Design of Patient Monitoring System (PMS) using Internet of Things (IoT) Transceiver

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Abstract: In current traditional medical industry, Patient Monitoring System (PMS) plays a vital role in observing critically sick patients like coronary artery diseases, head trauma, stroke, coma, pulmonary obstruction etc in both home care and hospitalized patients. Although bed rest and immobilization of critically ill patients often benefit the acutely affected part of the body, the point when prolonged, they often harm the rest of the body. Complications of immobilization would misfortune for sensation, paralysis and also torment with protective constraint from movement etc [5]. Hence it is essential to continuously monitor the electrical activity of muscles. At present, the module utilized in remote areas as well as in hospitals, does not incorporate wireless communication facilities through web service to transfer the monitored data and also only Global System for Mobile communication (GSM) based PMS is enabled, Electromyography (EMG) will keep track looking into the muscle actions and Gas sensor, which detects unsafe gas like Liquefied Petroleum Gas (LPG) clinched along home atmosphere by ceaselessly sensing the environment. This paper is conceptualized in outlining a PMS system framework with sensors using Internet of Things (IoT) transceiver in arduino platform, which encompasses the physiological parameters like Temperature, Gas, Electrocardiography (ECG), Pulse rate and EMG. The monitored physiological data's will be transferred to Physicians using Wi-Fi module where these parameters can be visualized in real time by accessing the Internet Protocol (IP) address of that particular Wi-Fi module.

Keywords: Arduino Platform, Wi-Fi module, Electromyography (EMG), Gas sensor, Electrocardiography (ECG), Pulse rate and Temperature.

1. INTRODUCTION

Looking into a recent report of World Health Organization (WHO), chronic malady patients are expanding as those numbers about elderly people expands in the public arena which profoundly demands highly effective and efficient healthcare to chronically and acutely sick patients [1, 2]. Moreover, it was highlighted that passing's due to chronic illnesses might increment around 17% by next 10 years, which roughly estimates around 64 million people. This illness is highly variable, where it may end the patient life if not monitored appropriately and treated instantly [3]. Further, elderly people from provincial areas will find troublesome on clinical visit every now and again to get medicament as indicated by the doctors [13] and which additionally expands the medicinal expenses step by step [11]. Considerably after arriving at the hospital, the risk of accessibility of specialized doctors for a specific issue is strenuous [4]. These provocations have headed to develop the remote screening system, which aides on providing high quality care to elderly, chronically and acutely ill patients by monitoring continuously in long term, anywhere, anytime as they go about their daily lives [1 – 4].

Liquefied Petroleum Gas (LPG) is one of the unsafe gases and is widely used for many applications, especially for household purposes. It is heavier than air, may lead to suffocation when inhaled. When the leaked LPG gas is ignited, it may lead to high explosion and deaths due to the explosion of gas cylinders have been increasing in recent years. There are some shortcomings in real time monitoring of indoor air quality and on data transmission [16 - 24]. Hence, Gas sensor is included to this system to monitor the unsafe gas like LPG in the surrounding environment and this data can be transferred via wireless networks, which helps to prevent home care patients from respiratory problems and accidents can also be reduced.

Chronically sick, acute and trauma individuals are especially at risk, because of less or no reserve physiologic functions. Considerably, these individuals are also facing additional challenges due to immobilization which bring out functional destructions. Issues emerging from immobilization can entangle a primary illness or trauma and might really end up with greater issues than the primary disorder, which is simple to prevent than to treat [5]. The above mentioned challenges can be solved by monitoring the electrical activity of the bedridden patient's muscle activity continuously. Conventional EMG machine is bulk and only well trained person can operate. In recent advancement in miniaturization field, EMG sensor is utilized which does not exist on any healthcare monitoring system.

Health care field is one of the most attractive applications areas of IoT and it also aides to decrease costs, increment the quality of life, and improve the user's background [3, 6]. This expeditious growth of IoT permits individuals to advance new products with lessened cost [31]. Finally, the monitored parameters will be transferred to the web through Wi-Fi and can be visualized in real time either through android mobile or laptop just by visiting the URL. Database and notification beyond threshold level are developed through firebase console.

