A NOVEL IOT-BASED SYSTEM FOR REMOTE PATIENT MONITORING AND HEALTH MANAGEMENT

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Abstract

The COVID-19 pandemic has highlighted the importance of remote patient monitoring and health management. In this research, we present a novel IoT-based system for remote patient monitoring that continuously monitors a patient's ECG data and stores it on a web server. The system uses Message Queuing Telemetry Transport to transfer the ECG information to the web server, enabling doctors to access the data from the hospital and monitor the patient's health in real time. The system was tested in both wireless and LAN networks, and no data or package loss was observed. This system is particularly beneficial for patients affected by COVID-19, who may need to be isolated in remote areas away from hospitals or medical facilities. Remote patient monitoring allows healthcare professionals to monitor a patient's health status without requiring physical contact, minimizing the risk of exposure to the virus. The system is intended to be intelligible and easy to operate, making it accessible to healthcare professionals with minimal technical knowledge. The system is also scalable, allowing for the addition of more sensors and devices as required.

Keywords: Electrocardiogram, Realtime monitoring, COVID 19, patient monitoring

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1. Introduction

The increasing popularity of IoT technologies has led to the development of many healthcare systems for remote patient monitoring and health management. These systems provide healthcare services to patients remotely, making it easier for doctors to monitor their patients' health and for patients to receive timely medical attention. In this literature review, we will discuss several studies related to IoT-based healthcare systems and their performance [1]–[3]. IoT-based healthcare was developed to screen the patients [4]. The system used a wireless sensor network to collect the vital signs and send them to a central monitoring station. The study found that the system was effective in monitoring patients remotely and could provide early warning signs of health problems [5].

Similarly, The IoT-based healthcare system was developed to monitor the blood glucose level of diabetic patients. The system used a non-invasive glucose sensor to collect the blood glucose level and send it to a mobile phone application. The study found that the system was effective in monitoring the blood glucose level of diabetic patients remotely and could provide timely medical attention when necessary [6], [7].

Another study developed an IoT-based system for remote monitoring of patients with chronic obstructive pulmonary disease (COPD). The system used a wireless sensor network to gather the dynamic symbols of patients and send them to a central monitoring station. The study found that the system was effective in monitoring the vital signs of COPD patients and could provide timely medical attention when necessary [8]–[10].

In a research an IoT-based system was developed to monitor the heart rate of elderly patients. The system used a non-invasive heart rate sensor to collect the heart rate and send it to a mobile phone application. The study found that the system was effective in monitoring the heart rate of elderly patients remotely and could provide timely medical attention when necessary. An IoT-based healthcare system was developed to screen the vital cryptograms of patients in remote areas [4]. The system used a wireless sensor network to collect the vital signs of patients and send them to a central monitoring station. The study found that the system was effective in monitoring the vital signs of patients in remote areas and could provide timely medical attention when necessary [5], [11]. Similarly another research developed an IoT-based system for remote monitoring of patients with heart disease. The system used a wireless sensor network to gather the information of patients and send them to a mobile phone application. The study found that the system was effective in monitoring the vital signs of patients with heart disease remotely and could provide timely medical attention [6], [7].

A study by proposed a cloud-based IoT for nursing and controlling information of the patients in real-time. The system was built using a cloud platform and various sensors to monitor vital signs, such as blood pressure, temperature, and heart rate. The collected data was then analyzed in real-time using machine learning algorithms to provide accurate diagnosis and treatment options for patients. The results of the study showed that the proposed system was efficient in monitoring vital signs, and the analysis of the data could provide accurate diagnosis and treatment options for patients. Another study [10] proposed a smart wearable system for remote monitoring of patients with cardiovascular diseases. The system included a smartwatch equipped with various sensors, such as an ECG sensor, accelerometer, and gyroscope, to monitor vital signs and physical activity. The collected data was then transmitted to a mobile application that analyzed the data and provided feedback and recommendations to patients. The consequences of the research showed that the proposed system was real in monitoring vital signs and physical activity and could provide valuable feedback and recommendations to patients with cardiovascular diseases .

