# Design And Application Of Iot Based Real-Time Patient Telemonitoring System Using Biomedical Sensor Network

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# Abstract

The field of Internet of Things (IoT) and Remote Patient Monitoring (RPM) system has been developing rapidly causing these technologies to be adopted in multiple domains all around the world. This paper presents the design of a real-time remote monitoring system for vulnerable patients. The proposed device measures body temperature, heart rate, blood pressure, Oxygen saturation level and electrocardiogram signals (ECG) of patients admitted into Intensive Care Unit (ICU) or Operating Room (OR), and automatically updates all these data on a corresponding hybrid cloud server in every 45 seconds to which a corresponding physician has access. More than 2000 cycles are conducted within a day where all five biomedical parameters are measured and stored on each cycle. Furthermore, the system includes alarm triggering system and emergency Short Message Service (SMS) alert service using GSM technology in order to initiate proper control actions in case of emergencies. This device facilitates doctors, nurses, relatives of patients, or anyone around the world to monitor real-time parameters of patients. The process was tested on 10 patients obtaining a satisfactory outcome. The system proposed in this paper reveals a new vision of biomedical engineering which tends to the era of remotely controllable ICU environment with more interactive, efficient and fast response of both patient and corresponding physicians.


# 1. Introduction

In this age of modern technology, internet based medical systems can play significant role on hospital and medical system. Many advanced technologies are being added to medical system day by day through the indefatigable research of scientists throughout the world. In this digital age, an e-healthcare system can play a vital role as a dedicated ecosystem for medical treatment and supervision. As an e-healthcare, IoT is a reliable technology that we can use to improve emergency health monitoring system. The usage of IoT with microcontroller and intensive healthcare process on basis of sensors is expanding rapidly, which makes human life easier, more productive and smarter.

Due to the rapid increase of population in different countries of the world and insufficient manpower in medical sectors, healthcare units hardly can provide equal medical aid for each patient. Due to this situation, the medical system is being modernized by including internet of Things (IoT) based system. In IoT based systems the medical sensors and wearable devices can capture essential health signs for health monitoring. Sensors can capture pressure level, glucose, weight, ECG signal, heart rate etc. to observe paralyzed and aged person [1]. The system may also alert in medical emergency situations like falling of old aged patients and emergency abnormal condition as within the medical aid unit (ICU) [2]. Both patients and doctors may persistently monitor the heart rate, can get more useful data and take proper actions to halt intense injuries by using smart devices [3]. Enabling every person to look after their health conditions and to advice the most efficient solutions whenever any emergency occurs, may save those human lives. Medical costs and treatment delays can be reduced by utilizing these monitoring systems for the long term [4]. So, it's clear that IoT is important to permit intercommunication between various systems and devices through the web.

In this paper, a real-time IoT-based patient monitoring system for e-healthcare using biomedical sensor network and GSM alarm triggering system is introduced, which records Oxygen saturation level, temperature, heart rate, blood pressure, and measures electronic signals generated by heart pulses of the patient's body. This system also sends real-time SMS alert, mentioning relevant cause, whenever any of those records go beyond the ideal limit or any abnormal situation arises. This system is more efficient and powerful due to inclusion of active processes integrated into a single system. It allows emergency patients to carry reasonable, low-cost, efficient and convenient devices for consistent networking between the patients, medical devices, and physicians. The sensors ceaselessly record signals which are interconnected with the basic physiological parameters to generate relevant signals by analyzing statistical data. The system stores these data through the dedicated channel of web server. Currently the system uses 'ThingSpeak' as the dedicated web server. At any crucial moment, the system sends SMS to the mobile phone through GSM module. Oxygen saturation level, temperature, heart rate, blood pressure, and electronic signals generated by heart pulses of the patient's body are recorded over ThingSpeak. With this system, patient's health can be accessed and monitored from anywhere over the internet. An alarm switch has also been attached to this system so that patients can press it on any emergency to notify an emergency alarm to any doctor, nurse or even relative. This system is capable of monitoring the real-time condition of any patient continuously.

This project has been designed as an addition of advanced model to the medical system. Due to the importance of observing medical patients, continuous remote monitoring is necessary. This will be very useful for continuous analysis of patients using a dedicated web server. The additional advantages of this system are that the device consumes very less power, performs smooth with high sensitivity and easy to set-up for remote monitoring on emergency. The system will be beneficial to all ages of people, ICU patients and paralyzed patients.

## 2. Literature Review

Different IoT related health monitoring publications have represented different methods and applications that are used in the medical field for monitoring a patient's condition of health.

To begin, Garbhapu and Gopalan can be mentioned who proposed a remote system to monitor patient's condition on the basis of IoT, constructed with a hub and spoke model where the spokes are related with the sensor nodes [5]. Almotiri et al., introduced a m-health monitoring system on the basis of android where the device information is collected through the internet [6]. The device used in this process conducts medical diagnosis. A system had been proposed by Gupta et al., which analyzes the data of electrocardiogram (ECG) and sends alert signals to the corresponding person based on abnormality [7]. An IoT based smart healthcare monitoring kit was proposed by Acharya et al., which can monitor basic health parameters such as heart beat, ECG, body temperature and respiration [8]. The major benefit of this system is that it can provide a versatile connection with multi-modal sensor network and IoT data that can help in emergency health services.

Z. Yang et al. introduced a wearable device which is based on nonintrusive sensor which collects data automatically [9]. Trivedi et al. proposed a mobile device which is Arduino-based that could be used to monitor necessary body parameters like temperature, heart rate by relevant sensors on a regular basis [10]. Here the analog information collected from the sensor is changed over into computerized information by an integrated A/D converter. Transmission of these digital data are conducted to monitoring devices via Wi-Fi module. The MCU results are shown by an LCD, and all sensors are operated through a microcontroller. However, it was not possible to integrate multiple sensors in this device.

Lin et al. suggested about the improvement of Real-Time Wireless Physiological Monitoring System (RTWPMS) [11]. A second-generation cordless phone, a GPS module and a module for measuring blood pressure, body temperature and heart rate are included with this system. D. Azariadi et al. designed an IoT device that provides medical facilities for ECG signals and monitors heart function [12]. A portable ECG monitoring system was proposed by Khalid Abualsaud et al., that can monitor ECG, respiration and temperature of the patient [13]. The proposed system also includes storing, encrypting and transmitting patient’s data over wireless interface to the cloud-server so that the data can be processed further after decryption. A wireless sensor network (WSN) was developed by Desai et al. for smart homes that can monitor heartbeat [14]. Nitin P. Jain et al., introduced an embedded system that can be used observing patient’s blood pressure, body temperature and heart rate remotely with the help of GSM technology [15]. Some more vital parameters of patient’s body were still required remotely to get complete the idea of patient’s condition and to take the most efficient recovery action as soon as possible.

There are many opportunities to expand and innovate in this research area. Based on the above discussion, all the systems can be classified into four different monitoring systems as follows:

(a) Microcontroller-based,

(b) Smartphone-based,

(c) Sensor-based,

(d) Cloud-based.

In this paper, a system combining all the above features together with a real-time monitoring system has been proposed. This system is the combination of microcontroller-based, smartphone-based, sensor-based and cloud-based smart health monitoring systems which includes blood pressure sensor, heart rate sensor, temperature sensor, $O_2$ oximeter/pulse oximeter, GSM module and ECG sensor. This system can measure Oxygen saturation level, temperature, heart rate, blood pressure, and electronic signals generated by heart pulses of the patient’s body. Moreover, an emergency button is provided for emergency calling. In this system, IoT acts as an interface between the doctors-nurses and patients for continuous monitoring of health conditions. The system sends an alert whenever any health parameter goes beyond the ideal limit. By receiving SMS alert, doctors and nurses can take necessary measures within a short time.

# 3. Proposed System Overview

In this project, we have designed IoT based remote patient monitoring system using biomedical sensor network and GSM alarm triggering system for monitoring the Oxygen saturation level, temperature, heart rate, blood pressure [16] and measuring the electronic signals generated by heart pulses of the patient's body. This proposed system can draw a significant role to improve the e-healthcare system [17]. A GSM module have been used in this system so that whenever any particular health parameter goes beyond the ideal limit or any abnormal situation arises, the SMS alarm system would send text SMS, mentioning relevant cause, to a pre-defined mobile number. Through this SMS, the corresponding doctor or nurse would be notified instantly allowing to provide the proper treatment in time. In this IoT system, the data are collected through the Arduino Mega 2560 and are stored in the dedicated ThingSpeak channel through the Wi-Fi internet system. This allows the concerned doctor to access data of patient's real-time condition from anywhere in the world through the user interface webpage. This system is introduced so that doctors, nurses or any other health worker can monitor the real-time condition of patient from anywhere in the world without any barrier. Anyone wanting to monitor the data of patient's condition must login with channel identity number and password dedicated for the specific channel. There is also an emergency button which allows patients to call the doctor, nurse or relatives in any emergency situation. The system will basically accelerate the agility of patient monitoring process by applying telemonitoring method mostly for hospitals by connecting every process in one single system in real-time frame [18]. This undoubtedly reduce discontinuations and delays caused by physical distance and complex environment. In fact, the proposed system would contribute to make the emergency response of a medical system more efficient.

The Figure 1 reflects that, data collected through sensors are processed through the Arduino Mega 2560 and are stored in the ThingSpeak cloud through the internet. To measure the body temperature of patient, temperature sensor (LM-35) is connected. Similarly, a $SPO_2$ sensor module (Max30105) is connected, which measures heart pulses to generate electrocardiogram signals, and helps to determine the amount of Oxygen on blood. All sensors are connected with Arduino. To add a bridge between the patient and doctor, a ThingSpeak server and a web portal are introduced. The Wi-Fi module (ESP8266) is linked with the Arduino causing patient's data to be stored via IoT interface through local internet. The sensors are interfaced by coding the microcontroller which is Arduino Mega 2560. Power is supplied via adapter or battery. A charge controller has been connected for minimizing excess voltage to control the power supply. The Arduino connection pin of 5 volts, analog input 0 and ground are connected to power supply and synchronous with the system.

# 4. Experimental Setup

The Figure 2 shows the final setup. All the components mentioned above were used to get the expected result of the proposed hybrid cloud-based patient telemonitoring system.

