IoT based system for Heart Rate Monitoring and Heart Attack Detection

TV Sethuraman, Kartik Singh Rathore, Amritha G, Kanimozhi G

Abstract :Heart rate monitoring is a vital aspect of maintaining heart health. People from different age groups have different ranges for maximum and minimum values of heart rate, the monitoring system must be compatible enough to tackle this scenario. In this paper, an IoT based system has been implemented that can monitor the heartbeat from the output given by a hardware system consisting of a NodeMCU and pulse sensor. Further, an alert system is added which is executed if the heartbeat goes below or above the permissible level given in the devised algorithm. The alert message is received by the doctor through a mobile phone application. By using this prototype the doctors can access the heartbeat data of the patient from any location. The nurses or the duty doctor available at the hospital can monitor the heart rate of the patient in the serial monitor through the real-time monitoring system. The real-time monitoring is done via Adafruit, this platform is more secure to store the information and uses MQTT protocol which has lots of advantages over others. IFTTT protocol is also used to create conditional statements called applets. The prototype is integrated with GPS technology to monitor the live location of the device from any part of the world and uses a local server to provide security, privacy and low latency. The heartbeat data and other personal details of the patient are stored in the cloud, this can be utilized for future studies on the health condition of the patient. The prototype is realized using NodeMCU, pulse sensor, Adafruit, and Blynk cloud.

Index Terms: Heart rate monitoring, sensors, NodeMcu, Internet of things.

I. INTRODUCTION

The heart is one of the most important organs in the human body. It acts as a pump for circulating oxygen and blood throughout the body, thus keeping the functionality of the body intact. A heartbeat can be defined as a two-part pumping action of the heart which occurs for almost a second. It is produced due to the contraction of the heart. When blood collects in upper chambers, the SA(SinoAtrial) node sends out an electrical signal which in turn causes the atria to contract. This contraction then pushes the blood through tricuspid and the mitral valves; this phase of the pumping system is called diastole. The next phase begins when the ventricles are completely filled with blood. The electrical signals generating from SA node reach the ventricle and cause them to contract. This phase of the pumping system is called systole. The tricuspid and mitral valves are closed tightly to prevent the backflow of blood; the pulmonary and aortic valves are opened. Once the blood moves from the pulmonary artery and aorta the ventricles relax and the pulmonary and aortic valves close. Tricuspid and mitral valves open because of the lower pressure from the ventricles leading to the start of another cycle. In today's scenario, health problems related to heart are very common. Heart diseases are one of the most important causes of death among men and women; it claims approximately 1 million deaths every year. Heart rate is a critical parameter in the functioning of the heart. Therefore heart rate monitoring is crucial in the study of heart performance and thereby maintaining heart health.

This paper proposes a heart rate monitoring and abnormality detection system using IoT. Nowadays treatment of most of the heart-related diseases requires continuous as well as long term monitoring. IoT is very useful in this aspect as it replaces the conventional monitoring systems with a more efficient scheme, by providing critical information regarding the condition of the patient accessible by the doctor in any remote place, at any time through the internet. In addition, the nurses or the duty doctor available at the hospital can monitor the heart rate of the patient in the serial monitor through the real-time monitoring system. Also, a warning system is incorporated in which if the patient's heartbeat goes below or exceeds a particular value the doctor receives an alert message through a mobile application. GPS technology is used in the software system for monitoring the live location of the device. The prototype can also store the data of the heartbeat as well as other details of the patient and this can be used by the doctor to analyze the heart condition of the patient and for other future purposes. Early recognition of the disease is very vital in preventing more complications in the future.

The suggested prototype consists of both hardware and software components. The hardware consists of NodeMCU, pulse sensor, and LCD display. The software consists of two IoT platform, Adafruit (along with GPS Technology), and blynk along with a mobile application. The system is based on a portable heart rate monitoring system designed in a cost-efficient manner. The prototype is also easy to use and access the data. And also can be used by people of different age groups. The real-time data can be viewed as well as stored for future studies with respect to the heart condition of the patient.