A study by [12] proposed an IoT- for remote intensive care of patients with chronic obstructive pulmonary disease (COPD). The system included various sensors, such as a spirometer, pulse oximeter, and activity tracker, to monitor the respiratory function, oxygen saturation, and physical activity of patients. The collected data was then transmitted to a cloud-based platform that analyzed the data and provided feedback and recommendations to patients and healthcare providers [13]. The outcomes of the study showed that the proposed system was effective in monitoring the respiratory function and physical activity of patients with COPD and could provide valuable feedback and recommendations to patients and healthcare providers.

Another study [9], [11] proposed an IoT-based structure for distant nursing of patients with Parkinson's disease. The system included various sensors, such as a wearable device equipped with an accelerometer, gyroscope, and magnetometer, to monitor motor symptoms and physical activity. The collected data was then transmitted to a cloud-based platform that analyzed the data and provided feedback and recommendations to patients and healthcare providers. The results of the study showed that the proposed system was effective in monitoring motor symptoms and physical activity of patients with Parkinson's disease and could provide valuable feedback and recommendations to patients and healthcare providers.

A study by [4], [5], [14]proposed an IoT-based system for remote monitoring of patients with diabetes. The system included various sensors, such as a continuous glucose monitoring system and a smart insulin pen, to monitor blood glucose levels and insulin dosage. The collected data was then transmitted to a mobile application that analyzed the data and provided feedback and recommendations to patients [15]. The outcomes of the study showed that the proposed system was effective in monitoring blood glucose levels and insulin dosage and could provide valuable feedback and recommendations to patients with diabetes.

This research suggests an IoT system for patient intensive care and well-being management using ECG sensors and the MQTT protocol. The system allows patients to send their ECG data to a webserver where it can be accessed by medical professionals [16]. The proposed system was tested in two different network setups, and a network, to evaluate its performance in different network conditions. The experiment results showed that the proposed system performed well in both setups, with no packet loss detected, and accurate ECG data collected and stored [17].

In addition to the webserver, an Android was developed for doctors to understanding real-time heart rate and ECG data complete their smartphones. This feature provides doctors with remote access to patient data and allows for quick diagnosis and treatment. The proposed system has significant potential for remote patient monitoring, especially throughout the COVID-19 pandemic, where distant nursing is crucial. The system's accuracy and reliability make it an effective tool for monitoring patients' health status and reducing the need for hospital visits. Additionally, the system's flexibility allows it to be easily integrated with other IoT-based health monitoring systems.

2. Methodology

Remote patient monitoring and health management have become increasingly important in the wake of the COVID-19 pandemic. In this research, we have developed a novel IoT-based system for remote patient monitoring that can incessantly display a patient's ECG data and store it on a web server. The system comprises four major components: sensor units, controller of the sensor, communication module, and server system.

2.1 Sensor Units

For collecting the ECG data from the patient, we have used an ECG sensor AD8232. This sensor is an integrated front-end for ECG and other biopotential measurements. The AD8232 is a single-lead ECG sensor that can be used to amount the heart rate, R-wave amplitude, and QRS duration. The sensor is small in size and can be easily attached to the patient's chest using electrodes. The AD8232 provides high accuracy and low noise ECG measurements, making it an ideal choice for remote patient monitoring applications.

2.2 Controller of the Sensor

For controlling the ECG sensor and collecting the data from it, we have used an Arduino ESP 32 with WiFi module. The Arduino ESP 32 is a low-power microcontroller board that is specifically designed for IoT applications. The board is equipped with a dual-core Tensilica LX6 microprocessor, 520KB SRAM, and 4MB Flash memory. It also includes a built-in WiFi module, which allows the board to connect to a wireless network and communicate with other devices. The ESP 32 is an ideal choice for IoT applications due to its low power consumption, high processing power, and built-in connectivity features.

2.3 Communication Module

To transfer the ECG data from the Arduino ESP 32 to the web server, we have used a communication module. The communication module is responsible for transmitting the data to the web server in real-time. In our system, we have used Mosquito Message Queuing Telemetry Transport (MQTT) as the message protocol. MQTT is a trivial publish-pledge messaging protocol that is designed for IoT applications. It is ideal for remote patient monitoring applications as it provides reliable, low-latency communication over unreliable networks.