The Figure 2 and Figure 3 shows the hardware setup of the proposed hybrid cloud-based patient monitoring system using multi- sensor network and GSM alarm triggering system. The above proposed work is implemented by combining blood pressure sensor, $SPO_2$ module, temperature sensor to determine the physical condition of the patient respectively. The brief description of the primary components for the proposed system are explained below.

### 4.1. Arduino Mega:

The ATmega2560 based microcontroller Arduino Mega 2560 runs various complex algorithms and processes multiple operations. For more precise operations than other boards within budget and functions to integrate multiple applications, this board is used in our proposed model.

### 4.2. Pulse Oximeter $SPO_2$:

MAX30100 is a system where function of measuring heart rate and Oxygen concentration within the blood are integrated. This can be used in wearable healthcare devices, fitness assistant devices, medical monitoring devices, etc. For those beneficial functions that are required to be integrated into our proposed project, this module is used in our proposed prototype [19].

### 4.3. OLED Display Module:

An Organic diode or OLED display is accustomed to create digital displays of varied equipment. This display works with none backlight because it emits nonparticulate radiation. An OLED screen provides a far better contrast ratio than LCD screen. For those beneficial characteristics, OLED display is utilized in our proposed project. Moreover, it is lighter, thinner, and it consumes less power than LCDs. These qualities are highly required for every instrument which is used for showing real-time values continuously whether or not there isn't any light, low power, or adverse scenario.

### 4.4. Wi-Fi Module ESP8266:

This is a self-contained System-On-Chip (SOC) with integrated TCP/IP protocol stack so that any microcontroller may gain access to any predefined Wi-Fi network [20]. This system can host an application or offload all Wi-Fi networking functionality from another application processor [21]. This Wi-Fi module is utilized in our proposed model to store collected data of patients within the dedicated ThingSpeak channel using the Wi-Fi system.

### 4.5. Transistor BCP56:

BCP56 is an NPN transistor that will use as MOSFET driver, amplifier, linear transformer, and power management purposes. This transistor includes exposed heatsink which is utilized for excellent thermal and electrical conductivity. It is a high-power dissipation capability. This transistor is used in our proposed model to drive the N-Channel MOSFET -RU3060L.

### 4.6. MOSFET - RU3060L:

RU3060L is an N-Channel advanced power MOSFET which is widely utilized in building Desktop Computers on the tactic of power management of motherboards. This MOSFET could also be used on portable devices and DC/DC converters.

### 4.7. Solenoid Valve:

Solenoid valves are basically electromechanically operated valve. These valves are most effective as control elements in fluidics because of having properties like mixing, releasing, shutting off, dosing or distributing fluids. This valve is used in our proposed model for fast and secure switching, low power consumption, compact design and high reliability.

### 4.8. GSM Module SIM800L:

This is a quad-band GSM/GPRS module that is eligible to work on 850MHz GSM, 900MHz EGSM, 1800MHz DCS and 1900MHz PCS frequencies. SIM800L has one SIM card interface. It coordinates with TCP/IP protocol. This module is used to enable the system send emergency text message in critical condition of patient.

### 4.9. Buck Converter LM2596 Module:

This step-down converter is used to reduce voltage from supply to load for controlling voltage level over GSM module.

### 4.10. LM35 Temperature Sensor:

This is a microcircuit sensor that can measure temperature with electrical output. It measures temperature more accurately than thermistor. This sensor is used in our proposed model to measure patient's body temperature.

### 4.11. Filter Capacitor:

A filter capacitor could also be a capacitor that filters out a particular frequency or range of frequencies from a circuit. During this model the filter capacitor is used for filtering the frequency of the circuit.

### 4.12. Battery 8V/2A:

A battery could be a device comprising of 1 or more electrochemical cells with outside associations for controlling electrical devices. During this model, batteries are used for power supply.

### 4.13. Buzzer:

The buzzer or beeper is a gadget that creates sound. It can be mechanical, electromechanical or piezoelectric. Buzzer is used in our proposed system for emergency alert in critical condition of patient.

# 5. Experimental Results Analysis

## 5.1. Initializing:

Our proposed health monitoring system depicts the real-time Oxygen saturation level, temperature, heart rate, blood pressure and electronic signals generated by heart pulses, in a word the overall health condition of patient. This system follows a fixed bunch of steps coded on the Arduino board to integrate particular tasks in a row causing all predefined parameters checked and stored in a complete IoT interface.

The process starts by initializing the system which can be seen on the OLED display like the Figure 4.

After the initialization of the system, it starts to activate all equipment as coded to begin the data configuration process of patient. At this point, the system would send a text message as shown in Figure 5 to a predefined contact number mentioning the system is being begun.

## 5.2. Data Processing and Monitoring:

After the system being ready, it starts to activate all sensors to measure different readings from patient's health. It takes 30 seconds to complete a cycle of measurement and display the real-time value as shown in Figure 6.

The data of a subject are measured on different times to capture the experimental values on different conditions of health. These values (Figure 7) are taken once in every 6 hours.

## 5.3. Analysis of standard value & experimental value at different time:

For the purpose of experiment, a healthy subject was chosen to measure different parameters with the proposed system. Data of the subject were taken once in every 6 hours for four different times of a day. The findings are discussed in Table I.

## 5.4. Standard vs Measured Blood Pressure:

By the research of medical science, the normal blood pressure is 120/80 mmHg [22]. The system is coded as when the diastolic pressure of patient turns less than 70 and more than 90, then the system sends an emergency SMS alert to correspondent user mentioning the specific issue in order to initiate the proper control actions. For diastolic pressure, safe zone parameter is 70 mmHg - 90 mmHg [23].

The findings are discussed in Table II.

A graphical comparison between standard and measured blood pressure in different times can be observed from Figure 8. It can be stated that, the values of standard and measured blood pressure are quite close.

## 5.5. Standard vs Measured Heart Rate:

From previous researches, it is stated that the heart rate of normal adults lies between 60 and 90 beats per minute (bpm) [24]. The system is coded as when the heart rate of patient turns less than 60 or more than 90, then the system sends an emergency SMS alert to correspondent user mentioning the specific issue in order to initiate the proper control actions.

The findings are discussed in Table III.

A graphical comparison between standard heart rate and measured heart rate in different times can be observed from Figure 9. It can be stated that, the values of standard heart rate and experimental heart rate are quite close.

### 5.6. Standard vs Measured $O_2$ Saturation Level:

The normal $O_2$ saturation level range must lie between 97%-100% [25]. Our proposed system is coded such that, if Oxygen saturation level is less than 96%, then the system sends an emergency SMS alert to correspondent user mentioning the specific issue in order to initiate the proper control actions.

The findings are discussed in Table IV.

A graphical comparison between standard and measured $O_2$ saturation level in different times can be observed from Figure 10. It can be stated that, the values of standard and measured $O_2$ saturation level are quite close.

### 5.7. Standard vs Measured Temperature:

From previous researches, it is stated that the normal body temperature is approximately 32°C-37°C [26]. The system is coded as when the temperature of patient turns more than 37°C, then the system sends an emergency SMS alert to correspondent user mentioning the specific issue in order to initiate the proper control actions.

The findings are discussed in **Table V.**

A graphical comparison between standard and measured temperature in different times can be observed from Figure 11. It can be stated that, the values of standard and measured temperature are quite close.

### 5.8. Analysis of conventional method vs proposed system of measuring parameters of 10 individual patients (Table & Graphical Representation):

For the purpose of experiment, 10 different patients were chosen to measure different parameters with both traditional and proposed system to observe the variation of data of patients individually. The findings are discussed in Table VI.

From the Table VI, it can be seen that,

The average systolic blood pressure measured with conventional method,

= {(122+123+122+126+126+123+128+128+128+122)/10} mmHg

= {1248/10} mmHg

= 124.80 mmHg

The average systolic blood pressure measured with proposed system,

= {(120+122+120+130+124+124+130+124+122+123)/10} mmHg

= {1239/10} mmHg

= 123.90 mmHg

Difference of average systolic blood pressure,

= (124.80-123.90) mmHg

= 0.90 mmHg

Percentage of error for systolic blood pressure,

= ± {(0.9×100)/124.8}

= ±0.72%

The average diastolic blood pressure measured with conventional method,

= {(77+76+76+78+78+77+73+66+76+77)/10} mmHg

= {754/10} mmHg

= 75.4 mmHg

The average diastolic blood pressure measured with proposed system,

= {(75+75+77+80+75+76+73+65+77+75)/10} mmHg

= {748/10} mmHg

= 74.8 mmHg

Difference of average diastolic blood pressure,

= (75.4-74.8) mmHg

= 0.60 mmHg

Percentage of error for diastolic blood pressure,

= ± {(0.6×100)/75.4}

= ±0.796%

A graphical comparison between conventional and proposed method of measuring blood pressure of 10 individual subjects can be observed from Figure 12. It can be stated that, the values found in conventional method and our proposed method are quite similar where the calculated difference or error is found within satisfactory range (Systolic ±0.72%, Diastolic ±0.796%).

From the Table VII, it can be seen that,

The average heart rate measured with conventional method,

= {(82+84+98+57+97+93+91+87+74+87)/10} bpm

= {850/10} bpm

= 85 bpm

The average heart rate measured with proposed system,

= {(83+83+96+61+94+88+96+85+72+90)/10} bpm

= {848/10} bpm

= 84.8 bpm

Difference of average heart rate,

= (85-84.8) bpm

= 0.2 bpm

Percentage of error for heart rate,

= ± {(0.2×100)/85}

= ±0.24%

A graphical comparison between conventional and proposed method of measuring heart rate of 10 individual subjects can be observed from Figure 13. It can be stated that, the values found in conventional method and our proposed method are quite similar where the calculated difference or error is found within satisfactory range (±0.24%).

From the Table VIII, it can be seen that,

The average $O_2$ saturation level measured with conventional method,

= {(93+98+97+95+95+96+98+100+100+98} %

= {970/10} %

= 97%

The average $O_2$ saturation level measured with proposed system,

= {(97+96+98+97+96+97+100+96+97+100)/10} bpm

= {974/10} %

= 97.40%

Difference of $O_2$ saturation level,

= (97.40-97) %

= 0.40%

Percentage of error for $O_2$ saturation level,

= ±{(0.40×100)/97}

= ±0.41%

A graphical comparison between conventional and proposed method of measuring $O_2$ saturation level of 10 individual subjects can be observed from Figure 14. It can be stated that, the values found in conventional method and our proposed method are quite similar where the calculated difference or error is found within satisfactory range (±0.41%).

