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IoT Enabled Tele ECG Monitoring System Using Rasberry Pi and Cloud Analytics

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Abstract: Continuous monitoring of cardiac activities plays a vital role in the early detection of cardiovascular diseases. This paper aims to present a tele-ECG monitoring system enabled through the Internet of Things (IoT) technology. The system will be implemented through the usage of a Raspberry Pi device and the ThingSpeak cloud-based analytics platform. The proposed tele-ECG monitoring system will include the usage of an ECG sensor module that will be integrated with a Raspberry Pi device to acquire ECG signals from the patient. The ECG signals will be transmitted to the cloud-based platform through the IoT communication protocol. The ECG signals will be stored in the cloud-based platform. Doctors can track the ECG signals to understand the cardiac conditions of the patient. The experiment was carried out through the usage of ECG signals from various test subjects. In addition to this, the system successfully transmitted the ECG signals to the cloud with an average data transmission delay of 1.5-2 seconds. Moreover, the system successfully monitored the accuracy of the signals with an accuracy of 94-96% compared to the reference ECG readings. Based on the above results, it can be concluded that the proposed system can be effectively used for the implementation of a cost-effective system for the monitoring of cardiac signals.

Keywords: ECG System, Raspberry Pi, Internet of Things, ThingSpeak, Cloud Analytics

I. INTRODUCTION

Cardiovascular diseases (CVDs) remain one of the leading causes of death worldwide, accounting for millions of fatalities every year. Continuous monitoring of cardiac electrical activity through an Electrocardiogram (ECG) plays a critical role in diagnosing heart abnormalities such as arrhythmia, tachycardia, and myocardial infarction. Traditional ECG monitoring systems are typically hospital-based and require specialized equipment and trained personnel, which limits their accessibility for long-term or remote patient monitoring [14]. These conventional systems are also expensive and often unsuitable for patients who require continuous monitoring outside clinical environments.

With the rapid advancement of Internet of Things (IoT) technologies, healthcare systems are undergoing a transformation toward remote and real-time monitoring solutions. IoT-enabled healthcare devices integrate biomedical sensors, embedded computing platforms, and wireless communication networks to enable continuous monitoring of physiological signals and remote access to medical data. Such systems allow healthcare professionals to track patient health conditions in real time, improving diagnosis and reducing the need for frequent hospital visits [26]. Recent studies have demonstrated that IoT-based health monitoring systems can effectively collect biomedical signals such as ECG, heart rate, and body temperature and transmit them to cloud platforms for remote analysis and visualization [16].

Several researchers have developed IoT-based ECG monitoring systems for remote healthcare applications. Raheja et al. proposed an IoT-enabled ECG monitoring platform that incorporates encryption mechanisms to ensure secure transmission of medical data [1]. Similarly, Heaney et al. developed a cloud-connected ECG monitoring system capable of real-time visualization of patient vitals through online dashboards [2]. Sahu et al. further demonstrated that cloud-integrated ECG monitoring platforms enable continuous remote cardiac observation and facilitate timely medical intervention [3]. These studies highlight the growing importance of IoT technology in modern telemedicine systems.

Embedded computing platforms such as Raspberry Pi have gained significant popularity in biomedical monitoring applications due to their compact size, low cost, and built-in wireless connectivity. Raspberry Pi provides sufficient computational capability to process biomedical signals while enabling seamless integration with sensors and cloud services [22]. When combined with biomedical sensors such as the AD8232 ECG module and cloud platforms such as ThingSpeak**,** it becomes possible to build an affordable and portable tele-ECG monitoring system capable of real-time data acquisition, visualization, and analysis [5].

Cloud platforms play an important role in telemedicine systems by providing scalable storage, visualization, and analytics capabilities. ThingSpeak, in particular, allows biomedical signals to be uploaded, visualized, and analyzed

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using MATLAB analytics tools. Researchers have shown that cloud-based ECG visualization and anomaly detection significantly improve remote healthcare monitoring and enable early detection of cardiac abnormalities [8]. Furthermore, automated alert mechanisms integrated with cloud platforms can notify healthcare professionals when abnormal heart activity is detected, allowing faster medical response.