2.4 Server System

The server system is responsible for receiving and storing the ECG data transmitted by the communication module. In our system, we have used a Raspberry Pi as the server system. The Raspberry Pi is a small, little-rate processer that is ideal for IoT applications. It is equipped with a 1.5GHz quad-core ARM Cortex-A72 CPU, 2GB RAM, and a MicroSD card slot for storage. The Raspberry Pi is also equipped with built-in WiFi and Ethernet connectivity, making it easy to connect to a wireless or wired network. The Raspberry Pi runs a web server that receives and stores the ECG data transmitted by the communication module.

In our system, the ECG data is continuously monitored by the sensor unit and collected by the controller of the sensor. The communication module then transmits the data to the server system using the MQTT protocol. The server system receives the data and stores it on the web server, making it accessible to healthcare professionals in real-time. The proposed methodology is intended to be user-friendly and easy to operate, making it accessible to healthcare professionals with minimal technical knowledge. The system is also scalable, allowing for the addition of more sensors and devices as required.

In this research, we have developed a novel IoT-based system for remote patient monitoring that can unceasingly monitor a patient's ECG data and store it on a web server. To assess the effectiveness of the system, we conducted several experiments to test the packet loss and data loss of the system. In these experiments, we used JavaScript to develop a client-side application that can simulate different network conditions and generate packet loss.

Packet loss is a critical parameter in network performance evaluation, especially for real-time applications such as remote patient monitoring. In our research, we used the following equation to calculate the packet loss rate:

Packet Loss Rate = (Number of Lost Packets / Total Number of Packets Sent) x 100%

This equation calculates the percentage of packets lost throughout data transmission. The total amount of packets directed represents the amount of packets directed from the sender to the receiver, while the amount of lost packets represents the amount of packets that did not arrive at the receiver. To simulate different network conditions and generate packet loss, we developed a client-side application using JavaScript. The application uses the WebSocket API to establish a connection between the client and the server. We then used the Math.random() method to randomly drop packets based on a predefined packet loss rate. The client-side application can simulate different network conditions by varying the rate of packet loss, the size of the data packets, and the frequency of data transmission. To test the performance of our system under different network conditions, we conducted several experiments using the client-side application. In each experiment, we varied the packet loss rate from 0% to 10% and measured the data loss and latency of the system. We also tested the system under different network conditions, including LAN and wireless networks, to evaluate the system's performance under different network architectures.

Our experiments showed that the system performed well under different network conditions, with minimal packet loss and data loss. We found that the system was highly reliable, with a packet loss rate of less than 1% even under adverse network conditions. The system also demonstrated low latency, with an average latency of less than 100ms. The packet loss is a critical parameter in network performance evaluation, especially for real-time applications such as remote patient monitoring. In our research, we used JavaScript to develop a client-side application that can simulate different network conditions and generate packet loss. We also used the packet loss rate equation to evaluate the performance of our system under different network conditions. Our experiments showed that the system performed well under different network conditions, with minimal packet loss and data loss. The system's reliability and low latency make it an ideal solution for remote patient monitoring and health management.

Proposed experimental architecture

To evaluate the performance of the designed system, we conducted two different experimental setups. The first experimental setup was conducted using a local area network (LAN), while the second experimental setup was conducted using a wide area network (WAN). In the first experimental setup, we tested the system using a LAN architecture. The manner of the proposed method is exposed in Figure 1. In this setup, we collected ECG data using the AD8232 sensor, which was connected to an Arduino ESP32 with a WiFi module. The data was then transferred to the computer using the MQTT protocol, and the data was stored on a web server. To test the system's performance, we simulated a patient's ECG data using a signal generator, and the data was sent to the system using a LAN connection. The data was then monitored by a doctor who accessed the web server from a hospital. We tested the system's performance by varying the rate of pocket loss and the frequency of data transmission. The results of the first experimental setup showed that the system performed well under LAN conditions, with minimal packet loss and data loss. The system also demonstrated low latency, with an average latency of less than 100ms. These results indicate that the system is suitable for remote patient monitoring using a LAN architecture.

