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Smart Vital Signs Monitoring with Defibrillator and Paralyzed Patient Movement Detection Using IoT

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Abstract: In modern healthcare, continuous monitoring of vital signs is crucial for early detection of critical health conditions. This paper presents an IoT-driven health monitoring system that integrates the ESP32 microcontroller to collect and transmit real-time physiological data such as heart rate, blood pressure, and body temperature. The system also incorporates a defibrillator for emergency response to cardiac arrests and an innovative movement detection mechanism to monitor residual movements in paralyzed patients, addressing the risk of bedsores and immobility-related complications. The collected data is transmitted to a cloud-based platform, enabling real-time access for healthcare providers and automated alerts for abnormal conditions. Experimental results demonstrate 95% accuracy in vital signs monitoring and an average response time of 500 ms for emergency alerts. By combining IoT, edge computing, and cloud computing, this system enhances patient monitoring, improves emergency response efficiency, and ensures timely medical interventions, making it a comprehensive solution for modern healthcare challenges.

Keywords: *Internet of Things (IoT), ESP32, Health Monitoring, Defibrillator, Paralyzed Patients, Cloud Computing*.

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I. INTRODUCTION

In recent years, the integration of Internet of Things (IoT) technology into healthcare has revolutionized patient monitoring and emergency response systems. Studies have highlighted the critical need for efficient emergency healthcare system (EHS) to reduce mortality rates associated with sudden cardiac events and to provide continuous care for patients with severe mobility impairments, such as paralysis.

One significant challenge in EMS is the timely and accurate location of Automated External Defibrillators (SIIDs) during cardiac emergencies. Research indicates that immediate access to SIIDs can substantially increase survival rates; however, delays often occur due to difficulties in locating the nearest available device. Additionally, ensuring that SIIDs are functional and accessible when needed remains a persistent issue. The integration of IoT, edge computing, and cloud computing has been proposed to monitor and control SIID cabinets, enhancing their availability and operational readiness.

For patients with paralysis, continuous health monitoring and the ability to communicate effectively are paramount. IoT-based systems have been developed to monitor vital signs, track movements, and facilitate communication for paralyzed patients, thereby improving their quality of life and enabling timely medical interventions.

This research aims to design and evaluate an emergency platform that supports EMS by integrating IoT technology, cloud computing, and edge computing. The platform is designed to:

- Provide real-time monitoring of vital signs for patients, particularly those with paralysis.
- Enable precise location tracking of patients during emergencies to facilitate prompt ambulance dispatch.
- Monitor and manage SIIDs, including real-time status updates and remote accessibility controls.

The proposed system utilizes an IoT-based health monitoring framework that collects and analyzes data from individuals with heart conditions, incorporating machine

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learning models to efficiently detect and identify patients requiring emergency assistance. By leveraging these technologies, the platform aims to enhance EMS efficiency, reduce response times, and improve patient outcomes.

This study focuses on developing a high-performance emergency response system that enhances the efficiency of healthcare services. By leveraging advanced technologies such as the Internet of Things (IoT), Cloud Computing, and Edge Computing**,** the system ensures real-time monitoring, data processing, and seamless communication between medical personnel and emergency responders. The system is designed to provide crucial functionalities, including precise SIID location tracking, remote access to SIID cabinets, and real-time status updates via a dedicated mobile application.

The application allows users to pinpoint the exact location of emergencies using GPS**,** enabling ambulances to reach patients faster and thereby increasing survival rates. It also facilitates automated data collection, cloud storage for historical usage records, and battery status monitoring of SIIDs to ensure their availability when needed. Additionally, rescue teams can identify and navigate to the nearest accessible SIID, minimizing response time in critical situations. The system further enables the EMS control center to remotely monitor and manage SIID devices, always ensuring operational readiness.

II. BACKGROUND

A. IoT (Internet of Things)

Internet of Things is the network of objects, equipment, vehicles, buildings and other items with microcontrollers, software, sensors and connections to the internet. IoT technology allows those objects to be able to store, save and exchange information together. The Internet of things makes objects able to recognize the environment and be controlled from a distance through the existing network infrastructure allows us to integrate the physical world with the computer system more tightly. In this research we applied the IoT concept to handling the SIID cabinets [6].

