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Centralized Emergency Room Monitoring System Using ESP8266

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Abstract
This paper focuses on the design and foundational implementation of a Centralized Emergency Room (ER) Monitoring System, an advanced Internet of Medical Things (IoMT) solution aimed at revolutionizing patient surveillance. The core objective is to achieve the real-time, wireless acquisition and centralized management of critical patient vital signs: Heart Rate (HR), Blood Oxygen Saturation (SpO2), and Body Temperature. The system utilizes a powerful two-tier architecture. The device layer is anchored by the ESP32 Development Board, selected for its dual-core processing and integrated Wi Fi/Bluetooth Low Energy (BLE) connectivity, which ensures robust, concurrent handling of sensor data and reliable transmission via HTTP/JSON. The gateway layer is a scalable Python Flask server that manages multi-patient data persistence in a SQLite database. Crucially, this server acts as the primary platform for the AI Anomaly Detection engine, which analyses incoming vital sign streams for subtle, non-threshold-based patterns indicative of patient deterioration, thereby offering a superior level of risk assessment than traditional systems.

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Keywords: ESP8266 Microcontroller, Vital Sign Monitoring, Real-Time Data Processing, Wireless Communication (Wi-Fi), Flask Web Serve, Data Visualization Dashboard, Anomaly Detection

1. Introduction

The Centralized Emergency Room Monitoring System is designed to enhance patient care and improve operational efficiency in emergency departments by enabling real-time monitoring of vital signs through a unified digital platform. In modern healthcare environments, emergency rooms are highly dynamic and often face challenges such as increasing patient inflow, limited medical staff, and the need for rapid and accurate decision-making. Traditional monitoring systems rely on standalone devices such as pulse oximeters, ECG monitors, and thermometers, which require continuous manual observation by healthcare personnel. This approach can result in delays in detecting critical conditions, increased chances of human error, and inefficient patient management, particularly during peak hours and emergency situations. To address these limitations, the proposed system adopts an Internet of Medical Things (IoMT) approach using the ESP8266 (NodeMCU) microcontroller as the core processing and communication unit. Biomedical sensors are integrated with the ESP8266 to continuously monitor vital parameters such as heart rate, blood oxygen saturation (SpO_2), and body temperature. The collected data is transmitted wirelessly over Wi-Fi to a centralized server or cloud platform, where it is processed, stored, and visualized through an interactive real-time dashboard accessible to healthcare professionals. This centralized monitoring system enables doctors and medical staff to track multiple patients simultaneously from a single interface, thereby improving efficiency and reducing workload. In addition, the system incorporates automated alert mechanisms and basic anomaly detection techniques to identify abnormal vital signs at an early stage, allowing for faster medical intervention and improved patient outcomes. The proposed solution is designed to be cost-effective, scalable, and easy to deploy, making it suitable for both small clinics and large hospitals. By integrating IoMT, wireless

communication, and real-time data analytics, this system overcomes the limitations of traditional monitoring methods and provides a smart, reliable, and efficient approach to emergency healthcare management.

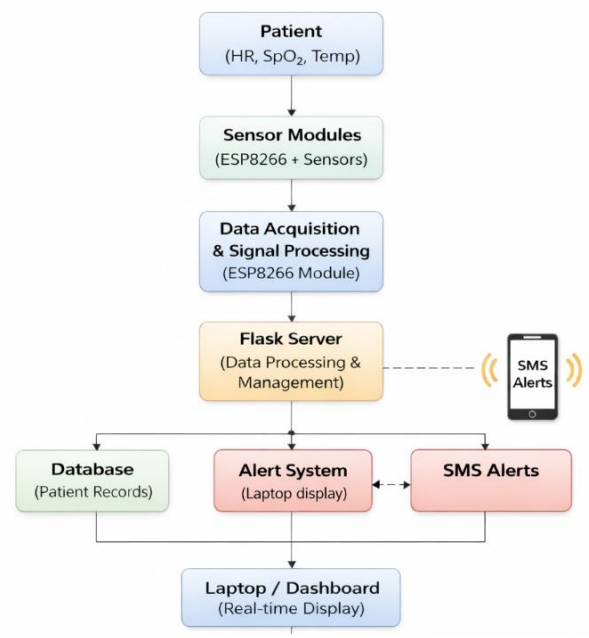

Fig 1: Data Flow Diagram of Centralized Emergency Room Monitoring System

Figure 1 This diagram illustrates a centralized emergency room monitoring system where patient vital data (heart rate, SpO_2, temperature) is collected via sensors, processed by ESP8266 and a Flask server, stored in a database, and displayed on a laptop screen with alert notifications.

