Patient Health Monitoring System Using Arduino Mega 2560 And Thingsboard Server

Dhiraj Sunehra, Shreeya Siddireddygari

Abstract: A number of patients die every year due to delay in timely diagnosis of diseases and diagnosis of patient's health condition while shifting the patient to a hospital in case of any emergency. Especially the elderly and ill patients need continuous monitoring of physiological parameters. Such patients cannot visit the hospital on a daily basis. A web based patient health monitoring system can be used to avoid such difficulties. In this paper, a patient health monitoring system based on Arduino Mega 2560 microcontroller board and ThingsBoard web server is implemented to monitor various physiological parameters including heart beat, oxygen saturation (SpO2), blood pressure, and electrocardiogram (ECG). The health parameters along with room temperature, humidity, air quality and patient's movement parameters (roll and pitch) are uploaded to monitor any event of patients fall. The health status of the patient obtained from various sensors is uploaded on to the ThingsBoard server on regular basis, which can be observed by the doctor or caretaker. With this system, doctors can monitor the patient's health status remotely by accessing the web server.

Index Terms: Arduino Mega 2560, NodeMCU, Physiological parameter measurement, Sensors, ThingsBoard server.

1 INTRODUCTION

IN India, about twenty percent of the total population loose their lives because they are not provided with timely treatment by the doctor. For aged and ill patients, continuous monitoring of patient's health parameters is necessary. A number of patient health monitoring systems are reported in literature. Sunehra and Ramakrishna proposed a web based system to monitor basic patient health parameters [1]. Raspberry Pi and Arduino microcontroller boards are used in this system and ZigBee is used for communication. An alert message is sent to the doctor or caretaker when any physiological parameter crosses the set threshold. Digarse and Patil implemented a system for monitoring patient's health parameters, viz. heart rate, body temperature and saline level [2]. Arduino Uno and GSM technology is used to alert the caretaker. Erlina et al developed a system to remotely monitor the condition of comatose patients by measuring the heart beat, respiratory rate and eyelid opening and the data is viewed on an android device [3]. An alert is sent to the family of the patient and the doctor in case of emergency. Divakaran et al proposed the design of a remote patient diagnostic system that will monitor and send patient's vital parameters and video of the patient using the internet of things (IoT) technology [4].

2 OVERVIEW OF BASIC PHYSIOLOGICAL PARAMETERS

2.1 Electrocardiogram (ECG)

Electrocardiogram (ECG) signal provides a recording of the heart's electrical activity. In order to measure the electrical activity of the heart of a patient, electrodes of ECG sensor are connected to the patient's body which aid to determine heart rate and other information regarding the heart's condition.

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ECG graph helps in detecting any heart attacks in past, heart failure, heart arrhythmias, enlargement of the heart at one side, clogging up of heart's blood supply due to cholesterol. Figure 1 shows the anatomy of Human heart [5]. It contains four chambers viz. left and right ventricle (LV and RV in lower chamber), left and right atrium (LA and RA in upper chamber) as shown in Fig. 1. The de-oxygenated blood collected from different parts of the body enters into the right atrium through inferior and superior vena cava and is pumped into the right ventricle. When right ventricle is filled, the de-oxygenated blood is pushed into the lungs through pulmonary artery (PA). Lungs purify the de-oxygenated blood and oxygen rich blood is pumped into the left atrium by pulmonary veins.