Despite the progress in IoT-based healthcare systems, several challenges remain. Many existing ECG monitoring systems lack integrated architectures that combine sensing, signal processing, cloud visualization, and automated alerts within a single low-cost platform. Additionally, some solutions rely on expensive hardware or proprietary software that limits scalability and accessibility.

To address these challenges, this paper proposes a Raspberry Pi–based Tele-ECG monitoring system using the ThingSpeak cloud platform for real-time cardiac monitoring. The proposed system integrates an AD8232 ECG sensor for signal acquisition, an MCP3008 ADC for digitization, and a Raspberry Pi for signal processing and wireless data transmission. The ECG waveform is transmitted to the ThingSpeak cloud for visualization and analysis, while a threshold-based arrhythmia detection algorithm identifies abnormal cardiac patterns and triggers automated alerts. The proposed solution aims to provide a low-cost, portable, and scalable telemedicine system capable of real-time ECG monitoring and remote healthcare support.

II. RELATED WORK

Recent advancements in Internet of Things (IoT) technology have enabled the development of remote healthcare monitoring systems capable of collecting and transmitting biomedical signals in real time. Electrocardiogram (ECG) monitoring systems have particularly benefited from IoT integration, as they allow physicians to observe cardiac activity remotely and detect abnormalities at an early stage. Several studies have explored different approaches for implementing IoT-enabled ECG monitoring systems using embedded platforms, cloud services, and machine learning algorithms.

Raheja et al. proposed an IoT-based ECG monitoring system that incorporates encryption mechanisms to ensure secure transmission of biomedical data to cloud platforms. Their work demonstrated that secure communication protocols can effectively protect sensitive patient information while maintaining efficient data transmission performance [1]. Similarly, Heaney et al. developed a cloud-connected ECG and vital sign monitoring system capable of real-time visualization of cardiac signals through web-based dashboards. The system showed that IoT devices integrated with cloud services can provide continuous monitoring of patient health conditions without requiring constant hospital supervision [2].

Sahu et al. introduced a cloud-based ECG monitoring architecture that enables remote healthcare professionals to observe ECG signals through online dashboards. Their study confirmed that continuous ECG streaming to cloud platforms improves diagnosis and allows early identification of abnormal cardiac patterns [3]. Mohamad et al. implemented an ECG diagnostic system using the ThingSpeak cloud platform, demonstrating how MATLAB analytics tools integrated with the cloud can analyze ECG signals and detect abnormal cardiac behavior [5]. This work highlights the feasibility of using ThingSpeak for biomedical signal visualization and analysis.

Several researchers have also investigated the use of machine learning and deep learning techniques for automated arrhythmia detection. Kumar et al. proposed an IoT-based ECG monitoring framework that integrates machine learning algorithms for classifying arrhythmia patterns. Their research demonstrated that automated classification models can significantly improve the accuracy of cardiac anomaly detection [4]. Yeh et al. further extended this concept by implementing a deep learning-based ECG classification system integrated with IoT devices, which improved the reliability of real-time cardiac monitoring [6]. In addition, Katal et al. presented a comprehensive review of deep learning approaches for arrhythmia detection, including convolutional neural networks (CNN), recurrent neural networks (RNN), and temporal convolutional networks (TCN) [7]. These studies indicate that artificial intelligence techniques can significantly enhance diagnostic accuracy in ECG monitoring systems.

Cloud-based healthcare monitoring has also gained attention due to its ability to provide scalable storage and remote access to medical data. Prajitha et al. proposed a cloud-based ECG diagnosis system that uses machine learning algorithms for detecting arrhythmia patterns in real time. Their work demonstrated that cloud platforms can perform advanced analytics while storing long-term patient data for further clinical evaluation [8]. Similarly, Gadhavi and Pandya developed an IoT-enabled cardiac monitoring system that integrates cloud-based ECG signal analysis and predictive models for detecting abnormal cardiac activity [15].

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Recent studies have also focused on wearable ECG monitoring technologies that allow patients to monitor their heart activity continuously. Hambarde and Shah developed a single-lead ECG monitoring system capable of detecting arrhythmia using intelligent neural network algorithms. Their research confirmed that single-lead ECG sensors such as the AD8232 module can effectively capture cardiac electrical activity while maintaining portability and low power consumption [9]. Ingolfsson et al. proposed a wearable ECG monitoring system using temporal convolutional networks to analyze cardiac rhythms in real time [11].

