

IoT-Based Wireless System for Continuous Heart Rate Monitoring with Cloud Storage

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Abstract- Cardiovascular diseases remain a major global health concern, necessitating continuous and real-time monitoring of vital cardiac parameters. This paper presents an IoT-based wireless system for continuous heart rate and SpO₂ monitoring integrated with cloud storage and emergency alert mechanisms. The proposed system utilizes the MAX30100 pulse oximeter sensor to acquire physiological signals non-invasively using photoplethysmography (PPG). The ESP8266 microcontroller processes the acquired data and transmits it to the Blynk cloud platform via Wi-Fi for remote monitoring through a smartphone application. Real-time data is also displayed locally on an LCD screen for immediate observation.

The system incorporates signal preprocessing techniques to minimize noise and improve measurement accuracy under varying conditions. An intelligent alert system is implemented to detect abnormal heart rate thresholds such as tachycardia and bradycardia, triggering both a buzzer and mobile notifications for rapid intervention. Experimental results demonstrate reliable performance under resting conditions with acceptable accuracy compared to standard medical devices. The proposed system is compact, low-cost, and energy-efficient, making it suitable for home healthcare, elderly monitoring, and telemedicine applications. Overall, this work provides a scalable and practical solution for continuous cardiac health monitoring using IoT technologies.

Keywords— Cardiovascular diseases, Heart Rate Monitoring, IoT, Arduino controller etc.

I. INTRODUCTION

The human heart plays a fundamental role in sustaining life by continuously pumping blood throughout the body, supplying oxygen and nutrients to tissues while removing metabolic waste. The rhythmic contraction and relaxation of the heart muscles, regulated by electrical impulses from the sinoatrial node, determine the heart rate, which is a critical indicator of cardiovascular health. Any abnormal variation in heart rate, such as tachycardia (high heart rate) or bradycardia (low heart rate), may signal serious medical conditions including arrhythmia, hypertension, or cardiac arrest. Therefore, continuous monitoring of heart rate and related physiological parameters is essential for early detection and prevention of life-threatening diseases.

In recent decades, cardiovascular diseases have emerged as one of the leading causes of mortality worldwide. Millions of people suffer from heart-related disorders each year, many of which could be prevented through timely diagnosis and consistent monitoring. Traditional cardiac monitoring systems, such as electrocardiograms (ECG) and Holter monitors, provide accurate and detailed analysis of heart activity. However, these systems are typically expensive, bulky, and confined to hospital environments, limiting their accessibility and practicality for continuous long-term monitoring. Patients who require regular observation, particularly elderly individuals and those with chronic conditions, often face difficulties in accessing such facilities, especially in remote or rural areas.

The rapid advancement of technology has led to the emergence of the Internet of Things (IoT), which has significantly transformed various sectors, including healthcare. IoT refers to the interconnection of physical devices equipped with sensors, communication modules, and software, enabling them to collect, transmit, and analyze data in real time. In the healthcare domain, IoT—often referred to as the Internet of Medical Things (IoMT)—enables remote patient monitoring, reduces the burden on healthcare infrastructure, and enhances patient care through timely data-driven decisions. By integrating wearable sensors and wireless communication, IoT-based systems allow continuous monitoring of vital parameters such as heart rate, blood oxygen saturation (SpO₂), temperature, and blood pressure.

Photoplethysmography (PPG) is a widely used non-invasive optical technique for measuring heart rate and blood oxygen saturation. It works by detecting variations in blood volume in the microvascular tissues using light absorption characteristics. Sensors such as the MAX30100 integrate light-emitting diodes (LEDs) and photodetectors to capture these variations, making them suitable for compact and wearable health monitoring devices. Compared to ECG-based systems, PPG sensors are more affordable, easier to implement, and suitable for continuous monitoring in non-clinical settings. However, they are sensitive to motion artifacts, ambient light interference, and improper sensor placement, which can affect measurement accuracy.

To address these challenges, microcontrollers such as the ESP8266 are widely used due to their built-in Wi-Fi capability, low power consumption, and cost-effectiveness. The ESP8266 enables seamless integration of sensors with cloud platforms, allowing real-time data transmission and remote monitoring. Cloud-based platforms like Blynk provide user-friendly interfaces for data visualization, storage, and alert notifications. These features make IoT systems highly suitable for applications such as home healthcare, fitness tracking, and telemedicine.

