# IoT Based Remote Heart Rate Monitoring System

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***Abstract*** **- As the human population continues to grow and healthcare expenses rise, public healthcare is receiving increased attention. To detect health conditions early and make accurate diagnoses, an effective health monitoring system is crucial. Electrocardiogram (ECG) monitoring is a widely-used method for diagnosing heart disease, but most existing portable ECG monitoring systems require a mobile application to collect and display data. In this paper, a new ECG monitoring method is proposed that utilizes Internet of Things (IoT) technology. ECG data is collected by a wearable monitoring node and after processing the data to calculate the heart rate, it is transmitted directly to the IoT cloud using Wi-Fi. The data is first sent to ThingSpeak, an IoT analytics platform, from the ESP8266 microcontroller, and then emailed and uploaded to Google Drive for cloud-based storage. The reliability of the system was tested on healthy volunteers, and the results showed that it can effectively collect and display real-time ECG data-based heart rate, which can be used in primary diagnoses of certain heart diseases.**

***Keywords– Real Time, ECG, Heart Rate, IoT, Portability***

## I. INTRODUCTION

Healthcare has emerged as one of the most important concerns for both individuals and governments due to the tremendous expansion in the human population and medical spending. Research from the World Health Organization (WHO) [1] indicates that the issue of population aging is becoming worse. Aged people typically require more regular health checks, which puts additional strain on the current medical infrastructure. Thus, there has been an increased interest in finding affordable, quick, and accurate ways to diagnosis human illnesses [2 - 4]. Electrocardiogram (ECG) monitoring has been extensively used in hospitals and medical research due to its prevalence in the identification of heart-related disorders [5].

The ECG signal is often acquired by huge, stationary equipment at specialized medical facilities. Twelve electrodes are typically used because of their effectiveness in short-term measurements with this type of equipment while collecting ECG data. Nevertheless, it is unclear that the technology would be portable, which significantly restricts the activities that patients can engage in while data is being collected. Also, patients must regularly visit hospitals since these devices are typically prohibitively costly for home usage, adding to the strain on hospitals.

In addition, availability of such devices and even trained medical professionals to operate the devices and analyze the results are rare in the more rural areas of a developing or underdeveloped countries. It is also difficult to get these devices in places that are not easily accessible such as a disaster-stricken zone. As a result, a portable device with cheap costs for long-term ECG signal detection is widely sought.

With this regard, in this paper, an ECG monitoring system based on the Internet-of-Things (IoT) cloud is firstly proposed. We designed and implemented a wearable ECG monitoring system. The ECG data gathered from the human body using the ECG module AD8232 is firstly processed to calculate the heart rate. This processing has been done in NodeMCU ESP8266 which has a WiFi module that allows transmission of the processed data to the cloud via the Internet. The processed data are also sent via Gmail as well as stored in Google Drive using MATLAB. The entire proposed system has been successfully deployed and fully tested with demonstrated effectiveness and reliability in ECG monitoring.

## II. HARDWARE SETUP

The ECG monitoring system can be divided into the following sub-systems: 1) Sensor module; 2) Controller and Wi-Fi module; and 3) Power module.
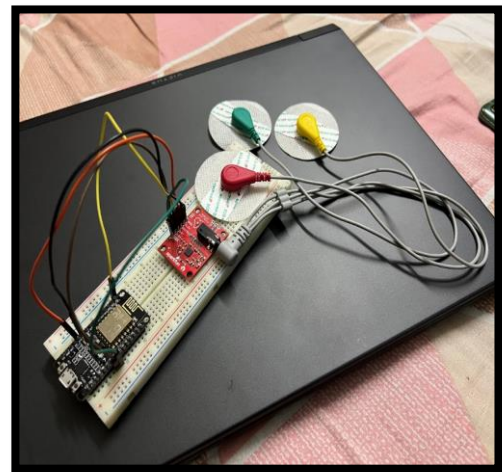


Fig. 1 Hardware Setup of the Heart Rate Monitoring System

### A. Sensor Module

The ECG sensing network plays a crucial role in the overall system by collecting physiological data from the body surface and transmitting it to the IoT cloud through a wireless channel. The use of wearable ECG sensors minimizes the impact on the user's daily life, allowing for continuous ECG data recording over an extended period. With the aid of AD8232 ECG sensor and certain peripheral circuit, weak ECG signals can be detected with satisfactory accuracy. ECG signal can be

recorded using any two arrangements: i) Right chest, Left chest & left stomach or ii) RA (Right Arm), LA (Left Arm) and RL (Right Leg). Additionally, there is an LED indicator light that will pulsate to the rhythm of a heartbeat. Biomedical sensor pads and sensor cables are required to use the heart monitor.