2. RESEARCH OBJECTIVE

Even though the existing patient monitoring system provides good facilities with continuous monitoring of physiologic parameters, it also contains some disadvantages too. It is expensive, large in size, difficult for developing countries to have many units in a particular clinics or hospitals, medical staffs need to record the parameters manually and fatal rate increases due to lack of monitoring. Researchers have already developed Internet of Things (IoT) and Global System for Communication (GSM) based Healthcare Monitoring System which also consists of few drawbacks. To monitor the air quality in the atmosphere and to trace the patient's muscle activity, Gas sensor and Electromyography (EMG) is not included in any of the present system. Proposed module is all about solving the above mentioned drawbacks. It is portable, easily accessible, real time data transmission, sensor based PMS which monitors Temperature, ECG, EMG, air quality, pulse rate with flexible arduino and Wi-Fi Platform, where the monitored data can be transferred simultaneously in real time to the web and helps doctors to treat the patient in right time.

3. METHODOLOGY

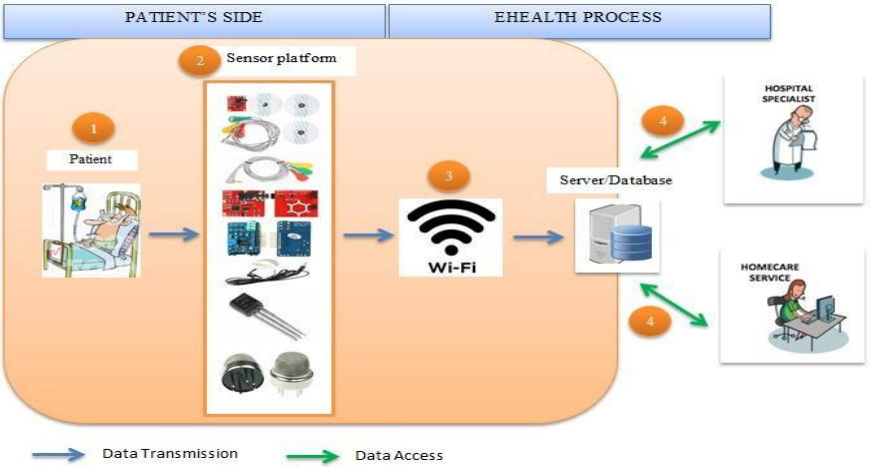


Figure 1: Architecture of Proposed PMS which demonstrates working of the system

The architecture of the proposed Patient Monitoring System (PMS) is shown in the figure 1. This depiction demonstrates about the combination of medical sensor which gathers the therapeutic information of the patient is then sent to Arduino microcontroller which reads the monitored information and finally Internet of Things (IoT) to transfer monitored data in real time to the web. This transmission of data allows medical professionals to access these patient's data at any time even if they are away.

This proposed system consists of both hardware components and software. The hardware part consists of Arduino Mega 2560, Touch screen Display, ECG sensor, EMG sensor, Pulse rate sensor, Temperature sensor to monitor patient's health and Gas sensor to trace the atmosphere air quality to avoid difficulties due to unsafe gas like Liquefied Petroleum Gas (LPG). The software includes Arduino Integrated Development Environment (IDE) in order to program arduino MEGA board.

Electrocardiography (ECG) Sensor: ECG is a standard approach to obtain Trans thoracic interpretation (across the thorax or chest) [13] of the electrical activity of the heart. It is recorded by placing electrodes on the surface either by chest leads or limb leads (Unipolar and Bipolar leads) system. These electrodes measures the electrical potential changes which occurs as the electrical impulses travels through the heart. In this PMS, AD8232 ECG sensor is shown in the figure 2 and is manufactured by Sparkfun, which traces the cardiac activity by placing unipolar limb leads avR- right arm, avL- left arm, avF- left leg and right leg will be Neutral.