From the Table IX, it can be seen that,

The average temperature measured with conventional method,

= {(37+34+32+29+34+34+38+30+37+36} °C

= {341/10} °C

= 34.10°C

The average temperature measured with proposed system,

= {(36+32+34+30+32+35+37+29+36+37)/10} °C

= {338/10} °C

= 33.80°C

Difference of temperature,

= (34.10-33.80) °C

= 0.30°C

Percentage of error for temperature,

= ± {(0.30×100)/34.10}

= ±0.88%

A graphical comparison between conventional and proposed method of measuring temperature of 10 individual subjects can be observed from Figure 15. It can be stated that, the values found in conventional method and our proposed method are quite similar where the calculated difference or error is found within satisfactory range (±0.88%).

### 5.9. Cloud Login:

While real-time data are being presented on OLED screen, all data of different parameters of a single patient are recorded on the basis of time at specific fields of IoT interface. ThingSpeak server has been used in our proposed model to record real-time data collected from a patient's body. All these data of a particular patient can be monitored by login to ThingSpeak server submitting relevant user login identity number and channel identity number shown as Figure 16 and Figure 17.

### 5.10. Cloud Data Recording and Monitoring:

After login to particular channel dedicated for a patient, the different data of that patient collected on different time frame can be seen stored. This is highly recommended to monitor fluctuations of various major data of patient that signifies the overall current condition and helps the corresponding doctor to estimate the upcoming threat or health issue from anywhere of the world. In ThingSpeak server, the data are arranged on different frames in accordance with relevant time shown as Figure 18, where one subject was chosen for the purpose of experiment to observe the fluctuations of real-time measured parameters stored over a week.

### 5.11. Emergency SMS Alert:

One of the remarkable features of our proposed model is the emergency SMS alert function. If at least one value of five parameters lies into abnormal range, then using GSM module and coded functionality, the system sends an emergency SMS alert to corresponding user mentioning the specific issue in order to initiate the proper control actions.

Another experimental test has been conducted with a patient having cardiac disorder. The Figure 19 depicts the SMS received by corresponding contact number for the real-time abnormal conditions faced by the patient in different times. It is to mention that, every SMS consists of the specific issue the patient faces in real-time domain.

### 5.12. Location:

In addition, our proposed model includes storing location data (latitude and longitude) of the patient in cloud server where the patient's real-time vital health parameters are stored. This allows the corresponding physicians to track patient's location, which might play significant role on taking recovery action on patient's emergency condition. The Figure 20 represents the location where experimental tests were conducted on subject.

## 6. Component List With Price

The cost of components and their prices are given in Table X. This can be seen from the above table that the total expense of the system is 148 US Dollars. This cost is much lower than the cost of other IoT based smart healthcare monitoring system.

# 7. Discussion And Recommendation For Future Development

The proposed IoT-based real time remote patient tele-monitoring system is effective in real-time monitoring for old aged patients mostly because of the functionality which serves both in general condition and any emergency situation providing instant notification alert. Currently our proposed system is built with the ability for measuring Oxygen saturation level, temperature, heart rate, blood pressure and the electronic signals generated by heart pulses of the patient’s body. All these real-time data are stored on a cloud server ThingSpeak, which can be monitored from anywhere around the world through the internet. A safe range for every term is set by the Arduino coding. If any value fluctuates to get higher or lower than the safe range, an emergency SMS alert would be sent to a predefined contact number to aware about patient’s condition mentioning the specific parameter so that in case of emergency, doctor, nurse, or patient’s relative may check the patient’s condition and take recovery action instantly.

Implementation of our proposed system faced some challenges with time management, material selection, and cost estimation. The Wi-Fi module used in our proposed model has a small range of around 366 meters [27], which is a limitation of this system. Security is one of the major facts for IoT systems. Hackers may get confidential information of users in case of buggy or outdated security protocols. To avoid this, more secure updated cloud server can be introduced in our proposed model where IoT interface can build private individual connection protocols. A substitute server can also be designed to ensure more security. The future developed systems can overcome the coverage area range limitations. Smart hybrid cloud and artificial intelligence (AI) can be introduced to monitor multiple patients’ condition by boosting up server capacity at a time [28]. External antenna can be introduced with Wi-Fi module instead PCB antenna to maximize coverage area if required. In order to provide more security on the terminal end, the system can be included biometrics to authenticate a particular patient. The sensors used in our proposed model can be minimized more for handier and more flexible interconnection with different systems. If the project is designed and implemented properly with above mentioned appropriate modifications, our proposed model can play a positive vital contribution to our medical system. The difference/error found in our proposed method lies within satisfactory range. The values found in conventional method and our proposed method are quite similar where the calculated difference or error is found within satisfactory range ±(0.24-0.88)%.

Our proposed system can be improved for measuring many other parameters such as blood sugar, respiratory rate, cardiac activities etc. Though extensive research activities have been revealed new horizons of smart health monitoring systems which are briefly described in this paper, more features are still to introduce for further development. Different algorithms of machine learning like SVM algorithm, linear regression, logical regression etc. can be assigned to get the data processing more precise. Raspberry-pi can be included for smooth and efficient maintenance of the process. The electronic signals generated by heart pulses of the patient’s body can further be improved using advanced technology for more precise result that can lead to acceptable outcome of ECG signals. Our proposed system is a novel addition in the field of medical science. Establishment of this system would result innumerable possibilities to develop medical sector providing healthcare, safety and security.

# 8. Conclusion

A novel low cost and secure system of monitoring health remotely, has been proposed in this paper which provides a dashboard for continuous monitoring biological parameters inside a secure environment. The combination of IoT and cloud computing is able to play a vital role on monitoring critical ICU and aged patients. Detailed framework of a data processing and monitoring system for Oxygen saturation level, temperature, heart rate, blood pressure and ECG has been explained in this paper. The proposed device continuously updates the measured data on ThingSpeak cloud server to which corresponding health-workers have access. The early identification of any health issue may help human to take early recovery actions which may possibly save lives. Moreover, it provides SMS alert to corresponding person if vital signs are beyond the secure range. Data taken from 10 individual patients over a period have been presented to validate the usefulness of the system. Furthermore, result analysis between the measured and standard values show the effectiveness of the proposed device.

The proposed low power health monitoring system may be a novel addition within the field of medical science and engineering which may reduce unwanted deaths and emergency situations. In addition, this system has the potential to reduce medical costs by cutting down periodical hospital check-ups and doctor visits.

# Declarations


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# Tables

**Table I:** Table of standard values vs measured values

| Parameter | Standard Values | Measured Values | | | |
|---|---|---|---|---|---|
| | | 7:00 AM | 1:00 PM | 7:00 PM | 1:00 AM |
| **Blood Pressure** | 120/80 mmHg | 114/75 mmHg | 114/65 mmHg | 128/66 mmHg | 126/73 mmHg |
| **Heart Rate** | 60-90 bpm | 74 bpm | 74 bpm | 81 bpm | 93 bpm |
| **SPO2** | (94-100)% | 100% | 83% | 100% | 100% |
| **Temperature** | (30-37) °C | 28°C | 28°C | 31.10°C | 30°C |

**Table II:** Table of standard vs measured blood pressure at different times

| Time (Hours) | Standard Blood Pressure (mmHg) | | Measured Blood Pressure (mmHg) | |
|---|---|---|---|---|
| | Systolic | Diastolic | Systolic | Diastolic |
| **7:00 AM** | 120 | 80 | 114 | 75 |
| **1:00 PM** | | | 128 | 66 |
| **7:00 PM** | | | 114 | 65 |
| **1:00 AM** | | | 126 | 73 |

**Table III:** Table of standard heart rate vs measured heart rate at different times

| Time (Hours) | Standard Heart Rate (bpm) | Measured Heart Rate (bpm) |
|---|---|---|
| **7:00 AM** | 60 | 74 |
| **1:00 PM** | 70 | 74 |
| **7:00 PM** | 80 | 81 |
| **1:00 AM** | 90 | 93 |

**Table IV:** Table of standard vs measured $O_2$ saturation level in different times

| Time (Hours) | Standard $O_2$ Saturation Level (%) | Measured $O_2$ Saturation Level (%) |
|---|---|---|
| **7:00 AM** | 97 | 100 |
| **1:00 PM** | 98 | 83 |
| **7:00 PM** | 99 | 100 |
| **1:00 AM** | 100 | 100 |

**Table V:** Table of standard vs measured temperature at different times

| Time (Hours) | Standard Temperature (°C) | Measured Temperature (°C) |
|---|---|---|
| **7:00 AM** | 32 | 28 |
| **1:00 PM** | 34 | 28 |
| **7:00 PM** | 36 | 31.1 |
| **1:00 AM** | 37 | 30 |

**Table VI:** Table of measured blood pressure in conventional vs proposed method for 10 patients

| Blood Pressure Measured with Conventional Method (mmHg) | | Blood Pressure Measured with Proposed System (mmHg) | |
|---|---|---|---|
| **Systolic** | **Diastolic** | **Systolic** | **Diastolic** |
| 122 | 77 | 120 | 75 |
| 123 | 76 | 122 | 75 |
| 122 | 76 | 120 | 77 |
| 126 | 78 | 130 | 80 |
| 126 | 78 | 124 | 75 |
| 123 | 77 | 124 | 76 |
| 128 | 73 | 130 | 73 |
| 128 | 66 | 124 | 65 |
| 128 | 76 | 122 | 77 |
| 122 | 77 | 123 | 75 |

**Table VII:** Table of measured heart rate in conventional vs proposed method for 10 patients

| Heart Rate Measured with Conventional Method (bpm) | Heart Rate Measured with Proposed System (bpm) |
|---|---|
| 82 | 83 |
| 84 | 83 |
| 98 | 96 |
| 57 | 61 |
| 97 | 94 |
| 93 | 88 |
| 91 | 96 |
| 87 | 85 |
| 74 | 72 |
| 87 | 90 |