### B. Controller & Wi-fi Module

NodeMCU(ESP8266) is used as a central controller and Wi-Fi module. It processes the data received from the sensor and then send the data via wifi module. The NodeMCU (*Node MicroController Unit*) is an open-source software and hardware development environment built around an inexpensive System-on-a-Chip (SoC) called the ESP8266. The ESP8266, designed and manufactured by Espressif Systems, contains the crucial elements of a computer: CPU, RAM, networking (WiFi), and even a modern operating system and SDK. That makes it an excellent choice for Internet of Things (IoT) projects of all kinds.

### D. Power Module

As the model can be run by 5V power supply, we powered it from our laptop for initial use. In our final model, we can set it up with a 5V battery.
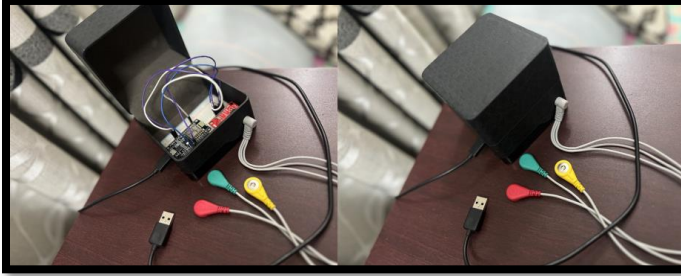


Fig. 2 Final Hardware Setup a) Open Box; b) Closed Box

In our final model, we set up everything inside a box to hide the open wiring and to get a better look. Otherwise, an open setup could lead to frequent loose connections. Only the 3-lead electrodes and the wire attached to it are free outside of the box. Figure [2] shows the final product. Table [1] is a breakdown of all the cost required to construct this device.

TABLE I
COST ANALYSIS OF THE ENTIRE SYSTEM

| Equipment | Cost (BDT) |
|---|---|
| AD3232 ECG MODULE | 1800 |
| 3 Disposable ECG Electrodes pad (One-time use) | 3x30 = 90 |
| ESP8266 | 345 |
| Bread Board | 70 |
| Miscellaneous (Wire, Tape etc.) | 25 |
| Total | 2330 |

### III. METHODOLOGY

### A. System Architecture

The block diagram in Figure [3] depicts the function of the IoT based remote health monitoring system. It first collects the data from the AD8232 ECG module. The data is collected using NodeMCU (ESP8266) at 100 samples/second sampling rate. Then the collected data can be processed either in Arduino IDE or MATLAB for further BPM calculation.
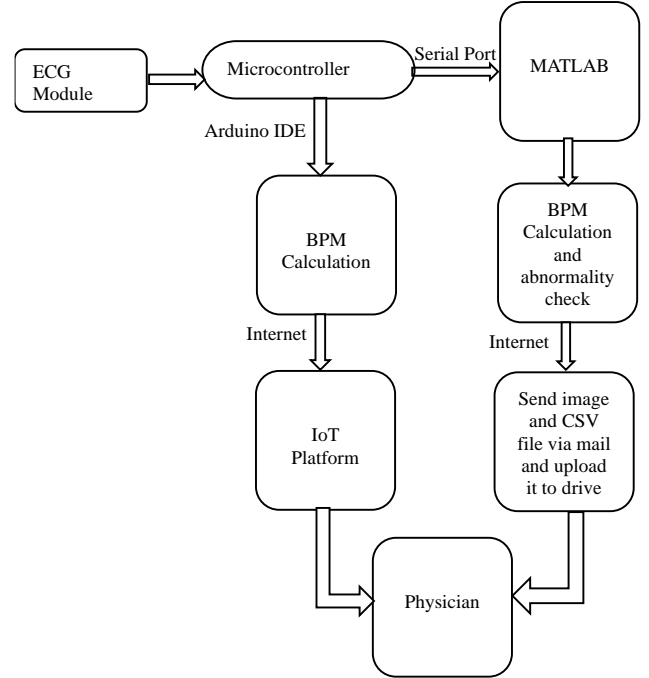