A system based on the ECG sensor and pulse sensor is adapted to design a wrist band for early detection of a heart attack and availing medical facilities as soon as possible [1]. The proposed layout consists of a smart wrist band using IoT technology where the device communication is made possible by using a Bluetooth device. The prototype is based

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on Lilypad Arduino and Android application, additionally, the panic button is provided as part of an alert system in case of heart attack detection. Moreover, a mobile application called ECG analytics is used for the analysis of the data collected from the sensor[2]. Real-time monitoring of the heartbeat is made possible through the Thing Speak platform.

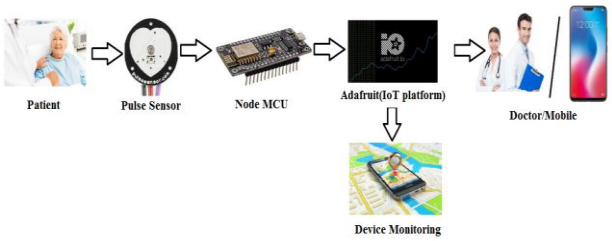

Fig. 1: Block Diagram representation of the prototype

Heart rate sensor, Wi-Fi Module, and Arduino are used as major components in modeling a heart rate monitoring system[3]. Combining IoT with this through a heart rate application is used to obtain the alert message, given, a heart attack occurs. The measurement and analysis of heart rate for subjects belonging to the age group of 20-80 years are carried out[4]. The data is obtained from the sensor by detecting the intensity of light. The output of the sensor is processed into a hub and sent to the software display unit. This data is further stored into the SD card to maintain a record of the person's heart rate characteristics.

The pulse sensor is used along with a temperature sensor for heart rate monitoring and heart attack detection [5]. Arduino board is utilized on the basis of the algorithm. A GPS module is incorporated to locate the specific location of the patient. Android application is developed and communication is made possible through Bluetooth module. IR sensor is incorporated with the hardware system along with Arduino to produce a PPG (photoplethysmography) [6]. The signals are gained from a fingertip. The software used for graphical representation and analysis is Processing software.

The sensor collects physiological data from the human body, a management unit is used to store and show the real-time data from the monitoring body [7]. The management unit can be combined with an IoT system that is a local host network. The results are presented via a monitor, mobile phone or laptop. The hardware system consists of Arduino UNO, pulse sensor, LEDs and Raspberry Pi 3[8]. Thing Speak, an IoT platform is used for real-time monitoring of the data. IR emitter-detector pair is used for heart rate measurement and the output of the sensor is again amplified by 741 OP amp IC[9]. A low pass filter is used for removing the noise from the signal. The ECG waveform can be visualized on a Personal computer screen. The data is uploaded in a database cloud through a Wifi module.

There are lots of healths monitoring systems available these days. Wireless communications, wearables, and portable remote health monitoring systems are a few among them [10]. The health monitoring systems have devised to make health care facilities easily available, comfortable to the patients and most important information regarding the health status of the patient must be easily accessible to the doctor irrespective of his location. IoT plays a key role in this scenario. Raspberry Pi is utilized in various aspects these days in many of the monitoring systems. ECG analysis is vital in diagnosing the heart health irrespective of the age group[11]. The signals collected from wearable monitoring node are sent to the cloud. A wifi module is usually used to achieve this. The IoT cloud is provided with both HTTP and MQTT protocols. This portrays the data into a graph and also supports real-time monitoring.

Prototypes are developed for heart rate monitoring as well as monitoring the interbeat intervals in individuals [12]. This is realized through Java scripts, using a wearable Smart watch Samsung gear S3 with library Web Socket. The communication between Samsung gear S3, server, and the client is implemented through the algorithm in the Java code. Continuous heart rate monitoring is an important factor in the health care of people suffering from cardiovascular diseases especially in the case of elderly people and private homes for patients[13]. The proposed system consists of the electric-optical sensor, an embedded system, along with a Bluetooth enabled hands-free module. The heartbeat signals are collected from the fingertip. The designed system is enabled with a provision to contact a clinician in a remote location during an emergency situation.

