IoT Based Heart Defect Monitoring System

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Abstract— **Public medical care is getting increasing attention as a result of population growth and health care expenses. It is authenticated that a health monitoring device can detect deformity or irregularity of one's health condition in real time and produce or release diagnostic measures according to the data received from the detector device. All portable ECG monitoring devices work on only mobile phone applications until now and they were accounted for data collection and displaying the analyzed data. In this paper, we are proposing to replace this technique of ECG monitoring backed by Internet of Things (IoT). We collect ECG data using ECG sensor and then transmit the data on the IoT cloud with aid of Wi-Fi module. HTTP and MQTT protocols are used in the IoT cloud for providing graphical view and ECG results to users in real time. Any smart terminal with an online browser can receive ECG data easily, which in turn has reduced cross-platform problems. Tests are conducted on healthy volunteers for checking the authenticity of overall system. This proposed is accurate in collecting and displaying the ECG data in real time, which helps in detecting heart defects in advance.**

Keywords- Internet of Things (IoT), ECG monitoring, Wi-Fi module, Real time, Healthcare, HTTP, MQTT, Portable device, Detect heart defect

I. INTRODUCTION

With a rapid climb in human population and medical expenditure, healthcare has become one amongst the most vital issues for both individuals and governments. Meanwhile, consistent with a report from World Health Organization (WHO), the matter of population aging is becoming more serious. Health conditions of aged people usually got to be checked more frequently, which poses a greater challenge to existing medical systems. Therefore, the way to identify human diseases in an exceedingly timely and accurate manner with low costs has been paid an increasing attention. Due to the dominance within the diagnosis of heart-related diseases, electrocardiogram (ECG) monitoring has been widely applied in both hospitals and medical research.

Usually, the ECG is detected through large and stationary equipment in professional medical institutions and hospitals. This kind of kit usually employs about twelve electrodes to gather ECG data thanks to their good performance in short-term measuring. However, the equipment is unlikely to be portable, which suggests that patients' activities are severely limited during the amount of data collection. Moreover, as these devices are usually too expensive for home use, patients need to attend hospital frequently, which can inevitably increase the burden of hospitals [1].

Therefore, a portable system for a long-term ECG detection with low costs is extremely desired. Thanks to the development of mobile Internet and wireless sensor networks (WSNs), portable ECG monitoring systems have emerged which are ready to detect ECG signals employing a non-intrusive sensor and transmit the signal to the smart phone through wireless transmission techniques, such as Bluetooth or WIFI modules [3]. At the expense of accuracy, it's sufficient to gather the essential information of the heart. These portable sensors are usually embedded into some wearable gadgets or clothes, which have little impact on the user's daily activities. With the help of those systems, long-term ECG are often monitored in a very cost-effective manner. But, to the best of our knowledge, almost all existing systems cannot work without a smart phone application, which is used as a receiver and processor of the ECG data. Due to limited power and computational capabilities, the complex tasks of data transportation and processing may have an excellent impact on the daily use of the smart phone [2]. We will be using IoT based platform which can be accessed via any web browser to display real time results of the heart condition.

II. PROBLEM STATEMENT

Unanticipated death due to heart failure is a major cause of mortality among middle aged and elderly people. At times the distance between patients and doctors is the case where in people does not have access to quality health services and thus having trouble for their regular health examine. So, an efficient heart monitoring system is required to find out the current heart condition and transmit the resulting data over the cloud to doctors or family members who lives at a distance so they can provide the necessary help which is needed in time.

III. SCOPE

IoT introduces all electronics objects in one domain and it is easy to access everything through internet. One of the applications of IoT is Smart health monitoring system. The automation of health care monitors the patient health status using IoT device to make medical equipment more efficient [4]. The heart rate monitor is one of the sub applications of IoT under Smart health monitoring System and it recognize emergency situations. It monitors the heart rate of the patient using ECG signal. A special microcontroller is used to communicate with the help of ECG signal and pulse sensor. So, the system can analyze the signal and detects whether the condition is normal or abnormal, result is displayed with the help of IoT. The end goal is to reduce the repetitive check-ups by physically going to the doctor. Thus, IoT brings one of the solutions to get regular follow-ups with the doctor without physically being present there [2][5].

