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Design and Implementation of an IoT Based Remote Health Monitoring System

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Abstract

Considering the quality of life, manpower, and expenditure, an IoT-based health monitoring system has been proposed and implemented. Devices are placed on the human body to collect data, which is then uploaded to an online data server. Specialist doctors can access this data as needed, allowing them to assess the patient's initial condition and provide advice at any time. This approach enhances the quality and reach of health services. The module, designed and installed using modern technology, minimizes latency and maximizes data accuracy while reducing delay and battery drain. An accompanying app motivates public acceptance and ease of use. Various sensors, including ECG, SpO_2, gyroscope, PIR, temperature-humidity, and BP, collect data processed by an Arduino microcontroller. Data transmission is handled by a WiFi module, with ThingSpeak and Google Sheets used for data processing and storage. The system has been fully tested, and patient data from two hospitals compared with the proposed model shows 97% accuracy.

Keywords

IoT, Patient Monitoring, MPU Sensors, Accuracy, Delay, Power Consumption

1. Introduction

Sensor networks play a vital role in modern diagnosis technology. It makes easier and more accurate results in diagnosis. In this project, we try to design a compact device that gives us diagnosis results more easily and with less time delay. It can be monitored from any remote area with less network connectivity [1]. It can be used in rural or city areas in emergency cases. Medical support is the primary period of emergency for a patient. It can be used in ambulances, ICU, cars, buses, public transport, houses, and anywhere we need. This device is totally manpowerfree, compact, portable, less weight, and easy to operate. So, by using this device, we can provide health monitoring services as quickly as possible in less time [2].

This section provides the preliminary description of the most important aspects relating to body sensing technology, including an outline overview of key ideas of a quality common to a group and operation general rules, a paper on current state-of-the-art applications and operation of making observations work on the thing talked of, and a discussion on the most important limiting conditions and special to some science or trade hurdles of this technology [3].

Regular rules and procedures that follow our rules for accepting medical services at hospitals are very costly and time-consuming. Not only that but in many cases, there is no rule that there is no beginning or end. The number of sufferers is so much that the normal patient becomes very critical and sometimes fatal [2]. Our thinking journey started from there; we thought of a lot of formality and tests, which would be very affordable, manpower available, and easy to use, which is at the hands of ordinary people in Bangladesh.

The specific aim of this paper is to achieve several goals. The first goal of this research is to design a portable IoT-based remote healthcare monitoring system. The system uses a microcontroller, which reduces the cost of the health care monitoring system. The design shall be able to show patients real-time data from remote places. Another goal of this paper is to design a system that involves less manpower and is cost-effective. The system consumes less power, saves battery draining, and provides better efficiency.

1.1. Related Works

Several similar works have been done recently. A health monitoring system using IoT was proposed by Yadukondalu *et al.* [4] in 2021. They have proposed a similar framework but had some limitations. The first limitation of the work is to have remote monitoring without saving any data. Also, the system is built with only one Arduino and has continuous data support. Another research based on a similar fashion was proposed by Mehedi *et al.* [5] in 2023. In that research, they have shown a real-time health monitoring system with data storing facilities but they have focused on only two sensors such as Heart rate and ECG.

Previous health monitoring systems were limited to fixed setups, meaning they could only track a patient's condition when they were in the hospital or confined to bed. This approach was time-consuming for both doctors and patients. In the existing system, patients must be hospitalized for regular monitoring or routine check-ups. These systems measure health parameters and transmit the data through platforms like Bluetooth or similar short-range communication protocols. However, these methods are restricted by their limited range, making it difficult for doctors to access detailed patient information at all times.

1.2. Existing Models

Many existing real-time health monitoring systems commonly use the ATMEL

89C51 microcontroller (μc 8051), which performs its functions with the help of additional devices. These microcontroller-based systems typically consist of four key components: the process, the analog-to-digital (A-D) converter, the control algorithm, and the clock. The moments when the signals are converted to digital form are known as sampling instants, while the time between successive samples is called the sampling period, denoted by "h". The output from the process is a continuous-time signal, which is digitized by the A-D converter at the sampling instants.

However, there are certain drawbacks to the current systems, especially in temperature and pulse monitoring. The reliance on the 8051 microcontroller adds significant complexity, making the entire device not only cumbersome to develop but also difficult and time-consuming to implement. It requires external components such as an A-D converter, an external clock, and a microcontroller development board for operation, further complicating the system's design and functionality.

Previous health monitoring systems were limited to fixed setups, meaning they could only track a patient's condition when they were in the hospital or confined to bed. This approach was time-consuming for both doctors and patients. In the existing system, patients must be hospitalized for regular monitoring or routine check-ups. These systems measure health parameters and transmit the data through platforms like Bluetooth or similar short-range communication protocols. However, these methods are restricted by their limited range, making it difficult for doctors to access detailed patient information at all times.

Figure 1 shows a remote patient monitoring system. The system will collect data from the patient's body and analyze it automatically. If everything remains normal in the patient's body the system indicates a normal state. If any abnormalities are detected by the system, system automatically shows the specific abnormalities. The doctor can monitor their patients from remote places. A database stores all the collected data from where the patient history can be extracted very easily [6].

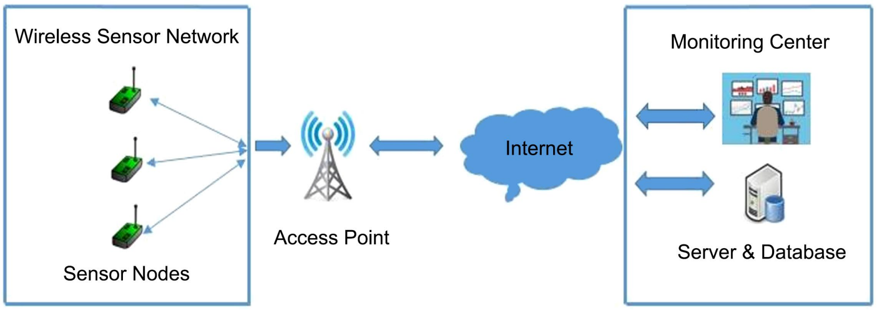

Figure 1. Architecture of a remote patient monitoring system.

