IoT-Based Heart Rate Monitoring System Using ESP8266 and Telegram Bot

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***This paper presents the development of an Internet of Things (IoT)-based heart rate monitoring system utilizing the ESP8266 microcontroller and a pulse sensor. The system is designed to measure heart rate in real-time and transmit the data via Wi-Fi to a Telegram bot, enabling remote monitoring and instant alerts. This approach offers a cost-effective and efficient solution for continuous cardiac monitoring, particularly beneficial for patients requiring regular observation and immediate response to abnormal heart rate conditions. Experimental results demonstrate the system's accuracy and responsiveness, highlighting its potential application in remote healthcare monitoring.***

***Keywords: IoT, Heart Rate Monitoring, ESP8266, Telegram Bot, Remote Healthcare.***

# Introduction

Cardiovascular diseases remain a leading cause of mortality worldwide, necessitating continuous and accurate heart rate monitoring to facilitate early detection and intervention. Traditional heart rate monitoring methods often involve bulky equipment and require patients to be physically present in healthcare facilities, posing challenges for continuous monitoring and timely medical response.The advent of the Internet of Things (IoT) has revolutionized healthcare by enabling remote monitoring of physiological parameters through interconnected devices. This paper proposes an IoT-based heart rate monitoring system that leverages the ESP8266 microcontroller and a pulse sensor to measure heart rate in real-time. The system transmits the collected data via Wi-Fi to a Telegram bot, providing instant notifications to healthcare providers and caregivers in case of abnormal heart rate readings.

Traditional heart rate monitoring systems are often expensive, non-portable, and require patients to visit healthcare facilities for regular check-ups. There is a pressing need for a cost-effective, portable solution that allows continuous and remote monitoring of heart rate, enabling timely medical intervention when necessary.

Develop a low-cost, portable heart rate monitoring system using the ESP8266 microcontroller and a pulse sensor. Implement real-time data transmission via Wi-Fi to a Telegram bot for remote monitoring. Provide instant alerts to healthcare providers and caregivers upon detection of abnormal heart rate readings.

# Proposed Methodology

The proposed system integrates hardware and software components to achieve real-time heart rate monitoring and data transmission.

The system comprises the following components:

Pulse Sensor: Detects the user's heartbeat by measuring the change in blood volume through photoplethysmography.

ESP8266 Microcontroller: Processes the sensor data and manages Wi-Fi communication.

Wi-Fi Module: Enables wireless data transmission to the internet.

Telegram Bot: Receives data and sends notifications to users.

Fig 1.1

The hardware setup involves connecting the pulse sensor to the ESP8266 microcontroller. The pulse sensor's output is connected to an analog input pin on the ESP8266, which reads the analog voltage corresponding to the heartbeat signal. The ESP8266 is powered via a 3.3V supply, and its built-in Wi-Fi module facilitates wireless communication.ESP8266 Wi-Fi Module: Acts as a communication device from the sensor to the Telegram bot, like a bridge.

The software component is developed using the Arduino IDE, with the ESP8266 programmed to perform the following tasks:

1. Data Acquisition: Reads analog signals from the pulse sensor.

2. Signal Processing: Filters and processes the raw data to calculate the heart rate in beats per minute (BPM).

3. Wi-Fi Communication: Connects to a Wi-Fi network to enable internet access.

4. Telegram Bot Integration: Sends the processed heart rate data to a Telegram bot using HTTP requests.

The Telegram bot is configured to receive data from the ESP8266 and send alerts to predefined users if the heart rate exceeds or falls below specified thresholds.