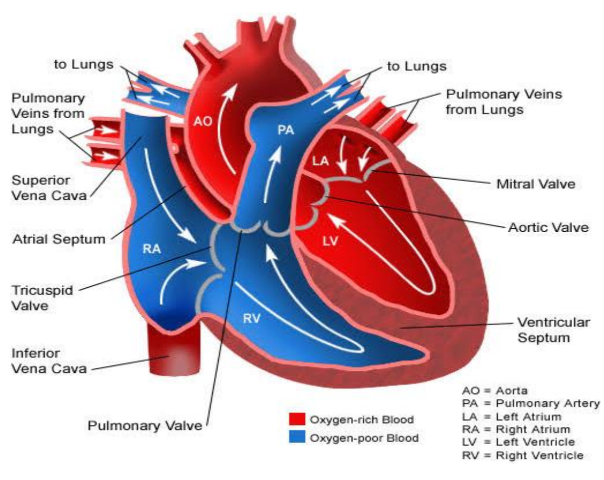

***Fig. 1**. Anatomy of Heart*

Left atrium pushes the oxygenated blood into the left ventricle where the blood is supplied to the remaining parts of the body through Aorta (AO). Figure 2 shows the sample ECG wave [6]. In both the atriums, an electrical impulse is produced that causes the atrium contraction, also called as depolarization (atrial depolarization is represented by P-wave). During contraction or depolarization of atrium, blood is pumped into the ventricles. Then ventricles contract or depolarize and pump the deoxygenated blood to the lungs and oxygenated blood to the body (ventricular depolarization is represented by QRS complex). After pumping the blood to the lungs and body, ventricular re-polarization occurs, where the ventricles get ready to depolarize or contract again (ventricular re-polarization is represented by the T-wave). This process continues in sequence.

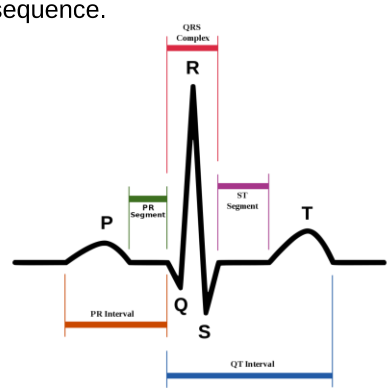

Fig. 2. *Sample ECG wave*

2.2 Blood Pressure

The blood exerts pressure on the walls of the blood vessels for circulation of blood throughout the body. This pressure is called Blood Pressure. The pressure that blood exerts on blood vessels during the heart beat is referred as Systolic blood pressure. The pressure that blood exerts on blood vessels between heart beats is referred as Diastolic blood pressure. Patients having high blood pressure have high risk of heart attacks. The typical values of systolic and diastolic for various categories of patients are indicated in Table 1 [7].

TABLE 1

TYPICAL VALUES OF BLOOD PRESSURE

BP condition	Systolic (mm Hg)	Diastolic (mm Hg)
Hypotension	< 90	< 60
Desired	90-119	60-79
Pre-hypertension	120-139	80-89
Stage 1 Hypertension	140-159	90-99
Stage 2 Hypertension	160-179	100-109
Hypertensive Crisis	≥ 180	≥ 110

2.3 Heart Rate

Heart rate is one of the basic physiological parameters to check the patient's health status. The number of contractions or the number of beats of the heart for every minute is referred as heart rate or heart beat speed. Based on the physical needs of the body, the heart rate varies. The physical needs include absorption of oxygen and excretion of carbon dioxide. General condition of the patient is indicated by the heart rate. Bradycardia (reduced pulse rate), tachycardia (increased pulse rate), missing heart beat are abnormal features of the heart.

2.4 SpO_2

Saturation of Peripheral Oxygen (SpO2) or oxygen saturation is the percentage of oxygenated blood present in the total blood. Pulse oximetry is used to measure SpO2, which is based on the principle that light transmittance through tissues containing oxygenated blood and deoxygenated blood at two wavelengths of light (650 nm and 950 nm) is different. The IR light (950nm) is absorbed by the oxygenated blood and passes through the deoxygenated blood. The Red light (650nm) is absorbed by the deoxygenated blood and passes through the oxygenated blood.

3 HARDWARE DESCRIPTION

3.1 Block Diagram of Patient Health Monitoring System

The block diagram of the Patient Health Monitoring System is shown Fig. 3. It consists of the Blood Pressure (BP) Sensor, Temperature and Humidity (DHT) Sensor, Accelerometer, Air Quality Sensor, Electrocardiogram (ECG) Sensor, Heartbeat and Oxygen saturation (SpO2) Sensor (MAX30100). The outputs from the various sensors are fed to the Arduino Mega 2560. The sensor values are then uploaded on to the ThingsBoard server through the NodeMCU which has an inbuilt Wi-Fi module. The physiological parameters can be viewed using the dashboard on the ThingsBoard. The physiological parameters of the patients can also be accessed remotely by the doctor by logging into the ThingsBoard server, so that immediate action can be taken to save the patient's life.