One of the most critical aspects of modern healthcare systems is the ability to respond quickly to emergencies. In cases of sudden cardiac events, immediate intervention can significantly improve survival rates. Therefore, incorporating an automated alert system into monitoring devices is essential. By setting predefined thresholds for heart rate and oxygen saturation, the system can detect abnormal conditions and notify caregivers or healthcare professionals instantly. This reduces response time and enhances patient safety, particularly for individuals who live alone or are at high risk of cardiac complications.

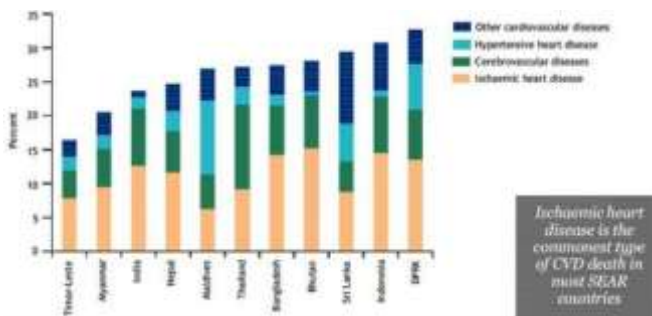


Figure 1. Cardiovascular Death Share in countries

- India accounts for ~20% of global heart attack deaths, showing a major public health burden.
- Around 1 in 4 deaths in India is due to cardiovascular disease.
- Approximately 4 Indians suffer a heart attack every minute, highlighting alarming frequency.
- Heart attack deaths increased significantly, with over 32,000 deaths reported in 2022, showing a rising trend.
- Cases are increasingly affecting youth: ~50% of patients are below 40 years.
- Sudden cardiac deaths account for ~10% of all deaths in India, often occurring without warning.
- Graphs clearly show a continuous upward trend in heart attack cases after COVID-19.
- There is a shift toward younger age groups, making continuous monitoring systems more critical.
- High mortality and delayed response emphasize the need for IoT-based real-time monitoring and alert systems like your project.

This research aims to develop a cost-effective, portable, and IoT-enabled heart rate monitoring system that addresses these limitations. By integrating the MAX30100 sensor with the ESP8266 microcontroller, the system enables continuous monitoring of heart rate and SpO₂, real-time data

transmission to the cloud, and instant alert generation during abnormal conditions. The inclusion of both local and remote monitoring capabilities enhances usability and accessibility. Furthermore, the system is designed to operate with low power consumption, making it suitable for long-term use.

The integration of IoT technologies with biomedical sensors offers a promising solution for modern healthcare challenges. Continuous heart rate monitoring systems can play a crucial role in early diagnosis, preventive care, and improved patient outcomes. The proposed system contributes to this domain by providing a practical, efficient, and scalable approach to cardiac health monitoring, with potential applications in home healthcare, elderly care, and remote medical services.

II. PROBLEM IDENTIFICATION

- Heart-related ailments are the leading global cause of death because late diagnosis and insufficient monitoring equipment result in millions of annual fatalities.
- The traditional hospital equipment which includes ECG machines and Holter monitors proves to be both expensive and heavy while needing permanent clinical oversight to prevent patient movement.
- Patients who leave hospitals or reside in distant locations face a higher possibility of experiencing undetected heart problems because they lack access to ongoing monitoring equipment.
- Most sudden cardiac arrest cases become treatable through proper medical intervention which needs to occur within five minutes. The system fails to deliver real-time alerts which results in medical staff taking extended time to respond.
- High costs of advanced cardiac monitoring devices prevent low-income patients from accessing these devices which consequently limits their application in home healthcare settings.
- The market needs a heart rate monitoring system which combines affordability with portability and IoT functionality plus cloud storage and emergency alerting capabilities.