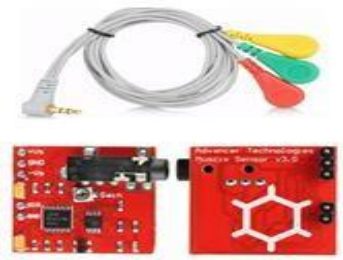
Figure 2: AD8232 Electrocardiography (ECG) Sensor

AD8232 ECG Sensor Pin details	Arduino Mega 2560 Pin details
Ground (GND)	Ground (GND)
Power Supply (3.3 V)	Power Supply (3.3 V)
Leads off Detection- (LO-)	Digital pin - 50
Leads off Detection+ (LO+)	Digital Pin - 52
Output (O/P)	Analog pin - A11

Table 1: Pin configuration of ECG sensor with arduino pin connection

Power supply for this sensor ranges between 2.0 V to 3.5 V and Common Mode Rejection Ratio (CMRR) is 80 dB. Final output will be in analog form and is sent to arduino microcontroller for further processing of this data. Pin configuration of ECG sensor along with arduino pin interface is shown in Table 1.

Electromyography (EMG) sensor: The sensor incorporated in this proposed PMS is shown in the figure 3. EMG is used for evaluating and recording the electrical activity of skeletal muscles [15]. It is used to examine the cause of muscle weakness, numbness, and several types of limb pain, cramping, muscle disorder such as polymyositis or biomechanics of living beings movement [14]. Power supply for this sensor will be positive voltage source (+Vs), negative voltage source (-Vs) and ground (GND) which ranges between ±3.5 V to ± 18 V. It incorporates potentiometer and operational amplifier. This sensor has electrode plug where the electrode cable is plugged in for the measurement. This electrode cable consists of three electrodes, where first two electrodes are placed on the biceps branchii muscle and the third electrode is a reference electrode which is placed on brachioradialis. Further this signal will be recorded and is sent to arduino microcontroller for further processing. Pin configuration of EMG sensor with arduino interfacing is shown in table 2.



EMG Sensor Pin details	Arduino Mega 2560 Pin details
Ground (GND)	Ground (GND)
Power Supply (+12 & -12 V)	Power Supply (+12 & -12 V)
Output (O/P) – A0	Analog pin – A13

Figure 3: Electromyography (EMG) Sensor

Table 2: EMG sensor pin configuration with arduino.

Temperature Sensor: Measuring and monitoring the human body temperature is generally done using temperature sensor [4]. Generally rise or fall in body temperature is a foremost indication for any diseases and disorders [9]. LM35 series precision centigrade temperature sensor which is highly précised and calibrated circuit [12] is used in this proposed PMS as shown in the figure 4, whose output voltage is linearly proportional to Celsius temperature [8]. It is more accurate than thermistor [7] and high output voltage than thermocouples. This sensor will continuously monitor the patients temperature and the output of this sensor is sent to the arduino microcontroller, which has inbuilt Analog to Digital Converter (ADC) for further processing. Pin configuration of temperature sensor with arduino pin interface is shown in Table 3.

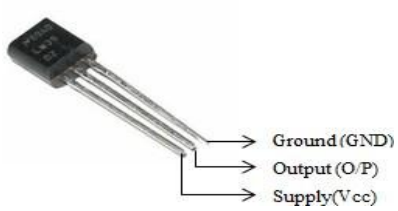


Figure 4: Temperature Sensor

LM 35 Temperature Sensor Pin details	Arduino Mega 2560 Pin details
Ground (GND)	Ground (GND)
Power Supply (5 V)	Power Supply (5 V)
Output (O/P)	Analog pin – A9