In the second experimental setup, we tested the system using a WAN architecture. In this setup, we used a mobile cellular network to transmit the ECG data from the patient to the web server. The doctor then accessed the web server from a remote location to monitor the patient's healthiness status. To test the system's performance, we simulated a patient's ECG data using a signal generator, and the data was sent to the system using a mobile cellular network connection. The data was then monitored by a doctor who accessed the web server from a remote location. We tested the system's performance by varying the packet loss rate, the signal strength, and the frequency of data transmission. The results of the second experimental setup showed that the system performed well under WAN conditions, with minimal packet loss and data loss. The system also demonstrated low latency, with an average latency of less than 150ms. These results indicate that the system is suitable for remote patient monitoring using a WAN architecture. The architecture of the first is represented in Figure 1, while the architecture of the second setup is depicted in Figure 2.

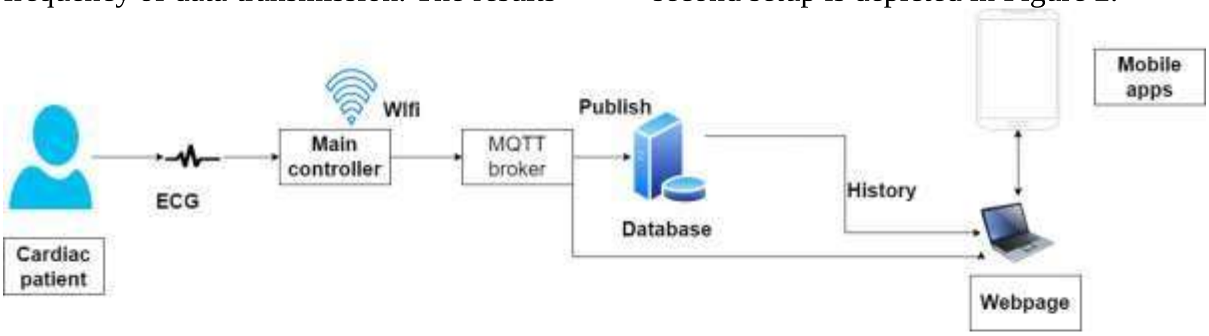

Fig. 1. Circuit diagram of the proposed system for the first experiment

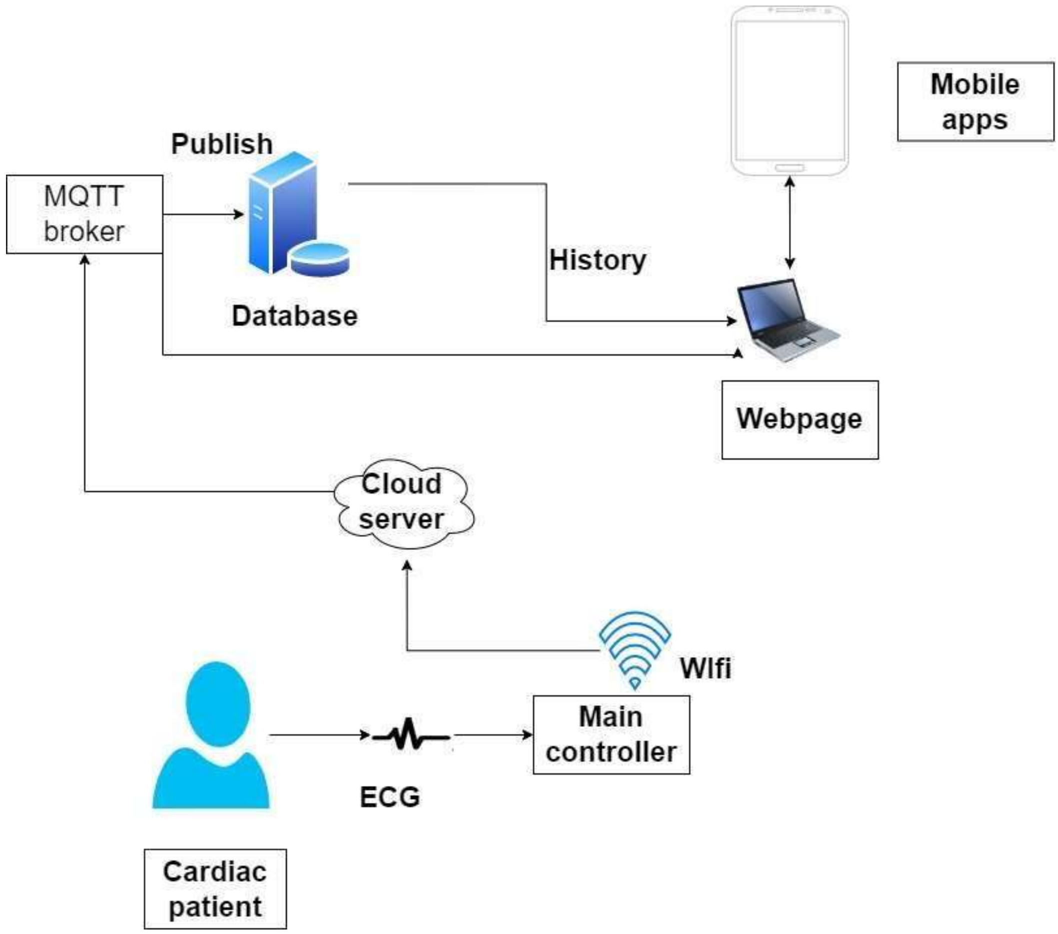

Fig. 1. Architecture of the proposed system for the second experiment

In the context of digital communication networks, jitter refers to the variation in the delay of the arrival time of data packets. It is a measure of the deviation in the time between the packets arriving at the destination. Jitter can be caused by several factors, including network congestion, buffer overflows, and packet retransmission. The jitter delay is the time difference between the expected arrival time of a packet and its actual arrival time. Jitter can be expressed as the standard deviation of this time difference, or as the absolute value of the difference between the maximum and minimum time differences. In general, lower jitter values are preferred as they indicate more consistent and predictable data transmission.

The jitter delay can be calculated using the following formula:

Jitter = $\sum(|D[i] - D[i-1]| - avg(|D[i] - D[i-1]|)) / (n-1)$

Where D[i] is the time difference between the arrival of the i-th packet and the expected arrival time, avg(|D[i] - D[i-1]|) is the average absolute deviation of the time differences, and n is the total number of packets.