1. Results and Discussion



Fig 1.2

The Mediot system was successfully developed and tested for real-time heart rate monitoring and alerting. During experimental trials, the system effectively detected abnormal heart rates and sent alerts via Telegram within 2-3 seconds of detection. The accuracy of heart rate measurements was evaluated by comparing the readings from the MAX30102 sensor with those from a standard ECG device, revealing an error margin of less than 5%, making it a reliable solution for continuous monitoring. The response time analysis showed that Telegram alerts were significantly faster than SMS or email-based notifications, enabling quick action by caregivers or emergency responders. The system provides a cost-effective, accessible, and efficient alternative to traditional heart rate monitoring solutions, particularly benefiting individuals with heart conditions, elderly patients, athletes, and caregivers. Unlike conventional hospital-based monitoring, which requires patients to be physically present, Mediot enables remote monitoring and automated notifications, reducing the risk of delayed medical intervention. The ability to send instant alerts ensures that medical attention can be provided at the earliest possible stage of a cardiac abnormality, potentially saving lives. Despite its advantages, the system has some limitations. Network dependency remains a challenge, as the system requires an active internet connection for real-time alerts, which may not be feasible in remote or low-connectivity areas. Additionally, sensor accuracy can be affected by factors such as finger placement, ambient temperature, and user movement, leading to occasional false readings. Data privacy and security concerns are another critical aspect, as sensitive health information is transmitted over the internet, requiring robust encryption and authentication to prevent unauthorized access. Overall, the Mediot system demonstrates strong potential as a real-time health monitoring solution, offering fast, reliable, and automated alerts to mitigate risks associated with heart rate abnormalities. Addressing its limitations through network-independent alert mechanisms, improved sensor calibration, and enhanced security features will further enhance its effectiveness. Future developments will focus on AI-based predictive analysis, integration with healthcare facilities, and support for multiple notification platforms, ensuring a comprehensive and scalable healthcare monitoring system.



Fig 1.3

This paper presented an IoT-based heart rate monitoring system using ESP8266, a pulse sensor, and a Telegram bot. The system effectively provides real-time heart rate monitoring and instant alerts via Telegram. Testing results confirm that the system is accurate and efficient, making it a cost-effective solution for remote healthcare.

With some limitations in the current project-including its dependency on Wi-Fi for connectivity and sometimes false positives-the amount of work conducted in this advancement certainly sets a sound base for future development and application. Improving features like facial recognition, the ability of ESP32-CAM to support improved lighting, and possibly adding voice assistants might make this system much more efficient and useful.

This project deals with immediate security challenges but also plays a role in a larger framework that discusses using IoT and assistive technologies as a means of empowering people toward greater independence and also a better quality of life. Further research is set as benchmarks for inclusive home automation and security systems.

IV. Challenges and Limitations

While the Mediot system provides an efficient solution for real-time heart rate monitoring and alerting, several challenges and limitations need to be addressed for broader adoption and improved reliability.

1. Network Dependency – The system relies on an active internet connection to send real-time Telegram alerts. In areas with poor network coverage or limited internet access, delays in notifications may occur, reducing the effectiveness of the system in critical situations.

2. Sensor Accuracy and Reliability – The MAX30102 sensor, while accurate under stable conditions, can be affected by finger positioning, skin tone variations, ambient light, and motion artifacts. This may lead to false readings or inaccurate heart rate measurements, impacting decision-making.

3. Power Consumption and Battery Life – Continuous monitoring and wireless transmission can lead to high power consumption, requiring frequent charging or external power sources. This can be inconvenient for users who need long-term monitoring in remote or outdoor environments.

4. False Alarms and Data Interpretation – The system may occasionally generate false alarms due to temporary heart rate fluctuations, causing unnecessary anxiety for users and caregivers. Additionally, non-medical users may struggle to interpret the severity of alerts without proper guidance.

5. Privacy and Security Risks – As the system transmits sensitive health data over the internet, there is a risk of data breaches, hacking, or unauthorized access. Ensuring robust encryption, secure authentication, and compliance with health data regulations is essential to protect user privacy.

6. Limited Integration with Medical Systems – Currently, the system functions as a standalone monitoring device, and it is not yet integrated with hospital or clinical databases. For effective emergency response, future enhancements should enable direct integration with healthcare providers for real-time intervention.

7. Device Wearability and User Comfort – If used as a wearable device, factors such as size, comfort, and long-term usability must be considered. Users may find finger-based monitoring inconvenient for prolonged use compared to wrist-worn or chest-strap alternatives.

Future Improvements

To overcome these challenges, future enhancements will focus on:

Offline alert mechanisms such as SMS or Bluetooth-based notifications.

AI-powered data filtering to minimize false alarms and improve accuracy.

Extended battery life through power-efficient components and sleep mode optimization.

Improved security measures including end-to-end encryption and multi-factor authentication.

Integration with healthcare networks to enable real-time doctor intervention.

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