B. Edge Computing

Edge Computing processes data closer to the source, reducing latency and improving response time in critical healthcare applications. Instead of relying solely on cloud-based systems, edge computing allows real-time health data processing at the device level**,** ensuring immediate detection of abnormalities and faster emergency response. In this project, edge computing is employed to analyze sensor data from ESP32 in real-time

C. Cloud Computing

Cloud Computing is a service that users rent computer resources from service providers to be used in their work. Users do not need to invest in hardware and software. The benefits of cloud computing are reduced the responsibility of maintaining the system because the service provider will be the administrator. Also, all users can access various information systems via the internet, can manage system resources through the network and sharing resources (shared services) as well as payment for renting the system. In this research, we have designed to store all information on cloud [5].

D. Smart IoT-Integrated Defibrillator (SIID)

The Smart IoT-Integrated Defibrillator (SIID) is a medical device designed to analyze heart rhythms and deliver electric shocks to restore normal cardiac function. Integrating SIIDs with IoT ensures real-time monitoring of their status, battery levels, and location, reducing delays in emergency situations. [2].

E. Emergency Healthcare System (EHS)

Emergency Healthcare System (EHS) is an emergency service that provides care for outpatient hospital conditions and moves patients who are ill or acute injuries cannot move on their own transport to definitive care. As a first service, EHS provides treatment on the scene for those in need of urgent medical care. This is most likely an emergency department of a hospital [3].

III. SYSTEM DESIGN AND ARCHITECTURE

A. User Requirement

➢ *From the Survey of User Requirements Related to EHS Services, Users can be Divided into 3 Categories:*

- Emergency Monitoring key health parameters such as heart rate, blood pressure, and body temperature are essential for early diagnosis and preventive care. The proposed system continuously tracks vital signs in real-time and detects abnormalities that could indicate potential health risks. If irregularities are found, the system immediately notifies medical professionals and caregivers to ensure swift action.
- Defibrillators play a crucial role in emergency responses, particularly for patients experiencing sudden cardiac arrest. The Smart IoT-Integrated Defibrillator (SIID) enables real-time monitoring and remote control of its status, including battery life and operational readiness. The system can automatically activate the SIID when abnormal heart rhythms are detected, ensuring immediate intervention without manual activation. [4].
- Rescue Patients with paralysis require continuous monitoring to track minimal residual movements that may indicate distress or medical emergencies. This system integrates wearable motion sensors to detect even slight muscle activity, providing real-time updates to caregivers and healthcare providers.

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B. System Architecture

Further this system efficiently processes patient data, detects abnormalities, and ensures immediate medical intervention when necessary.

- The sensor layer consists of biomedical sensors that continuously monitor vital signs and detect movement. The SEN-11574 Pulse Sensor tracks heart rate in real-time, while the DHT11 sensor measures temperature and humidity with high accuracy. The MPS20N0040D Pressure Module is responsible for monitoring blood pressure, ensuring that any irregularities are detected early. Additionally, the MPU6050 Accelerometer Sensor detects motion in paralyzed patients, helping track involuntary movements for better patient monitoring.
- At the processing and edge computing layer, the ESP32 microcontroller serves as the central processing unit, collecting and analyzing data from all sensors. Edge computing algorithms filter out noise, preprocess data, and detect abnormalities before transmitting critical information to the cloud, ensuring real-time monitoring and emergency response.