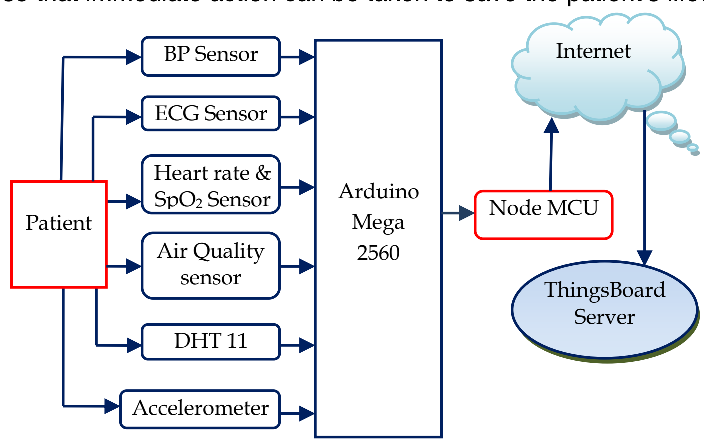

Fig. 3. *Block Diagram*

3.2 Arduino Mega 2560

Arduino Mega 2560 consists of ATMega 2560 microcontroller which has 70 pins including digital and analog. Out of the 54 digital pins, 14 pins can also support PWM output (Fig. 4). It is operated at a clock speed/frequency of 16MHz. The Mega board can be powered in three ways: by connecting the Personal Computer or Desktop directly with the USB cable, via Vin pin of the board, or through an AC-DC adapter [8].

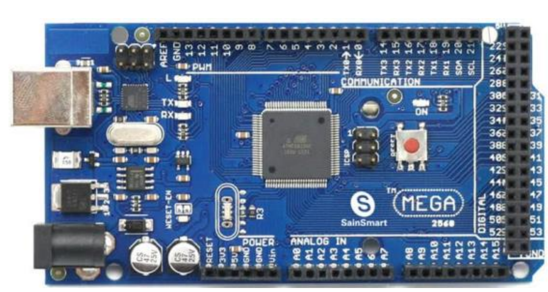

Fig. 4. *Arduino Mega 2560 Board*

3.3 NodeMCU

Node Microcontroller Unit (NodeMCU) is an open source LUA

(LUA is a robust and fast programming language and the main purpose of LUA is to be a lightweight embeddable scripting language) based firmware developed for ESP8266 Wi-Fi chip. NodeMCU is used mostly in wireless connectivity areas preferably in IoT applications. It provides a platform to connect the embedded components to the Internet. Therefore, NodeMCU microcontroller is designed along with Wi-Fi module (ESP8266) embedded on it, whereas as Arduino doesn't have inbuilt Wi-Fi module. NodeMCU can also use Arduino IDE for the programming purpose. It makes easy for the developers of Arduino to interface with NodeMCU without learning a new language.There are two types of NodeMCU boards, 0.9 and 1.0 versions. The 0.9 version is blue in color and contains ESP-12 chip. Version 1.0 is black in color, and contains ESP-12E (E – enhanced). NodeMCU Ver1.0 is used here.

***Fig. 5**. NodeMCU Board*

3.4 Electrocardiogram (ECG) Sensor

Please The AD8232 ECG sensor comprises of an integrated signal conditioning block which is used to acquire, amplify and filter the signal in the existence of noisy conditions. Figure 6 shows the AD8232 sensor module. It has a total of nine connections, out of which three pins, viz. right arm (RA), right leg (RL) and left arm (LA) are internally connected to a jack connector. The three electrodes green, red and yellow get connected to the RL, RA and LA pins respectively using the jack plug [9]. The remaining six pins are listed in Table 2 which describes their interfacing with the Arduino Mega 2560.

TABLE 2

INTERFACING BETWEEN AD8232 AND ARDUINO MEGA 2560

AD8232 Pin	Arduino Mega 2560 Pin
Supply Voltage (3.3V)	3.3V
GND	GND
Output	A0
Leads-off detection (LO+)	A10
Leads-off detection (LO-)	11
GND	GND

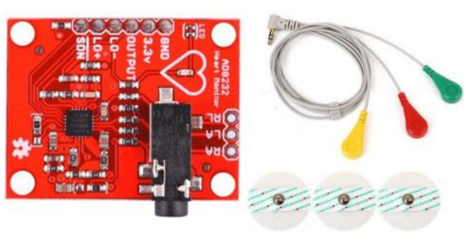

***Fig. 6**. ECG Sensor*

The three ECG electrodes are placed on the patient's body in one of the two ways as shown in Fig. 7. Noise may be introduced in the measurement due to motion or remote electrode placement.