**Table VIII:** Table of measured $O_2$ saturation level in conventional vs proposed method for 10 patients

| $O_2$ Saturation Level Measured with Conventional Method (%) | $O_2$ Saturation Level Measured with Proposed System (%) |
|---|---|
| 93 | 97 |
| 98 | 96 |
| 97 | 98 |
| 95 | 97 |
| 95 | 96 |
| 96 | 97 |
| 98 | 100 |
| 100 | 96 |
| 100 | 97 |
| 98 | 100 |

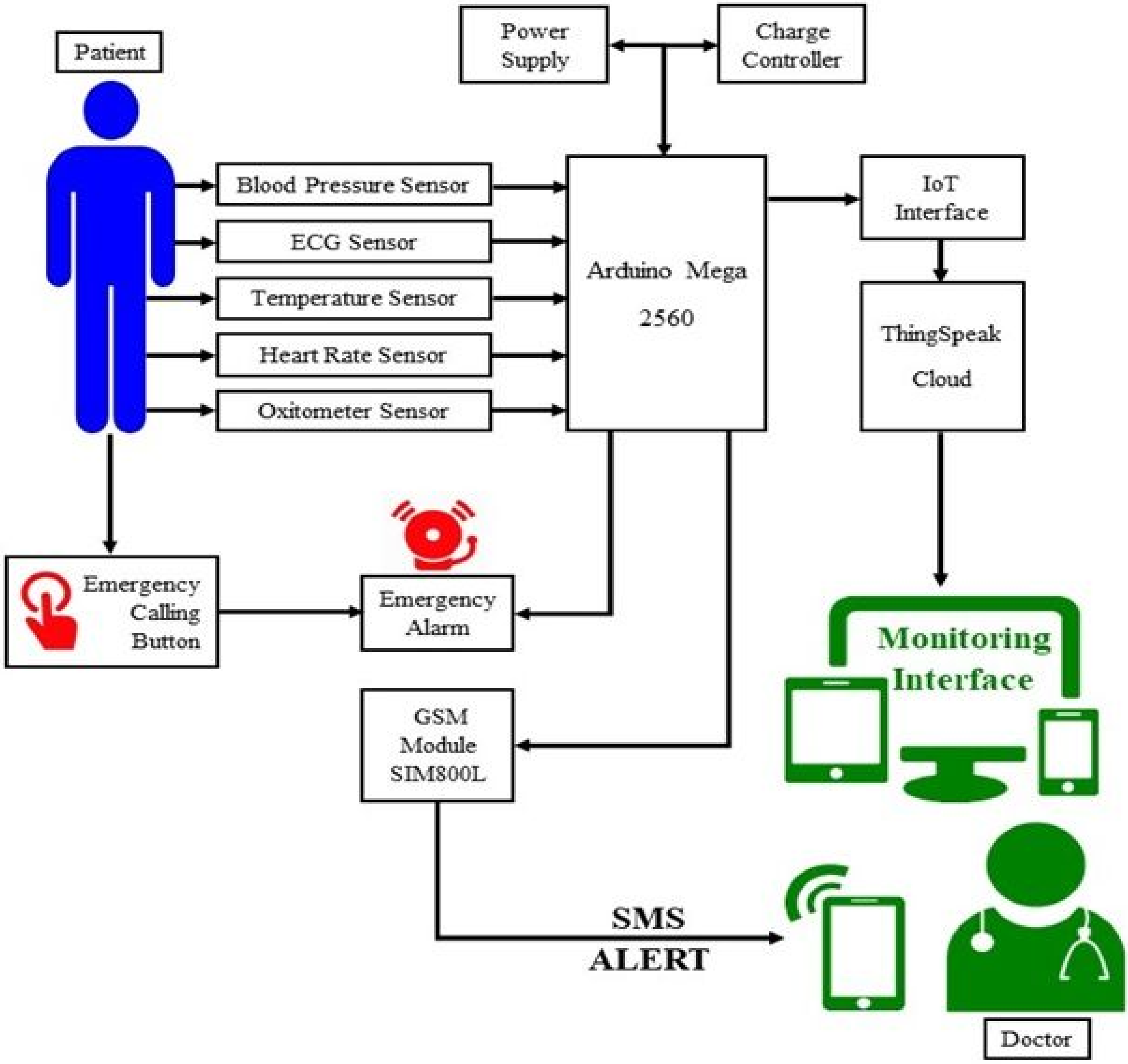
**Table IX:** Table of measured temperature in conventional vs proposed method for 10 patients

| Temperature Measured with Conventional Method (°C) | Temperature Measured with Proposed System (°C) |
|---|---|
| 37 | 36 |
| 34 | 32 |
| 32 | 34 |
| 29 | 30 |
| 34 | 32 |
| 34 | 35 |
| 38 | 37 |
| 30 | 29 |
| 37 | 36 |
| 36 | 37 |

**Table X:** Table of components required for proposed system and their prices

| Serial | Components name | No. of Quantity | Cost (USD) |
|---|---|---|---|
| 1 | Arduino mega | 1 | $10 |
| 2 | $SPO_2$ sensor module | 1 | $33 |
| 3 | Pressure sensor MXV50GP50 | 1 | $30 |
| 4 | OLED Display 1.5inch | 1 | $19 |
| 5 | Wi-Fi module ESP8266 | 1 | $2.5 |
| 6 | AD620A OP-Amp | 1 | $5 |
| 7 | OP07 op-amp | 2 | $0.8 |
| 8 | ECG probes | 1 SET | $10.50 |
| 9 | Air pump | 1 | $5 |
| 10 | Solenoid valve | 1 | $1.41 |
| 11 | MAX7660 | 1 | $2.35 |
| 12 | MOSFET RU3060L | 2 | $0.60 |
| 13 | Transistor BCP56 | 1 | $0.20 |
| 14 | Buzzer | 1 | $0.1 |
| 15 | GSM module SIM800L | 1 | $4.10 |
| 16 | Buck converter LM2596 module | 1 | $1.17 |
| 17 | LM35 temp sensor | 1 | $0.88 |
| 18 | Cap: 1000/16 | 1 | $0.12 |
| 19 | Cap: 10/50 | 6 | $0.35 |
| 20 | Cap: 22/50 | 2 | $0.20 |
| 21 | Cap: 100/50 | 1 | $0.08 |
| 22 | Cap: 0.1uF smd | 10 | $0.30 |
| 23 | PCB | 1 | $5.90 |
| 24 | Accessories | AS REQUIRED | $5.91 |
| 25 | Battery 8V/2A | 1 | $2.58 |
| 26 | Others | AS REQUIRED | $5.95 |
| | | | **Total: $ 148** |