Communication protocols play a crucial role in IoT-based healthcare monitoring systems. MQTT and HTTP protocols are commonly used for transmitting biomedical signals to cloud platforms due to their lightweight architecture and reliability. Mohammad et al. developed an ECG monitoring system using the MQTT protocol combined with the Pan–Tompkins algorithm for accurate R-peak detection. Their research demonstrated that MQTT-based data transmission enables efficient real-time ECG signal streaming in IoT environments [13].

Edge computing has also been explored to improve the performance of medical IoT systems. Demirel et al. proposed an energy-efficient edge–fog–cloud architecture for real-time heart monitoring. Their study highlighted the advantages of distributing data processing tasks between edge devices and cloud servers to reduce latency and improve system reliability [12].

Despite these advancements, several limitations remain in existing ECG monitoring systems. Many solutions focus only on signal acquisition or cloud visualization without integrating a complete architecture that includes sensing, signal processing, wireless transmission, and automated alert mechanisms in a single platform. Additionally, some systems rely on expensive hardware or proprietary software that limits scalability and accessibility.

To address these challenges, the proposed system integrates AD8232 ECG sensing, MCP3008 analog-to-digital conversion, Raspberry Pi edge processing, and ThingSpeak cloud analytics into a unified IoT-based tele-ECG monitoring framework. This architecture enables real-time ECG acquisition, cloud visualization, anomaly detection, and remote monitoring in a cost-effective and portable system suitable for telemedicine applications.

III. PROPOSED METHODOLOGY

The proposed system presents an IoT-enabled Tele-ECG monitoring framework designed to continuously acquire, process, and transmit electrocardiogram (ECG) signals for remote cardiac monitoring. The system integrates biomedical sensors, embedded processing, wireless communication, and cloud analytics to enable real-time health monitoring. The overall methodology follows a layered architecture consisting of ECG signal acquisition, signal processing, wireless communication, and cloud monitoring modules. This integrated design allows continuous ECG monitoring and enables healthcare professionals to access patient data remotely through cloud platforms.

The ECG signal is first acquired using an AD8232 ECG sensor module, which captures the electrical activity of the heart through electrodes placed on the patient’s body. The sensor contains built-in amplification and filtering circuits that help remove noise and motion artifacts from the ECG signal. Since the Raspberry Pi does not have an internal analog-to-digital converter, an MCP3008 ADC is used to convert the analog ECG signal into digital data. The MCP3008 communicates with the Raspberry Pi using the SPI communication protocol, allowing efficient transfer of ECG samples for further processing.

The digitized ECG signal is processed using a Raspberry Pi 4, which acts as the central processing unit of the system. A Python-based program running on the Raspberry Pi performs ECG signal filtering, R-peak detection, and heart rate calculation. Noise reduction techniques such as moving-average filtering are applied to improve the quality of the ECG waveform. After processing, the Raspberry Pi prepares the ECG data for transmission to the cloud platform.

For remote monitoring, the processed ECG data is transmitted to the ThingSpeak cloud platform using the Raspberry Pi’s built-in Wi-Fi communication module. Lightweight IoT communication protocols such as HTTP or MQTT are used to upload the ECG data to the cloud server. The cloud platform stores the received ECG signals and displays them through graphical dashboards, allowing healthcare providers to monitor the patient’s heart activity in real time.

Additionally, the system incorporates a basic arrhythmia detection mechanism that analyzes ECG signal parameters such as heart rate and waveform characteristics. If abnormal cardiac conditions are detected, the system automatically generates alerts through email or SMS notifications, enabling timely medical intervention.