2. Problem Statement

Problems make their way to a solution. Generally, problems arise when a patient goes for medical services in a rural area or city area. The traditional patient monitoring system has lots of drawbacks. Now, the problems in the existing ICU monitoring system must be figured out [7].

- Lots of weighty equipment needed for patient monitoring.
- Manpower needed for monitoring, setup and execution procedure.
- No data can be monitored from remote places.
- Cannot store any patient health data.
- Equipment setup and execution delay.
- Load shedding in a rural area makes a delay in patient monitoring service.
- In big cities traffic jam makes delay to arrive in hospital.
- Monitoring equipment is not portable.

Figure 2 shows a traditional patient monitoring system process. The usual practice involves a nurse or healthcare assistant visiting a patient to monitor vital signs and compare them with previous data. The frequency of these visits may follow a recommended schedule, but it can also vary based on the patient's condition and the nurse's subjective judgment. If a nurse notices a decline in the patient's condition, the visits are likely to become more frequent. However, this increased monitoring only occurs when the patient is consistently and effectively observed [8].

Patient monitoring is a labor-intensive task, with human resources being the most crucial component in delivering this care [9].

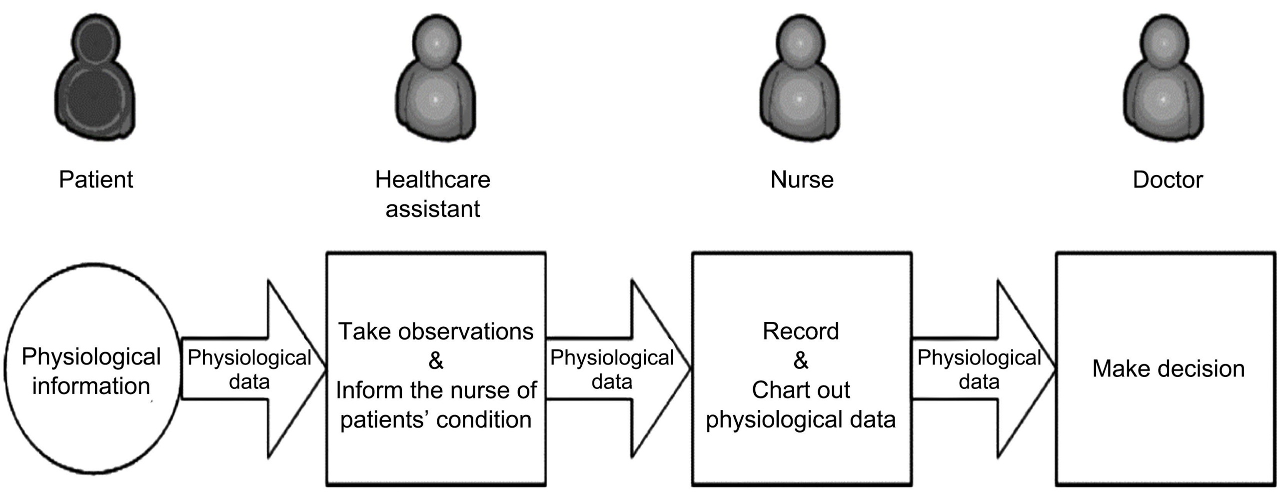

Figure 2. Traditional patient monitoring process [8].

Proposed Solution

In this project, we have tried to reduce and solve those problems. And we make a solution in the best possible way. We consider some parameters when we design and implement this project. Those are portability, reduced high cost, manpower, procedure delay, battery draining data execution delay, increased proper investigation, data accuracy and many more.

This proposed model is shown in **Figure 3**. It has many advantages such as:

- This device is portable and smart. We can move from one place to another when we need.
- Device build cost is low and also low maintenance cost.
- It also cost effective and the lowest possible manpower need to operate this.
- Only basic knowledge needs to operate this device.
- It transmits data through data server to store data and also for viewing from remotely.
- Doctor can monitor patient condition from remotely.
- It needs DC power source to operate and it has the highest possible data accuracy and lowest possible execution delay.
- This device is compact and smaller than traditional monitoring devices.

