the health sector, the Internet of Things coupled with the increasing efficiency of devices brings possibilities for remote healthcare administration and real-time health monitoring, thereby enabling healthcare-monitoring system advancement (Palamar et al., 2023). This has resulted in the sharing of significant volumes of data independent of location or time and also revolutionize how we monitor and manage patients' health data (Ram & Shankar, 2022); (Palamar et al., 2023).

These gadgets generate vital indicators that may be viewed remotely through web connectivity and continuously analyze factual data. This allows for timely response (emergency response) services in addition to real-time patient monitoring (Alsayaydeh et al., 2023).

This study seeks to provide an affordable and user-friendly data visualization system that will enable medical professionals to monitor patients' data in real-time, thereby reducing response times for critical conditions, and supporting preventive care. The system uses fingertip, temperature and heartbeat sensors connected to a Microcontroller Unit (ESP8266) to acquire patients' health parameters and the data collected are transmitted wirelessly via the Wi-Fi module to the IoT Cloud Platform (Ubidot) for real-time visualization and analysis. Also, an automated alert system to notify users or healthcare providers via SMS or email is integrated into the system.

## **2. Literature Review**

Various health monitoring systems are being developed around the world due to the current growth and interest in the Internet of Things. Therefore, as the health monitoring system becomes an integral part of the Internet of Things (IoT), it is imperative to look into previous works that have been done concerning health monitoring systems using wireless technology, thereby garnering more knowledge on the study in order to achieve the specified objective.

Senthamilarasi, C., Rani, J., Vidhya, B. and Aritha, H. (2018) developed an IoT-based mobile wireless healthcare monitoring system to assist healthcare professionals in the real-time monitoring of patients, who are either hospitalized or at home. This system consists of sensors, a data acquisition unit, and a microcontroller programmed in JAVA. The following parameters; temperature, heartbeat rate and EEG data of the patient are monitored, displayed and stored by the system and sent to the doctor's smartphone. This system helps in monitoring a patient's health effectively.

An enhanced Internet of Things-based patients' health monitoring system consisting of four vital sensors: a temperature sensor, a heartbeat sensor, a pulse sensor, and a UV sensor was developed by Odusami, M., Misra, S., Abayomi-Alli, O., Olamilekan, S., and Moses, C. (2022). The system enables the patient's health status to be relayed seamlessly to a cloud environment via an ESP8266-1 Wi-fi module that allows a microcontroller to have access to a Wi-fi network. The IoT platform can be logged into by the doctor in order to view the readings from each of the parameters measured by the sensors. The test carried out on 25 patients, for temperature, Heartbeat, pulse rate, and UV shows an automated response of sensors and significant improvements to the availability of patient's vitals in real-time with an average response time of 7 seconds each for 3 trials period. From the results obtained, it shows that patients' health can be monitored effectively using the health monitoring system.

A health monitoring system that makes use of the Internet of Medical Things (IoMT) was developed by Palamar et al., (2023). This system makes use of the ESP32 module (embedded with Wi-Fi and Bluetooth connectivity) and sensors for temperature, pulse, and oxygen saturation measurement with the sole aim of closing the gap between traditional healthcare and modern healthcare through the capabilities provided by IoMT. Every data obtained from the sensors are transmitted to the ESP32 module and is uploaded to an IoT cloud-based platform for storage and can be viewed by either the patient or health personnel. The system offers a quick response and an effective solution to healthcare management since it can be used remotely for health monitoring.

A health monitoring system consisting of a set of sensors and a Raspberry Pi 3 Model B+ with a fully functional communication module was developed by (Nidagundi, (2024). This system is connected to a doctor's computer or phone via the Internet of Things technology. The Raspberry Pi device comes pre-installed with Python software. Anywhere in the world, the suggested health monitoring system will assist physicians in making prompt diagnoses once they are aware of the health problems of their patients. Sensors in the system gather data about the patient, including heart rate, pulse rate, current temperature, humidity level, and air quality in the patient's room, as well as movement data in the event of bed rest. IoT technology is used to transfer the data collected by each of the sensors to cloud storage, where it is kept as a health data server. This server is accessible to both the patient and the doctor. With IoT-enabled devices, they can monitor patient data from any location in the world. As a result, both the doctor and the patients routinely check the health parameters of the patients. The suggested approach is certain to provide patients with prompt, accurate, and reasonably priced medical services.