Abnormal electro cardio signals can be monitored using a remote monitoring system, and the data can be transmitted automatically through mobile phone messages [14]. This is accomplished by using a GSM MODEM. Components used are heart rate sensor, MCU, interface circuit and MODEM. The system uses the AT89C52 MCU. The system requirements for low power consumption and convenient operation are met through internal resources integrated with AT89C52 MCU. Among the wide variety of applications in IoT smart and connected health care is the most important one [15]. IoT facilitates an evolution in the practice of medicine, enables personalization of the treatment and also helps in reducing the cost of healthcare. Real-Time Monitoring is one of the most important features of IoT.

II. PROPOSED METHODOLOGY

a.ECG Waveform

The electrical impulses of the heart that causes heartbeats are measured using a test called ECG(Electrocardiogram). It is primarily used as a diagnostic tool to examine the functioning of the heart. The ECG measures the heart rate as well as the rhythm of the heart, it can also give information regarding the blood flow to the heart. An ECG is realized by using a standard system of electrodes. Usually, ten electrodes are required to produce 12 electrical views of the heart. The pulses are recorded by these electrodes. The signals are transmitted to the electrocardiograph which displays the result on a monitor. The results are mainly a sequence of continuous wavy lines with a series of spikes. The electrode patches are placed on each arm, each leg and six on the chest wall. On the other hand, a heart monitor can obtain the results by just placing the electrodes one on each- right arm left arm and left chest. There are a series of waves in ECG these waves are a representation of Atrial and Ventricular polarisation and repolarization, the wave can be described as the P wave

followed by which is the QRS complex and then the T wave. The first deflection on ECG is P wave. It is caused by right and left atrial depolarization. For a normal P wave, the duration or the width is less than 0.12 seconds. A normal P wave is less than 2.5 mm tall. In general, the normal P wave axis is within a coordinate between 15° and 75°. It is usually in direction of lead II and away from lead aVR.Therefore a P wave will be always positive in lead II and negative in aVR during sinus rhythm.

The second wave that occurs in the ECG is QRS complex as shown in Fig. 2. It shows the spread of stimulus through the ventricle. The QRS complex constitutes mainly three deflections, which are caused due to the current associated with the depolarization of the right and left ventricles. It contains a Q wave, R wave, and an S wave. The first deflection in the QRS complex is called Q wave if it is negative. Consecutively R wave is the first positive deflection and S wave is the next negative deflection. Any positive deflection after S wave it is called as an R wave. The normal duration or width of a QRS complex is 0.12 seconds.The next part of the ECG waveform is the ST segment. It begins after the QRS complex and ends at the beginning of the T wave. J joint represents the junction between the end of the QRS complex and the starting of the T wave The current flow linked with the second phase of ventricular repolarization is depicted by the ST segment. The ST segment is normally isoelectric with baseline.The T wave represents the third phase of the ventricular repolarization. The T wave usually has the same polarity as that of the QRS complex. During the period of repolarisation extending from the peak of the T wave to its initial downslope, the ventricles are electrically unstable.

The region from the beginning of the P wave to that of the QRS complex is called the PR interval. This region is a measure of the time period from the initial depolarization of the atria to the initial depolarization of the ventricles. The normal range of this interval is 120 to 200 ms. The region from the beginning of the QRS complex until the end of the T wave is called the QT interval. This interval is a measure of the time in which ventricles depolarize and repolarize.