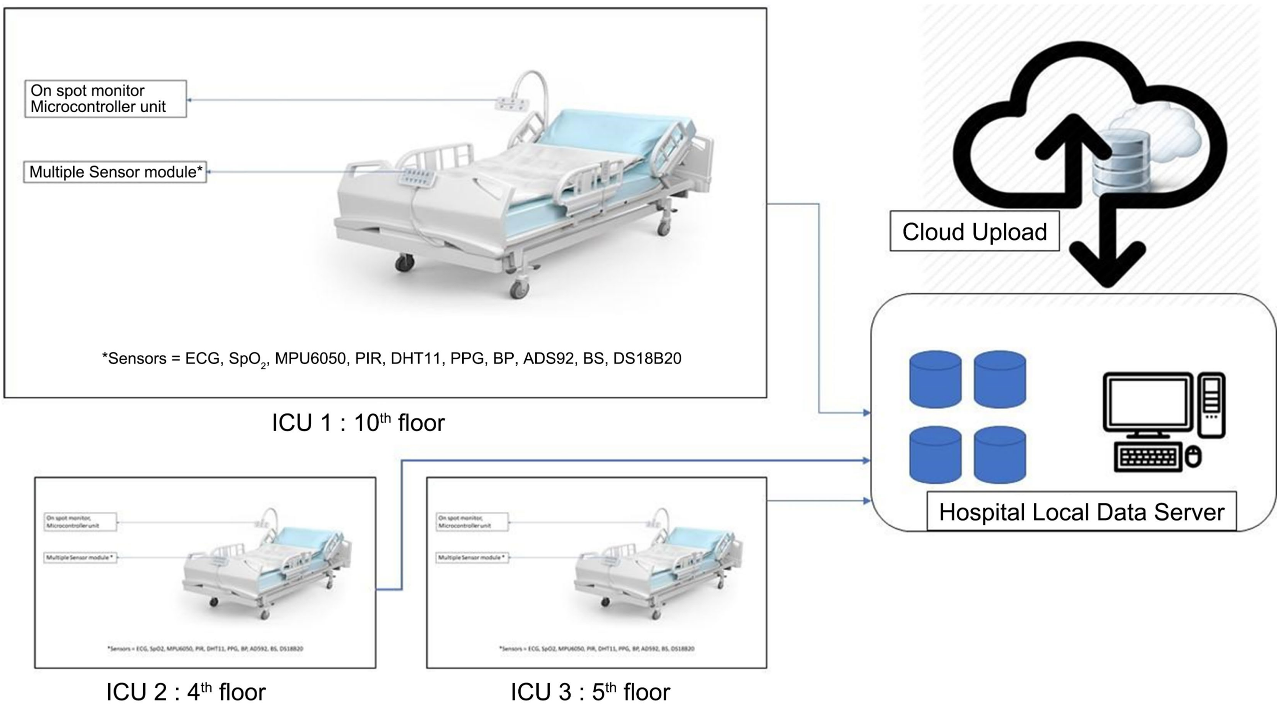

Figure 3. Proposed solution.

3. Design and Implementation

3.1. Project Diagram

The project diagram has been represented into two sections. The first one is the Project area diagram (Figure 4), which represents several sections or units of our whole project that offer sensors area, controller area, policy and test bed area also data accusation with web server.

On the other hand, Schematic diagram upholds the whole project's circuital pathway. Schematic diagram is divided into two parts. The first one is the continuous data sectional area, as shown in Figure 5. This unit is divided into several sections. Those are sensor unit, basic microcontroller unit, core microcontroller unit and output visualization unit. The sensor unit deals with sensors that operate in +5-volt DC. The sensors Serial Clock (SCL) and Serial Data (SDA) port are connected to the next basic microcontroller unit. And the core microcontroller unit consists of several basic microcontroller units [10]. The visualization unit consists of a display, Bluetooth, Wi-Fi to web and GSM where web server, data server, cloud, local web, google sheet and apps are connected with Wi-Fi to web module. The visualization unit also connected with core microcontroller unit.

The second one is sessional data area (**Figure 6**), which is divided into two sections. The first one is sensor unit and Secondary core microcontroller unit. The sensor unit deals with sensors which operate in +5-volt DC. The sensors Serial Clock (SCL) and Serial Data (SDA) port are connected to the next secondary core microcontroller unit. And secondary core microcontroller unit is connected to the core microcontroller unit.

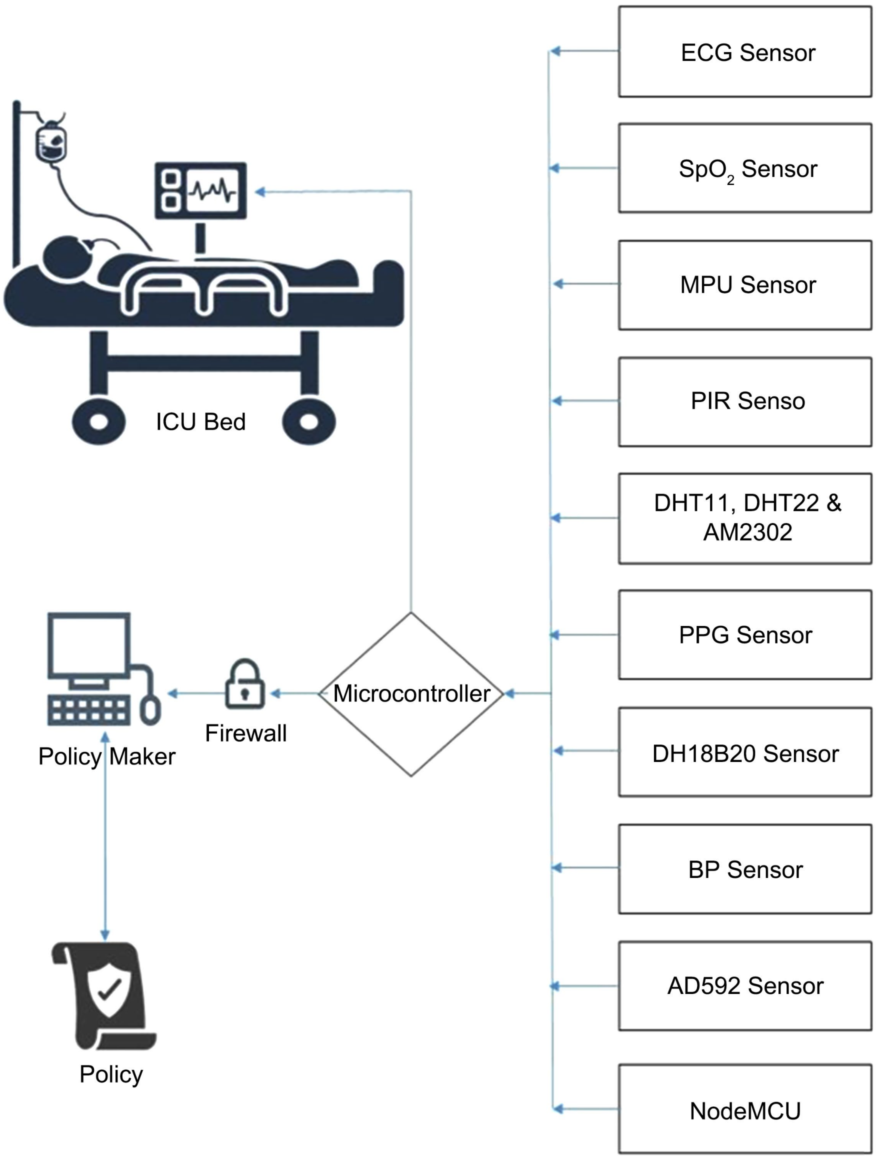

Figure 4. Project block diagram.