Table 3: Pin configuration of temperature sensor

Pulse Sensor: Easy plugin Pulse sensor of version V1.0 is used along with other physiological sensors to detect cardio-vascular pulse waveform from a fingertip which is displayed in the figure 5. It works on the principle of Photoplethysmography (PPG). Inside the sensor body, infrared (IR) light source on one side to illuminate the finger and a photo detector receives the transmitted light through the tissue on the other side which is shown in figure 6. PPG signal consists of two components: AC component which is a result of pulsatile changes in the arterial blood volume and is synchronous with the heart beat so it can be used to calculate heart rate in Beats Per Minute (BPM) and DC component which is related to bones, tissues and average blood volume which have to be removed for further analysis. Hence, AC component carries the vital information which displays systolic and diastolic peaks including heart rate [26 - 28]. The obtained data is sent to arduino controller for future processing. Table 4 shows the pin configuration of pulse sensor with details of arduino interface.

Figure 5: Pulse Sensor

Figure 6: Finger placement in between the sensor

Pulse Sensor Pin details	Arduino Mega 2560 Pin details
Ground (GND)	Ground (GND)
Power Supply (5 V)	Power Supply (5 V)
Output (O/P) – A0	Analog pin – A10

Table 4: Pin configuration of pulse sensor with the arduino interface

Gas Sensor: The proposed PMS is especially based on home care, so gas sensor is incorporated to keep monitoring the environment continuously for unsafe gas like LPG which helps to reduce accidents and also to avoid respiratory problems because when we inhale LPG it leads to suffocation[18, 22 - 24]. MQ2 semiconductor gas sensor is utilized which is shown in figure 8. Concentration of LPG in this sensor is 300 - 1000 ppm. When the target combustible gases exist, sensor conductivity increases which simultaneously increase the gas concentration. Figure 9 demonstrates the drive circuit for gas sensor and Table 5 depicts the explanation of pin configuration of this sensor along with arduino. This generates the output values and sent to the arduino controller.

Figure 8: MQ 2 Gas sensor

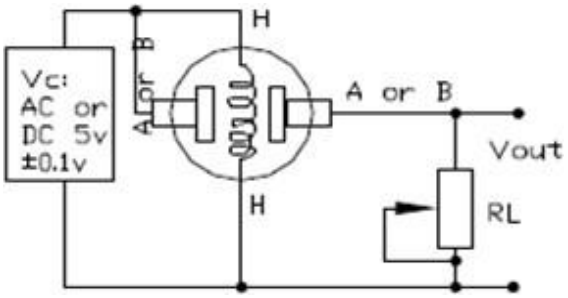


Figure 9: Drive circuit for MQ 2 gas sensor

MQ 2 Gas Sensor Pin details	Arduino Mega 2560 Pin details
Ground (GND)	Ground (GND)
Power Supply (5 V)	Power Supply (5 V)
Output (O/P)	Analog pin – A8

Table 5: Pin configuration of MQ 2 Gas sensor with arduino pin connection

Arduino Mega 2560: The output of ECG sensor, EMG sensor, Temperature sensor, Pulse sensor and Gas sensor are now fed to the control unit of arduino for further processing to display the output in touch screen LCD and to transfer the monitored data's to the web. Hence, our proposed system utilizes Arduino platform as main control unit since it is ease, flexible and compatible base for developing programming. It incorporates higher end version of Arduino which Mega 2560 and is shown in figure 10. It has inbuilt Analog to Digital Converter (ADC). This inbuilt feature helps in processing all raw data of the sensors output [4, 10, 12, 13] and this processed data will be the output of Arduino microcontroller. The output of each sensor will be displayed sequentially in the 2.4" touch screen LCD display.