2. Literature Survey

The domain of this paper lies in the Internet of Medical Things (IoMT), real-time patient monitoring, and intelligent healthcare systems. IoMT enables interconnected medical devices and sensors to collect and transmit patient data through the internet, improving healthcare efficiency and decision-making. In emergency room environments, real-time monitoring of vital parameters such as heart rate, SpO_2, and temperature is critical for timely treatment. Traditional hospital monitoring systems, such as ECG machines and pulse oximeters, operate as standalone units and require manual observation, leading to delays and possible human errors. Recent advancements have introduced IoT-based solutions using microcontrollers like ESP8266 and Arduino, along with sensors such as MAX30102 and DS18B20, to enable remote monitoring through cloud platforms like Firebase and ThingSpeak. While these systems provide low-cost and portable alternatives, most are limited to single-patient monitoring and lack centralized dashboards. Additionally, many existing solutions do not incorporate predictive analytics or robust alert mechanisms. Security and scalability also remain significant concerns in current implementations. Therefore, there is a need for a centralized, scalable, and intelligent monitoring system that supports multi-patient tracking, real-time alerts, and efficient data management, which is addressed by the proposed Centralized Emergency Room Monitoring System.

3. Methodology for Software Implementation

The software implementation of the Centralized Emergency Room Monitoring System was developed using a modular approach to ensure reliable communication and efficient system performance. Initially, the system was tested using simulated test variables representing patient data to verify the functionality of the software modules and ensure accurate data processing. Once the software operation was confirmed, the system was integrated with the hardware components for real-time implementation. The Arduino IDE was used to program the ESP8266 microcontroller, which collects data from sensors such as temperature and pulse sensors at regular intervals. The collected data is processed and transmitted wirelessly through Wi-Fi to a centralized monitoring system. A backend server was developed using Python with Flask to receive sensor data, manage communication, and securely store patient information in a structured database. A web-based dashboard was created using HTML, CSS, and JavaScript to display real-time patient parameters. Additionally, an SMS alert system was integrated to notify hospital staff members when any patient's condition becomes severe or abnormal readings are detected, ensuring timely response and improved patient safety.

4. Centralized Emergency Room Monitoring System Dashboard Interface

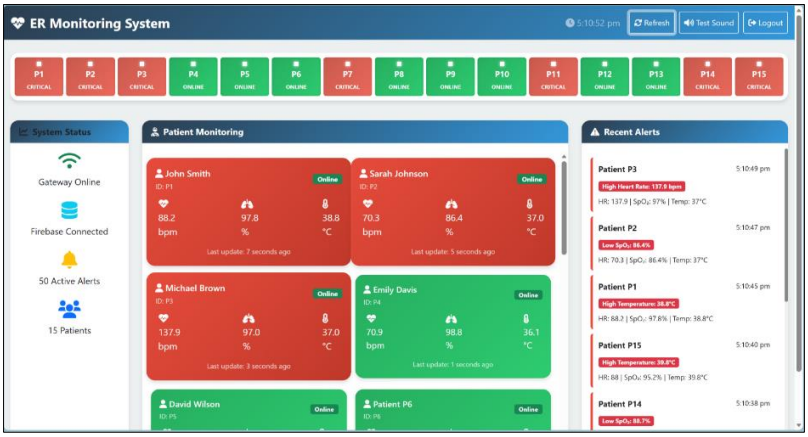

Fig 2: Final dashboard interface

Figure 2 shows the real-time dashboard displaying multiple patient statuses using color-coded indicators, along with system connectivity, active alerts, and total patient count, enabling centralized monitoring and quick identification of critical patients in emergency healthcare environments.