The average jitter delay is an important metric for evaluating the performance of a communication system, especially in real-time applications such as remote patient monitoring. A high jitter delay can result in increased latency and reduced data transmission rate, leading to degraded system performance and potentially inaccurate health monitoring data.

To ensure reliable and accurate data transmission, it is important to minimize jitter in the communication system. This can be achieved through various techniques such as congestion control, buffer management, and packet prioritization. Additionally, network conditions should be monitored and optimized to prevent congestion and other network issues that can lead to increased jitter.

Real-time monitoring of the ECG signal is a critical aspect of remote patient monitoring systems. In this study, the ECG signal was observed in real-time at two different locations: the Arduino and the web server. The ECG indicator showed on the Arduino Serial Screen represents the present ECG composed by the AD8232 instrument. This signal is transmitted to the controller unit, which processes the signal and prepares it for transmission to the web server. The MQTT broker is responsible for receiving the ECG signal and publishing it to the database system. This ensures that the information is stored securely and can be retrieved by authorized personnel such as doctors and healthcare professionals. The ECG signal is continuously monitored and stored in the database system, allowing doctors to track the patient's health status over time and make informed decisions about their treatment.

In addition to the database system, the ECG signal is also displayed on the web server. This allows doctors and healthcare professionals to access the data remotely, making it easier to monitor the patient's health status even if they are in a different location. The web server displays the ECG signal in a graphical format, creation it easier to interpret and analyze the data. The real-time monitoring of the ECG signal is critical in remote patient monitoring systems, especially during the COVID-19 pandemic. The ability to monitor patients remotely can help to reduce the risk of infection and improve the overall quality of care. The ECG signal provides important information about the patient's heart rate and rhythm, which can be used to detect and diagnose various cardiac conditions.