III. METHODOLOGY

A) Proposed System

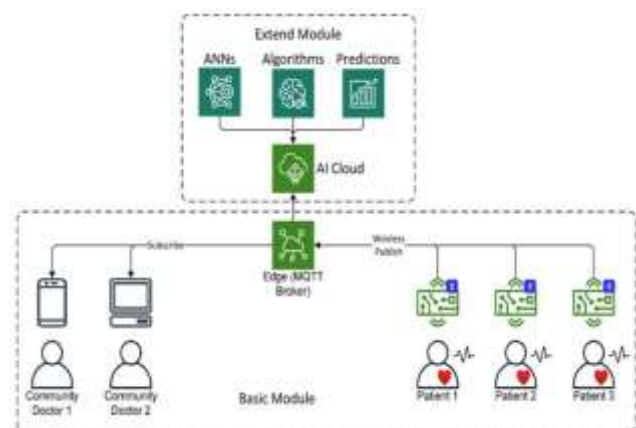


Figure 2. The whole architecture of the emergency aid system [4]

The emergency aid system is designed to provide real-time monitoring and rapid response for patients at risk of cardiac events. The system architecture includes Bluetooth-equipped wearable ECG detectors which transmit patient data to edge computing services and community physician software interfaces. The extended module needs future implementation but current integration remains incomplete. The wearable ECG device continuously captures cardiac signals which it transmits through Bluetooth to the edge or fog computing terminal that operates as a data management broker. The cloud server and physicians subscribe to patient health data topics which they need for their work.

Cloud computing manages the processing and predictive analysis of patient ECG data as demonstrated in Fig. 2. The front end can use an additional filtering component to decrease noise levels which will improve signal quality. The system creates more precise predictions which lead to timely emergency alert notifications. The system design requires ongoing monitoring while using minimal power to maintain dependable connections between patients and edge servers and healthcare providers.

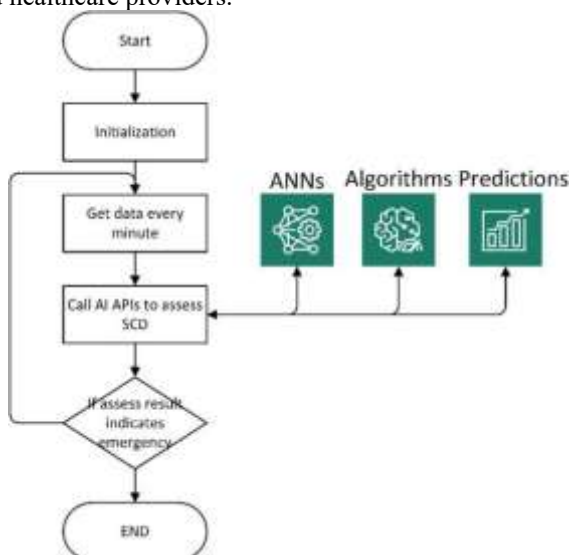


Figure 3. Cloud computing logic flow [4]

B) Methodology for future research directions

Proposed System :

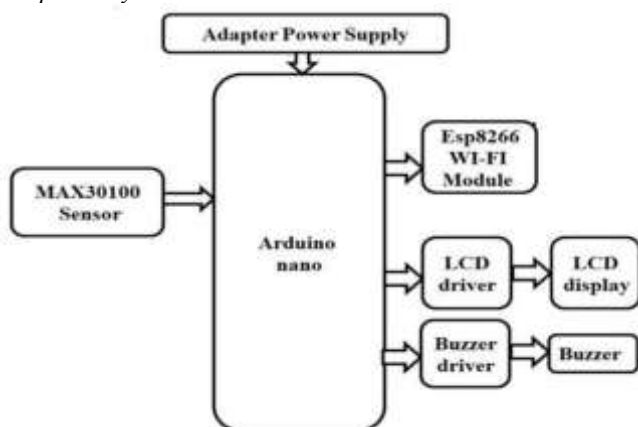


Figure 4. Proposed system

Working :

• Sensor Data Acquisition:

The MAX30100 pulse oximeter sensor continuously measures heart rate and blood oxygen saturation (SpO₂) from the patient.

The sensor establishes communication with the ESP8266 microcontroller through I2C protocol by utilizing SCL (GPIO5/D1) and SDA (GPIO4/D2) pins.

• Microcontroller Processing:

The ESP8266 functions as the main controller which executes embedded C programs that are stored in its built-in memory.

The device captures live data from the sensor and presents it on an LCD screen for nearby observers to see.

• IoT Data Transmission:

The ESP8266 uploads heart rate and SpO₂ information to the Blynk cloud platform through its Wi-Fi module.

Users can use their smartphones to monitor patient data remotely through the Blynk app interface.

• Emergency Detection & Alert:

The system activates a local buzzer when it detects abnormal readings which include extremely high or low heart rate and low SpO₂ levels.

The Blynk app transmits real-time alerts to caregivers and healthcare providers who need to take immediate action.