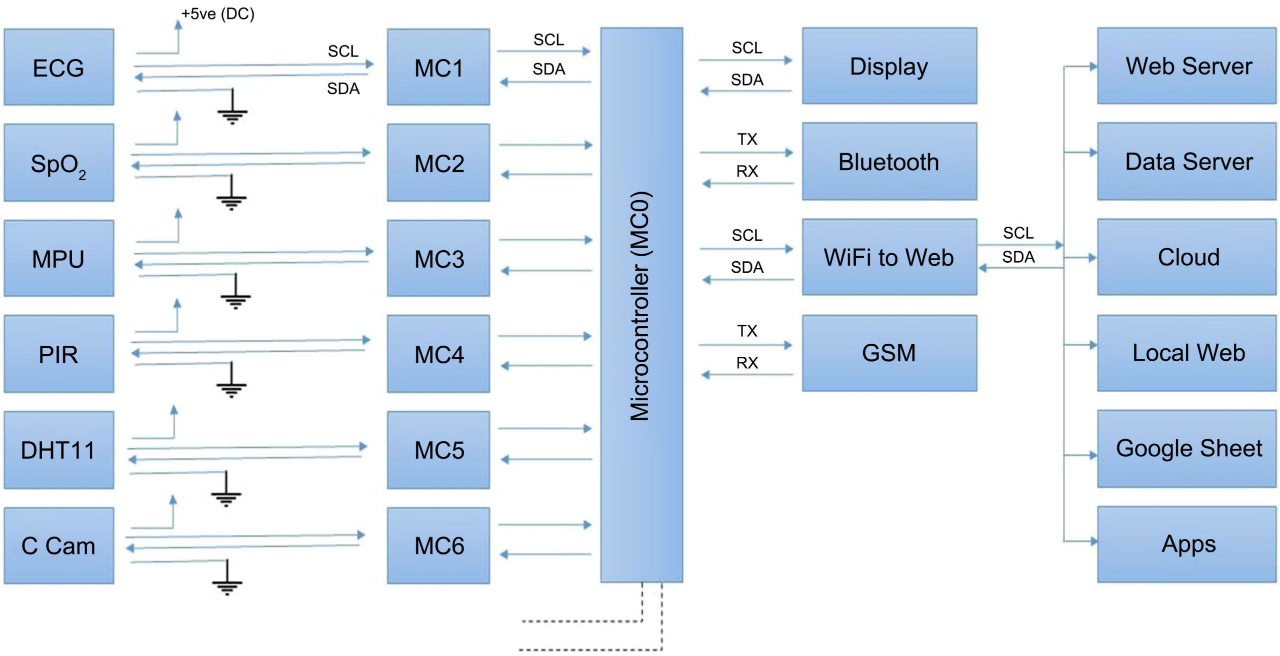

Figure 5. Schematic diagram (continuous data area).

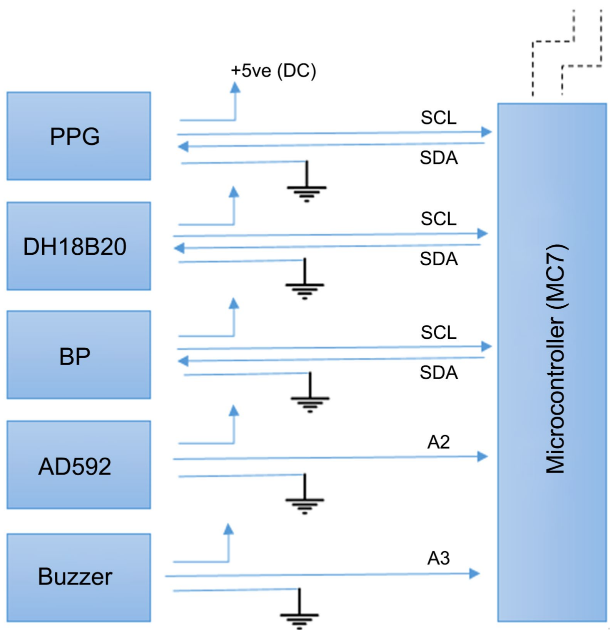

Figure 6. Schematic diagram (sessional data area).

3.2. Design Requirement

3.2.1. Hardware Requirement

This research is based on multiple core hardware equipment that collects data from the patient body. And sends data to basic microcontroller processing unit; after processing data it sends data to the core unit. Then, finally core unit transmits data to visualization unit. Five sensors have been used in this research such as ECG (Electrocardiography), Oxygen saturation (SPO_2), Passive Infrared Sensor

(PIR), Temperature-Humidity Sensor (DHT11/DHT22 and HS1101), Digital Temperature (DS18B20 & BME280), Blood Pressure Sensor (PGA90A) and Heart Rate sensor. The hardware implementation of the project is shown in **Figure 7**.

3.2.2. Software Requirements

Arduino console and Turbo C were used for code compiling. For data entry, a Google sheet was used. To store all the extracted data, a web development tool named Think Speak was used. It is an open source "Web developing" tools that are connected to Arduino device module via a wireless network; what has been done in this project to connect, programmed in Arduino, and transmit to the web to see the real time Data visualization anytime anywhere in the world. "Thing Speak" is an open-details Internet of things application and API to store and get back facts from things using the HTTP protocol over the Internet or via a Local Part Network [11].