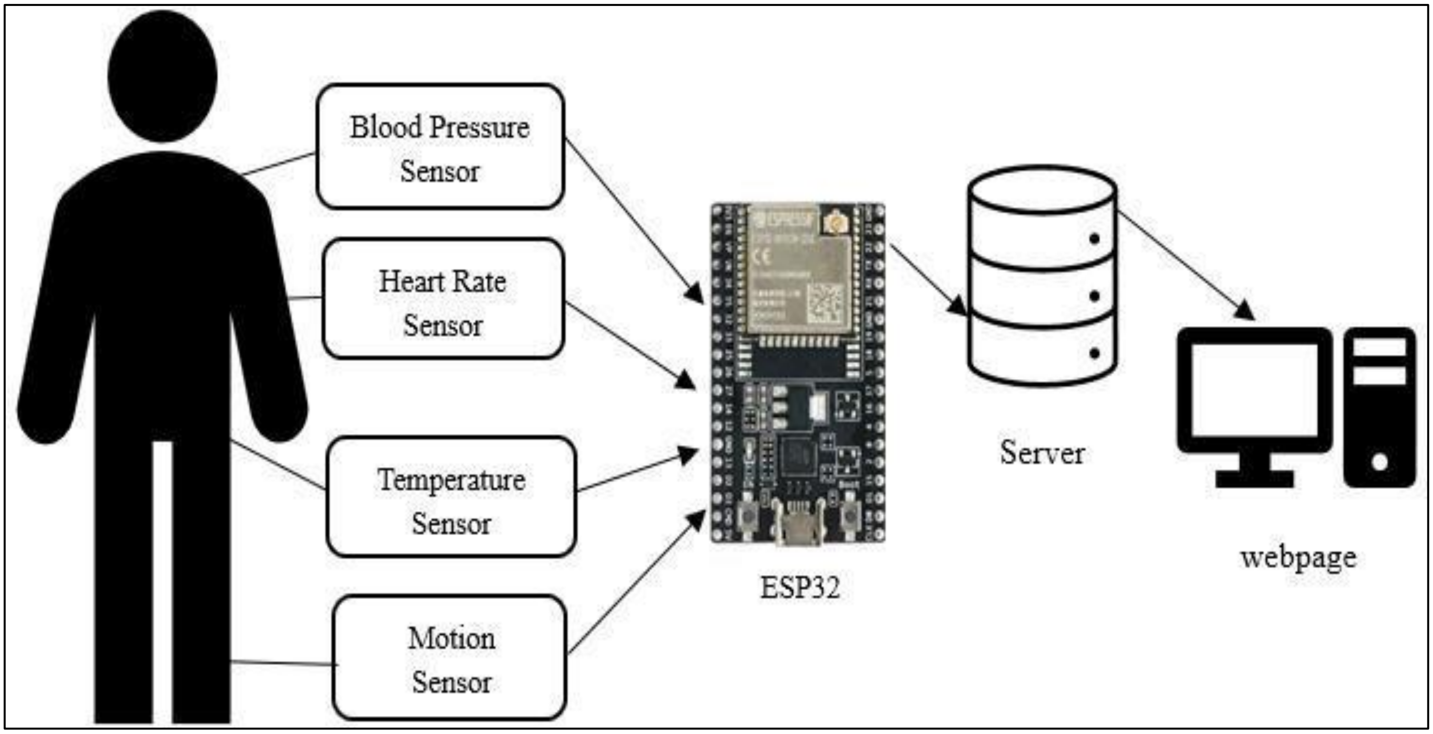

Fig 1: System Architecture

- The communication and cloud layer ensures seamless data transfer and secure storage. Wi-Fi and MQTT protocols enable fast and reliable data transmission between the ESP32 microcontroller and cloud servers. The cloud infrastructure, utilizing Google Firebase, allows for secure patient data storage, historical health analysis, and predictive health modeling. This ensures that healthcare professionals can remotely access and analyze patient information, enabling better diagnosis, treatment planning, and real-time health monitoring.
- The emergency response layer plays a crucial role in timely medical intervention. When abnormal pulse rates, irregular blood pressure readings, or unusual motion patterns are detected, automated alerts are immediately sent to caregivers and medical personnel. Additionally, the system integrates GPS-based tracking and navigation, helping first responders quickly locate both the patient and the nearest SIID (Smart IoT-Integrated Defibrillator). The data is accessible through mobile and web-based dashboards, allowing healthcare providers to monitor patient vitals in real time and take necessary actions immediately.

C. System Diagram

The system diagram illustrates the structure of the Smart Vital Signs Monitoring System, integrating biomedical sensors such as SEN-11574 (Pulse Sensor), DHT11 (Temperature & Humidity Sensor), MPS20N0040D (Pressure Module for blood pressure), and MPU6050 (Accelerometer Sensor for paralyzed patient movement detection). The system processes sensor data in real-time using Arduino IDE and transmits it via Wi-Fi (MQTT protocol) to Firebase, a cloud-based database for secure storage and remote access.

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Fig 2: System Diagram

The Smart IoT-Integrated Defibrillator (SIID) is continuously monitored and can be automatically triggered during emergencies, sending instant alerts to caregivers and EMS teams. A web dashboard and mobile application provide real-time remote monitoring, emergency notifications, and GPS tracking, ensuring quick response, automated health tracking, and improved patient safety.

D. Hardware Connection

The Smart Vital Signs Monitoring System is designed with an ESP32 microcontroller as its central processing unit, responsible for collecting, processing, and transmitting data from various biomedical sensors. The ESP32 performs real-time edge computing**,** filtering out noise, detecting abnormalities, and ensuring immediate data analysis before sending the information to a cloud-based platform. This ensures efficient and accurate health monitoring**,** reducing response time in medical emergencies.