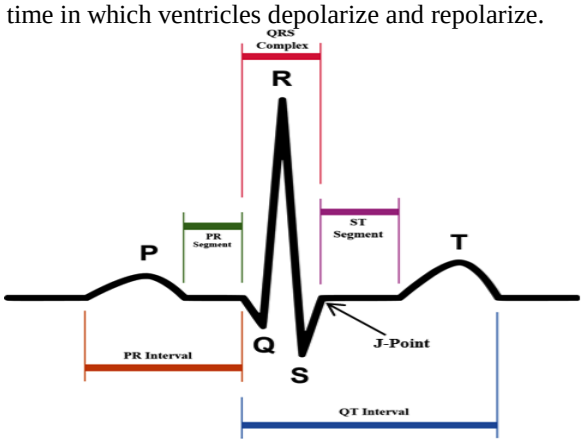

Fig. 2: QRS Complex

b. Heart rates and ranges:

The normal range of heartbeat is 60 to 100 beats per minute. Tachycardia is a heart rate faster than 100 beats per minute and bradycardia is a heart rate slower than 60 beats per minute. A slow rate in a healthy person can be caused due to being physically fit, sleep or a health condition such as propranolol or metoprolol. A faster heart can be caused due to exercise, pregnancy, a stimulus, nervous or excited. A slow rate can occur in diseased people due to reasons like heart attack, infections, high potassium levels in the blood or an underactive thyroid gland. A faster heart rate can occur in diseased people due to reasons like infections, overactive thyroid gland, heart problems, etc. Abnormal heart rhythms are called arrhythmias. This condition occurs in most of the people they are mainly harmless but some of them can be due to serious heart issues or other health problems. Heart diseases can be classified into different categories that are circulatory, electrical and structural.

There are two types of circulatory disorders, Heart attack, and Stroke. A condition in which the arteries get clogged leading to the reduction in the flow of blood to the heart or even stopping the blood flow is called a heart attack. This leads to heart muscle damage or in many cases kill the heart muscle. A stroke is caused due to the blockage or reduction in the flow of blood to the brain. Also called as brain attacks, strokes are not considered to be true heart disorders. Blood clots formed in the brain can travel to the brain and block the vessel thereby causing a stroke. Some strokes occur when the blood vessels burst open as well.

Structural disorders are of two types, Heart valve problems, and heart failure. Heart valve problems occur when the ability of the heart to push blood efficiently from chamber to chamber as well as to the rest of the body decreases. Heart valve problems can be inherited or developed on their own. Heart failure can be defined as a condition in which the heart muscles become too weak to pump the blood effectively. This heart condition is referred to as cardiomyopathy. There are several heart diseases caused due to electrical factors. Atrial flutter occurs due to a single electrical wave that circulates very rapidly in the atrium (about 300 times per minute). A harmless faster rhythm can lead to Sinus Tachycardia, a normal increase in heart rate that occurs usually due to fever, excitement, and exercise. Sick Sinus Syndrome is a group of symptoms that shows that the sinus node is not working properly, during this condition the heart rate can alternate between fast and slow heart rate. When the heartbeat is irregular or rapid due to disorganized signals from the heart's electrical system it leads to Atrial fibrillation.

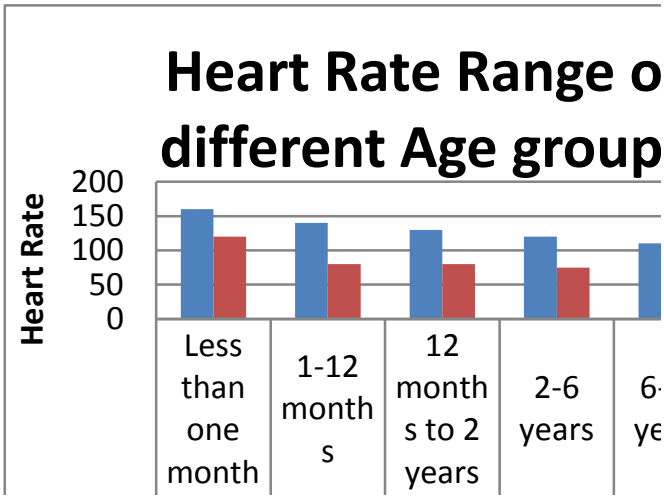

Table-1: Heart Rate Ranges for different age groups

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Ventricular Fibrillation, causes Sudden Cardiac Arrest. The heartbeat is fast and causes the ventricles or the lower heart chambers to spasm. Ventricular Tachycardia can lead to Ventricular Fibrillation. This disease is usually seen along with serious heart diseases. This is also seen in people with normal hearts. Heart blocks occur when the electrical signals from the atria cannot travel to the ventricles, this causes the ventricles to beat slowly thereby decreasing the amount of oxygen in the blood and body. Premature contractions refer to early, extra or skipped beats.. Long QT syndrome can be inherited, caused due to some medications or due to both the reasons. The people suffering from Long QT syndrome are at risk of Ventricular Fibrillation, this may even lead to sudden death.