Kumari et al., (2024) propose an "Internet of Things-based Smart Health Monitoring and ECG Denoising" system that will provide continuous monitoring of the user's health status using an Arduino Uno, an ECG sensor, and a MAX30102 sensor to measure important metrics like body temperature, heartbeat, and SpO2. The data from the sensors is sent to the Arduino Uno and is then uploaded on a cloud platform (Thing Speak) and from there the data can be viewed using a smartphone application, thereby facilitating efficient patient health monitoring by medical personnel and also giving the patients direct access to their medical records.

The system also includes LED indication lights and a buzzer for improve medication adherence -remind patients to take their medications at the appropriate time. For easy separation of clear ECG data from noise and analyzing of heart activity in order to find abnormalities or irregularities a Python code uploaded on a laptop is used. Data obtained gives an important insight into the patient's cardiac health which helps the health professionals to quickly address any anomalies. This system therefore provides an effective means of managing and monitoring health, using IoT technology and data analytic methods to promote a patient's health condition in real-time.

An IoT-based smart edge system for remote health monitoring was presented by Sharrath et al., (2022). Wearable sensors provide information to two cutting-edge software engines included into the system: the Criticality Measure Index (CMI) and Rapid Active Summarization for Effective Prognosis (RASPRO). The CMI

alerts engine computes an aggregate criticality score, and the RASPRO transforms vast volumes of sensor data into Personalized Health Motifs (PHMs), which are clinically valuable summaries. The system ensures a prompt distribution of warnings and PHMs to the doctors by carefully retrieving detailed data-on-demand (DD-on-D) from the cloud using a risk-stratified methodology. Clinical validation of patients demonstrated the efficacy of the IoT smart edge in remote monitoring.

Wu et al. (2023) suggested a wearable health monitoring system based on the Internet of Things (IoT) to remotely track the precise location and physiological conditions of people under quarantine in real-time. To offer real-time updates on physiological markers, the system combines extremely miniaturized optoelectronic and electronic technologies with a monitor terminal, a mini-computer, and an anti-epidemic watch. Heart rate, body temperature, and peripheral oxygen saturation (SpO<sub>2</sub>) are the most important parameters for critical care. A life-threatening event or a brief window of time during which irreparable harm could happen could be indicated by abnormalities in these three physiological indicators. In order to enable remote monitoring by healthcare practitioners, these parameters are automatically uploaded to a cloud database.

Multiple patients' real-time health data can be shown on the monitor terminal, which also gives medical personnel early warning capabilities. The system removes the need for manual patient monitoring, which greatly lessens the workload for medical professionals.

Goel et al., (2018) presented a health monitoring system that uses Arduino Uno, an LCD, an analogue heartbeat sensor, and a WiFi module in their work. This system works with the user simply attaching the Pulse Sensor to any organ of the body- finger, ears etc., where it can detect the pulse easily. The Pulse Sensor measures the change in the volume of blood, which occurs every time the heart pumps blood in the body. A change in the blood volume causes a change in the light intensity through that organ. The Arduino converts this change into the heartbeat per minute (BPM), with the LED connected blinking according to the heartbeat. The ESP8266 communicates with the Arduino and the data collected is to the Thing speak site for storage. This data sent to Thing speak is shown in a Graph format too and can be accessed anywhere over the internet.

Harshavardan et al., (2022) developed a device that can be used to measure temperature, pressure, sugar level, and other parameters that determine a person's fitness status. The data the data collected by the sensors is interpreted by a microcontroller (Node MCU) and is transmitted to the cloud via the ESP8266 module.