IV. OBJECTIVE

The objectives of our project are:

1) To design and fabricate monitoring system for monitoring heart rate signal.
2) To develop wireless system of monitoring heart defects using Wi-Fi module.
3) To reduce death rate due to unawareness of the heart defects.
4) To develop data monitoring system using integration between IC and web browser based (IoT) platforms.
5)

V. PROPOSED SYSTEM

In our proposed system we will use AD8232 ECG sensor to detect the ECG signals from the heart and send it to the cloud-based platform using ESP32 Wi-Fi module.

A. Requirements

1) Hardware

a) AD8232 ECG Sensor

Fig. 1. AD8232 ECG sensor

Arduino IDE is the required software environment to program the ESP32 by writing a code and upload it to the ESP32. It also gives the output results for analysis using both serial monitor and serial plotter. The version used in this project is 1.8.13 (Genuine) which supports both serial monitors to print the HR wave. The Arduino IDE supports the languages C and C++ which can be used to program the Arduino or microcontrollers. The Arduino IDE provides a software library from the Wiring project which supplies extensive common input and output procedures. User written code requires two basic functions i.e. only for starting the sketch and the main program loop, that are debugged, compiled and linked with a program sub main () into an executable cyclic supervisory program with GNU tool chain and including IDE distribution. The Arduino IDE appoints the program to convert into an executable code in a document in hexadecimal encoding that will be loaded into the Arduino board by a loader program in the board's firmware.

b) ESP32 microcontroller

Fig. 2. ESP32 microcontroller

ESP32 microcontroller is a low power, low-cost device which has integrated Wi-Fi and dual mode Bluetooth. The ESP32 uses a Ten silica Xtensa LX6 microprocessor in dual core and single core variations and consists of filters, power amplifier, built in antenna switches, low noise receive amplifier, RF Balun, and power management modules. ESP32 is developed by Espress and manufactured by TSMC using 40 nm processes. It's a successor to the ESP8266 Microcontroller.

c) Disposable ECG electrodes

Fig. 3. Disposable ECG electrodes

2) Software

a) Arduino IDE

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b) Ubidots (Web based software)

Ubidots is an IoT web based platform which empowers innovators and industries to develop prototypes and make production of IoT projects possible. Ubidots helps to create applications that can capture real-time data and convert it into desired actions and insights. Use of Ubidots platform aids to send data to the cloud from any Internet-enabled device. We can then configure actions and alerts based on real-time data and provide the output of our data through visual tools. Ubidots offers a REST API that allows us to read and write data to the available resources which are data sources, variables, values, events and insights. Our data will be protected with two more replication, encrypted storage and optional TLS/SSL data support. We can also customize the permissions of each module of the platform, making sure that accurate information is shown to the right user.

B.Circuit Configuration

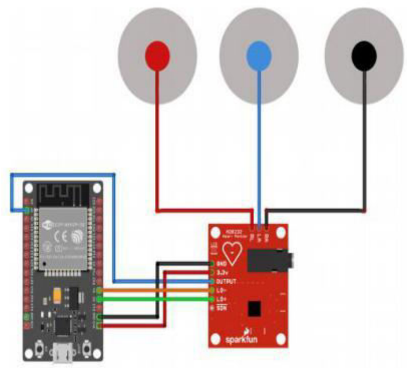

Fig. 4. Circiut Configuration

1. The VDD 3.3V power pin of ESP32 is connected to the 3.3V pin of AD8232 ECG sensor.

2. The ground terminal (pin 2) of ESP32 is connected to the ground pin of AD8232 ECG sensor.

3. The D2 (pin 4) of ESP32 is connected to the LO+ (Leads Off Comparator Output) pin of AD8232 sensor.

4. The D4 (pin 5) of ESP32 is connected to the LO- (Leads Off Comparator Output) pin of AD8232 sensor.

5. The EN (pin 15) of ESP32 is connected to the Output (Operational Amplifier Output) pin of AD8232 sensor.

6. The ECG electrodes are connected to RA, LA and RL pin of AD8232 sensor respectively.

VI. IMPLEMENTAION PLAN

Based on the architecture proposed, an IoT-based ECG monitoring system is implemented using the advanced techniques of mobile sensing, cloud computing and Web. Details about the monitoring node, IoT cloud and GUI are explained as follows:

A. ECG monitoring node

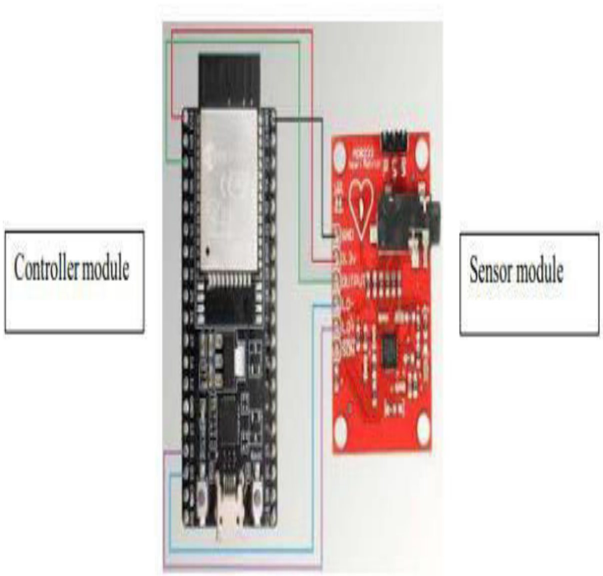

Fig. 5. ECG monitoring node

The ECG monitoring node is liable for collecting ECG data from the human skin then sending these data to the access point via a wireless channel. As depicted in Fig. 2, the ECG monitoring node in our system mainly includes: a) Sensor module; b) Controller module; c) Wi-Fi module; and d) power module. An image of the ECG monitoring node is shown in Fig. 5

a) Sensor module: The sensor module, which is the foundation of the monitoring node, is liable for collecting ECG data from the physical body. With the help of the AD8232 ECG sensor and certain peripheral circuit, weak ECG signals are often detected with satisfactory accuracy. Since the typical frequency of the ECG signal range between 0.5 Hz and 100 Hz, a band-pass filter is used in AD8283 to eliminate the noise outside this frequency band. After that, the filtered signal is amplified using an op-amp. Finally, with the aid of the sensor module, ECG signals from 0 v to 3.3 v are gathered.

b) Controller module: Because it is the core of the ECG monitoring node, it is used to process the gathered ECG signal and to send them to the Wi-Fi module. All the signal processing functions are implemented during a high-performance Microcontroller Unit (MCU), i.e., ESP32. The ECG signal is processed using this ESP32, which consists of mainly 4 procedures, i.e., sampling, ADC, buffering, and packetizing. The analog ECG signal is firstly digitized through sampling and ADC. After that, the ECG data are temporally stored within the buffer before being packaged in accordance with a particular format. Finally, the data is transmitted to the Wi-Fi module via a Universal Synchronous/Asynchronous Receiver/Transmitter (USART)

i. Procedure 1:

Sampling The ECG signal collected from the sensor is in analogue format, which must be sampled initially. The sampling rate is set to be 200 Hz, given that the bandwidth of the ECG signal is usually in the range of 0.5 Hz and 100 Hz. Using a 16-bit timer, the control module can enter a timer interrupt every 5 milliseconds for storing and sampling. The priority of the timer interrupt is made the highest for avoiding the effect of the other interrupts, such as the external interrupt or USART interrupt, etc.

ii. Procedure 2:

ADC The MCU has three built-in 12-bit ADCs, each of which shares up to 21 external channels, performing the analog-to-digital conversion within the single-shot or scan modes. Only one channel of an ADC is required to digitize the analog ECG signal.