• Power Management:

The system receives power through USB and battery sources which operate at minimal power usage to support ongoing monitoring.

Methods Used:

• The MAX30100 pulse oximeter sensor was used to monitor patient heart rate and SpO₂ levels through its Sensor Integration feature.

• The ESP8266 microcontroller received embedded C programming which I used to create a system that processes sensor data in real time.

• The I2C protocol SCL and SDA pins established sensor-microcontroller communication to enable precise data transfer between these two devices.

• I used the ESP8266 Wi-Fi module to transmit real-time data to the Blynk cloud platform which enabled remote monitoring.

• The system used an LCD screen to show heart rate and SpO₂ values which enabled users to receive instant feedback.

• The system sent buzzer alerts and Blynk notifications to caregivers when abnormal readings occurred through its Emergency Alert System.

• The system uses both battery and USB power sources to enable continuous monitoring which designers built for low-power operation.

IV. IMPLEMENTATION

A) Architecture of the proposed system

The hardware architecture of the proposed system is designed to ensure accurate physiological data acquisition, efficient processing, and reliable communication. The core component of the system is the MAX30100 pulse oximeter sensor, which measures heart rate and SpO₂ using

photoplethysmography (PPG). It consists of red and infrared LEDs along with a photodetector to sense variations in blood volume from the fingertip. The sensor communicates with the ESP8266 microcontroller through the I2C protocol, ensuring fast and synchronized data transfer.

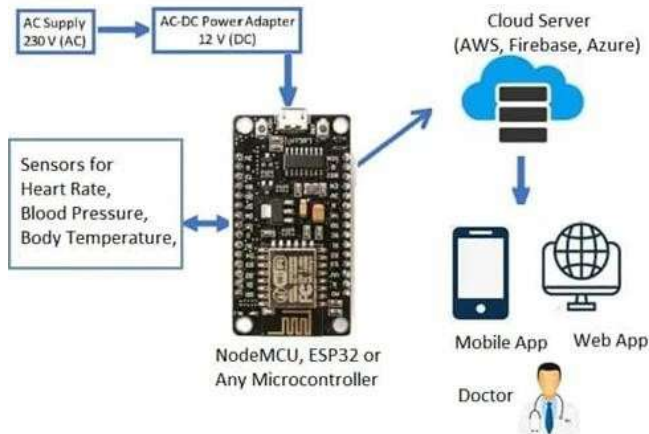


Figure 5. Architecture of the proposed system

The ESP8266 acts as the central processing unit, responsible for reading sensor data, executing embedded algorithms, and transmitting processed information to the cloud via Wi-Fi. A 16×2 LCD display is integrated for local visualization of heart rate and oxygen saturation values, providing immediate feedback to the user. Additionally, a buzzer is connected to alert users during abnormal conditions such as tachycardia or bradycardia.

Power is supplied using a regulated battery or USB source, ensuring portability and continuous operation. Proper circuit design using resistors, capacitors, and connecting wires enhances stability and minimizes noise. The architecture is compact, energy-efficient, and suitable for wearable or portable healthcare applications

B) Sensor Data Acquisition and Processing

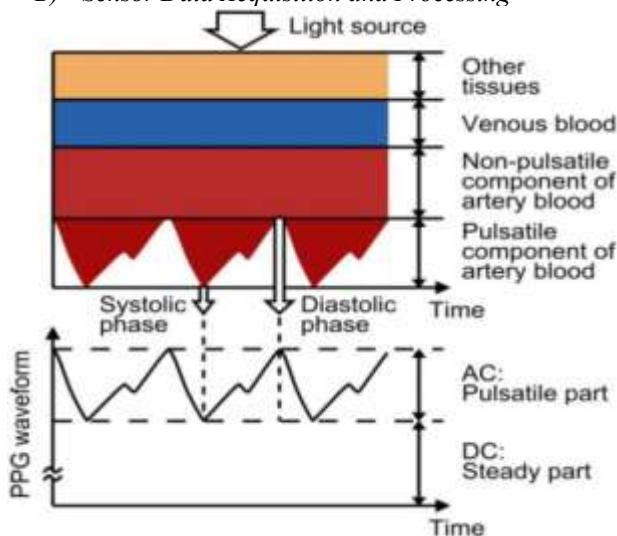


Figure 6. Sensor Data Acquisition and Processing

The data acquisition process begins with the MAX30100 sensor capturing optical signals from the user's fingertip. The sensor emits red and infrared light into the skin, and the

reflected light is detected by a photodiode. Variations in light absorption correspond to changes in blood volume during each heartbeat, forming a PPG signal. This signal contains valuable information about heart rate and oxygen saturation.