3.3. Implementation

The hardware implementation of the paper is shown in **Figure 7**. Six sensors have been built on this work, and they are connected with two microcontrollers for extracting sessional and continuous data. Five sensors have been used placed on the human body surface where another sensor has been used to monitor the room temperature and the humidity. A GSM module has been used to send alert for critical case. Two LCD display have been used here to see the sensor outputs. The implementations of ECG, SpO_2, PIR, Temperature-Humidity Sensor, Accelerometer and Gyroscope etc. are discussed here accordingly.

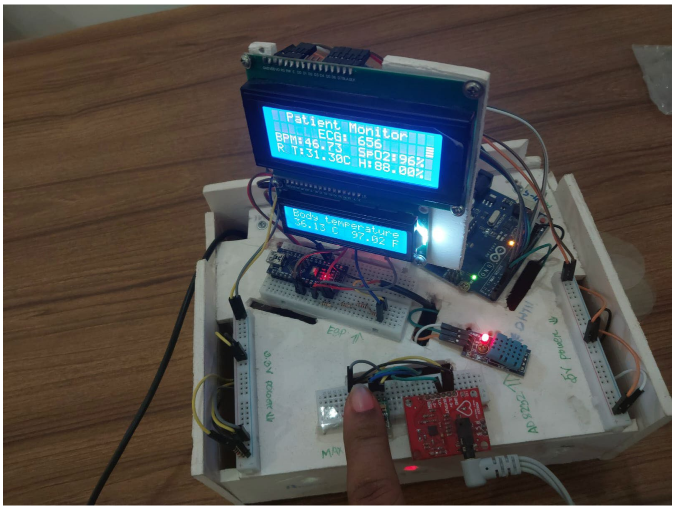

Figure 7. Hardware implementation.

***Electrocardiography* (*ECG*):** ECG sensor directly connected to patient body and also wired connection with a micro controller which is called basic microcontroller unit. Basic microcontroller execute data from ECG sensor. Basic microcontroller unit send it to core microcontroller unit and serial monitor for in spot real time data monitoring. The core microcontroller unit send data to cloud platform [12]. The implementation is shown in Figure 8 and Figure 9.

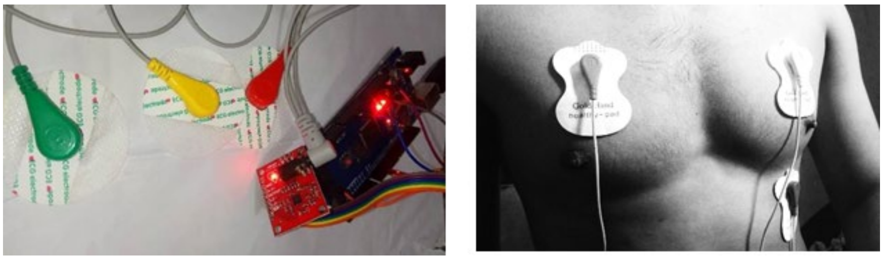

Figure 8. ECG sensor connection on human body.

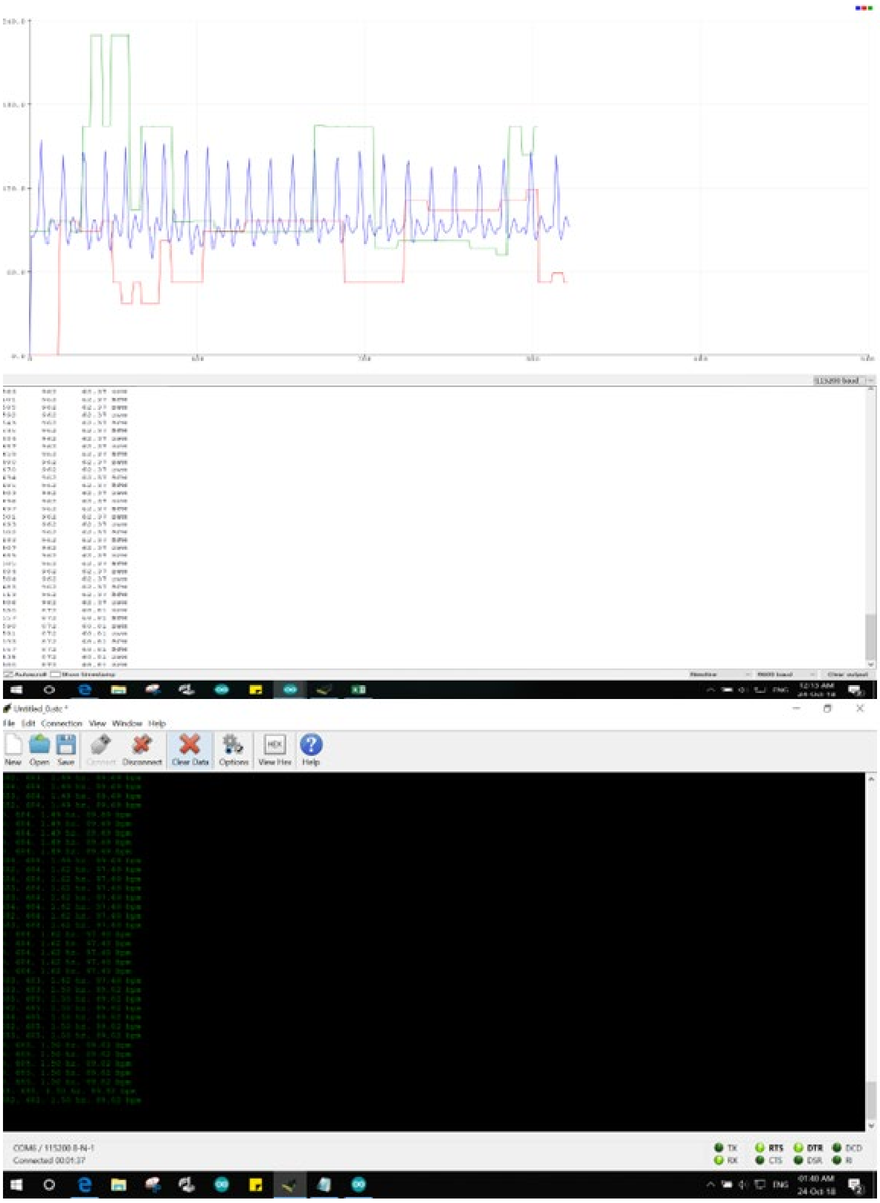

Figure 9. Real time ECG data from patient body; cloud monitoring (Top), web server (Middle), data server (Bottom).