iii. Procedure 3:

Buffering Before being packetized, the ECG data are temporarily stored. The MCU has 48 Kb of embedded SRAM, which is enough for buffering the data. When the ECG data accrue to 1 Kbytes, they're going to be packetized in accordance with a particular format. Other than that the new data is also stored in the remaining space of the buffer.

iv. Procedure 4:

Packetizing All ECG data are packetized before they're sent to the Wi-Fi module through the USART. A complete data packet usually consists of a series of knowledge fields, e.g., the header, flags, payload, checksum, etc. Data fields are cxreated to improve the accuracy and efficiency for data transmission.

c) Wi-Fi module: The Wi-Fi module employed to collect the ECG data USART. The Wi-Fi module gives a fast and easy access to the web, which can transmit real-time ECG data to the IoT cloud. Due to the utilization of the powerful MCU, data are packetized and transmitted consistent with certain communications protocols.

d) Power module: the facility module provides a reliable energy supply to each module within the ECG monitoring node. Two modes of power supply are provided for users, i.e., the USB and also the lithium battery, thanks to their long lifetime and high portability [1][5][3].

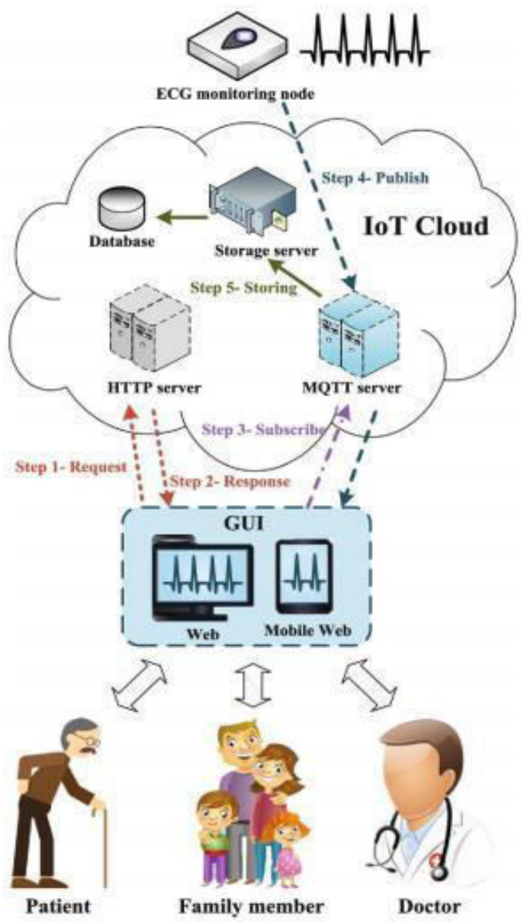

Fig. 6. Architecture of the IoT cloud for ECG monitoring

B. *IoT Cloud for ECG Monitoring*

After the system obtains large amounts of ECG data through the monitoring node, an IoT cloud aids to provide a speedy and convenient way to store data into database, and then display the ECG signal when required. Therefore, based on the state-of-the-art techniques of web services, cloud computing and data storage, an IoT cloud is implemented which is illustrated in Fig 6.

a) *Servers:*

Three kinds of servers of varied functionalities are utilized in the IoT cloud, i.e., the storage server, HTTP server and MQTT server. Thanks to the development of virtualization technologies, these servers are often established on visual machines so as to make efficient use of physical resources, e.g., CPU, memory, etc. The servers deployed within the IoT cloud are elaborated as follows [5].

i. HTTP server:

Based on the traditional request response mechanism, the HTTP server is capable of accepting users' responses and respond accordingly. In order to gain access to the ECG data, users need to send a request to the IoT cloud using a URL. Then a file written in the Hypertext Markup Language (HTML) code is send to the browser through the HTTP protocol. The browser is capable of converting the HTML file into a user friendly graphical interface so that the users can securely log into the server. After gaining access to the server, the HTTP server sends another HTML file which is used to provide a graphical interface for displaying the ECG signal.