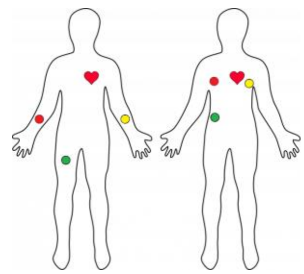

***Fig. 7**. Placement of ECG electrodes*

Electrical activity of the heart is detected by the electrodes and sends the signal to the jack. The analog output obtained from the jack is connected to the analog pin (A0) of Arduino microcontroller.

3.5 Blood Pressure Module

Blood Pressure (BP) is measured when the person is in relaxed, lying or sitting position. The variation in the blood pressure is due to body position, exercise, breathing or emotional state, and sleep. Conventionally, an instrument called sphygmomanometer is used to measure systolic and diastolic pressure. The blood pressure sensor used here has a liquid crystal digital display with serial output (TX-OUT) for interfacing with the Arduino (Fig. 8). It provides systolic, diastolic and pulse rate. The BP sensor is fixed to the wrist and has an automatic compression and decompression feature eliminating the need of manual pumping. There is a switch to start the measurement. The module can store 60 BP measurements in the internal memory. It requires a +5V DC supply which is obtained from the arduino. It outputs the three parameters in 8-bit ASCII format at a baud rate of 9600 [7]. The typical BP of a young adult is 120/80 mmHg.

***Fig. 8**. BP sensor module*

3.6 Accelerometer

ADXL335 is a small, low power three-axes sensing accelerometer operates at a voltage of 1.8 to 3.6 V. It is used to measure the acceleration due to gravity for tilt and motion sensing applications. The sensor consists of a polysilicon structure built on the top of a silicon wafer. In between these two are polysilicon springs for resistance against accelerations forces. The acceleration is measured with a differential capacitor method having moving plates and fixed plates. The output amplitude is proportional to the acceleration along the three axes X, Y, and Z [10].

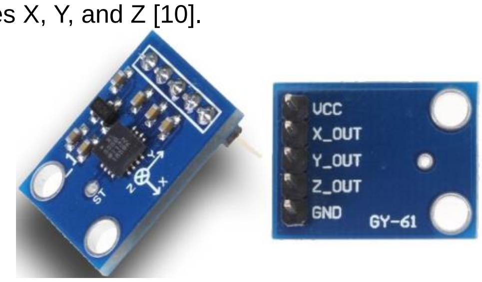

***Fig. 9**. Accelerometer Sensor*

3.7 DHT11

Digital Humidity and Temperature (DHT) sensor includes a thermistor or NTC (Negative Temperature Coefficient) and a capacitive humidity sensor. Humidity sensing component is used to measure level of humidity in the air. This component contains two electrodes, a substrate which holds moisture is fixed. According to the humidity changes in the air, the conductivity of the substrate changes. A thermistor or NTC component in the sensor measures the atmosphere temperature.In this paper, DHT11 is used for the measurement of temperature and humidity of atmosphere, which is a single wired sensor. The value of relative humidity (RH) is obtained in percentage, and the range lies in between 20% to 90%. Temperature is measured in °C. Figure 10 shows the DHT11 sensor.

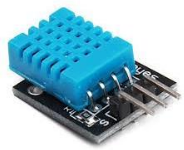

***Fig. 10**. Temperature and Humidity Sensor*

3.8 MQ2 Air Quality Sensor

MQ2 is an air quality sensor that is used to measure the presence of harmful gases such as LPG, methane, hydrogen, CO and smoke. It consists of a sensing element made up of aluminum oxide based ceramic coated with tin oxide enclosed in a stainless steel mesh (Fig. 11). The resistance of the sensor changes when it comes in contact with any harmful gases. The analog output voltage obtained from the gas sensor is proportional to the concentration of gas. It can detect harmful gases, if the concentration ranges from 200 to 10000 ppm.