# Figures




## Figure 1

Block diagram of proposed system

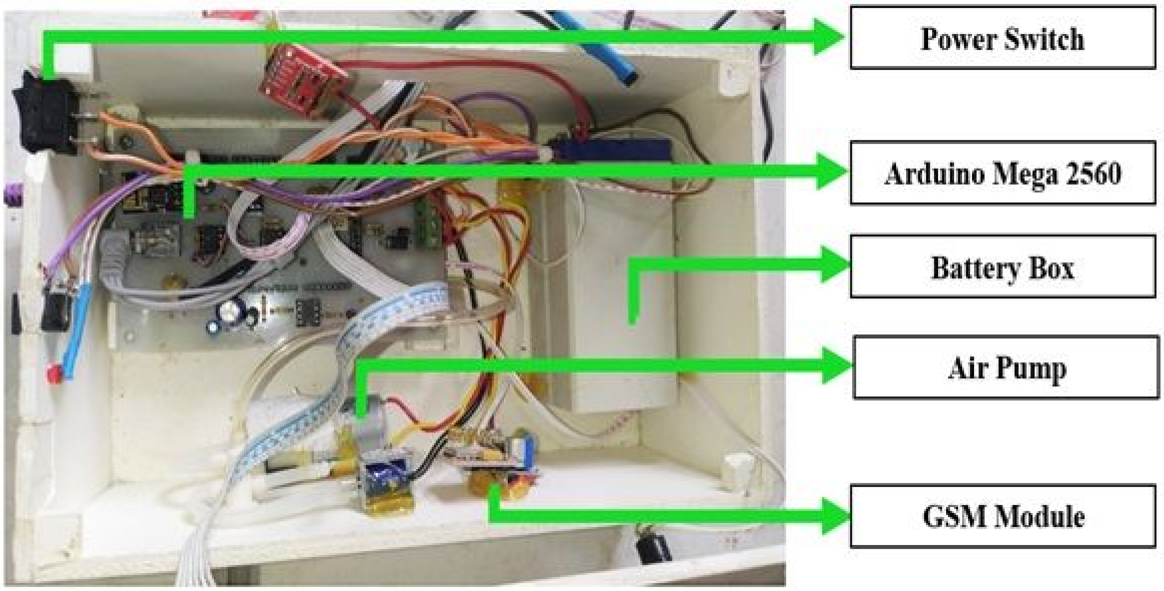



**Figure 2**

Inside portion of experimental setup

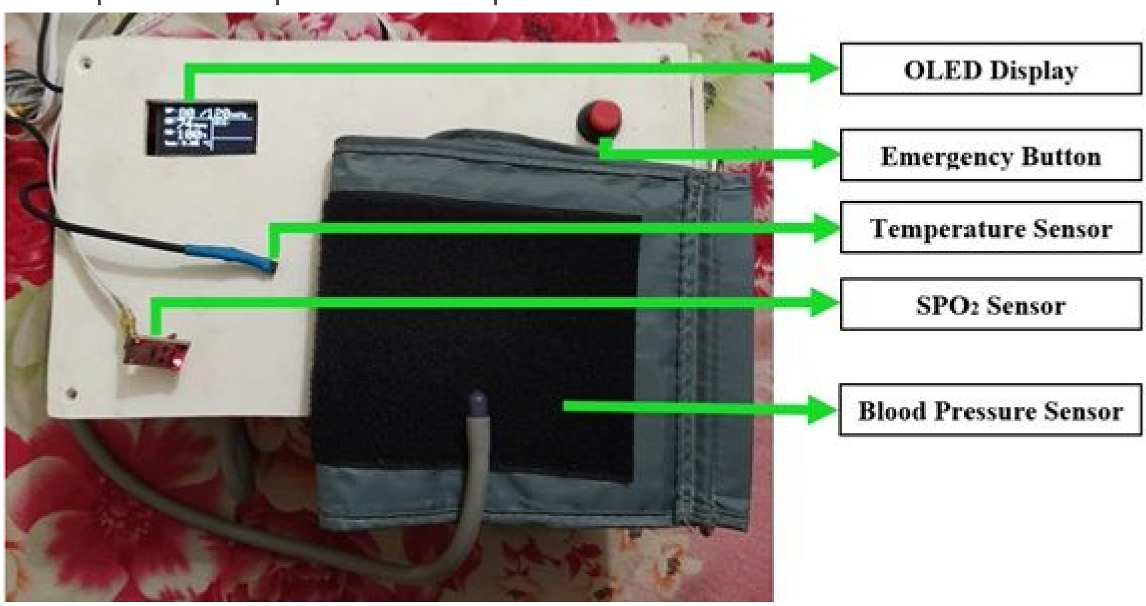



**Figure 3**

Outside portion of experimental setup

**Figure 4**

Initializing system

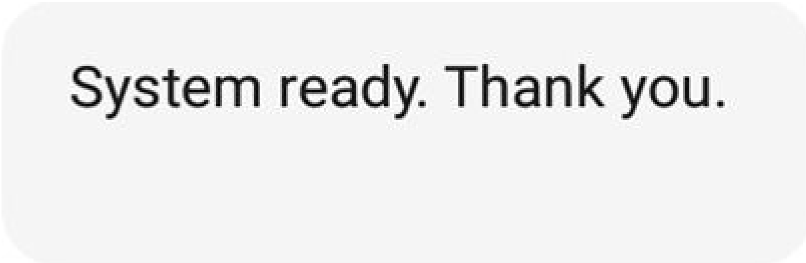



**Figure 5**

Initializing system


**Figure 6**

Real-time data of patient's health observed on OLED Display

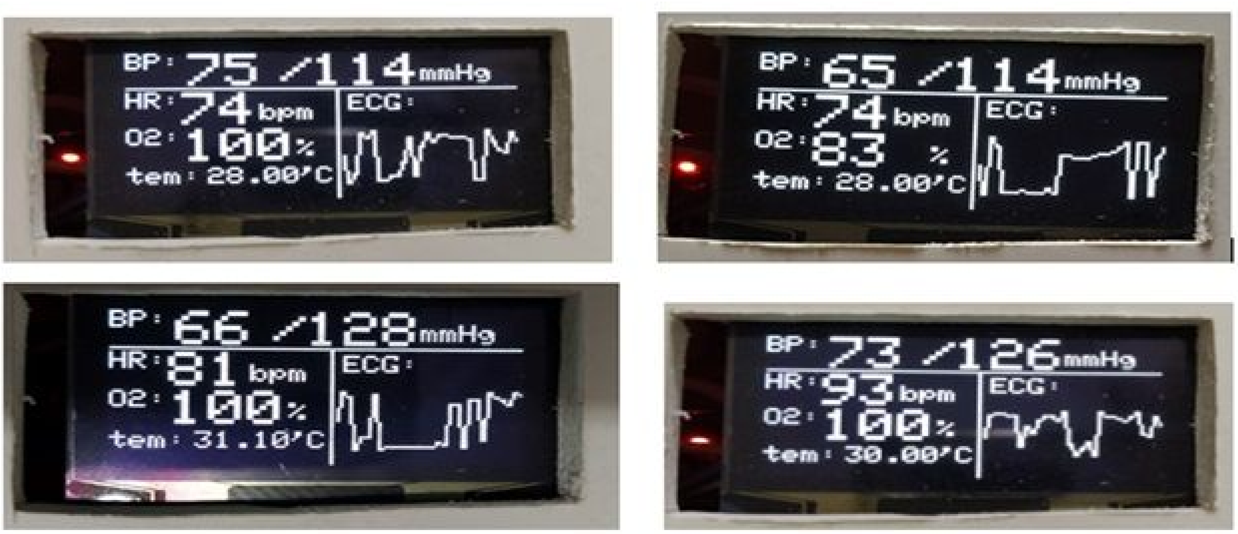



**Figure 7**

Real-time data of patient's health observed on OLED Display

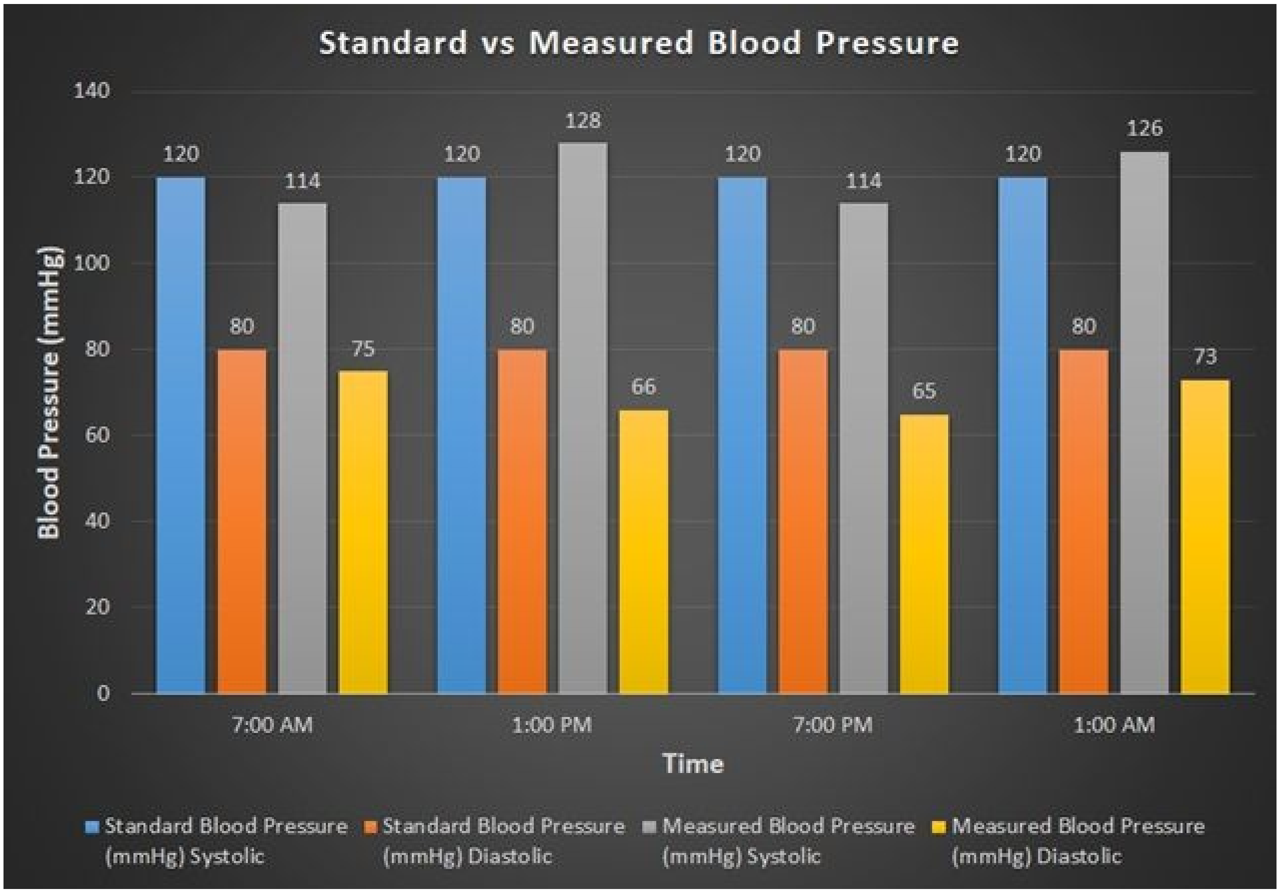



Figure 8

Bar graph of Standard vs Measured Systolic and Diastolic blood pressure

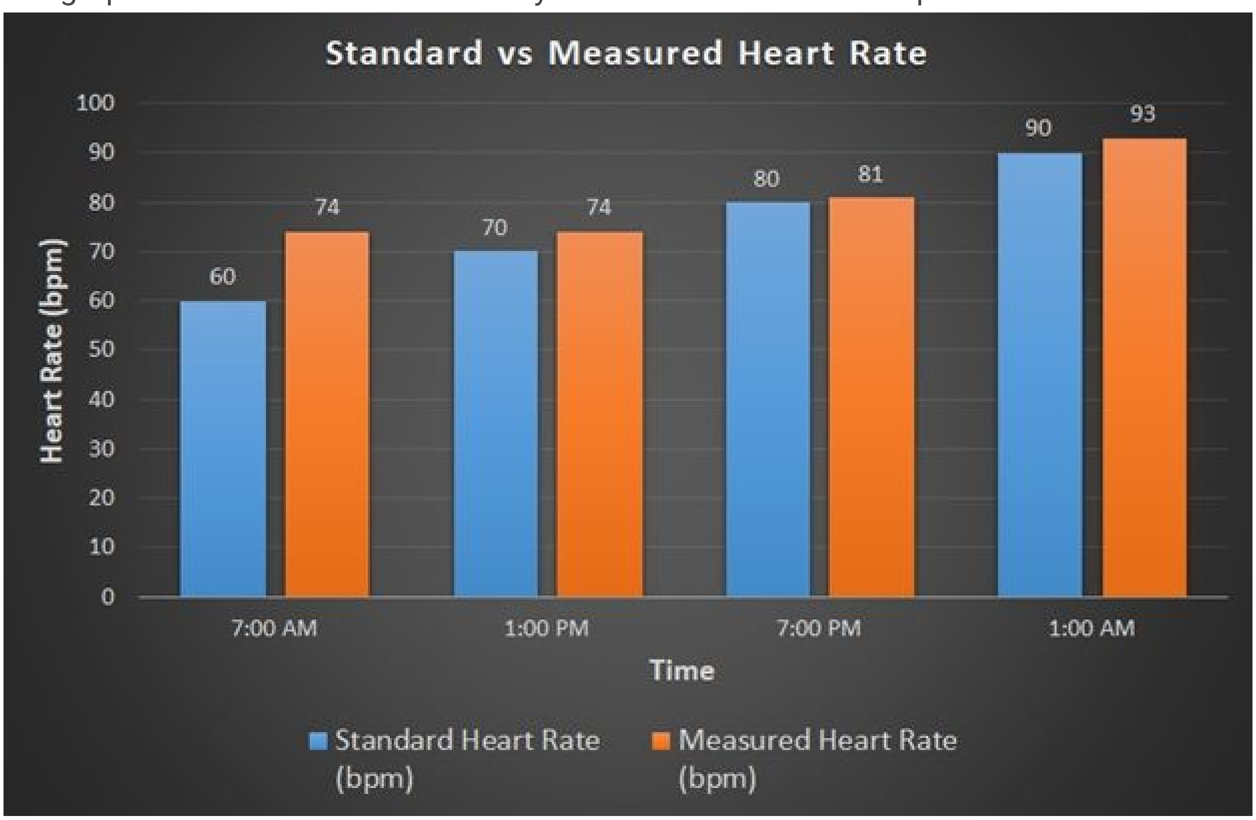


**Figure 9**

Standard vs Measured Heart Rate (bpm)

