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A Portable IoT-cloud ECG Monitoring System for Healthcare

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ABSTRACT

Due to the exponential growth in the human population, rising medical costs, and the COVID-19 pandemic, public healthcare has recently become a major issue. One of the most important variables in preserving a life, especially in the case of a heart attack, is speed. As a result, a healthcare gadget is required to remotely monitor and follow up on heart health concerns without requiring the patient to visit a medical facility. As a result, this research suggests a portable electrocardiogram (ECG) monitoring system that may be used at home or in an ambulance to improve heart attack patient treatment. The suggested system receives the patient's ECG signals and communicates the ECG values via Wi-Fi to a MySQL database on the IoT-cloud. Based on the HTTP protocol used in the IoT-cloud, the signals are displayed as an ECG data chart on a webpage that the patient's doctor can access. The suggested system analyses the patient's ECG data to determine the total number of heartbeats, the number of normal heartbeats, and the number of irregular heartbeats, which can assist the doctor in determining the patient's health status and deciding on an appropriate medical intervention. As a result, this approach has the potential to save not just time and lives, but also money. This article outlines the five primary benefits of the proposed ECG monitoring system and offers some suggestions for further development.

Keywords: *ECG monitoring, Healthcare, IoT-cloud, Machine Learning, Sensors.*

1. INTRODUCTION

Access to healthcare has become one of the most important issues for individuals and governments alike, given the continued global population expansion and rising costs of medical treatments, as well as the recent emergence of the COVID-19 pandemic, which has resulted in lockdowns around the world. Many individuals have been stopped from seeking medical help as a result of the epidemic, which has impeded the follow-up and monitoring of health issues such as heart disease [1]. Electrocardiogram (ECG) monitoring has been widely used in both hospitals and medical research for many years in the diagnosis of heart-related disorders. However, given the current global situation, detecting the presence of diseases in a timely and accurate manner at a low cost and without the need to visit a medical facility has become an issue that is attracting more attention than ever before. As a result, the use of healthcare for individuals at risk of heart attack or heart failure is gaining more scientific interest; with one route being studied is the development of an ECG monitoring system that is both smart and portable [2], [6], [10].

An ECG is traditionally obtained using big, stationary equipment in a medical facility. Due to its good performance in capturing measurements over a short period of time, this type of gadget normally uses 12

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electrodes to record ECG data. This type of equipment, however, is heavy and difficult to carry. This means that during the data collecting time, patients' movements and activities are highly restricted. Furthermore, because these gadgets are usually prohibitively expensive for home use, patients are forced to visit the hospital frequently, putting further strain on hospitals. As a result, a low-cost portable device for long-term ECG signal computation is extremely desirable [1], [2], [3], [6].

One of the most essential bioelectrical signals is the ECG. The ECG signal has been widely employed in the diagnosis of a variety of heart problems since its discovery in 1887. The contraction and expansion of the myocardium causes the ECG signal to be produced. P, QRS complex, and T waves are the three primary waves that make up the ECG signal. The P wave indicates atrial depolarization, the QRS complex wave indicates ventricular depolarization, and the T wave indicates ventricle repolarization. Figure 1 shows a typical ECG waveform with the beat-to-beat (R-R interval) and fundamental waves [6], premature ventricular contraction (PVC) beats, which occur frequently or consecutively, can indicate a heart problem, which can result in sudden cardiac arrest (SCA) and death. Sudden cardiac arrest is one of the leading causes of death in the United States, with around 325,000 individuals dying of SCA each year. Furthermore, SCA is responsible for 50% of all heart-related deaths. As a result, in clinical cardiology, calculating aberrant beats is crucial. Indeed, most occurrences of SCA could be averted if early detection based on timely ECG recordings was possible. Abnormal heartbeats are easily distinguished by the naked eye from recorded ECG signals because they differ significantly from normal heartbeats. Detecting the existence of abnormalities, on the other hand, is a difficult task. However, detecting irregular heartbeats requires the use of monitoring equipment that can record a large number of beats over a lengthy period of time.