ii. MQTT server:

The HTTP server can only provide a graphical interface to the ECG signal. All the transmission of ECG data from the monitoring node is executed by the Message Queuing Telemetry Transport (MQTT) protocol. The MQTT protocol is designed such that it can maintain a long lived connection between the device and the client. Therefore, the data transmission latency can be reduced to a certain extent. In addition, the MQTT protocol requires less communications overheads compared with the HTTP, which helps save bandwidth for data transmission.

b) *Steps for data transmission through the IoT cloud:*

i. Step 1-Request: For accessing the web page user sends a request to the HTTP server.

ii. Step 2-Response: User gets an HTML file in the response to the request send from HTTP server which is later converted to webpage by web browser.

iii. Step 3-Subscribe: The webpage is capable of subscribing certain topics related to the ECG monitoring node with the help of Application Programming Interface (API) of the IoT cloud.

iv. Step 4-Publish: The ECG data is published by the ECG monitoring node on the MQTT server the related to topics chosen by the user. These data are dispatched to all the webpage that are subscribed the same topics.

v. Step 5-Storing: Storage server stores the ECG data in database.

VII. ANALYSIS

Conventional 12 lead systems are widely used in medical institutions, which accurately capture ECG signals for professionals. However, too many electrodes may negate the portability of the system and comfort ability of the patient. However, a 3lead placement is sufficient to capture the primary features of the ECG signal. For best results of the ECG signal, the electrodes must be placed around the heart and in a triangular shape. The 3lead placement employed in our system is shown in Fig.8 [2]. Key parameters of the ECG sensor, Wi-Fi module and server are listed Fig.7

	Parameter	Value
ECG Sensor	Type	AD8232
	Power voltage	3.6V
	Output voltage	0-3.3V
Wi-Fi Module	Wireless transmission protocols	IEEE 802.11 b/g/n
	Power voltage	3.3V
	Power consumption	<71mA
Server	CPU	Intel Core i7-3632QM 2.2GHz/i7-3770 3.4GHz
	Operating System	Windows 10 64bit
	HTTP Server	Ubidots

Fig. 7. Key parameters of the ECG monitoring system

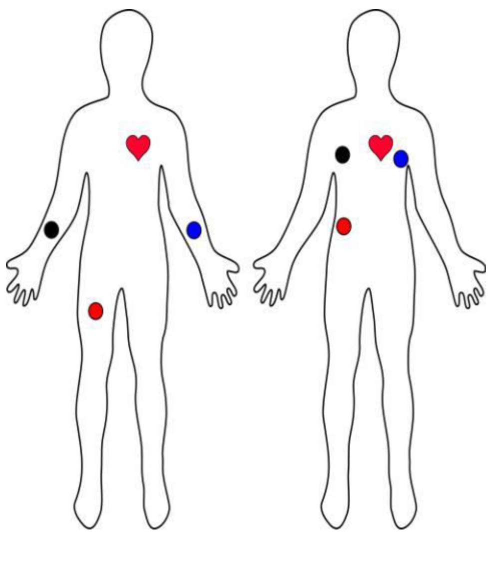

Fig. 8. 3 Lead placement of ECG electodes

VIII. ECG FEATURES

Typical ECG signals mainly consist of five types of waves, i.e., the P wave, T wave, Q wave, R wave, and S wave, as illustrated in Fig 8. The variations of these waves are usually used to diagnose a variety of heart diseases. Among all the features of these waves, four features are most commonly used in medical diagnosis, i.e.,

1. RR interval: As one of the most noticeable characteristics, the R wave is often used to identify the period of an ECG signal. RR interval indicates the time interval between two adjacent R waves, which may become irregular in the event of some heart defect, e.g., the arrhythmia.

2. PR interval: The PR interval indicates the time between the beginning of the P wave and that of the QRS complex. It indicates the time that impulse takes to reach the ventricles from the sinus node.