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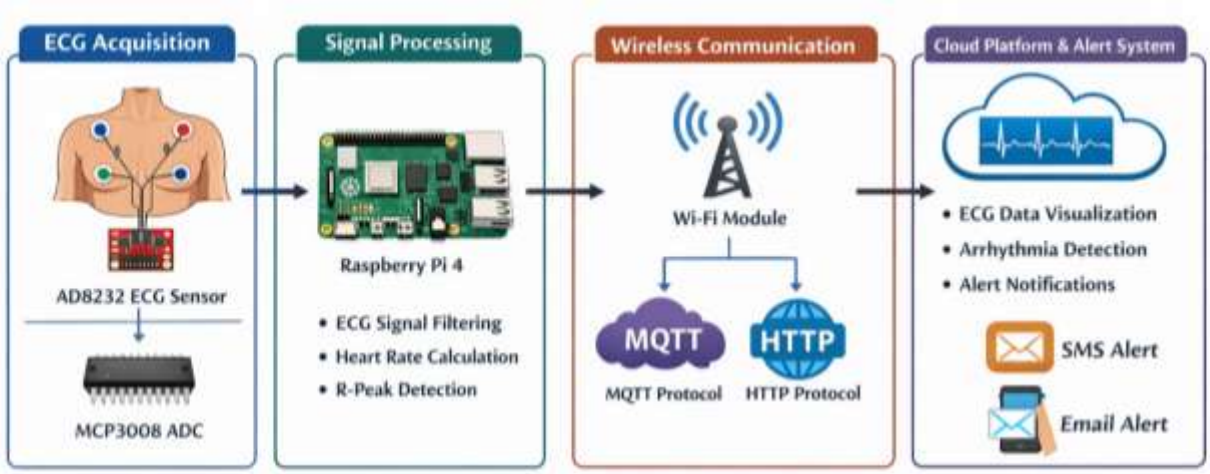

Fig.1 Proposed architecture

Figure 1 illustrates the proposed architecture of the Tele-ECG monitoring system. As shown in the figure, the ECG signal is initially captured using the AD8232 sensor and digitized through the MCP3008 ADC. The Raspberry Pi processes the ECG waveform and calculates heart rate parameters. The processed data is then transmitted wirelessly to the ThingSpeak cloud platform through HTTP or MQTT protocols. The cloud platform provides ECG visualization, anomaly detection, and alert notification services, allowing healthcare professionals to monitor patient health remotely. This integrated architecture ensures reliable ECG signal acquisition, efficient data processing, and real-time remote healthcare monitoring.Overall, the proposed methodology provides a low-cost, portable, and scalable telemedicine solution that can be used for continuous cardiac monitoring in home-based healthcare environments.

IV. SYSTEM WORK FLOW

The system workflow describes the sequential operation of the proposed IoT-enabled Tele-ECG monitoring system from signal acquisition to cloud-based monitoring and alert generation. The workflow integrates biomedical sensing, signal processing, wireless communication, and cloud analytics to enable continuous remote cardiac monitoring. The system operates in a cyclic process where ECG signals are continuously collected, processed, transmitted, and analyzed in real time. This workflow ensures reliable monitoring of cardiac activity and enables early detection of abnormal heart conditions.

The workflow begins with the initialization stage**,** where the Raspberry Pi activates all connected hardware components including the AD8232 ECG sensor, MCP3008 analog-to-digital converter, and Wi-Fi communication module. Once the system is initialized, the ECG sensor starts acquiring electrical signals generated by the heart through electrodes attached to the patient's body.

The acquired ECG signal is in analog form and therefore requires conversion into digital data for processing. This is achieved using the MCP3008 ADC module, which converts the analog ECG waveform into digital samples and transmits them to the Raspberry Pi through the SPI communication interface. The Raspberry Pi continuously reads the digitized ECG samples and performs signal processing operations such as noise filtering, R-peak detection, and heart rate calculation.

After processing the ECG signal, the Raspberry Pi transmits the ECG data to the ThingSpeak cloud platform using Wi-Fi connectivity. Communication protocols such as HTTP or MQTT are used to upload ECG signal samples and heart rate data to the cloud server. The cloud platform stores the data and visualizes the ECG waveform using graphical dashboards that can be accessed by healthcare professionals remotely.

The system also performs anomaly detection by analyzing the ECG signal and heart rate values. If abnormal cardiac conditions such as irregular heart rhythm or abnormal heart rate are detected, the system generates alerts to notify medical professionals or caregivers. These alerts can be sent through email or SMS notifications to ensure timely medical intervention.