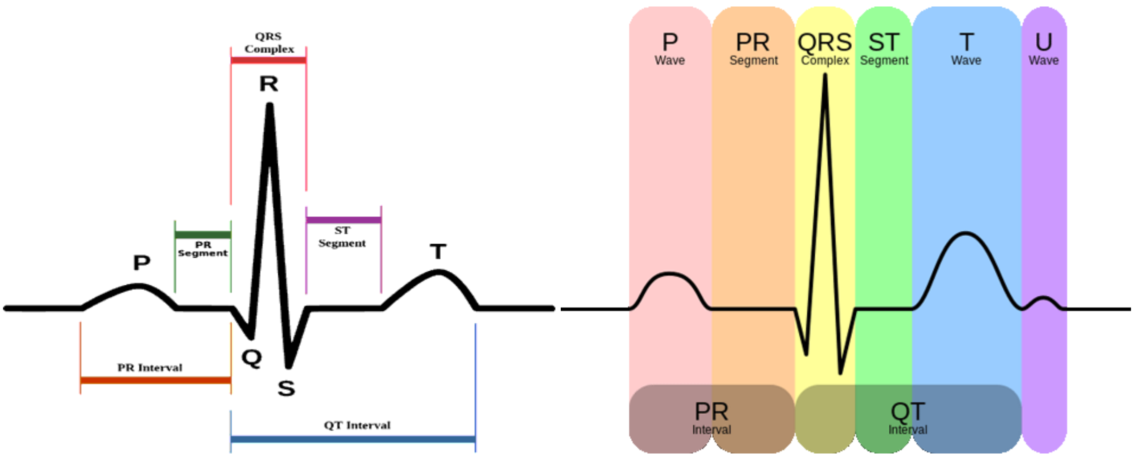

Figure 1. ECG signal showing P, Q, R, S and T waves

This work intends to present architecture for an ECG monitoring system based on IoT-cloud technology, in light of the ongoing COVID-19 epidemic, which deters or stops patients from coming to medical centres where their health issues can be monitored and followed up. A portable ECG monitoring system is built and implemented based on the suggested architecture to remotely monitor and follow up on patient health without the requirement

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for the patient to visit a medical centre. The ECG data collected from the human body is communicated directly to the IoT-cloud over Wi-Fi without the use of a mobile terminal using the suggested approach. This is due to the fact that Wi-Fi can deliver faster data speeds and a larger coverage area. A storage server and an HTTP web server are also deployed in the IoT-cloud to offer the user with quick and rapid access to ECG data. The collected data is saved in a relational database, such as MySQL, which can considerably improve data storage speed and versatility. A web-based GUI is also created using the PHP programming language to allow doctors and patients to quickly access the data services supplied by the IoT-cloud via smart phones running on various operating system platforms. Furthermore, the suggested system calculates the total number of heartbeats, the number of regular heartbeats, and the number of abnormal heartbeats, with the output assisting clinicians in assessing patients' heart health and rapidly deciding on the most appropriate medical intervention. As a result, the suggested method has the ability to save time, lives, and money [9], [10].

2. BLOCK DIAGRAM

Figure 2 explains different components required for designing proposed system and it also shows connectivity of components.