Alsayaydeh et al., (2023); Kumar et al., (2024) all developed a patient health monitoring system for older patients who are at risk of sudden death due to neglect in medical care. Alsayaydeh et al., (2023) in their own work, made use of an Arduino UNO connected with a heartbeat sensor and a Node MCU connected with an infrared temperature sensor is been used to monitor the patients for any abnormal sign in their health. Every data collected by the sensors are transmitted over a Wi-Fi connection to a web platform for easy view of the measured parameters. This system shows the patient's health status in real-time, thereby helping the patients to receive timely medical assistance in the event of an emergency as the by healthcare workers receive notifications on their phone. This system allows for numerous patients to be monitored at once thereby reducing the stress on medical professionals.

AlsayaKumar et al., (2024) in their own work made use of an Arduino Board and a Wi-Fi module for processing and transmission of data. This system collects and send data the following data; blood pressure, pulse, body temperature and GPS location wirelessly. This system allows for Real-time data collection, analysis, and storage, notifying medical personnel of any critical condition.

A system that incorporates temperature, ECG, and pulse rate sensors to measure patients' vital health condition was developed by Shah (2024). This system incorporates some sensors which are used for the measurement of patients' health condition and a microcontroller which is used to receives data from the sensors. The data can be easily accessed by the doctor and in case of an emergency, the system's GSM module would send an SMS. This system provides better and precise healthcare and also reduces the need for human intervention.

Ianculescu et al. (2025) developed a health monitoring system (Monit4Healthy) to address problems of processing biological signals, energy efficiency and data transfer in real time. The following physiological sensors were used for this work and this include; EKG, galvanic skin reaction, electromyography, photoplethysmography all combined with wireless communication components in the system's architecture to allow for the remote collection and evaluation of health parameters. The Edge computing was employed for real-time data filtering and feature extraction in order to speed up anomaly detection and lessen network load.

The Monit4Healthy system combines a flexible design with effective wireless communication to improve existing IoT health solutions. Laboratory testing and under typical monitoring conditions, the system shows reliable wireless connectivity.

A health monitoring system that combines Internet of Things (IoT) with wireless sensor networks (WSNs) to provide advanced data processing capabilities and extensive data storage was developed by Najim et al., (2024). A WSN and IoT framework for patient monitoring in high-speed 5G communications is used. Using Internet of Things (IoT) technology, an intelligent health monitoring system based on an Artificial Neural Network (ANN) was created to track a person's temperature, heart rate, blood pressure, and oxygen saturation. In addition, the system facilitates communication and updates between the hospital and the elderly in crucial situations at home. This allows for prompt treatment, particularly in rural places. The outcomes demonstrated the suggested system's superiority and efficacy. Furthermore, 96% accuracy was attained by using ANNs to extract the fundamental features. After the suggested approach was put into practice, the outcomes were shown in real-time and contrasted with those of commercial medical equipment. SpO2 (1.05), systolic blood pressure (3.4), diastolic blood pressure (2.89), body temperature (2.94), and heart rate (2.19) had the highest relative errors. However, regardless of the detection accuracy, the suggested solution is significantly faster than previous wireless communication techniques.

Numerous studies on healthcare monitoring systems have been carried out, including those that calculate temperature, light sensors, fall detection sensors, nasal/oral airflow, heart rate, and ECG. Research on health monitoring via sensor networks has been conducted by a variety of researchers. Some studies used many microcontrollers and senders and receivers between the microcontrollers to interact, while other studies used built-in programs, such as a few parameters, and out-of-date tools for study development. In the area of sensor-based health monitoring systems, however, no effective, affordable, and modern work has been suggested. In order to remotely monitor electrocardiograms (ECGs), pulse oximetry, heart rate, and body temperature, a mobile system based on Android was developed by Alruwaili et al., (2023). Ten distinct patients of varying ages were used to test the device's performance in terms of temperature, SpO2, ECG, and beats per minute (BPM).

To provide a accurate reading of the pulse rate, the system makes use of a tiny pulse sensor. A temperature sensor is also incorporated in the system for temperature measurement. The following parameters; blood oxygen level, pulse rate, ECG data and temperature, are all measured by the system via a microcontroller (MCU) and the data is sent to a server (Firebase). The system was tested on different patients with different age range. The difference in the system readings for BPM and that of the cardiac monitor was not much.