***Fig. 11.** Air quality Sensor*

3.9 Heart Rate and SpO2 Sensor

MAX30100 (Fig 12) is used to measure both heart rate and SPO2. It has an infrared LED of 950nm wavelength, a red LED of wavelength 650nm and a photodiode detector.When this sensor comes in contact with the body (for example: finger) , both infrared and red light pass through the tissues of the finger, the two LEDs are alternately flashed and resulting light after passing through the finger falls on the photodiode. Photodiode is used to produce an output current or voltage proportional to intensity of incident light [11].Based on the quantity of oxygen which a person has in his/her blood the ratio of absorbed red light and infrared light will be different. With this ratio, the oxygen level in the blood (hemoglobin) can be calculated. To measure heart beat, infrared light is needed whereas to measure saturated oxygen levels in the blood both red and infrared lights are required.

***Fig. 12**. Heart rate and Oxygen Saturation sensor*

4 SOFTWARE TOOLS

4.1 Arduino IDE

Arduino Integrated Development Environment (IDE) and Embedded C are the software tools used to write the necessary software for the health monitoring system. Arduino IDE is an environment which provides a text editor for writing program code (also called Sketches and saved as.ino extension) that is uploaded onto the Arduino board. Program is written in Embedded C language. As it is an open source it can run on a range of platforms such as MAC OS X, Windows, and Linux.

4.2 ThingsBoard Web server

It is an open source platform for data collection, processing and device management for IoT projects. In this, data is collected using MQTT protocol and visualized on real time dashboard of ThingsBoard. Thingsboard can be installed on Windows, Linux and Raspberry Pi 3.

5 SCHEMATIC DIAGRAM

The schematic diagram of patient health monitoring system is shown in Fig. 13. ECG sensor's LO-, LO+, output, VCC and GND are connected to digital pin 11, digital pin 10, A0, 3.3V and ground pin of the Arduino board respectively. Air Quality sensor's VCC, GND and output pins are connected to extended 5V, ground and A4 respectively. VCC, GND, SCL and SDA pins of MAX30100 heart beat and SpO2 sensor are connected to 5V pin of ICSP circuit, ground, digital pin 21 and digital pin20 of Arduino board respectively. DHT11 sensor's GND, output, and VCC pins are connected to GND, GPIO8, and 5V pins of Arduino board respectively.

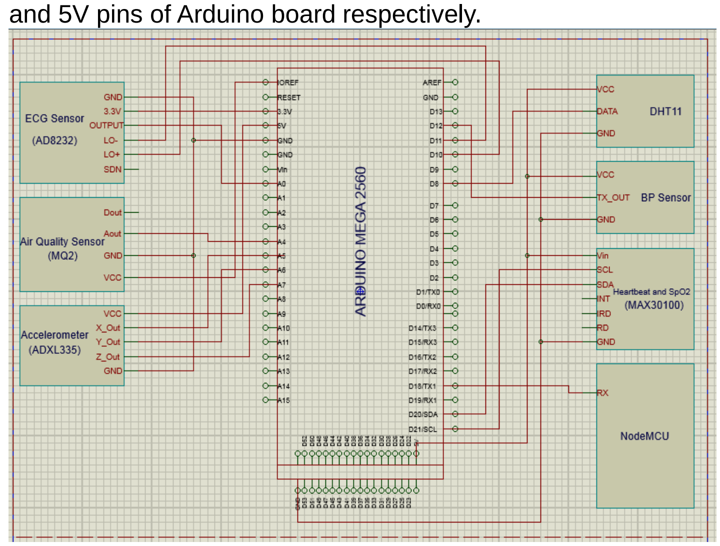

***Fig. 13**. Schematic Diagram*

Accelerometer sensor's X, Y, Z axes pins are connected to Analog pins (A5, A6, and A7) of ATmega 2560 microcontroller. Accelerometer's GND and VCC are connected to ground and extended 5V pin of Arduino respectively. Blood Pressure sensor's VCC, GND and TX output are connected to IOREF, ground and GPIO12 pin of Arduino board respectively. The receiver pin of NodeMCU is connected to GPIO19 (Transmitter pin) of Arduino, power supply to NodeMCU is given through USB from PC similar to Arduino.