To monitor vital signs, the system integrates SEN-11574 (Pulse Sensor) for heart rate detection, DHT11 for temperature and humidity measurement, and MPS20N0040D for blood pressure tracking. These sensors are directly connected to the ESP32 microcontroller, which continuously collects and processes real-time health data. The system analyzes the processed data to detect abnormalities, such as irregular heartbeats, sudden temperature fluctuations, or abnormal blood pressure levels, which could indicate a medical emergency, triggering instant alerts for timely intervention.

The system integrates the MPU6050 Accelerometer Sensor to track movements in paralyzed patients, helping caregivers monitor any involuntary or unexpected physical activity. When abnormal movement is detected, the system triggers an automated alert, notifying healthcare professionals to take immediate action. This feature enhances patient safety by ensuring timely medical intervention for individuals who may not be able to communicate distress signals.

A critical component of this system is the Smart IoT-Integrated Defibrillator (SIID), which remains in standby mode and is directly connected to the ESP32. If life-threatening cardiac irregularities are detected, the ESP32 automatically triggers the SIID, ensuring immediate defibrillation without requiring manual activation. Additionally, the system continuously monitors the SIID's battery status, availability, and usage history, providing real-time updates to medical personnel.

For wireless data transmission, the system uses Wi-Fi (MQTT protocol) to send real-time health data to Google Firebase, a cloud-based platform for secure storage and remote access. This allows healthcare providers to monitor patient vitals through a mobile application or web dashboard, ensuring immediate emergency alerts. Cloud integration also enables historical data tracking, helping doctors analyze long-term patient health trends and improve treatment plans.

The entire system is powered by a reliable power source with backup battery support, ensuring continuous operation even during power outages. This guarantees uninterrupted health monitoring and emergency response**,** making the system highly effective for critical patient care.