Kartheek & Kumal, (2022) design an IoT-based real-time health monitoring system that requires the following sensors- temperature sensor, pulse sensor, ECG sensor and Accelerometer sensor. The temperature sensor is used to measure the patient body temperature, the Pulse sensor for measuring the heart beats per minute and the ECG sensor to detect the heart blockage, while the Accelerometer is used to send messages through hand gestures. A Push Button is included in this system for sending emergency messages while a Buzzer triggers an alarm in the case of any abnormality. The measurements are displayed on the LCD screen. To process and convert the signals and transmit the data to the cloud in the human-readable form an Arduino Mega with an Inbuilt microprocessor is used.

Das et al., (2021) in their research made use of the following sensors a heartbeat sensor to gauge the patient's heart rate and a temperature sensor to take their temperature. Placing the temperature sensor on the tongue or under the armpit produced the most accurate reading. The Arduino board was linked to every sensor. The Arduino system converted the temperature sensor's output to degrees Celsius and the pulse sensor's output to heart rate in beats per minute or BPM. The LCD panel displayed these results. This application requires a Wi-Fi connection to function. The captured data is subsequently sent to the IoT cloud via the Wi-Fi module. The inputs are rated and shown on the LCD panel. When the application is started, the measured data shows on the screen after this data is concurrently sent to the IoT cloud. The smartphone screen will provide a notification if the available value exceeds or falls below the limit value range.

Amin et al., (2024) suggested a new method to improve the health monitoring systems. It employs deep learning algorithms, specifically convolutional neural networks (CNNs) and recurrent neural networks (RNNs), to collect data on a patient's health conditions in real time through Internet of Things (IoT) sensors. The data collected is processed for to check for any unusual changes in the patient's health. By comparing a patient's medical history with the present health condition, the system may determine the likelihood of a patient contracting a particular disease. This system will help for early illness detection and in monitoring individuals with chronic illnesses.

### 3. Methodology

This system is composed of two sensors (DS18B20 and MAX30100) and a microcontroller (ESP8266) as shown in Figure 1. The system works on 5V power supply which is obtained by the Battery Management System (BMS). The BMS serves as the power supply to the microcontroller (ESP8266) as any voltage above this would damage the system. The system architecture shows an integrated and comprehensive and framework peripheral sensing, wireless networking and cloud integration) that enables health monitoring in real-time and easy visualization of data through the cloud-based (Ubidot) platform.

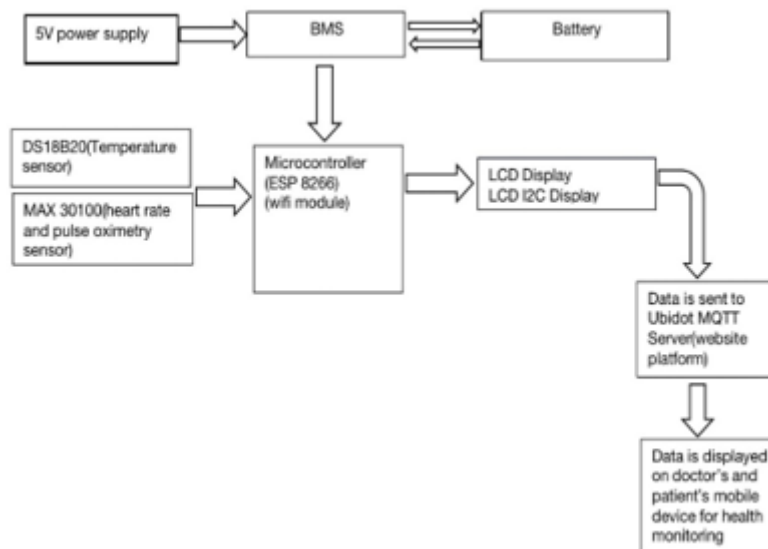
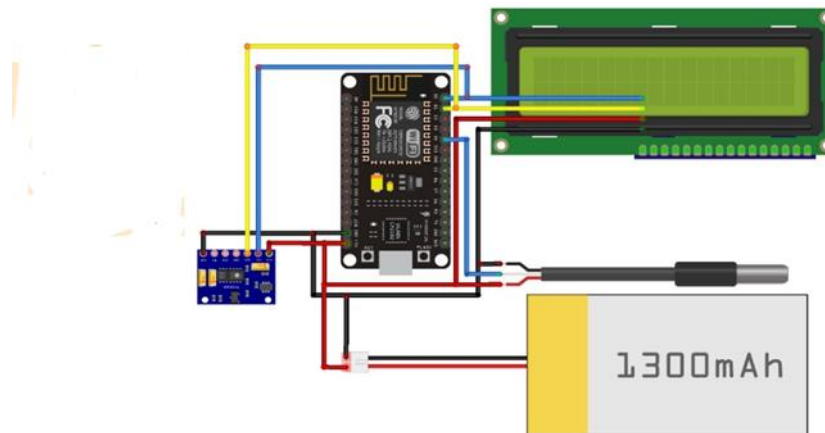