Disease	Heart rate
Bradycardia: Slow Heart Rate	Less than 60 bpm.
Atrial Fibrillation (AF or AFib)	300-400 times a minute.
Atrial Flutter (AFL)	300 times a minute.
Ventricular Tachycardia (VT)	Greater than 170 bpm.
Long QT Syndrome (LQTS)	Less than or equal to 110.
Heart Attack (Myocardial Infarction)	Greater than 100.

Table 2- Heart Rate ranges for different heart-related diseases.

III. SOFTWARE DESCRIPTION

Adafruit

Adafruit is an IoT platform to display, respond, and interact with the user's data. It can handle and visualize multiple feeds of data. This platform keeps the data private and secure. Adafruit uses MQTT protocol for device communication. MQTT(Message Queue Telemetry Transport), has a faster response, lower battery and bandwidth usage. This makes MQTT a better option than HTTP.

Blynk

Blynk is an IoT platform. It is a platform with iOS and Android apps to control Arduino and Raspberry Pi. It can be stated as a digital dashboard a graphic interface can be built by simply dragging and dropping widgets. Its functionality is very simple and it supports the hardware of our choice.

IV. HARDWARE DESCRIPTION

For the hardware implementation of the heart rate monitoring system, the major components required are pulse sensor and NodeMCU.

a.NodeMCU

NodeMCU is an open source IoT platform. It is based on ESP8266 WI-FI Soc from Espressif systems. The hardware is based on ESP-12 module. It uses the Lua scripting language. NodeMCU uses an on-module flash-based SPIFFS file system as shown in Fig. 3a.

b.Pulse Sensor

A pulse sensor or heart rate sensor is a plug and play type sensor. The normal operating voltage is +5V or +3.3V and current consumption of 4mA. The sensor shown in Fig 3b has two sides, one side consists of an LED with an ambient light sensor and the other side contains circuitry which amplifies the signals and filters the noise.