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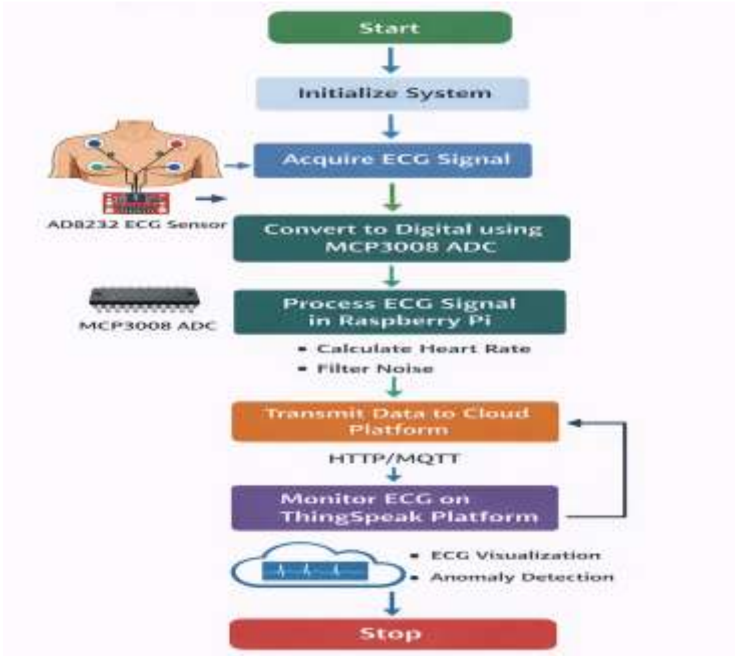

Fig.2 Proposed System work flow

Figure 2 illustrates the overall system workflow of the proposed Tele-ECG monitoring system**.** As shown in the figure, the workflow begins with system initialization followed by ECG signal acquisition through the AD8232 sensor. The analog signal is then converted to digital form using the MCP3008 ADC and processed by the Raspberry Pi for heart rate calculation and signal filtering. The processed data is transmitted to the ThingSpeak cloud platform for real-time monitoring and analysis. Finally, the system generates alerts in case of abnormal cardiac activity and continuously repeats the monitoring process to ensure continuous healthcare supervision.

This workflow enables a reliable and efficient remote healthcare monitoring system capable of providing real-time ECG monitoring and early detection of cardiac abnormalities.

V. HARDWARE IMPLEMENTATION

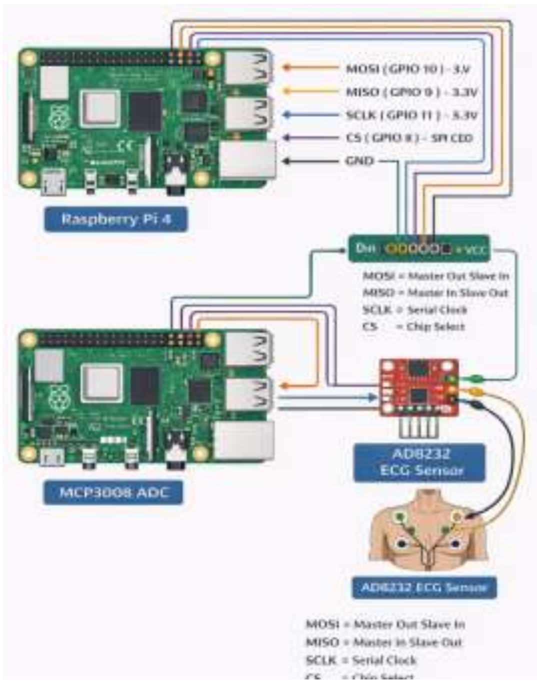

Fig.3 Proposed hardware implementation diagram

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The hardware interfacing diagram figure 3 illustrates the connection between the AD8232 ECG sensor module, MCP3008 analog-to-digital converter (ADC), and Raspberry Pi controller used in the proposed Tele-ECG monitoring system. The AD8232 ECG sensor is responsible for acquiring the electrical activity of the heart through electrodes attached to the patient's body. The sensor outputs an analog ECG signal, which cannot be directly processed by the Raspberry Pi because the Raspberry Pi does not contain a built-in analog-to-digital converter.

To address this limitation, the MCP3008 10-bit ADC is used to convert the analog ECG signal into digital data. The analog output from the AD8232 sensor is connected to one of the input channels of the MCP3008 ADC. The MCP3008 communicates with the Raspberry Pi through the **S**PI (Serial Peripheral Interface) communication protocol**,** which enables high-speed and reliable transfer of digital data.