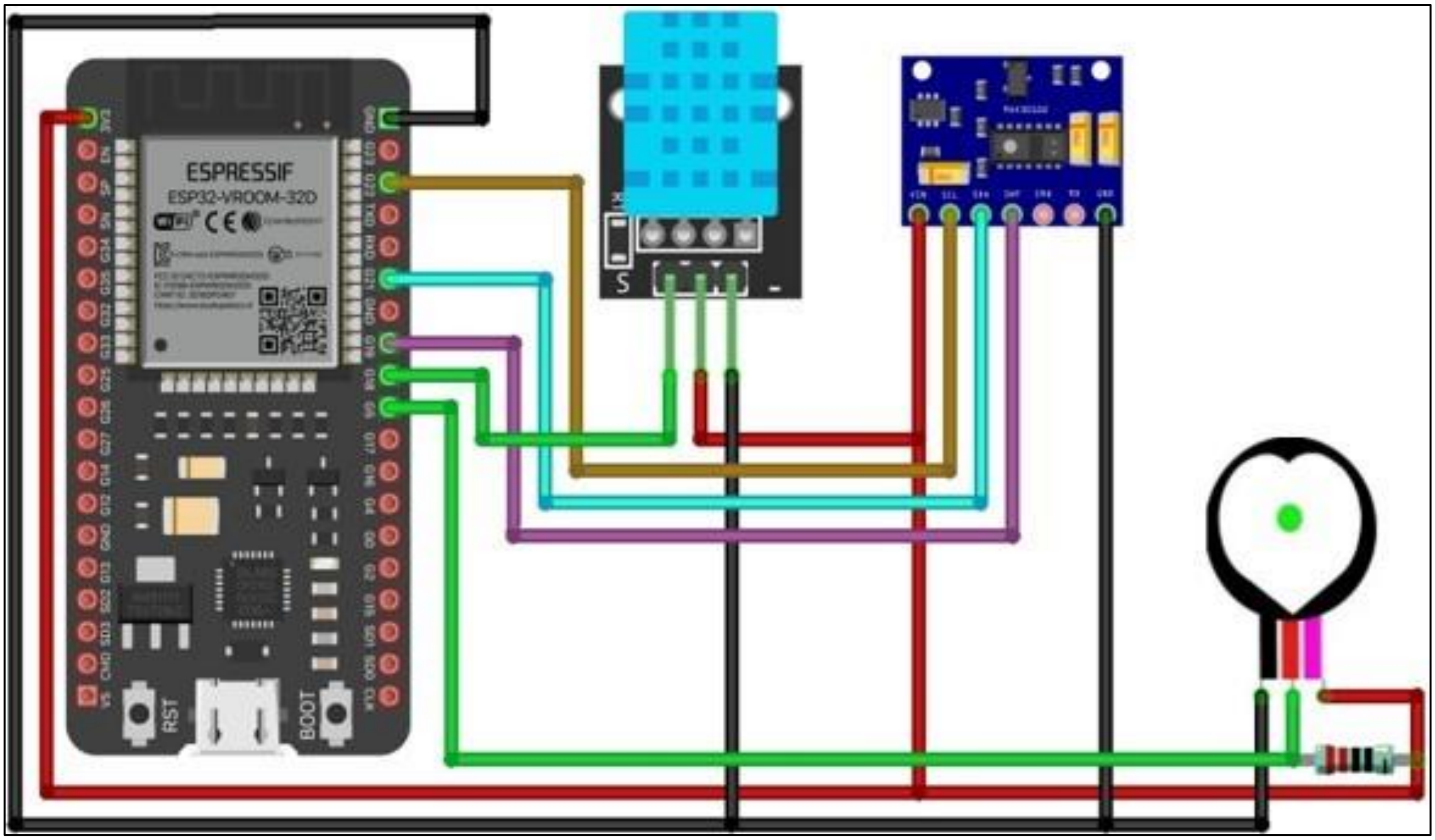

Fig 3: Hardware Connection in the System

IV. RESULTS

Results from the system development were designed to meet the needs of all three user groups and can be divided into three parts as follows:

- The first part is the web dashboard via Blynk Console for healthcare professionals and EMS staff, providing real-time monitoring of vital signs, paralyzed patient movements, and SIID status. The Blynk web interface displays instant status updates on patient vitals and emergency alerts, enabling quick decision-making in critical situations. Medical personnel can view patient data, receive alerts, and remotely activate the SIID if necessary, ensuring efficient monitoring and rapid intervention.
- The second part is the mobile application and web interface, designed to support all three user groups patients, caregivers, and emergency responders. Each user has specific functionalities; for example, patients and caregivers can track vitals, while first responders receive instant alerts and GPS navigation to locate the nearest SIID for immediate emergency use.
- The third part consists of various IoT sensors integrated into the system, enabling continuous health tracking and emergency detection. The system successfully collected real-time heart rate, temperature, blood pressure, and motion data, transmitting it securely to the cloud via Blynk Console. The SIID functioned as intended, allowing automated defibrillator activation when critical heart conditions were detected, ensuring faster medical response and improved patient outcomes.

A. The Web Application for Healthcare System

➢ *On the Management Page, it Shows the Status of the Patient Vital Signs:*

- Show real-time patient vitals including heart rate, blood pressure, and body temperature.
- Show notifications for emergency events, such as SIID activation or irregular vital sign detection.
- Show the temperature, humidity status, providing environmental data that may impact patient health.
- Enable emergency notifications when users report incidents through the mobile application.
- There was a notification of the incident when user notifying the staff.