6 EXPERIMENTAL SETUP

Figure 14 shows the experimental setup of the patient health monitoring system. The ECG, Accelerometer, BP sensor, Air quality sensor, heart beat and SpO2, and DHT are interfaced with Arduino board. The Arduino code written has to be dumped into the Arduino microcontroller to access the data from the sensors. Further, NodeMCU code should also uploaded to the board to interface NodeMCU board to the ThingsBoard web server. Thereafter, NodeMCU receives the data from Arduino via USART pins and the received data is updated on to the ThingsBoard server by connecting to the Internet.

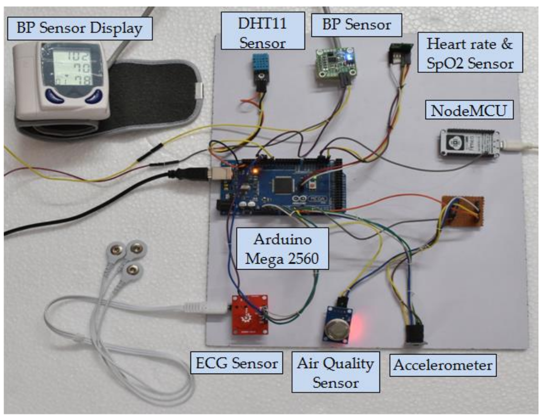

Fig. 14. *Experimental Setup*

7 FLOWCHART

Figure 15 shows the flowchart of the system. Embedded C code of Arduino Mega is uploaded. To connect all the devices to a single network, Wi-Fi username and password are defined. Then we create a device dashboard on the ThingsBoard server. Copy the access token and paste it in the code of NodeMCU as shown below:

```
#define WIFI_AP F("xxx")
#define WIFI_PASSWORD "yyyyy"
#define TOKEN "U1XjhwIblblmM54VByrq"
```

All the GPIO pins of both the controllers are initialized. Check whether all sensors are activated. After initialization, Pulse oximetry… Success is displayed on the serial monitor. Otherwise, Pulse oximetry…Failed is displayed. In the second case, check MAX30100 connection and retry until Pulse oximetry… Success is displayed. After successful connection of pulse oximetry, the Arduino reads the data from all the sensors. Place the finger of hand on the glowing LED of MAX30100 such that it reads the heart beat and SpO_2. Temperature and Humidity of the room or atmosphere are calculated by NTC component and humidity sensing component present inside the DHT 11 module.

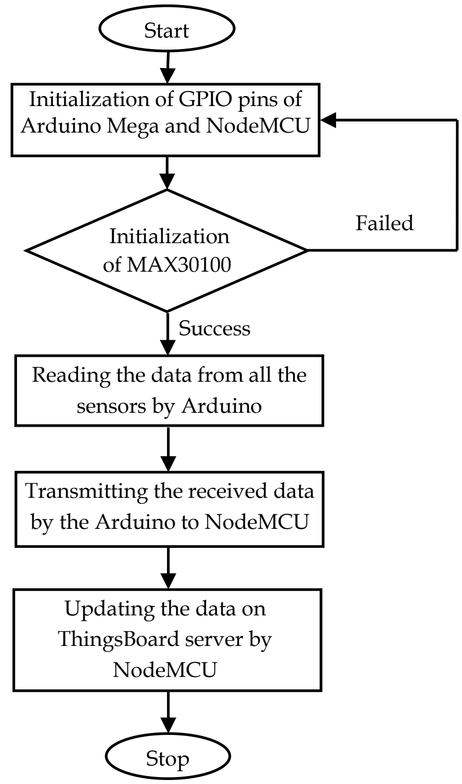

Fig. 15. *Flowchart*

The output obtained is sent to GPIO 8 pin of Arduino Mega. Then air quality of the air is measured through MQ2 sensor and the output is updated to the Arduino Mega.The output of the accelerometer, roll and pitch is calculated using the acceleration values along x, y and z directions and given to Arduino Mega. For measuring ECG, the three electrodes must be placed at appropriate positions as shown in Fig 7. A0 of the Arduino Mega reads the output of ECG. If no signal is observed at that pin, exclamation mark (!) output will be seen on the serial monitor. Otherwise a non-zero value is observed. A graphical representation of ECG can also be viewed. Thereafter, Blood pressure is measured by wearing the BP module on to the wrist of the hand and pressing ON button of the module. After pressing ON button, pressure will be exerted on the wrist up to a possible high level and decreases. Thus, BP measurement is done. To view the value of the BP, press memory button. All the sensor readings are fed to the Arduino Mega. The measurements obtained from various sensors are concatenated and sent to the NodeMCU by Arduino Mega via USART pins. NodeMCU updates the values of the sensor on to the ThingsBoard server.