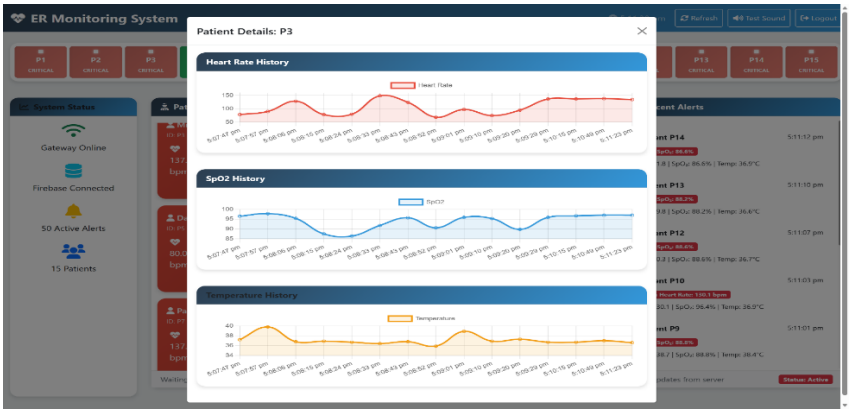

Fig 3: Graphical representation of single patient data

Figure 3 shows individual patient data monitoring along with graphical representation of heart rate, SpO_2, and temperature trends recorded over the last few hours, helping medical staff analyse patient conditions and identify abnormal variations effectively in real time.

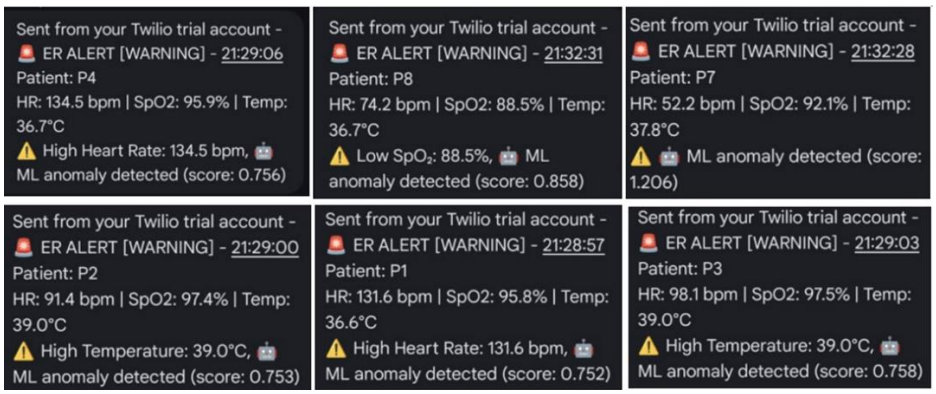

Fig 4: SMS alert notifications

Figure 4 shows SMS alert notifications sent to hospital staff when abnormal patient parameters are detected. The message includes patient ID, heart rate, SpO_2, temperature readings, and warning details, enabling immediate response during critical emergency conditions.

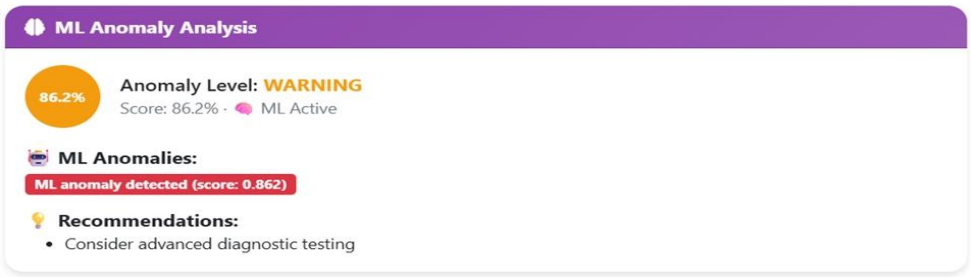

Fig 5: ML anomalies detection and recommendations

Figure 5 shows the machine learning anomaly detection interface displaying warning levels based on patient data analysis. It highlights detected anomalies with corresponding scores and provides recommendations for further diagnostic actions to assist medical staff in timely clinical decision-making.