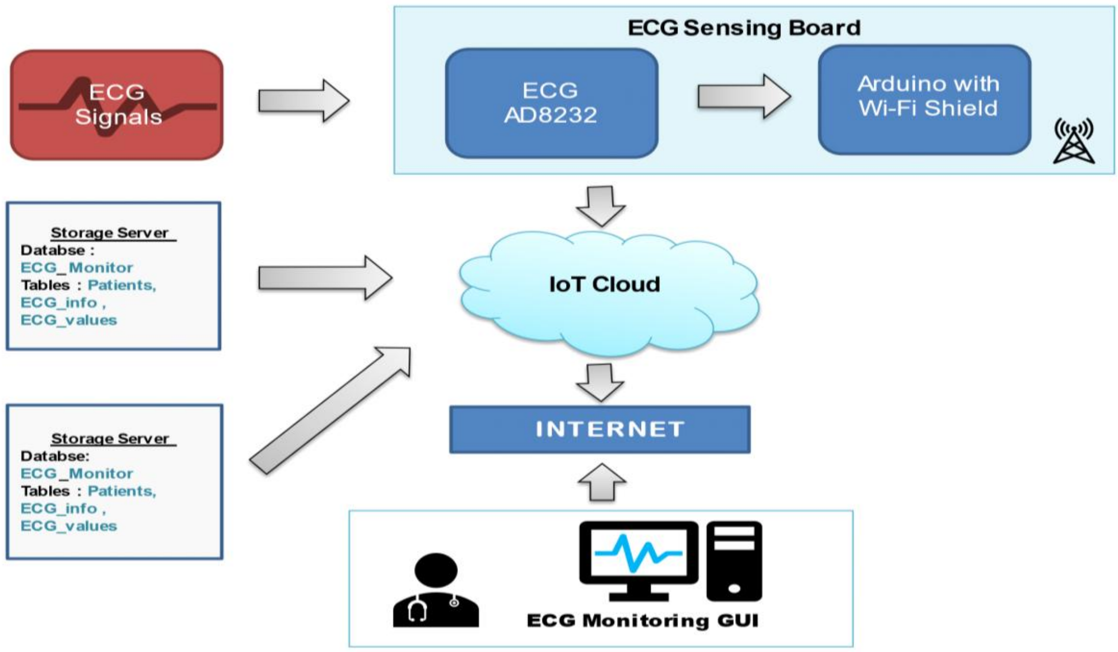

Figure 2. Proposed architecture of IoT-cloud ECG monitoring system

3. ARCHITECTURE & IMPLEMENTATION OF IOT CLOUD ECG MONITORING SYSTEM

The proposed architecture of the IoT-cloud ECG monitoring system is illustrated in Fig. 2. The architecture mainly consists of three components: ECG sensor boards, IoT-cloud technology, and an ECG monitoring GUI.

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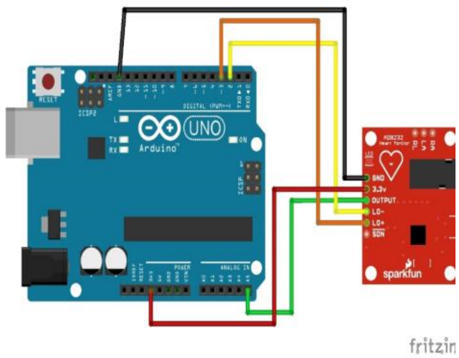
3.1 ECG Sensor Board

The IoT-cloud ECG monitoring system's proposed architecture, as shown in Fig. 2, consists of an AD8232 ECG heart monitor sensor board and an Arduino with Wi-Fi shield board. The AD8232 ECG heart monitor sensor board is a low-cost board that can be used to assess the electrical activity of the heart with good resolution. This electrical activity can be graphed as an ECG and read as an analogue number (ECG signal). Electrocardiography is the practice of employing electrodes put on the body to record the electrical activity of the heart throughout time. The microscopic electrical changes on the skin caused by the heart muscle's electro physiologic pattern of depolarizing and repolarizing throughout each beating are detected by these electrodes. Because the ECG signal can be very noisy, the AD8232 heart monitor sensor board uses an op amp to help extract a clear signal from the PR and QT intervals. For ECG and other bio potential measurement applications, the AD8232 heart monitor sensor board contains an integrated signal-conditioning block. The AD8232 heart monitor sensor board is designed to extract, amplify, and filter tiny bio potential signals. The AD8232 heart monitor sensor board consists of nine pins. Six of these pins, i.e., GND, 3.3V, OUTPUT, LO+, LO-, and SDN, are essential for connecting and operating this board with an Arduino with Wi-Fi shield development board, as shown in Fig. 3 below. The remaining three pins for RA (Right Arm), LA (Left Arm), and RL (Right Leg) are provided on this AD8232 heart monitor sensor board through ECG electrodes are connected to, as shown in Fig. 4 below.

The Arduino Company produced the Arduino with Wi-Fi shield board, which is an open source microcontroller board. The board has digital and analogue I/O pins that may be connected to various expansion boards (shields) such as an Ethernet shield and other circuits to allow communication.



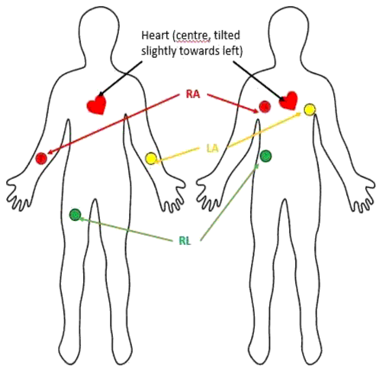


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Figure 3. Diagram of connections between AD8232 sensor board and Arduino with Wi-Fi shield board

Figure. 4. AD8232 electrodes

As previously stated, the AD8232 heart monitor sensor board is linked to this board through six pins on the AD8232 (GND, 3.3V, OUTPUT, LO+, LO-, SDN). The ECG signal data from the AD8232 heart monitor sensor board is received by the Arduino with Wi-Fi shield, which is processed using the Arduino IDE (Integrated Development Environment) with embedded C programming on the Windows OS platform. As

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illustrated in Fig. 2, the Arduino board has a Wi-Fi shield, allowing it to transfer data to the IoT-cloud through Wi-Fi, which enables high data speeds and wide coverage regions. The Arduino with Wi-Fi shield is employed in the proposed ECG monitoring system's architecture since it not only functions as a portable computer but also requires a DC voltage, allowing it to be used in a moving vehicle like an ambulance.