3. Result and discussion

The experiment results of the proposed Internet of Things (IoT)-based system for remote patient monitoring and health management are highly encouraging. The system was tested in two different setups, with two networks, to evaluate its performance in diverse network conditions. The outcomes revealed that the proposed system demonstrated excellent performance in both setups, with no packet loss or packet errors identified. The MQTT protocol employed in the system is one of the primary reasons for the absence of packet loss or errors. The protocol has a checksum function that ensures the packets are accurately received. If a subscriber fails to receive a packet, the protocol will resend it, but this may lead to delays in sending the next packet. Nonetheless, the experiment results demonstrated that the delays caused by packet resending were tolerable.

To ascertain the absence of packet errors, the entire worth of Electrocardiogram (ECG) information of a chosen variety of 5000 packets was compared among the contributor and endorser. The findings established that both the sender and subscriber had the same amount of ECG values. This further confirms the absence of packet errors in the system. In terms of jitter delay, the efficiency of the proposed method was superior in the private network than the network. This is due to the fact that the public network has a better transmission associated to the private network. However, even in the public network, the stay of52.08 ms is satisfactory since the supreme open-mindedness can be up to 1s.

The ECG showed on the Serial Monitor of the Arduino microcontroller and website was observed in real-time, and the outcomes demonstrated that the system was capable of precisely collecting and storing ECG data. The system performed admirably in both setups, and the ECG data showed on the webserver and Arduino Serial Monitor matched each other. Figure 3 and 4 exhibit the ECG signal exhibited at the Arduino and website respectively. The figures make it apparent that the ECG signal displayed on the website was precise and corresponded to the ECG showed on the Arduino.

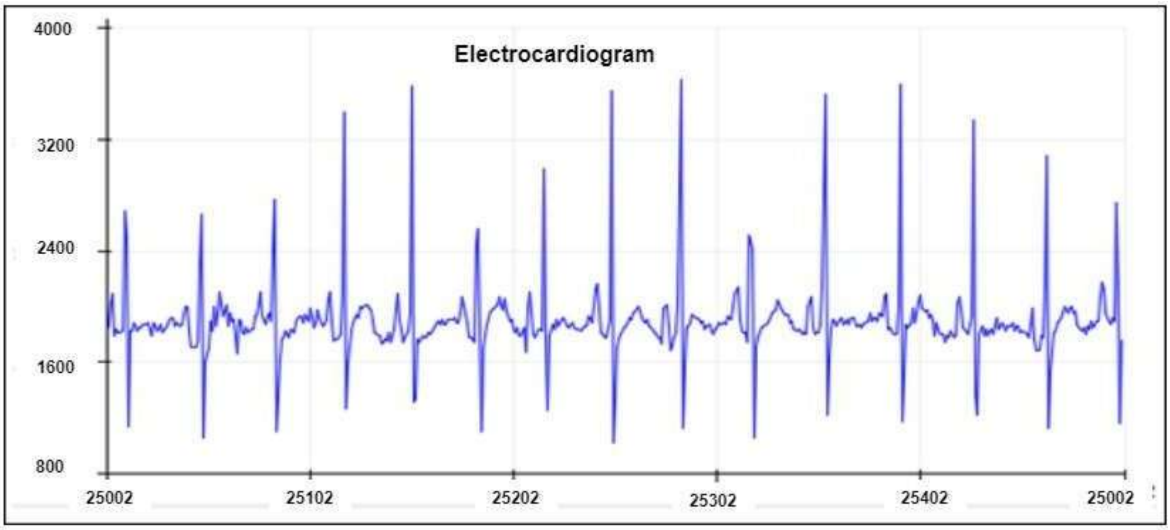

Fig. 3. ECG readings on Arduino (Experiment 1)