Fig. 3 Block diagram of IoT Based Remote Health Monitoring System Monitoring System

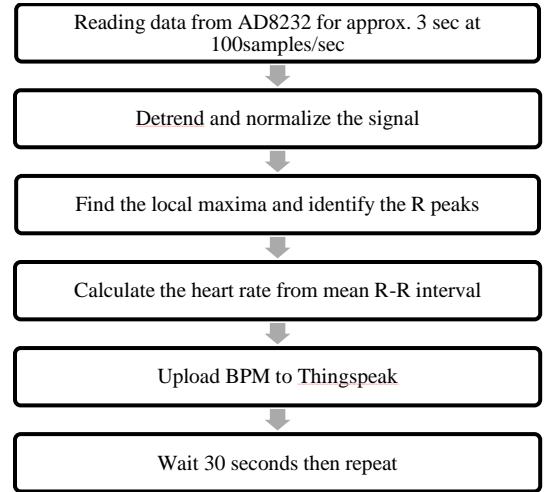### B. System Algorithm: BPM Calculation & Uploading to ThingSpeak



Fig. 4 Process for calculating BPM

NodeMCU is connected to Arduino IDE through which it will receive the sensor data for approx. 3-second sliding window. Then the chunk of received data is used for data processing.

- De-trending the ECG signal is an important preprocessing step before further analysis, such as heart rate calculation, is performed. De-trending the ECG signal involves removing any DC offset or baseline wander or low-frequency noise present in the signal. This is necessary to accurately identify and analyze the high-frequency features of the ECG signal, such as the QRS complex and T-wave, which are of clinical significance.

- Normalizing the ECG signal to scale the signal so that its amplitudes fall within a certain range or have a certain distribution. Normalization is also used to standardize ECG signals across different subjects, recordings, or devices, as well as to facilitate the comparison and analysis of ECG signals.
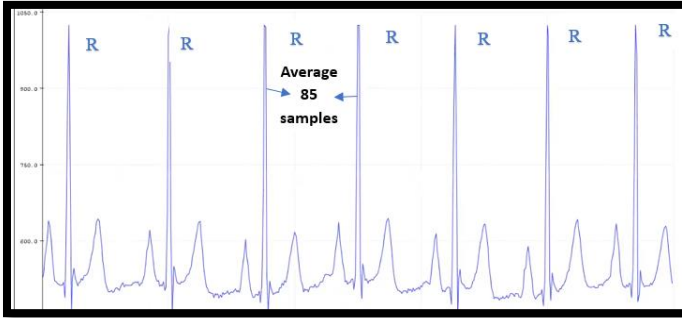


Fig. 5 ECG data display with R peaks

- In Figure [5], R peak corresponds to the highest point of the QRS complex, which represents the depolarization of the ventricles of the heart. A peak detection algorithm is used that identifies the highest points in the signal and determines if they meet certain criteria to be classified as R peaks.
- The heart rate is calculated from the mean R-R interval, which represents the average time between consecutive R peaks in the ECG signal. Usually, the R-R interval is measured in time units such as seconds or milliseconds. However, in this particular case, the R-R interval is measured in the number of samples, which represent the discrete data points in the ECG signal. To convert the R-R interval from sample units to time units such as seconds, it is multiplied by the time interval between each sample.

$$\textbf{Heart Rate} = \frac{\textbf{60}}{\textbf{Ts(interval between each sample)} * \textbf{R−R Interval(avg no of samples)}}$$

- The system will transmit all the calculated heart rate wirelessly through Wi-Fi to a cloud-based IoT analytics platform called ThingSpeak which comes with built-in support for MATLAB.
- It is not feasible to upload the entire ECG signal to an IoT platform due to potential data loss and delays in transmission. An attempt was made to use EEPROM to store a large amount of data, which would then be transmitted wirelessly after a significant delay. However, this approach was not successful due to the loss of data packets during wireless transmission. Therefore, the next viable solution is to use MATLAB to process and visualize the ECG data, which can then be sent via email in the form of data points and plots.