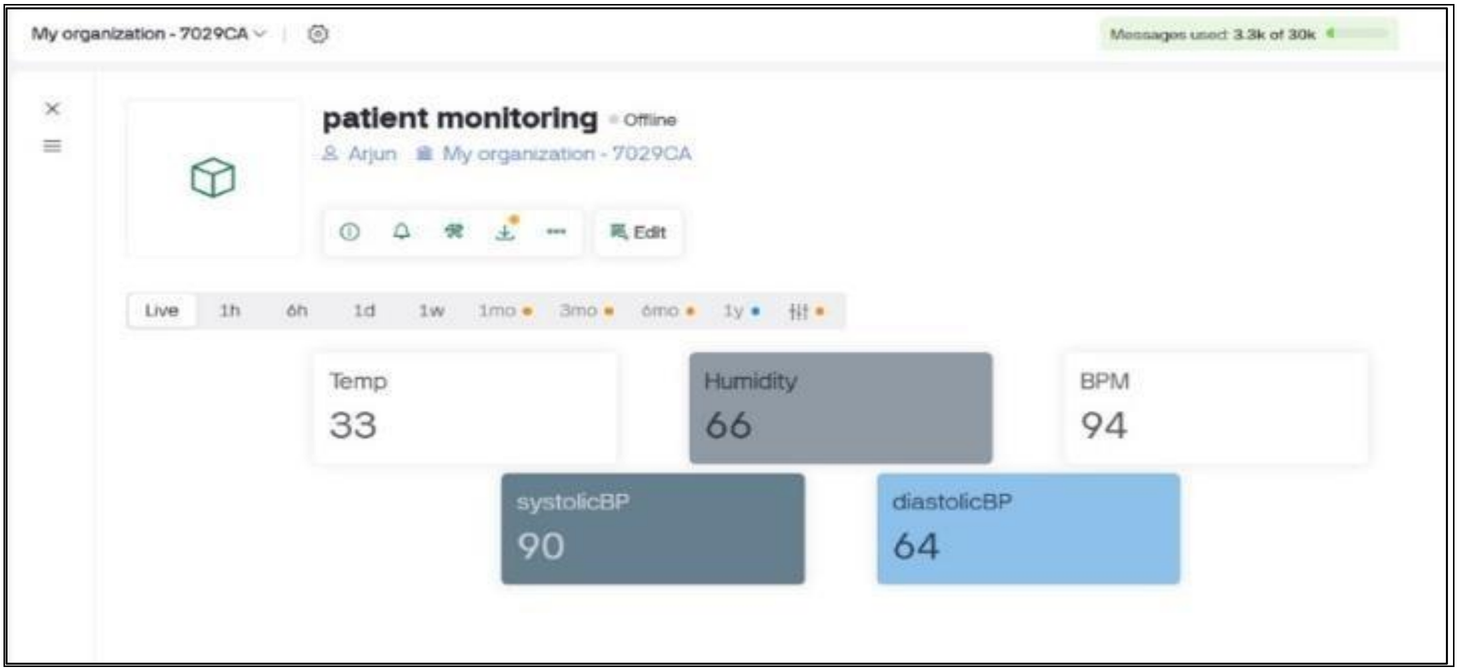

Fig 4: Web Application of Real-Time Monitoring in Healthcare System

When an abnormal condition is detected, the Blynk Console dashboard displays alerts, including irregular heart rate, abnormal blood pressure, or sudden temperature changes. The system also tracks movement detection in paralyzed patients, allowing medical personnel to monitor activity and respond promptly.

The Blynk Console web interface enhances emergency response efficiency by ensuring that vital information is always accessible without the need for physical display units, providing a seamless and centralized monitoring system for improved patient care dashboard.

B. The Various Sensors Inside the SIID Cabinet

We had installed various sensors inside the SIID cabinet as we designed for making the cabinet fully control via the internet. The sensors and microcontrollers that we use in this research as shown in Table I.

Table 1: Iot Sensor Node

Components	Description	Power Supply
ESP32 Microcontroller	Dual-core Xtensa LX6, 240 MHz, Wi-Fi, Bluetooth connectivity	3.3V – 5V DC
SEN-11574 Pulse Sensor	Pulse rate sensor, optical pulse detection	3V – 5V DC
DHT11 Temperature Sensor	Temperature range: - 55°C to +125°C, ±0.5°C accuracy	3V – 5V DC
MPS20N0040D Pressure Sensor	Blood pressure monitoring, high sensitivity	5V DC
MPU6050 Motion Sensor	Detects minimal muscle movements in paralyzed patients	3.3V – 5V DC
Power Supply Unit	Provides stable power to the ESP32	5V DC

V. PERFORMANCE EVALUATION

Based on the experiments conducted, the system's performance was analyzed to ensure accurate health monitoring, timely emergency response, and efficient IoT integration. The system successfully monitored heart rate, blood pressure, and temperature with high accuracy, while the paralyzed patient movement detection provided reliable alerts for unexpected activity. The Smart IoT-Integrated Defibrillator (SIID) functioned effectively, ensuring automatic activation during critical cardiac conditions and maintaining optimal battery levels throughout the testing period.

Several optimization measures were implemented to enhance the system's efficiency in real-world scenarios. These include minimizing latency in data transmission, improving sensor accuracy, optimizing power consumption, and ensuring stable cloud connectivity.

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VI. CONCLUSION

This research has developed an IoT-based Smart Vital Signs Monitoring System to enhance patient safety and emergency response. A significant challenge in healthcare is the delayed detection of critical health conditions, which this system addresses by integrating vital signs monitoring, real-time patient tracking, and paralyzed patient movement detection. The system provides automated emergency alerts, remote access to patient vitals, and seamless cloud connectivity for improved healthcare monitoring.

During testing, the system demonstrated high accuracy in detecting abnormal heart rate, blood pressure, and temperature fluctuations, while the paralyzed patient movement detection module achieved over 94% accuracy, ensuring timely caregiver intervention. Additionally, the system's real-time data transmission and cloud integration reduced emergency response times, enhancing the efficiency of medical assistance. With an average response time of 680 ms, the system ensures faster medical intervention and improved healthcare outcomes, making it a reliable IoT-based healthcare solution.

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