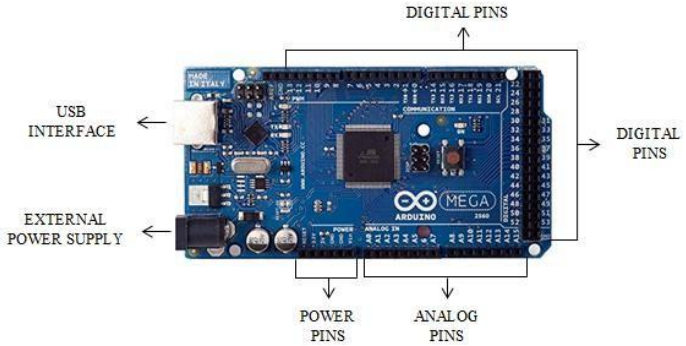


Figure 10: Arduino Mega 2560

4. RESULTS AND DISCUSSION:

As discussed in the methodology, the same architecture was implemented as shown in figure 11 and the live results of ECG, EMG, temperature, gas level and pulse rate are captured from the hardware module.

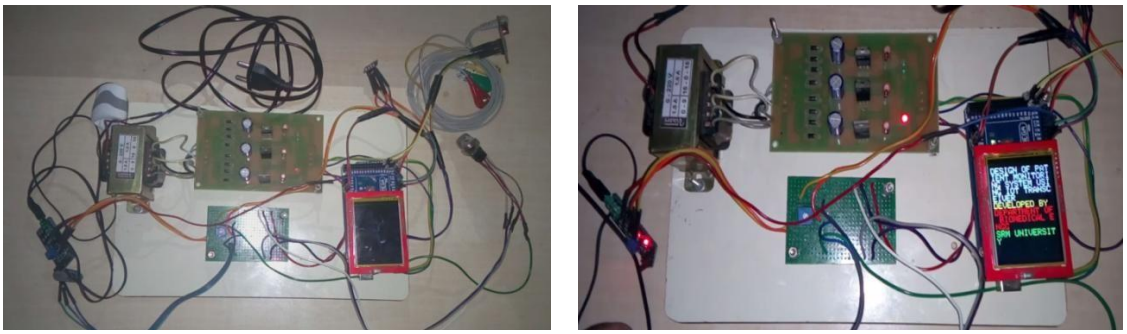


Figure 11: Hardware of Telecare System using Wi-Fi

Temperature sensor generally produces output around +10.0 mV/ºC. Hence, further conversion process takes place in arduino mega platform and the final output is displayed in Celsius. Usually, MQ 2 gas sensor measures gas level in parts per minute (ppm). The output of this gas sensor is sent to arduino board by interfacing in analog pin, which configures the measured data with appropriate conversion and displays in the percentage. When it senses hazardous gases, it will send notification via Firebase Console Messaging. The output of temperature sensor and gas sensor from the designed hardware is shown in figure 12.

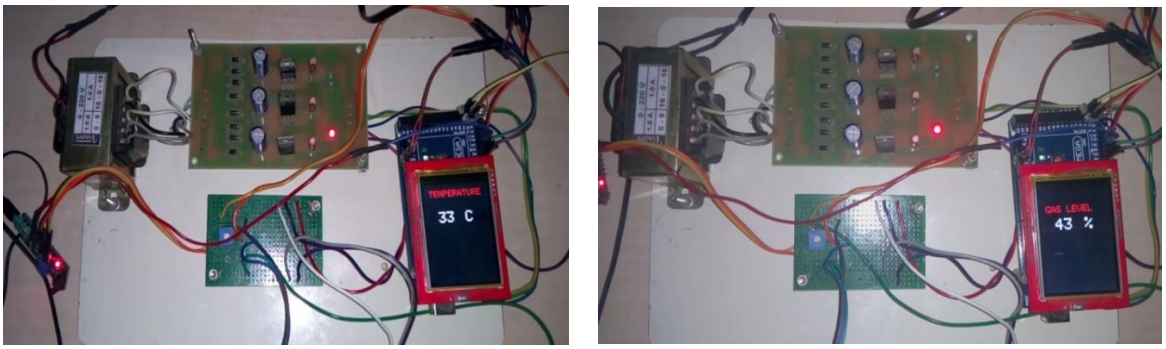


Figure 12: Output of temperature sensor and gas sensor is displayed on LCD.