### C. Sending Mail via integrating MATLAB

The Serial object is used to receive the sensor data automatically in MATLAB over the serial port. Initially, the ECG data is received from the sensor for a duration of 12 seconds, and then it will create a CSV file of the received data and plot a graph to save it as an image file. Subsequently, both the CSV file and image file are sent to a physician or hospital for further analysis if required.

MATLAB will collect data from the sensor for a sliding window 3 seconds. The chunk of data received during this period will be utilized for subsequent data processing and heart rate calculation. In case the instantaneously calculated BPM value exceeds 120 or is less than 60 for five consecutive readings, it will be flagged as an abnormal event. Whenever an abnormal event is detected, it will receive ECG data from the sensor for a duration of 12 seconds, and generate a CSV file and plot a graph based on the received data. Following this, both the CSV file and the image file will be sent to a physician or hospital for further analysis.
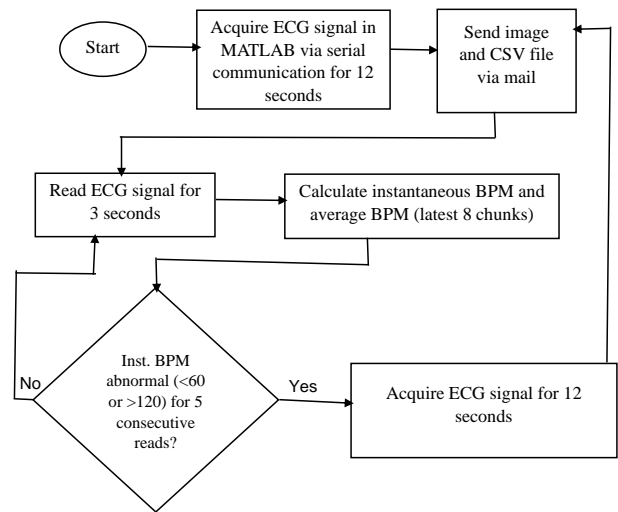


Fig. 6 Working Flowchart for Emailing in MATLAB

## IV. RESULT AND OBSERVATIONS

### A. Calculated Heart Rate

A 3-lead electrode sensor [7] not only captures the fundamental properties of an ECG signal but is also easily portable and usable. The electrodes are placed in accordance to the placement demonstrated in Figure [7].
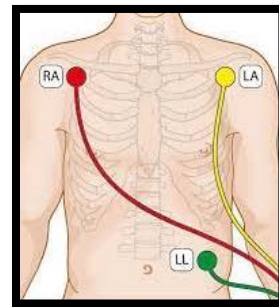


Fig. 7 3-Lead Electrode Placement

Multiple experiments were conducted on several healthy volunteers with the same conditions and settings to ensure

generalization. Figure [8] shows part of the acquired signal from one volunteer.

The peaks can be identified even before implementing any signal processing. To demonstrate the key features of the measured ECG signal, two cycles of the signal are chosen as examples. This is illustrated in Figure[8].
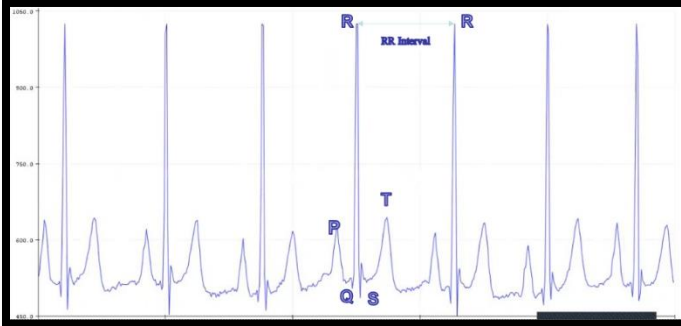


Fig. 8 ECG signal acquired from a healthy volunteer

To find the heart rate from this signal, the interval from successive R-R peaks are determined. Since the interval between the peaks are all relatively same, it can be said that the volunteer shows no primary signs of having a heart disease.