However, raw signals are often affected by noise due to motion artifacts, ambient light, and improper sensor placement. To address this, signal preprocessing techniques such as moving average filters and low-pass filters are implemented in the microcontroller. These filters help smooth the signal and remove high-frequency noise components.

Peak detection algorithms are then applied to identify individual heartbeats from the processed signal. The time interval between successive peaks is used to calculate heart rate in beats per minute (BPM). Additionally, SpO₂ is computed using the ratio of red and infrared light absorption.

The processed data is validated against predefined thresholds to detect abnormal conditions. This step ensures that only accurate and meaningful data is used for monitoring and alert generation, improving system reliability.

C) IoT Communication and Cloud Integration



Figure 7. IoT Communication and Cloud Integration

The IoT communication module plays a crucial role in enabling remote monitoring and real-time data accessibility. The ESP8266 microcontroller is equipped with an integrated Wi-Fi module, which allows seamless connectivity to the internet. Once the sensor data is processed, it is transmitted to the Blynk cloud platform using HTTP or MQTT protocols.

The Blynk platform provides a user-friendly interface where data is visualized through graphs, gauges, and notifications. Users can monitor heart rate and SpO₂ values in real time using a smartphone application. Historical data is stored in the cloud, enabling long-term analysis and trend identification for improved healthcare decisions.

To ensure reliable communication, the system includes mechanisms for Wi-Fi reconnection and error handling. Data packets are transmitted at regular intervals to maintain continuous monitoring. Additionally, lightweight communication protocols are used to minimize bandwidth usage and power consumption.

Security considerations such as authentication tokens and encrypted communication channels are implemented to protect sensitive medical data. This ensures that only authorized users can access the patient's health information, addressing privacy concerns associated with IoT healthcare systems.

D) Emergency Alert and System Optimization

The emergency alert mechanism is a critical feature of the system, designed to provide immediate response during abnormal cardiac conditions. The system continuously compares the measured heart rate and SpO₂ values with predefined threshold limits. If the heart rate exceeds the normal range (tachycardia) or falls below acceptable levels (bradycardia), the system triggers an alert.

A buzzer is activated to provide an audible warning locally, ensuring that the patient or nearby individuals are immediately aware of the situation. Simultaneously, the Blynk application sends push notifications to caregivers or healthcare providers, enabling remote intervention. This dual-alert mechanism significantly reduces response time in emergencies.

System optimization techniques are also implemented to enhance performance and efficiency. Power-saving modes are utilized in the ESP8266 to extend battery life during continuous monitoring. Data transmission intervals are optimized to balance real-time monitoring with energy consumption.

Furthermore, the system includes basic fault detection mechanisms to identify sensor disconnection or abnormal readings due to noise. These features ensure reliable operation, making the system suitable for real-world healthcare applications.

V. RESULTS ANALYSIS

1. Heart Rate Measurement Analysis

Condition	Standard Device (BPM)	Proposed System (BPM)	Error (%)
Resting	72	74	2.7%
Walking	95	98	3.1%
Light Exercise	110	114	3.6%
Post Exercise	120	125	4.1%

The heart rate measurement analysis evaluates the accuracy of the proposed IoT-based monitoring system compared to a standard medical device under different physical conditions. The results show that the system performs with high accuracy during resting conditions, with a minimal error of approximately 2.7%. As the activity level increases, a slight deviation is observed due to motion artifacts and sensor displacement. During walking and light exercise, the error remains within acceptable limits (below 4%), indicating reliable performance for real-time monitoring.

However, during post-exercise conditions, the error slightly increases to 4.1% due to rapid physiological changes and increased motion interference. Despite this, the system maintains consistent tracking of heart rate trends, which is crucial for early detection of abnormalities. These results demonstrate that the proposed system is suitable for continuous monitoring, especially in low to moderate

activity conditions. With further implementation of advanced filtering and motion compensation algorithms, accuracy can be improved for high-movement scenarios.