The output of pulse sensor, ECG sensor and EMG sensor is shown in figure 13. By placing finger in the pulse sensor, it measures the blood volume changes by transmitted light intensity across the fingertip which correlates with heart rate of a patient. These analog values will be converted into digital values via arduino mega platform. Similarly, EMG and ECG sensor also generates analog values continuously and can be viewed in serial monitor of arduino software. This data's are further processed and plotted as waveform which is shown in LCD display.

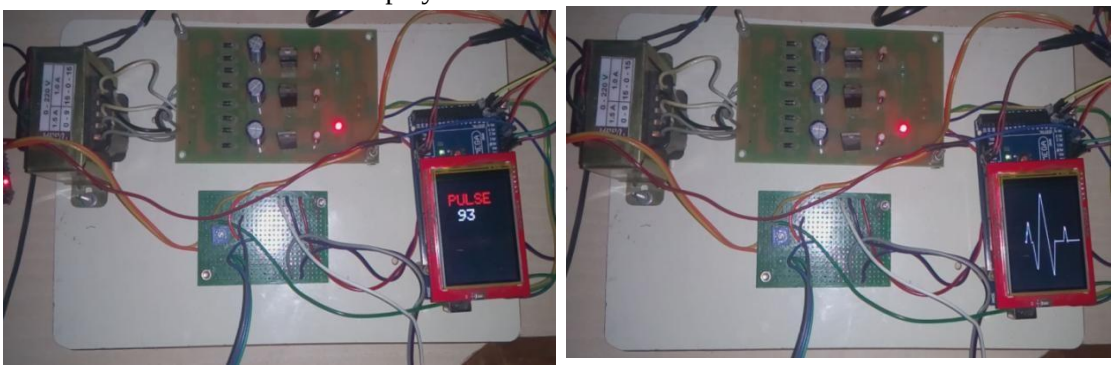
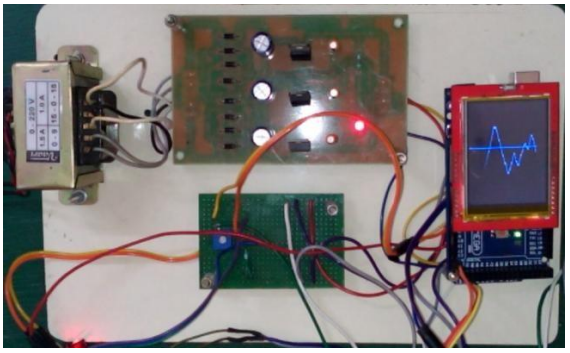


Figure 13: (a) Output of pulse sensor (b) ECG sensor waveform is displayed on LCD.



(c) EMG sensor waveform is displayed on LCD

Heroku is a cloud application platform which is used to display the monitored data's in a particular dashboard. Initially, the values are transferred though Wi-Fi which hits the server and then the firebase console to displays the output in real time. An advantage of this system is that, it is compatible for both

android and web applications by accessing the particular Universal Resource Protocol (URL). Firebase console is to create database storage simultaneously when it deviated from the threshold, notification can be sent through firebase console messaging application. The application is displayed in the figure 14.