The heart rate calculated from the signal is cross checked with a pulse oximeter. Table[2] shows a part of the observed results.

TABLE II
COMPARISON OF RESULTS FROM THE PROPOSED SYSTEM AND A PULSE OXIMETER

| Heart Rate from signal (bpm) | Heart Rate from Pulse Oximeter (bpm) |
|---|---|
| 90 | 92 |
| 92 | 94 |
| 91 | 92 |
| 91 | 93 |

The results from the signal closely follows that of the pulse oximeter proving this system to be a reliable one.

### B. Implementation of The IoT Infrastructure

The average heart rate of the volunteer is automatically uploaded to an IoT cloud platform at an interval of 30 seconds. ThingSpeak platform is chosen for the system for its simplicity and functionality. ThingSpeak is used to upload the data, store it in its database and access it whenever and wherever needed. Apart from the patient himself or herself, anyone related to this person has access to these private data, such as family members and doctors. Thus treatment for a potential heart disease is more likely to be carried out in time. The affiliated app of the IoT platform, ThingView can be used to access the same data from smartphones. Figure[9] shows the public view dashboard of the platform. The current heart rate is shown on the right. The graph on the left gives an idea about the fluctuation of heart rate of the person being monitored.

### C. Remote Access with Email and Google Drive

As an additional method of remote access, an option of email and google drive backup is implemented. To give a third-party platform such as MATLAB access to Gmail account, a 16-digit passcode generated from google was used as the password to the account. An image of the acquired and processed signal is saved and attached to an email. The email is sent to a doctor or any medical professional. The corresponding values of the signal are attached as well to aid in any further analysis if desired. The email can be sent manually as per the operators wish, or it can be set in monitoring mode where email will be sent automatically if any anomaly is detected in the heart rate. To backup these attachments in an additional storage automatically, Pabbly Connect, an online integrator application was used as a mail parser. The mailed image is automatically backed up in the designated google drive account.
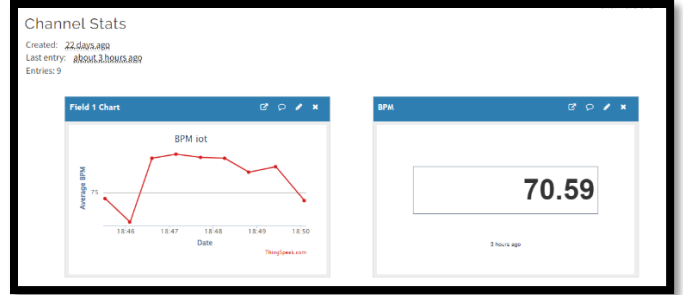


Fig. 9 ThingSpeak Dashboard

## V. TANGIBLE FUTURE WORKS

The overall system was made into a prototype to be a sellable replacement of the conventional ECG monitoring schemes by the hospitals. Although a computer was used to send data to designated emails & cloud storages, it also increases the overall secondary cost of the environment that is needed to successfully run the prototype. Hence, integrating the entire system with only the microcontroller might be an actual and achievable task that can be completed in the future.

## CONCLUSION

We have developed and implemented an ECG monitoring system utilizing IoT techniques. Our system utilizes a wearable monitoring node with three electrodes to collect real-time ECG signals with satisfactory accuracy. After processing the collected data, the heart rate is calculated and transmitted to the IoT cloud using Wi-Fi technology, which supports high data rates and wide coverage areas. The IoT cloud is responsible for visualizing the ECG data to users and storing the valuable data for further analysis. The implementation of our system is based on three servers, namely the ThingSpeak server, Gmail server, and Google Drive server. To provide versatility, the system features a web-based GUI that eliminates the need for mobile applications and is independent of any mobile operating system platform. Future studies on ECG monitoring are required to improve the accuracy of diagnostic results based on the ECG signal to enhance disease diagnosis reliability. Advanced signal processing to remove noises in the signal such as power fluctuation, muscle noise, movement noise will further refine and improve the reliability of the results. Integrating the IoT portion and email portion into one whole concise system is left for future improvement. Our system represents an exciting development towards achieving long-term and user-friendly ECG monitoring that can mitigate existing healthcare problems to a certain extent.

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