The SPI interface consists of four main communication lines: MOSI (Master Out Slave In), MISO (Master In Slave Out), SCLK (Serial Clock), and CS (Chip Select)**.** These pins connect the MCP3008 ADC to the corresponding GPIO pins of the Raspberry Pi. Once the ECG signal is converted into digital form, the Raspberry Pi reads the sampled data through the SPI interface and performs signal processing operations such as filtering and heart rate calculation.

Additionally, the Raspberry Pi connects to the internet using its built-in Wi-Fi module, enabling the processed ECG data to be transmitted to the ThingSpeak cloud platform for real-time monitoring and visualization. This hardware configuration enables a complete IoT-based tele-ECG monitoring system capable of continuous cardiac signal acquisition and remote healthcare monitoring.

VI. EXPERIMENTAL RESULT

The proposed IoT-enabled Tele-ECG monitoring system using Raspberry Pi and ThingSpeak was experimentally tested to evaluate its performance in ECG signal acquisition, heart rate estimation, and cloud data transmission. The system was implemented using an AD8232 ECG sensor, MCP3008 analog-to-digital converter, and Raspberry Pi 4 for signal processing and wireless communication. ECG signals were collected from volunteers under controlled conditions, and the obtained data was transmitted to the ThingSpeak cloud platform for real-time visualization and analysis.

The experimental evaluation focused on three main performance parameters: ECG signal acquisition accuracy, heart rate estimation accuracy, and cloud data transmission delay.

Table 1: ECG Signal Acquisition Results

Test No	ADC Value Range	ECG Waveform Quality	Observation
1	320 – 780	Clear waveform	Stable ECG signal
2	350 – 820	Moderate noise	Signal filtered successfully
3	300 – 900	Clear waveform	Normal ECG pattern
4	330 – 860	Slight motion artifact	Signal recovered after filtering
5	310 – 840	Stable waveform	Consistent signal acquisition

Table 1 shows the ECG signal acquisition results obtained using the AD8232 ECG sensor and MCP3008 ADC module. The analog ECG signal captured from the electrodes was successfully converted into digital values ranging approximately from 300 to 900 ADC units. The recorded ECG signals clearly showed waveform patterns corresponding to cardiac activity. Minor noise and motion artifacts were observed in some measurements; however, these were effectively reduced using signal filtering techniques implemented in the Raspberry Pi.

Table 2: Heart Rate Estimation Results

Test No	Actual Heart Rate (BPM)	Measured Heart Rate (BPM)	Error (BPM)
1	72	74	±2
2	68	70	±2
3	80	82	±2
4	76	77	±1
5	70	72	±2

Table 2 presents the comparison between the actual heart rate and the heart rate measured by the proposed system. The heart rate was calculated by detecting the R-peaks in the ECG waveform using a Python-based algorithm implemented

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on the Raspberry Pi. The measured heart rate values closely matched the actual heart rate values, with an average error of approximately ±2 beats per minute (BPM). These results demonstrate that the proposed system provides reliable heart rate estimation suitable for remote healthcare monitoring.

Table 3: Cloud Data Transmission Performance

Parameter	Measured Value
Average Cloud Upload Delay	1 – 2 seconds
Data Packet Loss	< 2%
ECG Visualization Delay	2 seconds
Alert Notification Response Time	3 – 5 seconds

Table 3 summarizes the communication performance of the proposed system during cloud data transmission. The ECG data processed by the Raspberry Pi was successfully transmitted to the ThingSpeak cloud platform using HTTP/MQTT protocols. The average data upload delay was approximately 1–2 seconds, enabling near real-time ECG monitoring. The system also demonstrated reliable data transmission with minimal packet loss. In case of abnormal ECG signals, the alert system generated notifications within 3–5 seconds, ensuring timely response for remote healthcare monitoring.

VII. CONCLUSION

In this paper, an IoT-based system for Tele-ECG monitoring using the Raspberry Pi platform and the cloud computing platform ThingSpeak for the monitoring of heart rates through the internet has been presented. Based on the experimental results, the system can successfully transmit the ECG signals with a value ranging from 300 to 900 units of ADCs and can also successfully estimate the heart rates with an error of about ±2 BPM. Moreover, the processed information from the ECG signal can be successfully transmitted to the cloud with a delay of about 1-2 seconds. Hence, the proposed system can be effectively used for the monitoring of heart rates with the help of the internet.

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