***Peripheral Capillary Oxygen Saturation* (*SpO₂*):** SpO₂ placed on a finger using a pad then we connected SpO₂ Sensor with separate basic microcontroller unit. Then basic microcontroller unit connect to core microcontroller unit. The core microcontroller unit execute data and send data to web and other cloud system to store the Oxygen saturation data of the patient [13]. Using this principal SpO₂ directly send real time data to cloud platform using Node-MCU. The implementation is shown in Figure 10.

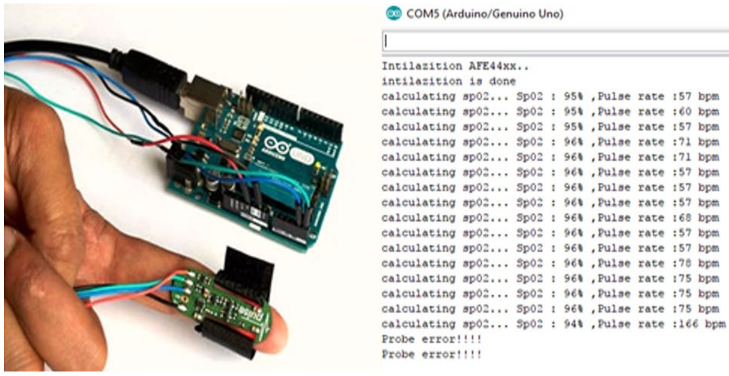

Figure 10. Real time SpO_2 data from patient body.

***Passive Infrared Sensor* (*PIR*):** PIR sensor is attached with patient bed and also connected with microcontroller unit. When PIR sensor detects any movement of patient in the room it sends signal to microcontroller unit. Microcontroller unit send data to on spot serial monitor and core microcontroller unit to send data to cloud platform. The implementation is shown in Figure 11.

***Temperature-Humidity Sensor*:** DHT11 sensor placed on patient room to observe patient room temperature and humidity. DHT11 connected with a basic microcontroller unit [14]. Basic microcontroller unit process the sensor signal then send data to core microcontroller unit and on spot real time serial monitor [15].

***Accelerometer and Gyroscope* (*MPU6050*):** MPU6050 sensor is attached to patient body. when sensor detect any movement of patient body it sends signal to nearly connected basic microcontroller unit. Basic microcontroller unit process the sensor signal then send data to core microcontroller unit and on spot real time serial monitor [16]. Core microcontroller unit upload this data to web and other cloud platform. Implementation of Accelerometer and Gyroscope is shown in Figure 12.

***Body temperature digital thermometer*:** Accurately measuring human body temperature is crucial for assessing health in medical and clinical settings. While there are various methods to measure temperature, not all meet the stringent accuracy required for clinical thermometry. The MAX30205 temperature sensor is specifically engineered for this purpose. In this project, we integrated the MAX30205 sensor to monitor human body temperature, displaying the results on an LCD screen and transmitting real-time data to a cloud platform [17]. The implementation has been illustrated in Figure 13.

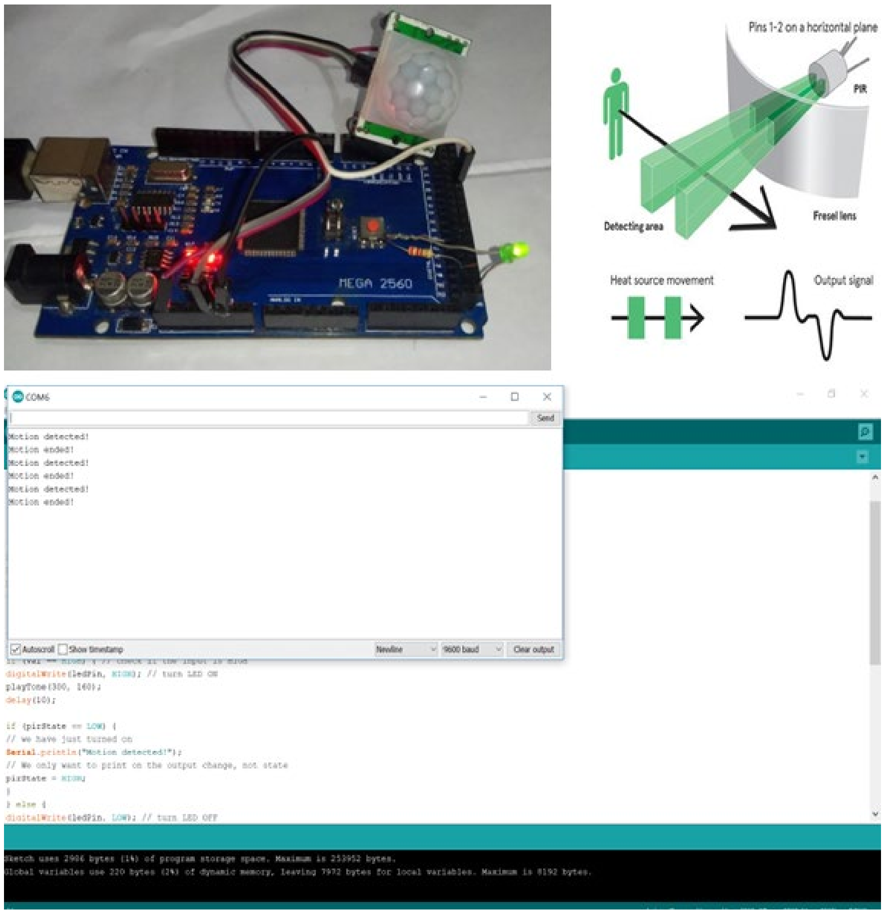

Figure 11. Real time PIR data.