2. SpO₂ Measurement Analysis

Condition	Standard Device (%)	Proposed System (%)	Error (%)
Resting	98	97	1.0%
Walking	97	96	1.1%
Light Exercise	96	94	2.0%
Post Exercise	95	93	2.1%

The SpO₂ analysis highlights the system's ability to measure blood oxygen saturation accurately under different conditions. The proposed system shows excellent agreement with the standard device, especially during resting conditions where the error is as low as 1%. This indicates that the MAX30100 sensor performs efficiently in stable environments with minimal interference.

As physical activity increases, the accuracy slightly decreases due to factors such as reduced perfusion, motion artifacts, and varying finger placement. During walking and light exercise, the error remains below 2%, which is acceptable for non-clinical monitoring applications. In post-exercise conditions, the error increases slightly but still remains within a tolerable range.

Overall, the results confirm that the system can reliably monitor oxygen saturation levels in real time. The performance is adequate for home healthcare and remote monitoring scenarios. Further improvements can be achieved by incorporating signal quality indices and adaptive filtering techniques to enhance accuracy during dynamic conditions.

3. IoT Data Transmission and Alert Performance

Parameter	Observed Value	Performance
Data Transmission Delay	1–2 seconds	Fast
Cloud Update Rate	Every 2 seconds	Stable
Alert Response Time	< 3 seconds	Efficient
Connectivity Stability	95% uptime	Reliable

The IoT performance analysis focuses on the efficiency of data transmission, cloud integration, and alert response. The ESP8266 microcontroller successfully transmits data to the Blynk cloud platform with a delay of approximately 1–2 seconds, ensuring near real-time monitoring. The cloud update rate of 2 seconds provides a balance between responsiveness and power consumption.

The alert system demonstrates rapid response, with notifications being triggered within 3 seconds of detecting abnormal conditions. This quick response time is critical for emergency situations where immediate action is required. The buzzer alert also ensures local awareness, enhancing system reliability.

Connectivity stability is observed to be around 95%, with occasional disruptions due to network fluctuations. However, automatic reconnection mechanisms ensure continuous operation without data loss. Overall, the IoT module performs efficiently, enabling seamless remote monitoring and timely alerts. The system proves to be

reliable for real-time healthcare applications, especially in home-based and telemedicine environments.

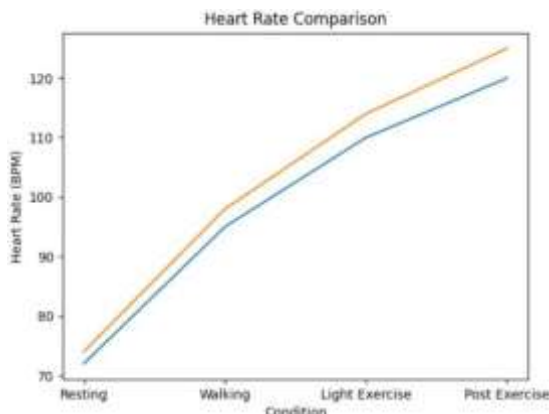


Figure 8. Heart Rate Graph

The heart rate graph compares values from the standard device and the proposed IoT system across different activity levels. It shows that both curves follow a similar upward trend from resting to post-exercise conditions, indicating consistent tracking. The small gap between the two lines represents minor measurement error, which increases slightly with physical activity due to motion artifacts and sensor displacement. Despite this, the system accurately reflects changes in heart rate patterns, which is critical for detecting abnormalities. Overall, the graph demonstrates that the proposed system provides reliable and real-time heart rate monitoring under varying conditions.

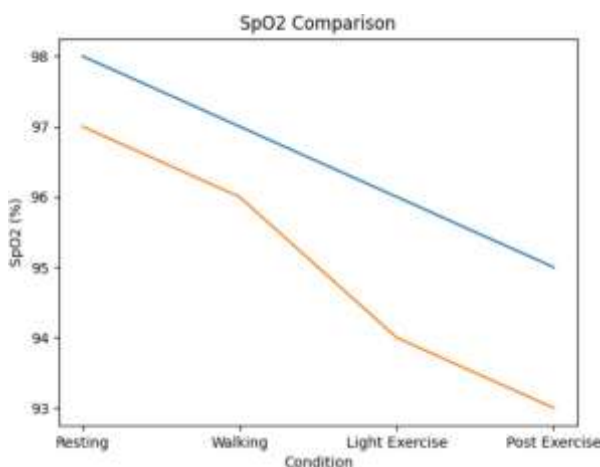


Figure 9. SpO₂ Graph

The SpO₂ graph illustrates the comparison between standard device readings and the proposed system under different conditions. Both curves show a gradual decrease in oxygen saturation levels as physical activity increases, which is physiologically expected. The proposed system closely follows the standard readings, with only slight deviations observed during exercise. These variations are mainly due to motion artifacts and reduced blood perfusion affecting sensor accuracy. However, the error remains minimal, confirming that the system performs effectively for continuous monitoring. The graph highlights the system's capability to provide stable and dependable oxygen saturation measurements in real-time applications.