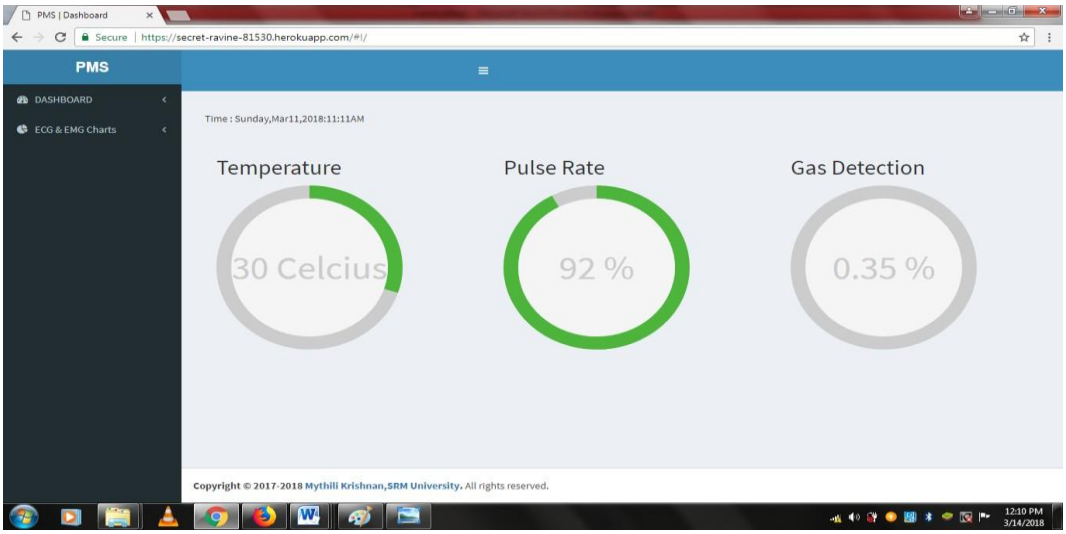
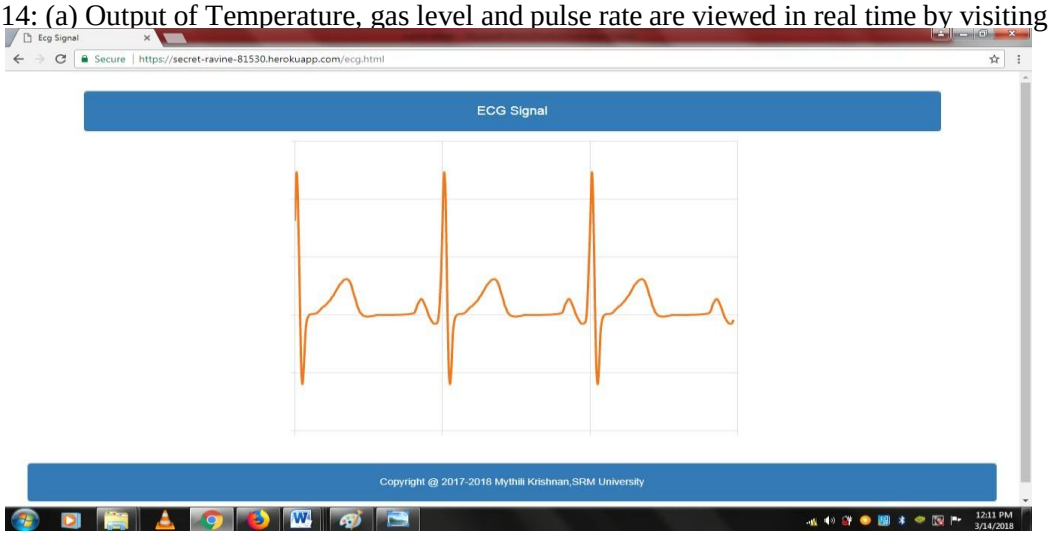


Figure 14: (a) Output of Temperature, gas level and pulse rate are viewed in real time by visiting URL



(b) Output of ECG are viewed in real time by visiting URL

(c) Output of EMG are viewed in real time by visiting URL

5. CONCLUSION

In this paper, initially we reviewed the existing IoT based Health Monitoring System along with their working mechanism, advantages and disadvantages. Based on those disadvantages, the proposed framework of IoT Transceiver based PMS was designed and further system implementation was explained. This system is entirely based on sensor platform which continuously monitors the common physiologic parameters such as Electrocardiography (ECG), Temperature, and Pulse Rate. Along with these parameters Electromyography (EMG) and Air quality monitoring are additional parameters and very new approach with all the existing system. These monitored values are displayed on the patient's end and simultaneously these data's are transferred to the web, where the doctors can view these real time data's for providing treatment to the patient at right time to reduce mortality rate.

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