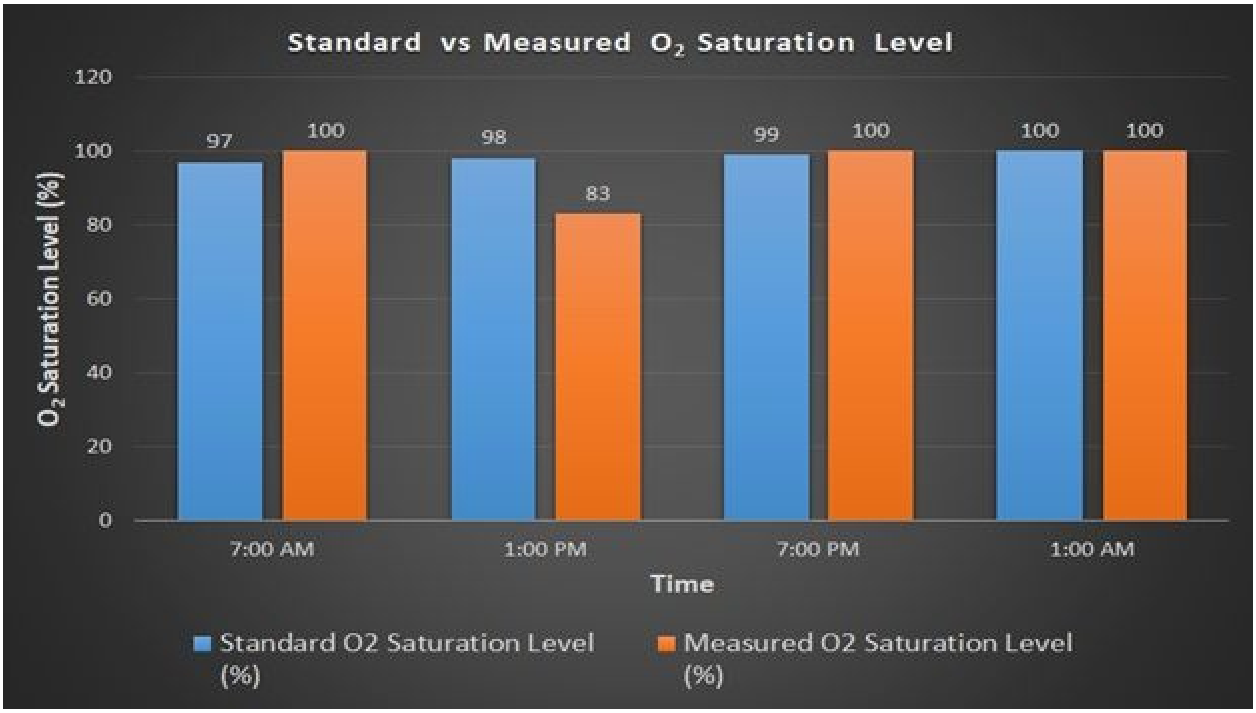



**Figure 10**

Standard vs Measured O2 Saturation Level (%)

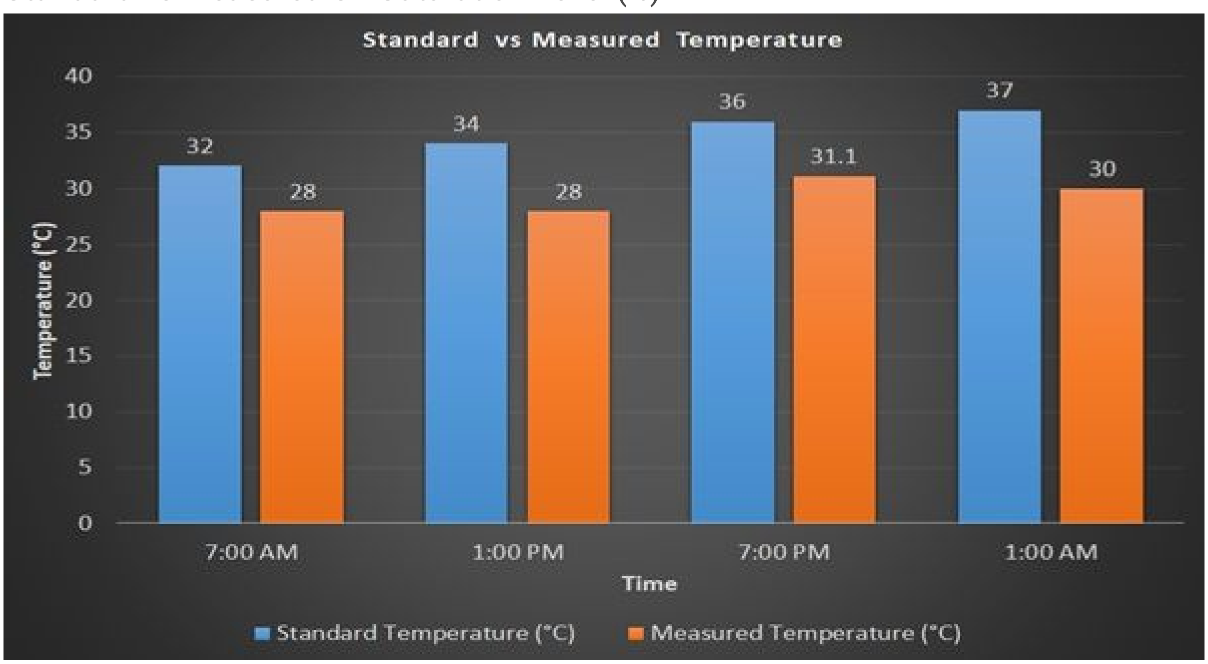
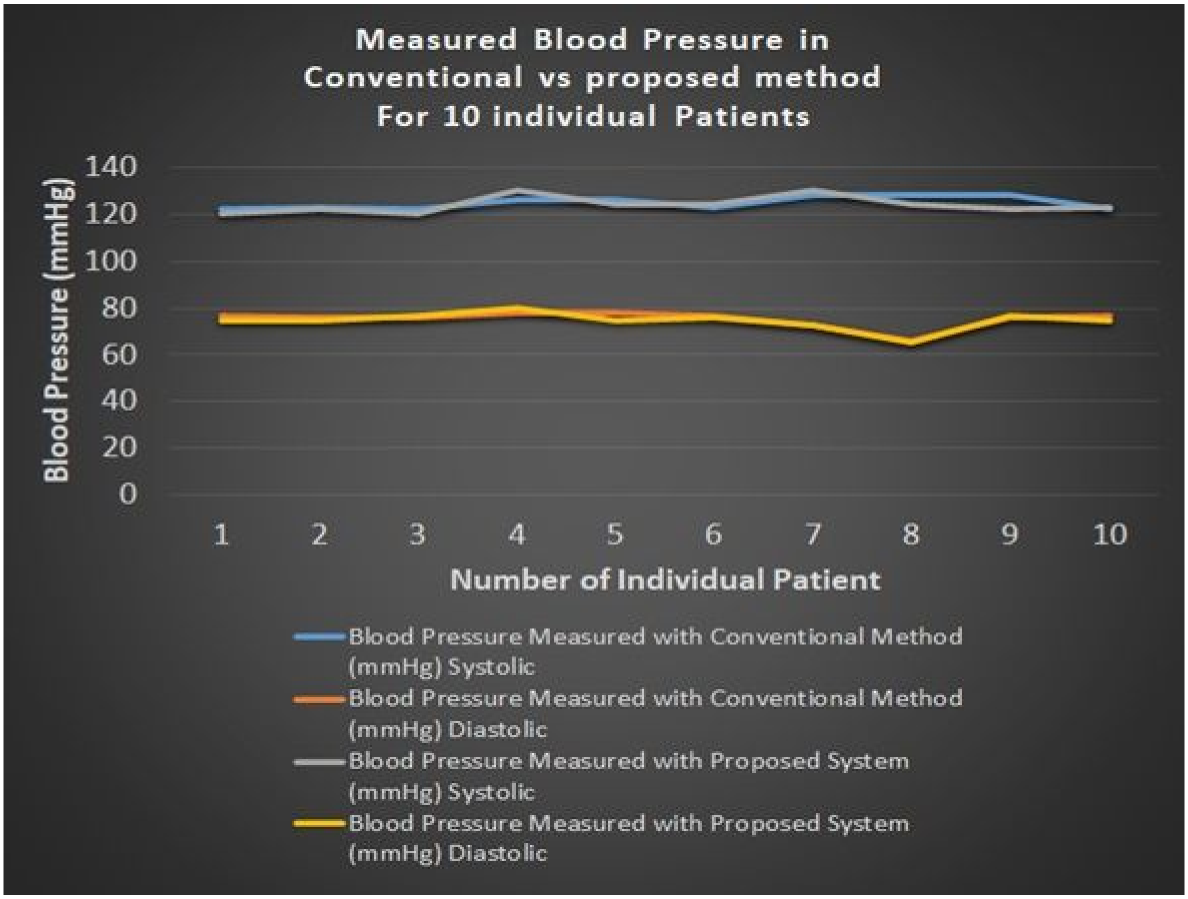