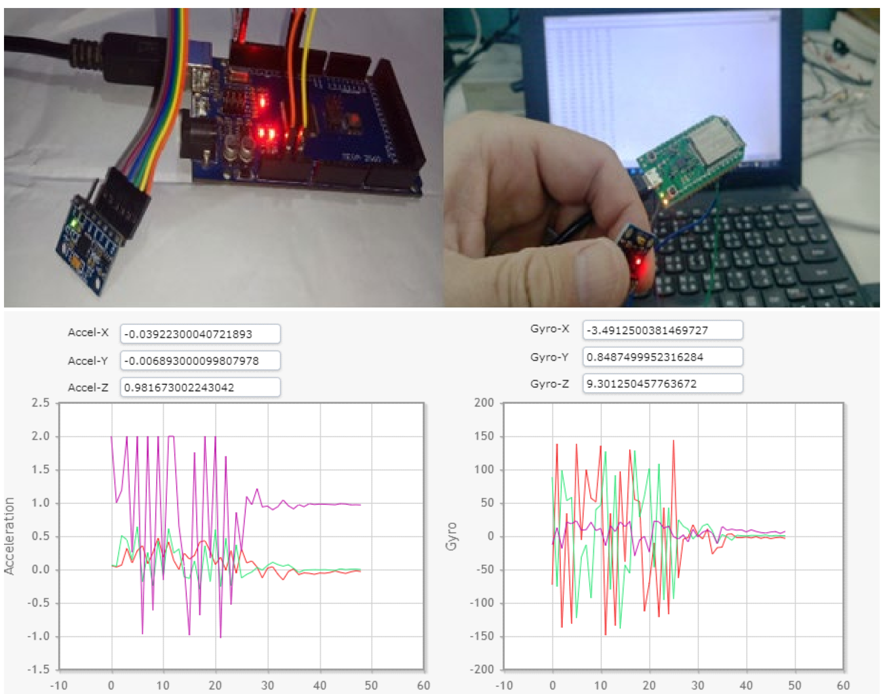

Figure 12. Implementation of *Accelerometer* and *Gyroscope*.

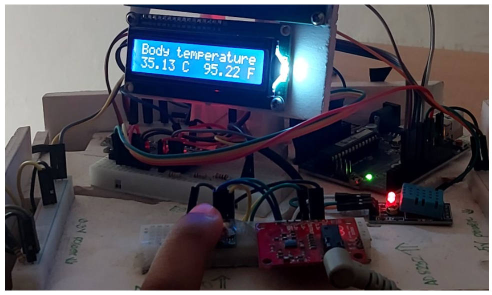

Figure 13. Implementation of human body temperature.