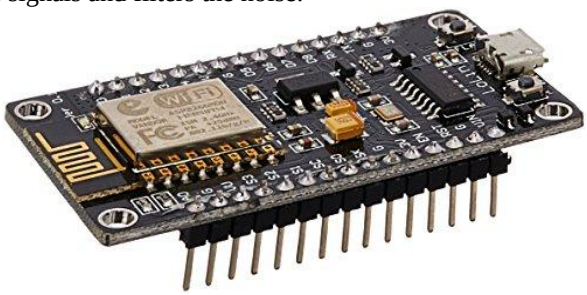


Fig. 3a:Node MCU

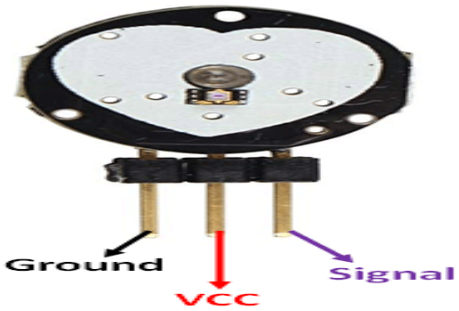


Fig. 3b: Pulse sensor

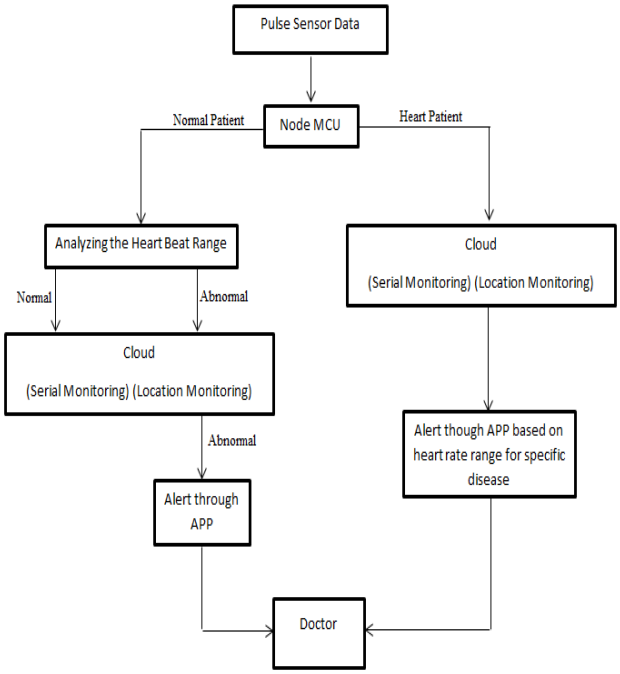


Fig. 4: Flowchart for the proposed design.

The proposed prototype is a device that can be attached to the wrist of the patient. The pulse data from the patient's wrist is collected by the pulse sensor. The process of working is given in the flowchart as shown in Fig. 4. The data is transferred to the microcontroller, nodeMCU coded with different algorithms for heart patients and normal people. From the nodeMCU, the data is sent to

the cloud, Adafruit. Adafruit, an IoT platform is used for serial monitoring as well as location monitoring using GPS technology as shown in Fig. 6. A local server is used to provide security, privacy, and low latency. IFFFT protocol is also used to create conditional statements called applets.

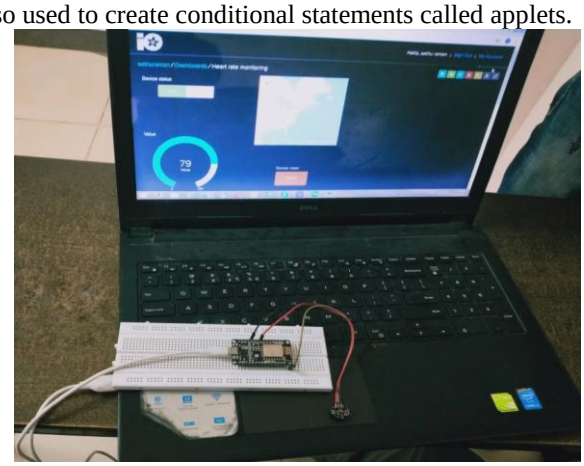


Fig. 5: Hardware implementation

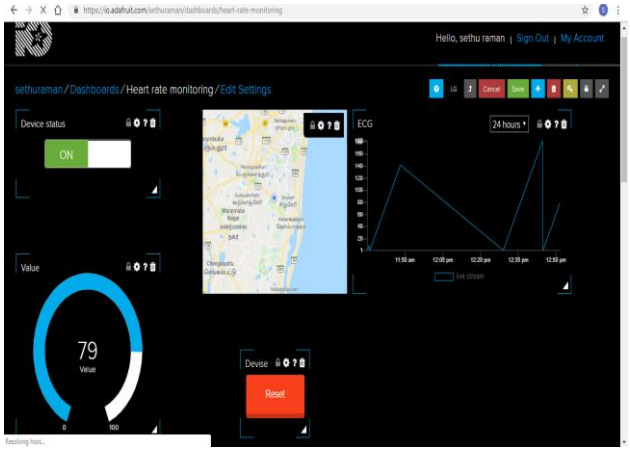
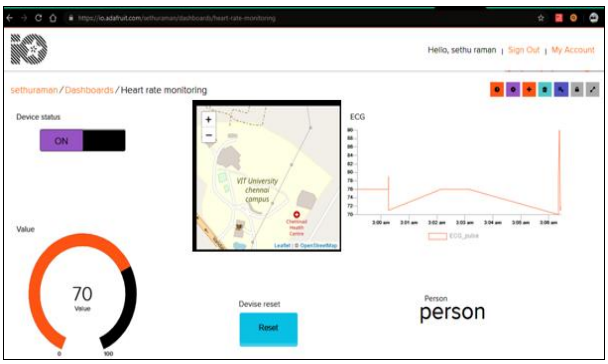
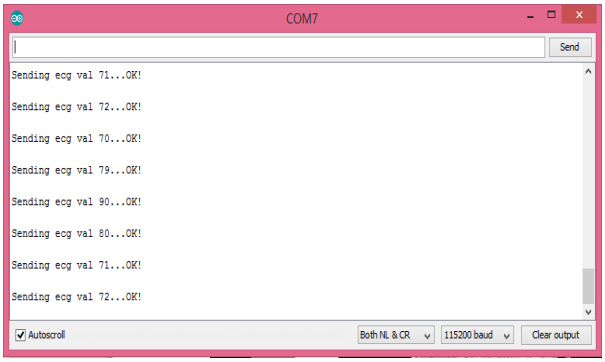