**Figure 1:** Block diagram of IoT-based health monitoring system

The components used for this system as shown in Figure 2 were carefully selected base on availability, accuracy and dependability. circuit diagram in, shows the actual connection of each of the components used.

The DS18B20 which is a temperature sensor shows accurate measurement in the temperature readings, while the MAX30100 a pulse rate sensor also measures the patients' heart rate and oxygen saturation (SpO<sub>2</sub>) level accurately. The data from the sensors are shown on the LCD, thereby offering quick response by the health personnels. Doctors and patients can obtain the data by email or SMS on their desktops or cellphones once the ESP8266 simultaneously sends it over Wi-Fi to an IoT cloud platform (Ubidots). This method enables better health outcomes, timely medical treatments, and continuous remote health monitoring, especially in rural or home-based care settings. To provide uninterrupted operation and power stability even in the event of a main power outage, the Battery Management System (BMS) regulates power between a 5V supply and a rechargeable battery to accommodate mobile and distant usage scenarios.



#### 4. Results and discussion

Six samples were used to compare the accuracy of the IoT-based health monitoring system to a conventional clinical thermometer. Blood oxygen saturation (SpO<sub>2</sub>), body temperature, and heart rate (BPM) are among the characteristics that were measured. Table 1 summarizes the SpO<sub>2</sub>, BPM, and temperature readings from both systems along with their variations.

**Table 1:** IoT Monitoring System comparison against Standard Clinical Thermometer readings

| S/N | SpO <sub>2</sub> | BPM | IoT (°C) | Clinical Thermometer (°C) | Deviation in Temperature (%) |
|-----|------------------|-----|----------|---------------------------|------------------------------|
| 1.  | 71               | 95  | 37.01    | 37.44                     | 1.15                         |
| 2.  | 68               | 95  | 37.47    | 37.73                     | 0.69                         |
| 3.  | 76               | 100 | 36.08    | 36.55                     | 1.29                         |
| 4.  | 63               | 97  | 36.82    | 36.58                     | 0.66                         |
| 5.  | 64               | 98  | 37.40    | 37.57                     | 0.45                         |
| 6.  | 98               | 98  | 36.01    | 35.83                     | 0.50                         |

Six distinct readings were obtained from participants in this study using the IoT-based health monitoring system in addition to a digital clinical thermometer the gold standard. The differences in the temperature measurement between the two devices as shown in Table 1 were found to be very minimal, with a minimum of 0.45% and a maximum of 1.29%. This data shows that the sensors used (DS18B20 or MLX90614), both have dependable heat sensitivity and good calibration.

The largest variation is seen in Sample 3 (1.29%), with a temperature of 36.08°C as against 36.55°C been measured by the clinical thermometer. Even though this difference is marginally higher than the average deviation, it is still within the permissible range of clinical tolerance ( $\pm 0.5^\circ\text{C}$ ).

Sample 5 had the lowest variance (0.45%), suggesting that the two readings were almost exactly in agreement. Sample 6 displays a well-aligned value of 36.01°C (IoT) against 35.83°C (Clinical), indicating a deviation of only 0.50%. These results demonstrate the accuracy of the IoT temperature measurement, particularly when automated and non-invasive patient monitoring is done continuously.