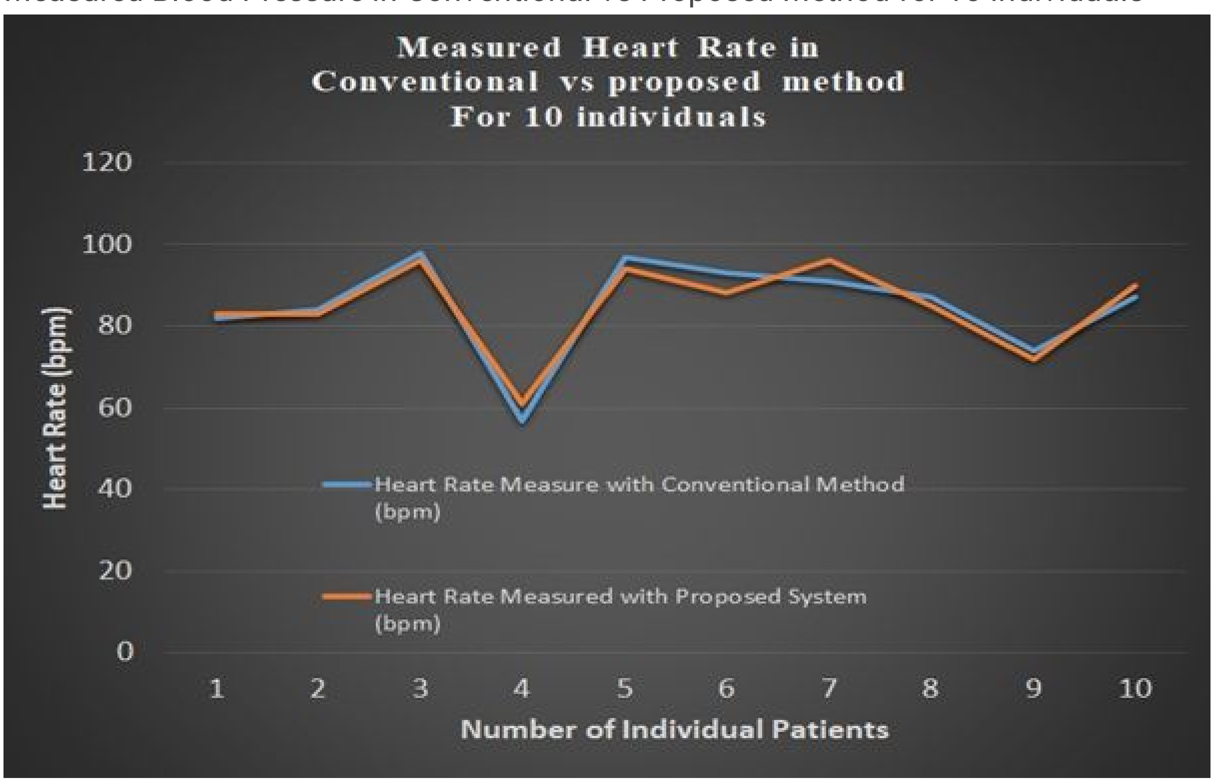

**Figure 11**

Standard vs Measured Temperature (°C)




## Figure 12

Measured Blood Pressure in Conventional vs Proposed Method for 10 individuals




## Figure 13

Measured Heart Rate in Conventional vs Proposed Method for 10 individuals

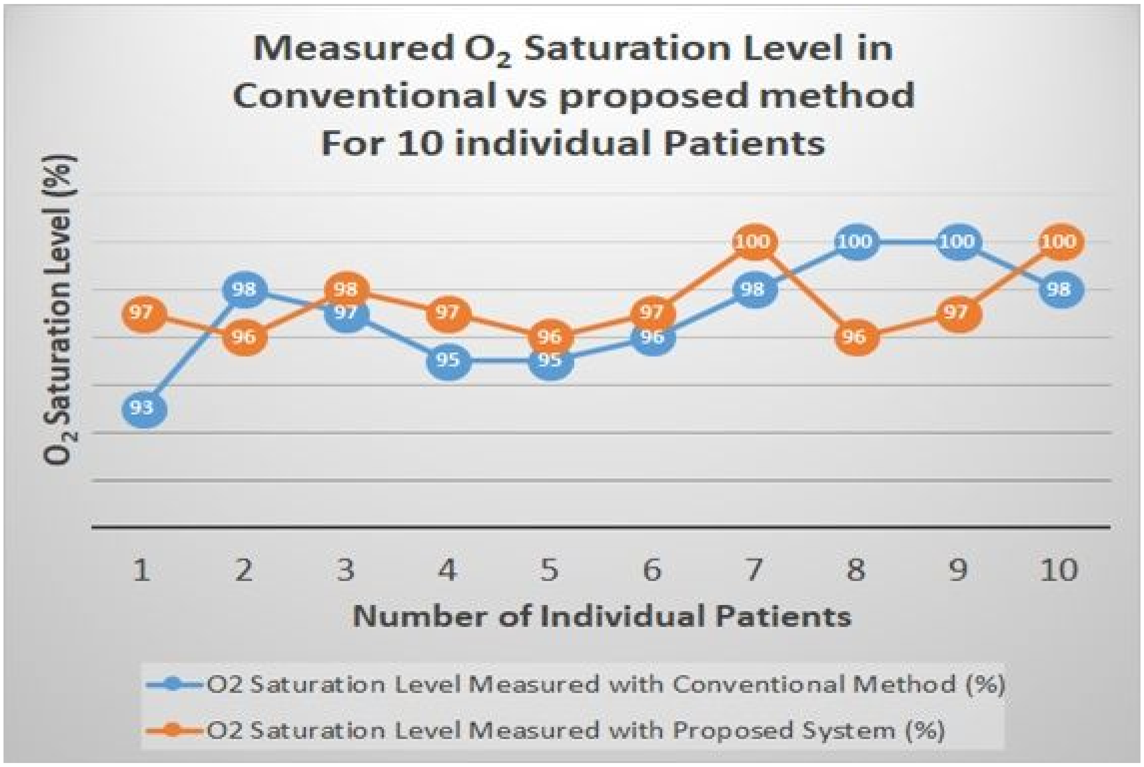



**Figure 14**

Measured O2 Saturation Level in Conventional vs Proposed Method for 10 individuals