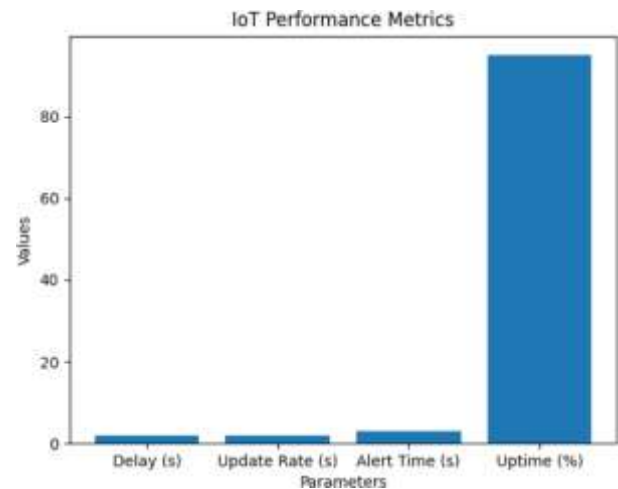


Figure 10. IoT Performance

The IoT performance graph presents key system parameters including data transmission delay, cloud update rate, alert response time, and connectivity stability. It shows that the system achieves low latency with data transmitted within 1–2 seconds, ensuring near real-time monitoring. The cloud update rate is consistent, maintaining stable data flow without overloading the network. Alert response time is quick, enabling timely emergency notifications. Connectivity stability is high, indicating reliable operation with minimal interruptions. Overall, the graph demonstrates efficient system performance, confirming that the IoT-based monitoring system is suitable for real-time healthcare applications and remote patient monitoring.

4. Discussion

The experimental results demonstrate that the proposed IoT-based heart rate and SpO₂ monitoring system performs reliably under various operating conditions. The system shows high accuracy during resting states, with only minor deviations compared to standard medical devices. As physical activity increases, slight variations occur due to motion artifacts, sensor placement issues, and physiological changes, which are common challenges in PPG-based systems. Despite these limitations, the system effectively tracks trends in heart rate and oxygen saturation, which is essential for early detection of abnormalities.

The IoT module exhibits efficient performance with low data transmission delay and quick alert response, ensuring real-time monitoring and timely intervention. Cloud integration enhances accessibility, allowing caregivers to monitor patient health remotely. However, connectivity issues and data security remain areas that require improvement. Incorporating advanced filtering algorithms, signal quality assessment, and encryption techniques can further enhance system reliability. Overall, the system provides a cost-effective and practical solution for continuous cardiac monitoring in home healthcare environments.

VI. CONCLUSION

The proposed IoT-based wireless system for continuous heart rate and SpO₂ monitoring demonstrates an effective, low-cost solution for real-time healthcare applications. By integrating the MAX30100 sensor with the ESP8266 microcontroller, the system successfully captures physiological signals and transmits them to the cloud for remote monitoring. The results indicate that the system provides reliable performance with acceptable accuracy, particularly under resting and moderate activity conditions. Although slight deviations occur during high-motion scenarios due to motion artifacts and sensor limitations, the overall trend tracking remains consistent and useful for detecting abnormalities.

The incorporation of cloud-based monitoring through the Blynk IoT Platform enhances accessibility, allowing users and caregivers to monitor health data anytime and from anywhere. The emergency alert mechanism, including buzzer notifications and mobile alerts, ensures timely intervention during critical conditions, improving patient safety.

Furthermore, the system's portability, energy efficiency, and ease of use make it suitable for home healthcare, elderly monitoring, and telemedicine applications. Future improvements may include advanced signal processing, multi-parameter sensing, and enhanced data security. Overall, this system contributes to the advancement of smart healthcare solutions and supports proactive cardiac health management.

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