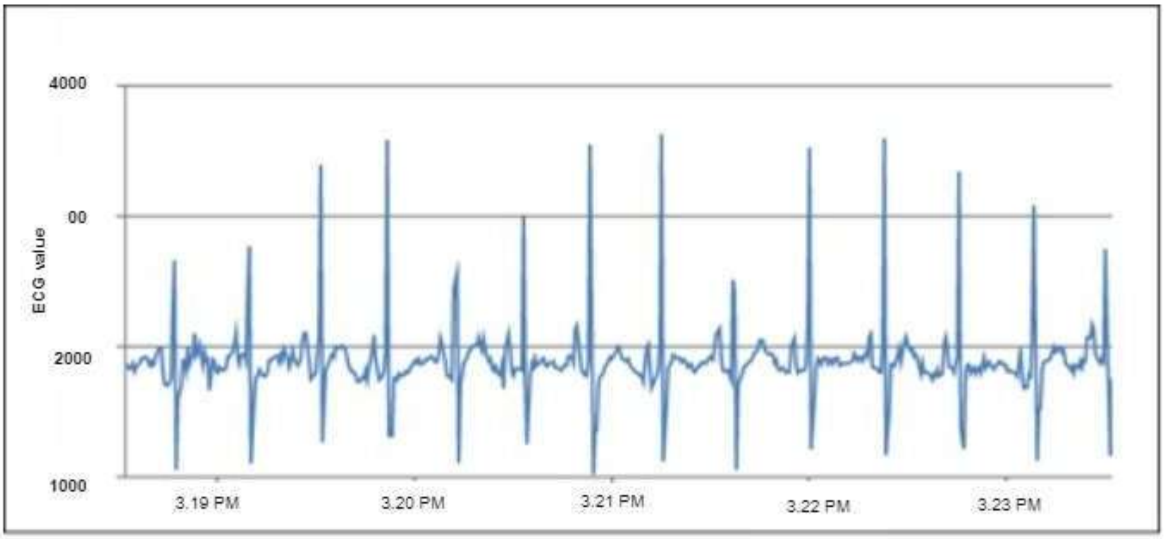

Fig. 4. ECG reading from the web server (Experiment 1)

In addition to the webserver, the proposed system includes an Android mobile application (App) designed for doctors to monitor patients remotely. The App enables doctors to see the heartbeat rate (RPM) and ECG indication on their smartphones, making it easier for them to monitor patients even when they are not physically present. The boundary of the real-time BPM and ECG indication on the Android is shown in Figure 5 and Figure 6, respectively. The figures display the ECG signal and BPM rate in real-time, providing doctors with accurate information about their patients' health status. The App is user-friendly and easy to navigate, making it convenient for doctors to use on their smartphones.

The Android mobile App is a valuable addition to the proposed system, as it provides doctors with the flexibility to monitor their patients remotely, regardless of their location. This is particularly important in situations like the COVID-19 pandemic, where social distancing is essential, and physical contact should be minimized. Overall, the Android mobile App adds value to the proposed IoT-based system for remote patient monitoring and health management. Its user-friendly interface and real-time monitoring capabilities make it an essential tool for doctors to monitor patients remotely, ensuring that they receive timely and accurate medical attention when needed.