In addition to temperature, the device detects SpO<sub>2</sub> and BPM simultaneously, which enhances diagnostic utility and permits thorough health evaluations. SpO<sub>2</sub> is a crucial measure of blood oxygenation and respiratory efficiency; levels less than 90% usually signify hypoxemia. Notably, in this study: Samples 1 (71%), 2 (68%), 4 (63%), and 5 (64%) all had SpO<sub>2</sub> levels substantially below normal criteria (usually > 95%), suggesting probable respiratory difficulties. Sample 6 showed normal oxygen saturation, but samples 3 and 6 had higher SpO<sub>2</sub> levels (76% and 98%, respectively). All samples had heart rate (BPM) measurements between 95 and 100 bpm. Although these are within the clinically recognized range, they are somewhat higher than the average adult resting heart rate (60–100 bpm). As observed in multiple samples, elevated BPMs along with low SpO<sub>2</sub> may indicate compensatory tachycardia, which could be a sign of stress, anxiety, or underlying medical issues.

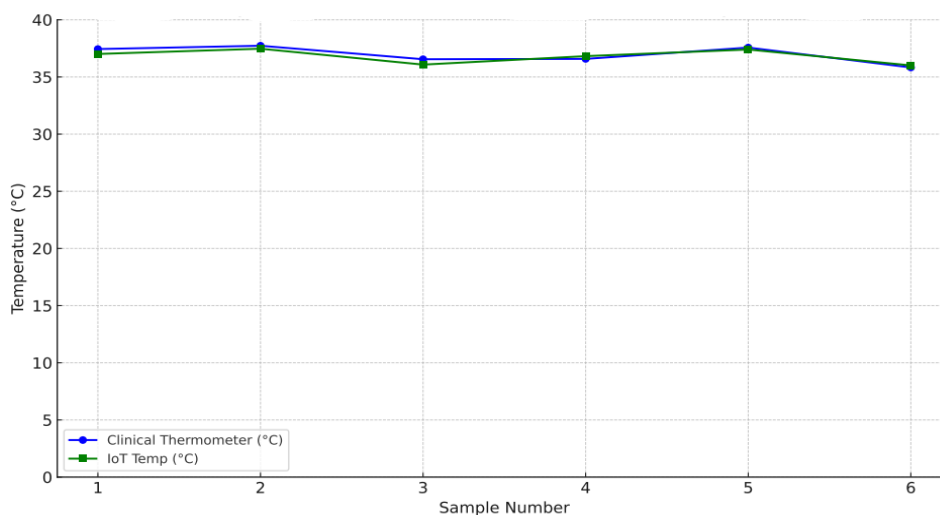


**Figure 3:** Comparison of Clinical Thermometer and IoT Temperature Readings

The graphical representation of the temperature readings as shown in Figure 3 shows that the system followed the changes observed in the standard thermometer readings consistently. From the data plotted, both curves (IoT and Clinical) are seen aligning closely, with not much deviation. As health practitioners are more concerned with relative changes (i.e., the rise or fall in temperature over time) than with single static measurements, the ability of this system to follow real-world fluctuations in body temperature confirms that it is well-suited for health monitoring and management of chronic illness.

## 5. Conclusion

In this era, the age of digital transformation, the development of a health monitoring system based on the IoT is very significant as it has the potential to impact the healthcare sector positively. The health monitoring system presented in the research aims to monitor patients' vital signs by collection and transmission of vital health data which helps in providing prompt medical response in real-time, thereby bridging the gap between traditional healthcare with this digital age. The system architecture aligns with the Internet of Medical Things (IoMT) concept by integrating intelligent sensing, wireless communication, edge processing, and cloud-based analytics.

The ability of this system to measure temperature, SpO<sub>2</sub>, and BPM in real-time with high accuracy and its consistent performance when compared with a standard clinical instrument is confirmed by a graphical comparison that shows the two temperature data sets' close alignment, little drift, and great correlation which further supports its importance for integration into smart healthcare solutions system. With further refinement, this system can play a pivotal role in shaping the future of personalized, preventive and remote healthcare.

## Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

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