3. QT interval: QT interval represents the time between the beginning of the Q wave and the end of the T wave, which is related with the ventricular depolarization and re-polarization. If the QT interval exceeds the normal value then there is an increased risk of ventricular fibrillation or even sudden cardiac death.

4. QRS complex: QRS complex is especially associated with the ventricular depolarization, which includes three important waves, i.e., Q wave, R wave and S wave. Through analyzing the morphology and the duration of the QRS complex, certain diseases may be detected, e.g., electrolyte imbalance or drug toxicity [5].

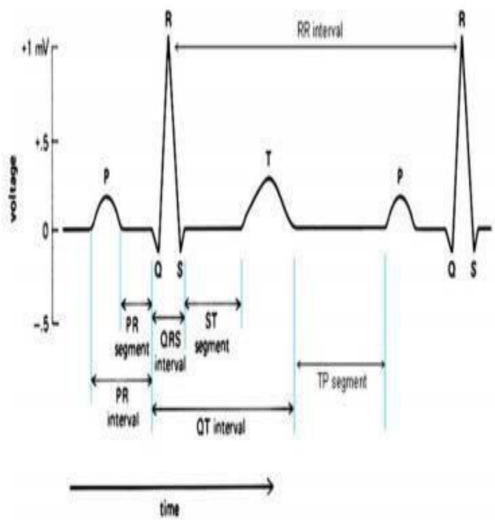

Fig. 9. Standard ECG signal

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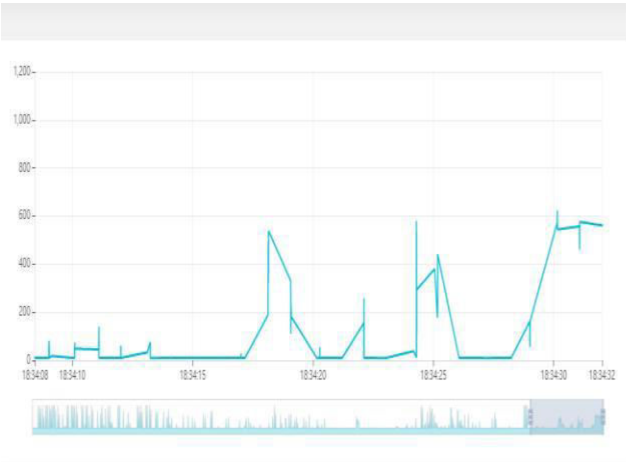
The normal values of ECG parameters are listed in Fig. 10

Signal Interval Features	Normal Range (seconds)
RR interval	0.6 - 1
PR interval	0.12 -0.20
QT interval	0.32-0.44
QRS duration	<0.12

Fig. 10. Normal values of ECG parameters

IX. RESULT



X. CONCLUSION

We have designed and implemented an IoT technology based, cloud ECG monitoring system for early detection of heart defects or failures. Firstly, we have presented architecture of ECG monitoring system. Normal ECG sensing system including Bluetooth and Wi-Fi were introduced and compared. Based on the proposed architecture, we have implemented an IoT-based ECG monitoring system. Using a monitoring node with three electrodes, ECG signals can be obtained with satisfactory accuracy in real time. The gathered data is transmitted to the IoT cloud using Wi-Fi module, which supports high data rates and wide coverage areas. The IoT cloud is liable for providing graphical interface of the ECG data to users and storing these ECG data on the servers for further analysis, which is implemented on the basis of various servers, i.e., the HTTP server, MQTT servers which eliminates the need of mobile applications, the web-based GUI provides a versatile means which is independent of any mobile OS platform for users to access to the ECG data anywhere and on any device. Further studies on ECG monitoring are still required in the future. For example, the system can be made more compact using MEMS or NEMS technology, the accuracy of diagnostic results based on the ECG signal can be improved so as to provide a more reliable disease diagnosis. We believe that advancement in this project on a long-term basis and creating a user-friendly ECG monitoring can greatly help reduce or eliminate existing healthcare problems to a certain extent.

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