3.2 IoT-Cloud Technology

It allows common devices to be more intelligent and interactive; the Internet of Things is regarded as the next phase in the evolution of the Internet [8]. The Internet of Things (IoT) is a network of interconnected computing devices, mechanical and digital machinery, items, animals, and people with unique identifiers and the ability to transfer data without requiring human-to-human or human-to-computer interaction. An IoT ecosystem is made up of web-enabled smart devices that gather, send, and act on data from their surroundings using embedded systems such as CPUs, sensors, and communication hardware. When a device is IoT-enabled, it can connect to an IoT gateway or other edge device and share the sensor data it collects, which can then be transferred to the cloud for analysis or analysed locally. These gadgets may occasionally communicate with one another and act on the information they receive. Although individuals can engage with the devices to set them up, give them instructions, or retrieve the data, the gadgets do the majority of the job without human participation. The connectivity, networking, and communication protocols that these web-enabled devices use are primarily determined by the IoT applications that are installed.

The main purpose of pursuing the IoT approach is to help people live and work smarter, as well as gain complete control over their lives. In addition to the IoT enabling the use of smart devices to automate homes, it is essential for businesses because it can provide them with a real-time perspective on how their systems really work, delivering insights into everything from the performance of machines to supply chain and logistics operations. The IoT also has huge potential to assist medical professionals to monitor and follow up patient health. For example, sensors could be connected to a patient's body at home or in another setting outside of a medical centre. In the case of a patient with a heart problem, the signals received from the sensors could be used to monitor any deviation from the expected heartbeat values or signals of that patient, this would allow doctors to follow up the patient remotely and take any necessary action quickly that could potentially save the patient's life. The key benefits of using the IoT are the ability to access information from anywhere at any time on any device; improved communication between connected electronic devices; time and cost savings in transferring data packets over a connected network; and improving the quality of services by automating tasks and reducing the need for human intervention.

Cloud computing is essential for the successful deployment and operation of an IoT enabled application such as an ECG monitoring system since it provides high processing capabilities as well as vast storage capacity. ECG data may be saved and analysed effectively and efficiently using advanced IoT techniques paired with the cloud. Computing-intensive data processing and analysis operations can be carried out in powerful servers with the help of an IoT-cloud, considerably reducing the load on smart devices. Data storage and data analysis are usually the two functional elements of an IoT-cloud for ECG monitoring. After the monitoring system has collected a considerable amount of ECG data via the ECG sensor boards, the IoT-cloud must provide a quick and easy way to store this information in a database, as well as a way to detect and show ECG signals as needed. As a result, the IoT-cloud in the proposed design consists of the following components: a storage server that includes a storage server (MySQL database) and an HTTP web server that can take user replies and reply appropriately.

In the Proposed system Dataset obtained by the ECG is stored in a MySQL database, which is currently the most popular open-source relational database available. As shown in Table 1 below, the ECG data is stored in the storage server on the IoT-cloud, in a MySQL database with name "ECG_Monitor System". This database consist of two tables: Patient information table, Details about ECG.

Table 1. ECG Database details: (a) Patient information table, (b) Details about ECG

(a) Patient information table

Patient ID	**Patient Name**	**Patient Age**
1	Sami Ali Jaberi	55
2	Salem Mohammad Omari	60
3	Ibrahim Bader Al-Faisal	64

(b) Details about ECG

ID info	**ECG Timestamp**	**ECG Duration**	**No of Beats**	**No of Normal**	**No of Abnormal**	**Patient ID**
100	2020-08-12 12:00:00 am	5 min	430	427	3	1
101	2020-08-12 04:00:00 am	5 min	400	371	29	1
102	2020-08-12 10:00:00 am	5 min	370	355	15	1
200	2020-08-13 02:00:00 am	5 min	340	288	52	2
300	2020-08-14 10:00:00 am	5 min	332	299	33	3

3.3. Graphical User Interface for ECG Monitoring.

Data visualization and management are accomplished using the ECG monitoring GUI. It gives the user quick access to data stored in the IoT-cloud. A user with the appropriate authorization, such as a doctor, can log onto the cloud to obtain real-time visualization of ECG data for a specific patient. In general, the user can visualize ECG data using one of two types of graphical user interfaces (GUIs): a mobile app or a webpage. In terms of maintenance and updating, a mobile app can provide a rapid response to user input, whereas webpages are more convenient.