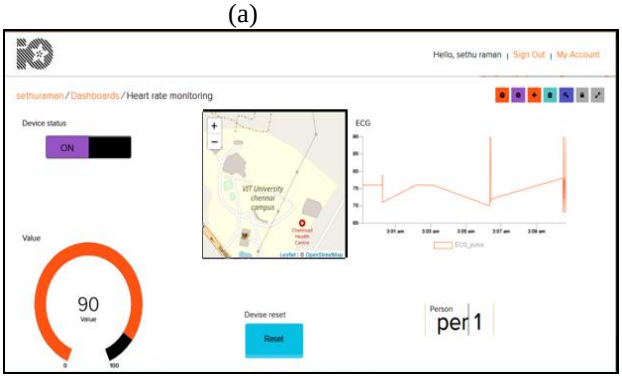
Fig. 6: Serial Monitoring

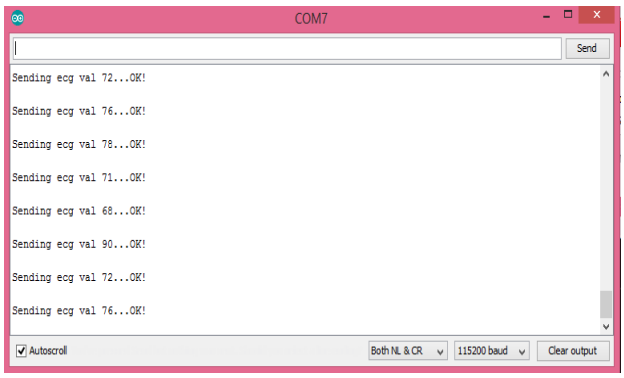
If the heartbeat values exceed or go below the heartbeat ranges given in the algorithm, an alert is sent to the doctor's mobile through a mobile app.The mobile application is realized using Blynk. By using the GPS technology the device location is monitored this helps the doctor in locating the patient.





(a)





(b)

Fig 7 (a)and (b) Serial monitoring depicting different heart rate and location.

Fig 7 (a) and (b) shows the serial monitoring screen depicting heart rate 70 and 90 along with the patient location. The heartbeat is monitored through real-time monitoring and the data can be stored for future studies regarding the health of the patient. The alert message sends through the mobile app helps the doctor in availing the right medical help to the patient during emergency situations.

V. V.CONCLUSION

In this system a real time heart rate monitoring and heart attack detection system is realised by using IoT. The proposed design is advantageous to patients of different age groups by providing real time heart health monotoring. It also provides security and privacy to the datas of the patient. The proposed design is implemented as the real time monitoring system which helps in providing immediate health care facilities to the patient by using MQTT protocol and IFTTT protocol, alert system and location monitoring are other features of the design. In addition to this a local server is used to provide security, privacy and low latency.

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