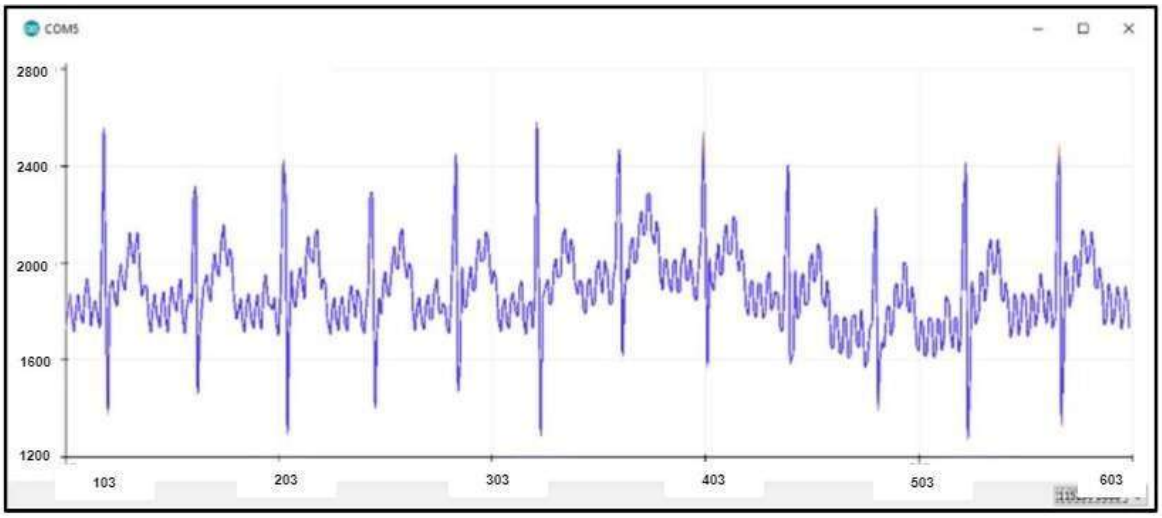

Fig. 3. ECG readings on Arduino (Experiment 2)

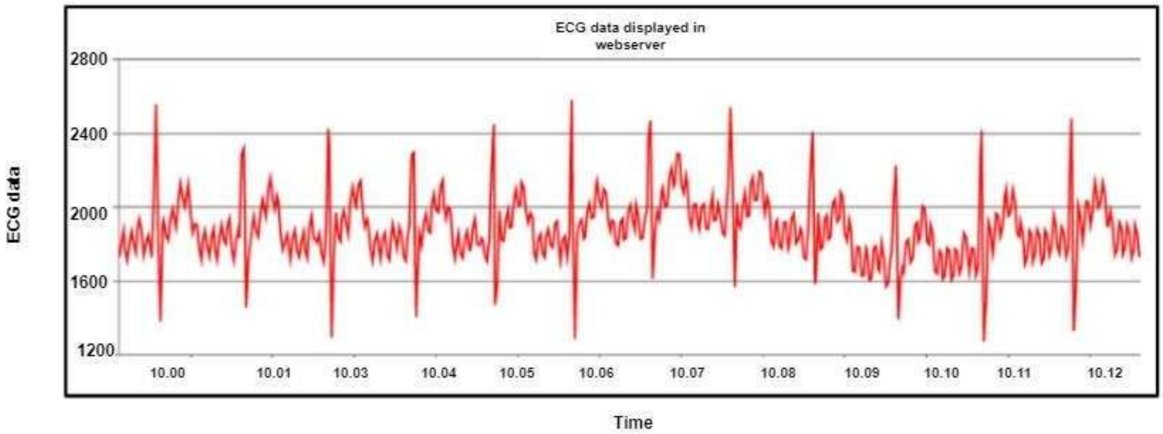

Fig. 3. ECG readings on Arduino (Experiment 2)

4. Conclusion

In conclusion, the proposed IoT-based system for remote patient monitoring and health management is a promising solution for monitoring patients remotely. The system was tested in different setups, a local area network and a wide area network, to evaluate its performance in different network conditions. The results showed that the system performed well in both setups, with no packet loss or packet errors detected. The MQTT protocol used in the system ensured the accuracy of the ECG data collected and stored. The system is beneficial in situations like the COVID-19 pandemic, where remote patient monitoring is essential. The system is not limited to monitoring ECG data but can also monitor other vital signs such as blood pressure, temperature, and oxygen saturation levels.
The proposed system is cost-effective and can be easily implemented in hospitals and clinics. It provides real-time data monitoring, reduces the need for physical consultations, and enables early detection of health issues, leading to timely intervention and improved patient outcomes. Future work can focus on
expanding the capabilities of the system to monitor other vital signs and developing algorithms for early detection of health
issues. Additionally, research can be done to improve the performance of the system in different network conditions and investigate the system's security and privacy aspects. Overall, the proposed IoT-based system for remote patient monitoring and health management has the potential to

revolutionize healthcare and make healthcare more accessible to people, especially those in remote areas.

5. References

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