Real-time ECG monitoring GUI in this study is in the form of a website that was created and programmed using the PHP programming language. The website displays all of the data contained in the IoT-MySQL cloud's database (ECG Monitor DB). It has three pages: one for the doctor, one for the patient, and one for the ECG Patient. The doctor webpage includes a link to the Patient webpage as well as information on the patients (patient ID, patient name, and patient age) who are under the care of a specific doctor. The Patient homepage shows all of the ECG data for a specific patient, including the ECG ID, timestamp, and length, as well as a link to the ECG Patient webpage. In the top portion of the page, the ECG Patient webpage displays all of the patient and ECG information from the other two sites for a specific patient, while the bottom portion of the page delivers live ECG data in the form of a chart. This page displays the ECG data that was identified and calculated as the total number of heartbeats, normal heartbeats, and irregular heartbeats. Because this chart is live, it can assist the doctor in evaluating the patient's status when the patient is at home and needs to be followed up on on a regular basis, avoiding the need to visit a medical facility, which is especially useful given the current COVID-19 pandemic and the worldwide lockdown

3.3 Advantages of Proposed IoT-Cloud ECG Monitoring System

The proposed ECG monitoring system acquires ECG signal data in the time domain, detects and calculates the total number of heartbeats, number of normal heartbeats, and number of abnormal heartbeats to assist the doctor in monitoring and following up on the heart health of patients and taking appropriate steps where needed. There are five major benefits to the proposed IoT-cloud ECG monitoring system:

1. Portability

Because the proposed system is portable and employs Wi-Fi connection, it may be employed in a variety of scenarios. Because the system uses Wi-Fi, there is no need to use mobile apps that are often OS-specific because the web-based GUI provides a versatile way to retrieve ECG data that is independent of any mobile OS platform. Most crucially, the proposed method allows doctors to remotely observe and analyses patients' ECG data and heart conditions. This is especially beneficial for people who do not have access to a doctor or a healthcare center. A suggested approach can save a lot of time and perhaps save lives

2. Reachability

The ECG signal data is sent to a MySQL database on the IoT-cloud via an Arduino with Wi-Fi shield board. The stored ECG signal data can then be seen at any time on the ECG monitoring website. As a result, the doctor can check prior and current data on a patient's heart status without the patient having to go to a medical centre for tests.

3. Real-Time System

The suggested solution takes advantage of the cloud's benefits, allowing for real-time ECG monitoring. Every time readings are taken, the AD8232 sensor board sends all of the ECG signal values to the MySQL database server on the IoT-cloud via the Arduino with Wi-Fi shield board. These details can be viewed on the doctor's website practically immediately. The webpage gives the doctor up-to-date ECG data in chart form, allowing him or her to take necessary action as needed.

4. Simplicity

The suggested system makes use of the AD8232 heart monitor sensor board, a compact device that only requires a few small electrodes to record a patient's ECG readings. This eliminates the requirement for the patient to travel to a medical facility for tests on a large machine like a stationary ECG monitor.

4. CONCLUSION

Proposed architecture was primarily made up of three components: ECG sensor boards, IoT-cloud technologies, and an ECG monitoring GUI. The electrical activity of the heart was measured with a high enough gain to acquire a good resolution and sent to the IoT-cloud using standard ECG sensor boards, such as the AD8232 ECG heart monitor sensor board and the Arduino with Wi-Fi shield board. Wi-Fi connectivity, which offers high data rates and vast coverage regions, was used to send data to the IoT-cloud. The storage, display, and analysis of these vital ECG data were made possible thanks to the use of IoT-cloud technology. The total number of heartbeats, number of regular heartbeats, and number of aberrant heartbeats are calculated and used to predict the presence of heart problems while the data is saved in the IoT-cloud. This component of the suggested system can assist clinicians in evaluating patients' heart conditions in a fast and accurate manner and, as a result, selecting an appropriate medical procedure. The IoT-cloud was built on two servers: a storage server and a web server that served HTTP requests. Because the web-based GUI provides a varied way for users to access ECG data regardless of mobile OS platform, the designed architecture eliminates the necessity for mobile apps. A long-term and user-friendly ECG monitoring system can make a significant contribution to alleviating existing healthcare concerns by enabling follow-up and intervention through more effective, long-term remote monitoring. Also such a system can aid in the early detection of heart anomalies that are suggestive of a variety of cardiovascular disorders, hence assisting in the prevention of major repercussions such as cardiac arrest and death.

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