5. Methodology for Hardware Implementation

The hardware implementation of the Centralized Emergency Room Monitoring System was carried out using a systematic approach to ensure accurate data acquisition and reliable system operation. The ESP8266 microcontroller was used as the main processing unit to interface with the sensing components and manage data transmission. Temperature and pulse sensors were connected to the ESP8266 to continuously monitor patient vital parameters. Each sensor was carefully calibrated and tested individually to ensure accurate readings before integrating them into the complete system. A regulated power supply unit was used to provide stable voltage to all hardware components to prevent fluctuations during operation. The hardware connections were assembled on a development board and later secured properly to ensure stable and long-term functioning. Once the hardware setup was completed, it was integrated with the software system to enable real-time data transmission through Wi-Fi to the centralized monitoring server.

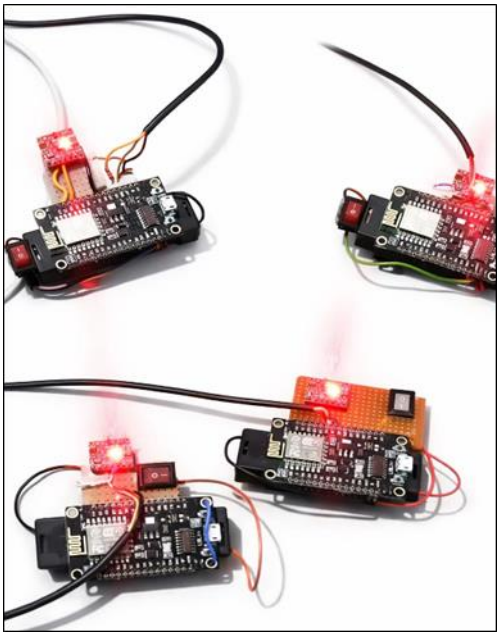

Fig 6: Hardware kits

Figure 6 shows hardware kits of a centralized emergency room monitoring system. It uses ESP8266 modules to sense patient data such as heart rate, SpO, levels, and temperature, and transmits it wirelessly to a laptop via a Flask server for real-time monitoring and analysis.

5. Results and Discussion

The proposed Centralized Emergency Room Monitoring System was successfully implemented and tested using the ESP8266 microcontroller and connected biomedical sensors. The system was able to accurately measure and transmit vital parameters such as heart rate, SpO_2, and body temperature in real time over a Wi-Fi network. The data was efficiently displayed on a centralized dashboard, allowing simultaneous monitoring of multiple patients. The integration of Firebase ensured near real-time data synchronization with minimal delay. The alert mechanism functioned effectively by triggering notifications when abnormal threshold values were detected, enabling timely intervention. The system demonstrated reliable performance in terms of data transmission, responsiveness, and ease of use. However, minor delays were observed during unstable network conditions. Overall, the results validate that the proposed system provides a low-cost, scalable, and efficient solution for real-time emergency room monitoring and improves the effectiveness of patient management.

6. Conclusion and Future Scope

The Centralized Emergency Room Monitoring System successfully demonstrates an efficient and reliable approach

for real-time monitoring of patient vital signs using IoMT technology. By integrating biomedical sensors with the ESP8266 (NodeMCU) microcontroller, the system is capable of continuously measuring important health parameters such as heart rate, blood oxygen saturation (SpO_2), and body temperature. The wireless transmission of data to a centralized server and its visualization on a real-time dashboard enable healthcare professionals to monitor multiple patients simultaneously, thereby improving response time and reducing manual workload. The implementation of automated alert mechanisms ensures early detection of abnormal conditions, allowing timely medical intervention and enhancing patient safety. The system proves to be cost-effective, scalable, and suitable for deployment in both small clinics and large hospitals.

Despite its effectiveness, there is significant scope for further improvement and enhancement. Future developments can include the integration of advanced artificial intelligence and machine learning algorithms for predictive analysis, enabling early detection of critical health deterioration based on trends rather than fixed thresholds. The system can also be expanded to include additional parameters such as ECG, blood pressure, and respiratory rate for more comprehensive monitoring. Enhancing data security through encryption and secure communication protocols is another important area for improvement. Additionally, the development of a dedicated mobile application and SMS-based alert system can improve accessibility and responsiveness. Further optimization for handling large-scale hospital environments with multiple sensor nodes can enhance scalability. Overall, the proposed system lays a strong foundation for developing intelligent, automated, and patient-centric healthcare monitoring solutions in the future.

7. Acknowledgment

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