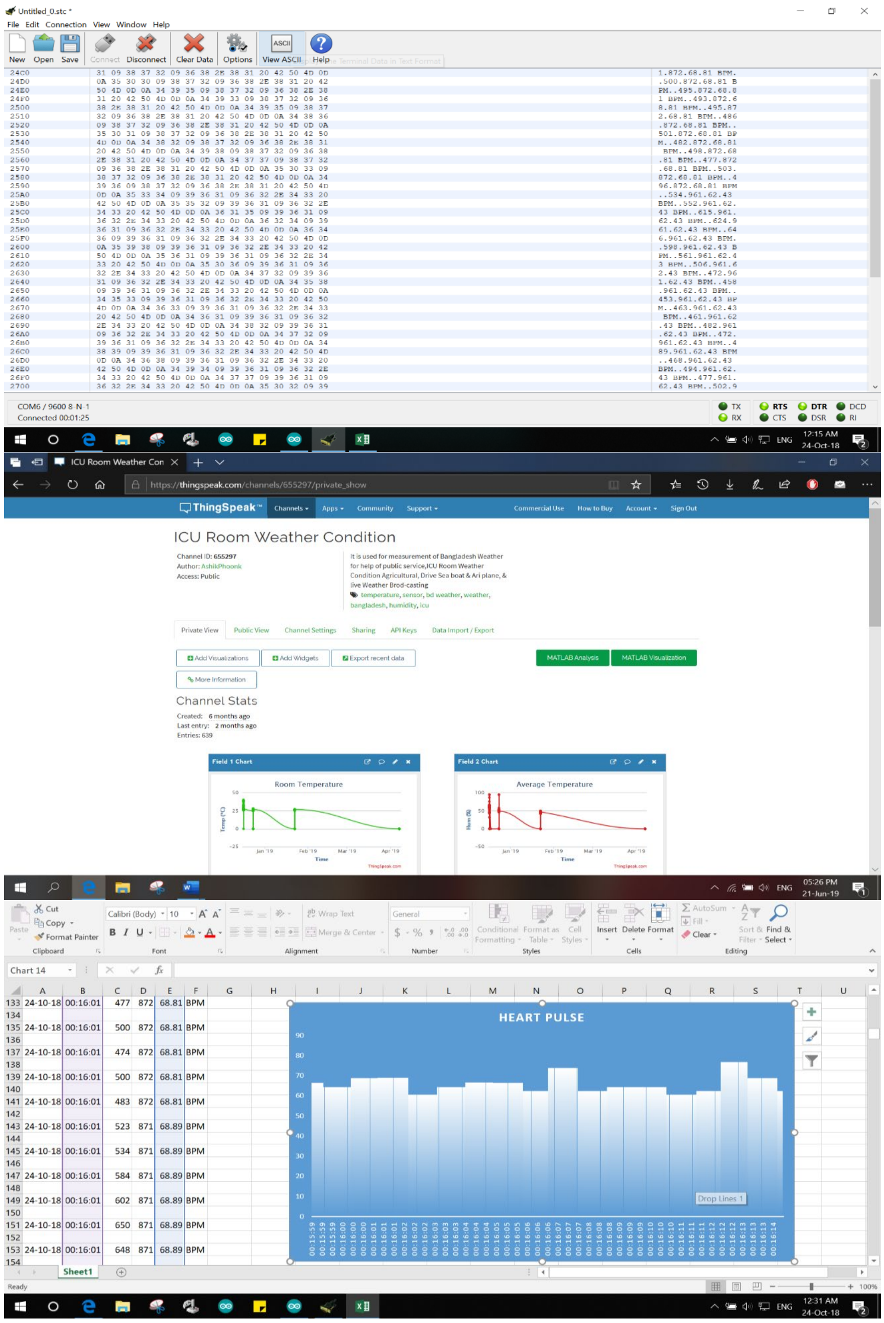

Figure 14. Data upload to data server (top), web interface (middle), Google sheet (bottom).

***Data server* (*IoT based*):** Everything that we collect from the patient's body is directly uploaded to data server so that anywhere in the world, one can access data for their needs. We varied in two sections, one in Think Speak and the other one in Google Sheet. The implementation is shown in Figure 14.

4. Performance Analysis

4.1. Delay

This sensor module system project is based on a testbed survey compared with hospital reference. Every step takes the data on its processor unit to compare the reference for giving an exact value. The level of delay is negligible for transmission loss, but we can't avoid such loss. Rather, we took challenge over it. Table 1 shows the delay analysis of heart rate measurement, where the delay was measured at 2.77% in a normal scenario and less than 1% in a critical scenario compared with the reference data.

Table 1. Delay analysis using PPG reference value.

Reference PPG	Ref. Data	Ref. Data TX-RX rate	Data TX-RX rate	Delay
Normal	65 - 96	0.2315 ms	0.2592 ms	**0.0277 (2.77%)**
Critical	80 - 145	0.0701 ms	0.0010 ms	**0.0009 (0.09%)**

Table 2 shows the delay analysis of patient Oxygen saturation using SpO_2 sensor compared with reference data model where our proposed model gave less than 2% delay in the normal, risk or error levels.

Table 2. Delay analysis using SpO_2 reference value.

Reference SpO_2	Ref. Data	Ref. Data TX-RX rate	Data TX-RX rate	Delay
Normal level	95 - 100	0.1315 ms	0.2592 ms	0.0177 (1.77%)
Risk level	80 - 91	0.0701 ms	0.1710 ms	0.1009 (1.09%)
Error level	<64	0.2118 s	0.3302 ms	0.0184 (1.84%)

4.2. Power Consumption

Power consumption is usually measured in units of watts (W) or milliwatts (mW). The power for a given time used by necessary things is always more than the power for a given time really needed [18]. The average power consumption of the proposed model is 63%, where 5% of the power was wasted due to setup and restart issues. The power consumption of the system is shown in Figure 15 and Table 3.

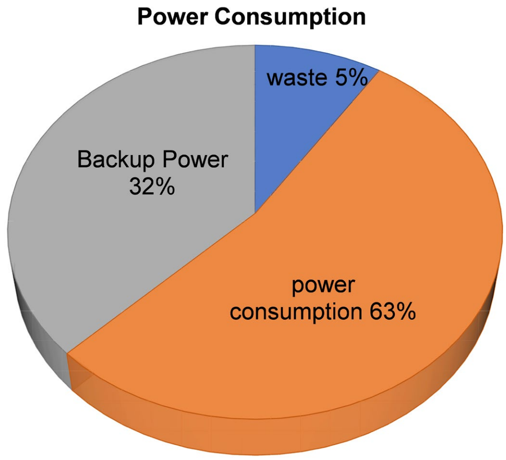

Figure 15. Power consumption ratio.

Table 3. Power consumption using microcontroller reference value.

Reference microcontroller	Reference power level	Data	Consumption
Normal	9.0653 mW	5.424 mW	64%
Risk level	9.5771 mW	5.388 mW	61%

4.3. Data Accuracy

Accuracy is calculated as the ratio of correctly classified samples to the total number of samples in the dataset. Error-free data is a key aspect of data quality [19]. In our Sensor module, we try to ensure the maximum data accuracy for health monitoring using microcontroller data processing. Data accuracy of the proposed model is illustrated in **Table 4**, where the proposed model showed data accuracy of about 99% in all scenarios.

Table 4. Accuracy of project data vs hospital survey data.

Reference model	Hospital survey data	Project data	Data accuracy
ECG 680/690	681/686	683/987	98.97%
PPG 65-96	77	61 - 95/77	99.99%
SpO_2 95% - 100%	99%	95 - 100/98%	99.71%
BP 80/120	86/126	86/127	99.81%
DS18B20 98.6’ F	99.12’F	99.09’F	98.97%

5. Conclusion

In this project section, we have gone over a wide range of topic about sensor networks. Our target was to develop an IoT based remote patient monitoring system that would be portable and affordable. This model has been developed in such a way that it can store patient data over a long period of time, which can be used further if needed. Using this device, we get all data from the patient body on one screen from any remote place. The sensor network is designed to consist of modern scientific equipment that copes with recent smart technology. Adding more advanced sensors like ZigBee and hardware upgrades such as advanced microcontrollers like Raspberry Pi could enhance the performance of the model. In the future, the WBAN frameworks that are introduced in clinics will require security, which is a major issue nowadays. Security issues like confirmation patients' e-reports that are spared within the cloud database are to be moved forward by utilizing any best optimization method. Patients don't need to uncover their individual life issues with any obscure individual. In the end, we feel that several non-technical factors would also play crucial roles in the success of the WBAN technology development, such as affordability, legal, regulatory and ethical issues, and user friendliness, comfort and acceptance.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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