8 RESULTS AND DISCUSSION

The air quality (presence of any harmful gases), blood pressure, temperature, humidity, heart rate, SpO2, patient movement (roll and pitch) information is captured using relevant sensors and the results are displayed on the dashboard of ThingsBoard server along with date and time as shown in Fig. 16.

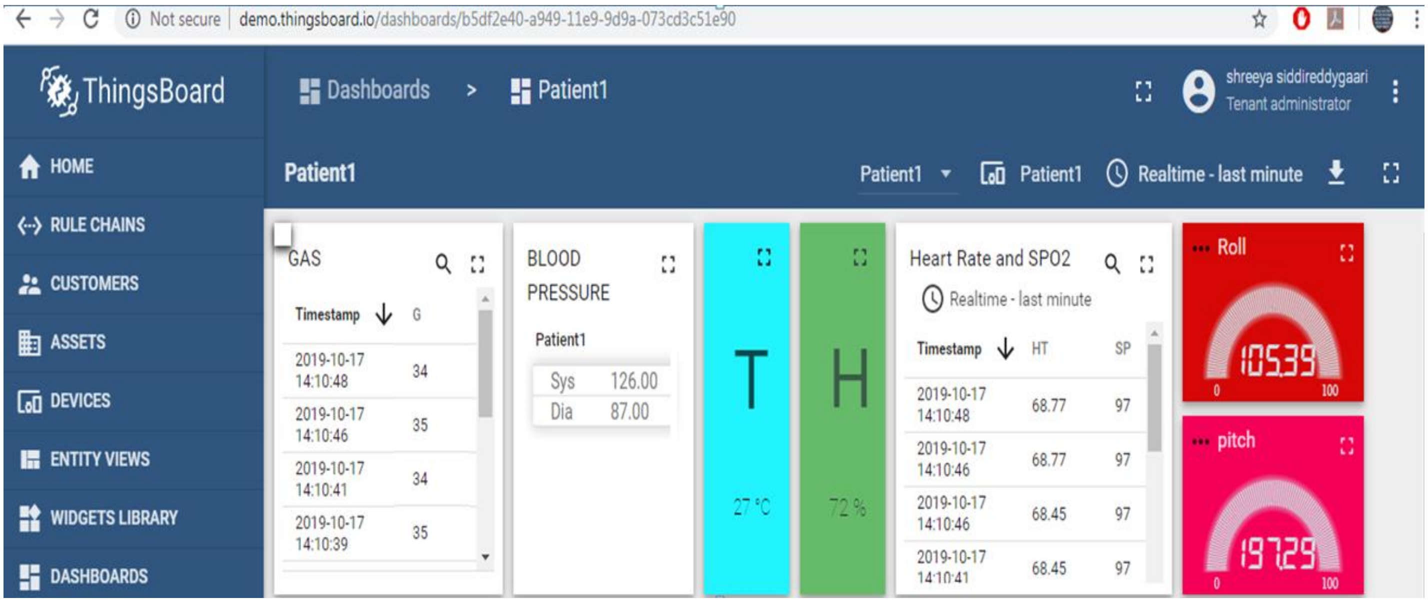

Fig. 16. Snapshot of Results displayed on the dashboard of ThingsBoard Server

Blood Pressure (BP) output on the module display:
The Blood Pressure (BP) of the patient can also be viewed on the display of the BP Sensor as shown in Fig. 17.

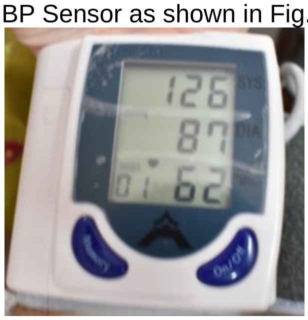

Fig. 17. BP reading displayed on the BP module

Fig. 18 ECG output observed on the serial monitor

ECG output:
The sample ECG output of the patient observed on the serial monitor of Arduino IDE is shown in Fig. 18.

Table 3 shows the captured results of the various physiological parameters of the three patients, viz. patient 1, patient 2, and patient 3 and air quality, temperature and humidity of the patient's environment.