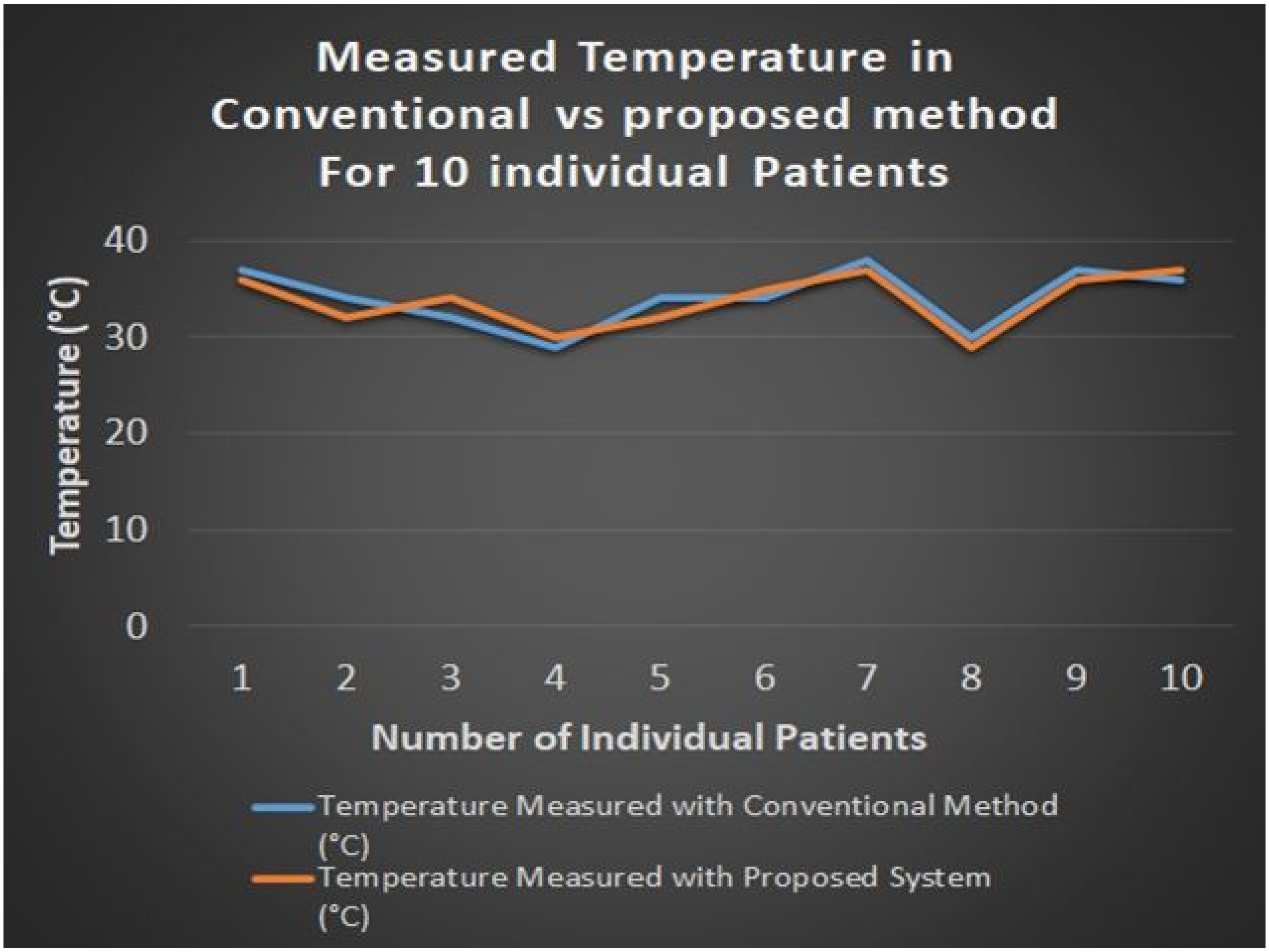



**Figure 15**

Measured Temperature in Conventional vs Proposed Method for 10 individuals

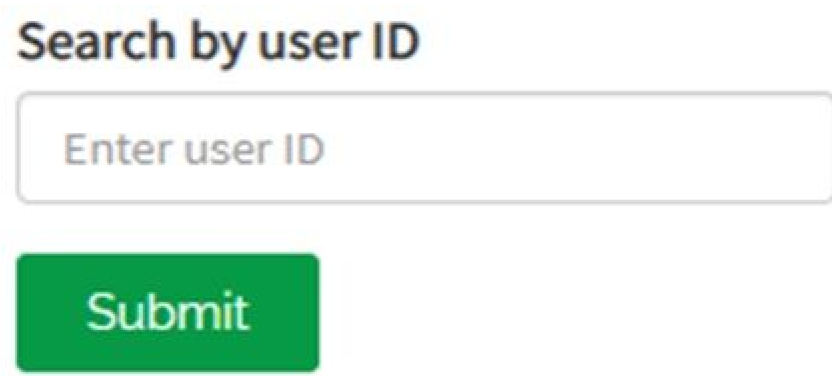



**Figure 16**

Login Page

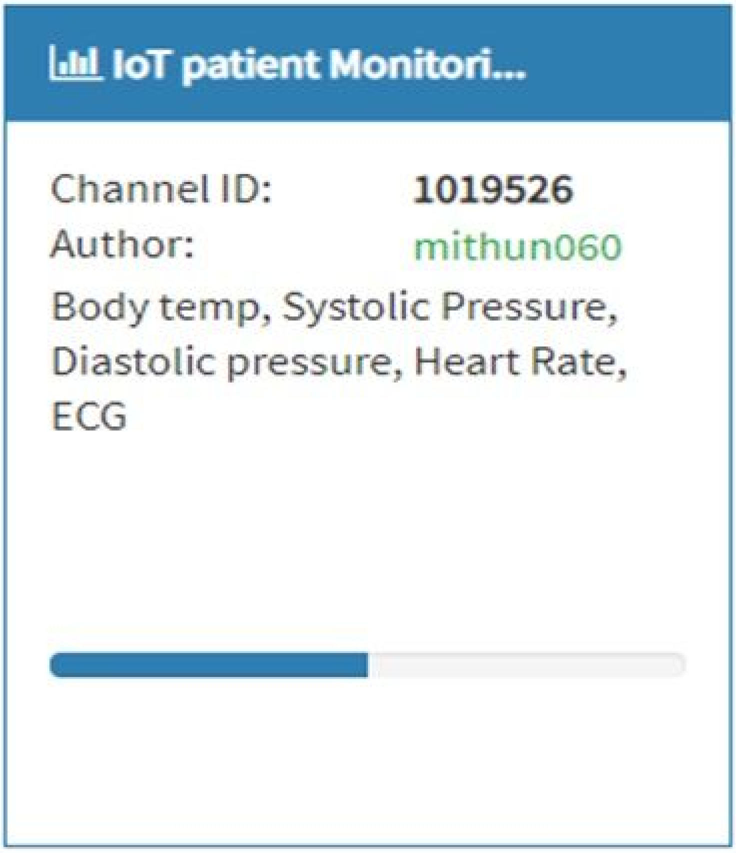
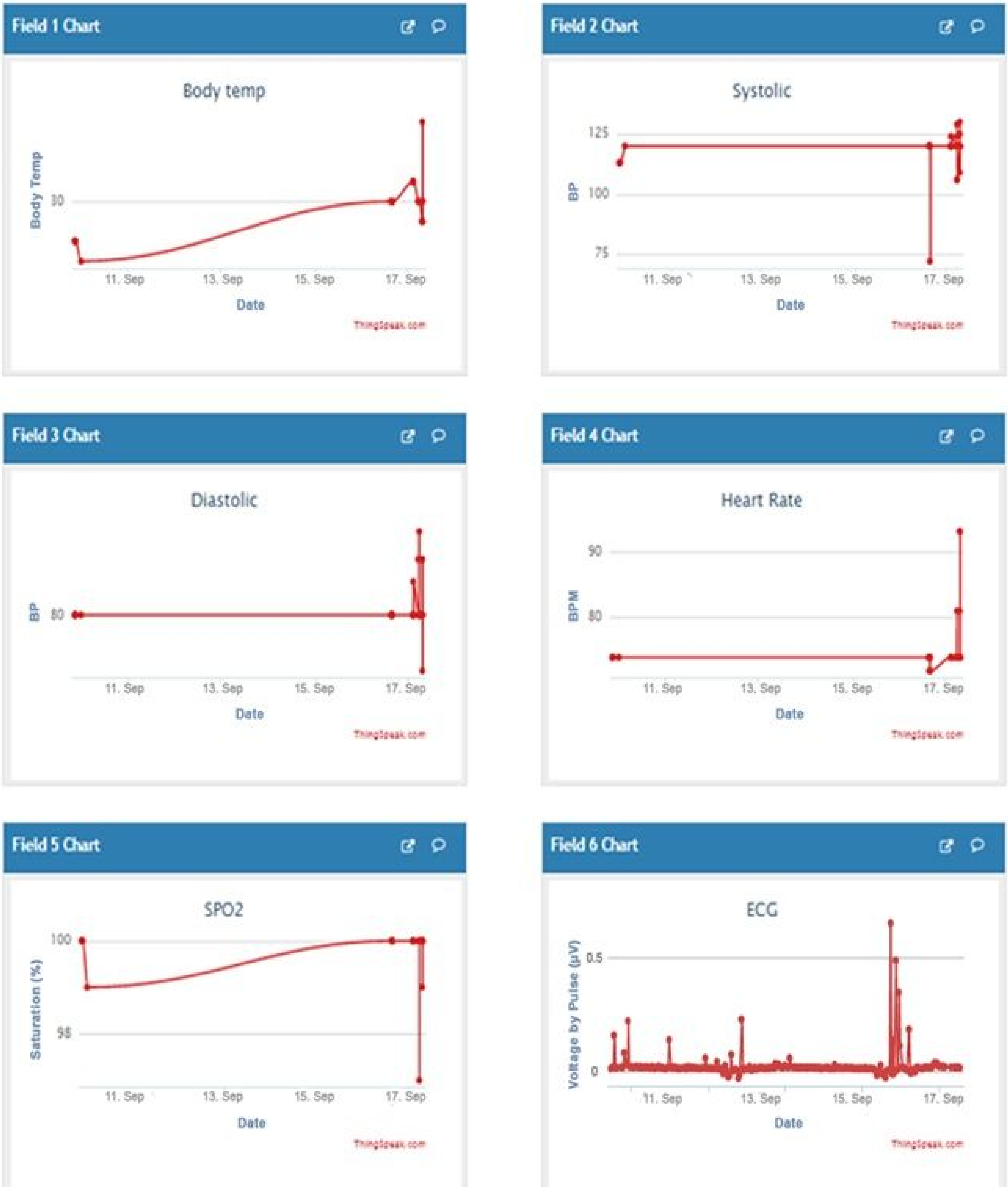



**Figure 17**

Particular patient channel ID




## Figure 18

Stored data in dedicated channel for a particular patient in Thing Speak cloud

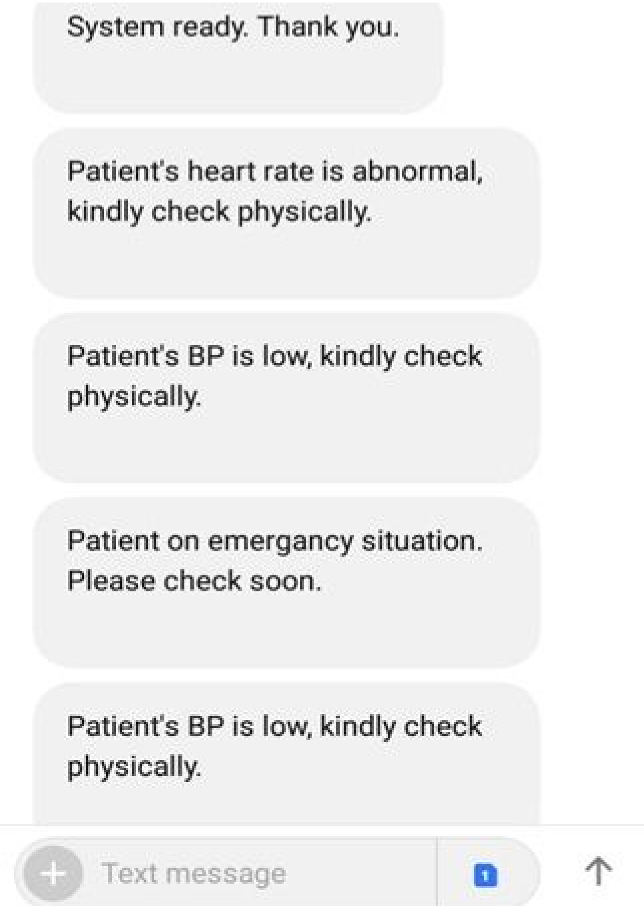



**Figure 19**

Real-time SMS received by corresponding contact number for real-time abnormal conditions faced by the patient in different times

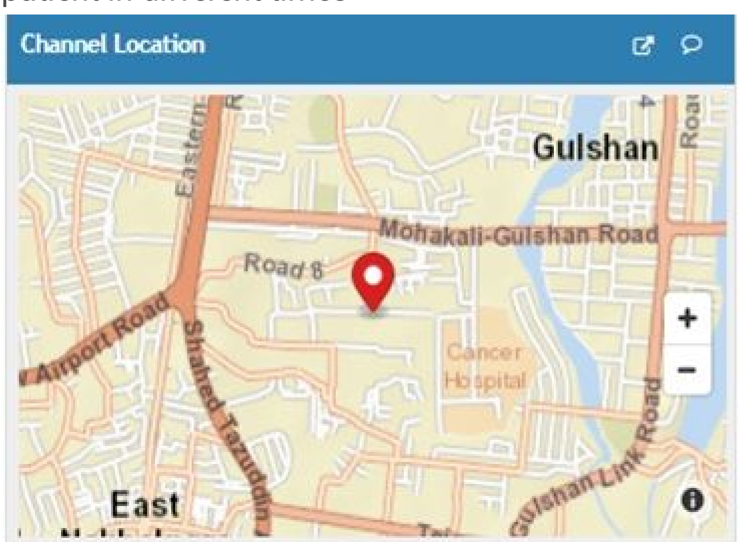



**Figure 20**

Experimental Location of Patient or Subject