TABLE 3

SAMPLE RESULTS OBTAINED USING PATIENT HEALTH MONITORING SYSTEM FOR THREE DIFFERENT PATIENTS

PATIENT DETAILS	DATE	TIME	BLOOD PRESSURE (MMHG)		HEART RATE (BPM)	OXYGEN SATURATION (SPO_2) (%)	ACCELERATION (G)		TEMPERATURE (°C)	HUMIDITY (%)	AIR QUALITY (PPM)
			SYSTOLIC	DIASTOLIC			ROLL	PITCH			
PATIENT 1	17-10-19	14:10:48	126	87	68.77	97	105.39	197.29	27	72	34
PATIENT 2	17-10-19	14:21:29	123	88	75.52	95	82.46	170.93	28	74	48
PATIENT 3	17-10-19	14:46:12	131	97	92.9	97	82.63	165.66	28	75	35

Figure 19 shows the results on the ThingsBoard server in the event of leakage of any harmful gases near the patient. The gas concentration in the event of gas leakage is found to range between 220 ppm to 344 ppm for the given samples.

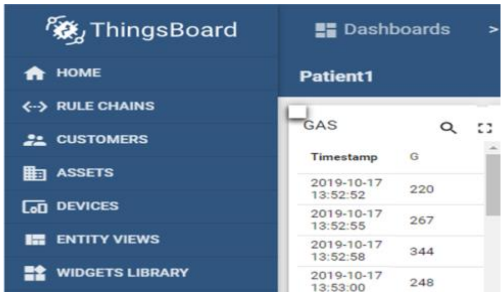

Fig. 19 *Air Quality output observed in the presence of harmful gas leakage*

9 CONCLUSIONS

The patient health monitoring system developed in this work is very useful to know the basic physiological parameters of the patient almost in real-time. This information is useful to the doctor or care taker to the monitor the patient's health status and take appropriate measures in case of any emergency. As this system is completely automatic, more number of patients can be treated in a short span of time. With this system, comatose patients can be treated in the patient house itself by equipping the system in the patient house. In case of frequent health checkups of the patient, this system is more useful as patient need not visit the health care center every time. This system reduces the nursing workload. As this system is based on IoT concept, the status of patient can be observed from the web server by connecting to the internet remotely any time and diagnosed accordingly.

10 REFERENCES

[1]. D. Sunehra and P. Ramakrishna, "Web based patient health monitoring system using Raspberry Pi", 2nd International Conference on Contemporary Computing and Informatics (IC3I 2016), Dec. 14-17, 2016, Noida, pp. 568-574.
[2]. P. W. Digarse and S. L. Patil, "Arduino UNO and GSM based wireless health monitoring system for patients", International Conference on Intelligent Computing and Control Systems (ICICCS 2017), June 15-16, 2017, Madurai, pp. 583-588.
[3]. T. Erlina, M. R. Saputra and R. E. Putri, "A Smart Health System: Monitoring Comatose Patient's Physiological Conditions Remotely", International Conference on Information Technology Systems and Innovation (ICITSI 2018), Oct. 22-26, 2018 Bandung - Padang, Indonesia, pp. 465-469.
[4]. S. Divakaran, L. Manukonda, N. Sravya, M. M. Morais and P. Janani, "IOT clinic-Internet based patient monitoring and diagnosis system", IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI 2017), Sept. 21-22, 2017, Chennai, pp. 2858-2862.
[5]. V. Mahadevan, "Anatomy of the heart", Surgery (Oxford), Vol. 36, Issue 2, Feb. 2018, pp. 43-47.
[6]. Website: https://www.alivecor.com/education/ecg.html
[7]. Website:https://www.sunrom.com/p/blood-pressure-sensor-serial-output
[8]. Arduino Mega 2560 datasheet: www.arduino.cc
[9]. ECG(AD8232)datasheet: https://www.analog.com/media/en/technical-documentation/data-sheets/AD8232.pdf
[10]. Accelerometer (ADXL335) datasheet:
[11]. https://www.sparkfun.com/datasheets/Components/SMD/adxl335.pdf
[12]. Heart rate and SpO2 (MAX30100) datasheet:
[13]. https://datasheets.maximintegrated.com/en/ds/MAX30100.pdf