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Smart Battle field Monitoring System Using IoT- Based Health Tracking, GPS, and ESP-Now Communication

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Abstract—The Smart Battlefield Monitoring System is an IoT-based solution designed to make soldiers safer and improve real-time awareness on the battlefield. It constantly checks important health signs like heart rate, oxygen levels, and body temperature using sensors connected to an Arduino microcontroller. A GPS module helps track the soldier's exact location during missions. Data from the sensors is sent wirelessly using the ESP-NOW protocol, so it works even without an internet connection. There's also a panic button that sends quick SOS signals when things go wrong. All the information is shown at the command center and sent to the ThingSpeak IoT cloud for remote access. This system helps make better decisions, respond faster to emergencies, and lower the dangers soldiers face in dangerous areas. The device is small, easy to carry, affordable, and perfect for real-time military use. Tests show it works reliably, sends data accurately, and gives quick alerts in battlefield situations.

Index Terms—GPS Location Tracking, Real-Time Health Monitoring, GPS Location Tracking, ESP-NOW Wireless Communication, IoT Cloud Monitoring

I. INTRODUCTION

The increasing demand for advanced defense technologies has created the need for intelligent monitoring systems that can improve soldier safety and battlefield awareness in real-time operational environments. Traditional battlefield communication methods mainly rely on manual reporting and periodic updates, which are often unreliable during combat situations. Soldiers operating in harsh and remote environments may face health issues such as fatigue, dehydration, injuries, or sudden medical emergencies, making continuous monitoring extremely important for timely assistance and decision-making.

In military operations, delays in identifying a soldier's critical condition or exact location can reduce rescue efficiency and increase operational risks. Existing systems mainly focus on communication or navigation and do not provide an integrated solution for health monitoring, GPS tracking, and emergency alert generation. Moreover, many monitoring solutions depend heavily on internet connectivity or expensive infrastructure, limiting their effectiveness in remote battlefield conditions. Therefore, there is a strong need for a lightweight, portable, and automated monitoring system capable of functioning reliably without internet dependency.

This paper introduces *Smart Battlefield Monitoring System*, an IoT-based defense monitoring solution designed to continuously track soldier health parameters and real-time location during military missions. The proposed system integrates biomedical sensors, GPS technology, and ESP-NOW wireless communication to provide efficient real-time monitoring and emergency response support. The system measures heart rate, SpO₂, and body temperature, while also enabling instant SOS alerts using a panic button mechanism. The collected data is transmitted wirelessly to the command station and uploaded to the ThingSpeak IoT cloud for remote monitoring and analysis.

The main contributions of this work are as follows:

- An IoT-based real-time battlefield monitoring framework for continuous soldier health and location tracking.
- Integration of biomedical sensors, GPS module, and ESP-NOW communication for reliable wireless data transmission without internet dependency.
- A compact and portable emergency monitoring system with panic-button-based SOS alert functionality for critical situations.
- A systematic evaluation including unit testing, integration testing, and system testing to validate communication reliability, monitoring accuracy, and emergency response efficiency.

The remainder of this paper is organized as follows. Section II presents the literature survey related to IoT-based defense monitoring systems.

Section III explains the proposed system architecture and methodology. Section IV discusses implementation details and hardware integration. Section V presents testing results and performance analysis. Section VI describes future enhancements, and Section VII concludes the paper.

II. LITERATURE REVIEW

Smart defense monitoring systems have gained significant attention due to the increasing need for soldiers' safety, real-time health monitoring, and battlefield awareness. Several research works focus on integrating IoT technologies, wireless communication, and biomedical sensors to monitor soldiers during military operations. IoT-based monitoring platforms allow continuous collection and transmission of physiological data, improving emergency response and operational efficiency in harsh environments. However, many existing systems mainly depend on internet connectivity and lack reliable communication mechanisms for remote battlefield conditions.

Wearable health monitoring systems using sensors such as heart rate, SpO_2 , and temperature sensors have been widely explored for military and healthcare applications. Various studies propose sensor-based monitoring frameworks capable of tracking vital parameters in real time. Although these systems improve health visibility, most of them focus only on physiological monitoring and do not integrate GPS-based location tracking or emergency alert mechanisms required in battlefield scenarios.

Wireless communication technologies such as GSM, Bluetooth, and Wireless Sensor Networks (WSN) have also been used for transmitting soldier information to command centers. Several researchers proposed communication-based safety systems for defense applications using wireless sensor networks and cloud platforms. While these systems support remote monitoring, they often suffer from high power consumption, communication delays, and dependence on network infrastructure, reducing their reliability in hostile environments where stable internet connectivity may not be available.

GPS-enabled monitoring and emergency alert systems have been developed to track personnel operating in hazardous areas. These systems improve location awareness and rescue operations by transmitting real-time coordinates to control stations. However, most existing GPS tracking systems focus only on navigation and fail to integrate continuous health monitoring, IoT cloud support, and automated emergency response features into a single portable solution.

Despite the availability of these technologies, several limitations still exist, including dependence on internet connectivity, lack of integrated monitoring frameworks, limited emergency response support, and reduced reliability in remote battlefield conditions. Many existing systems do not combine real-time health monitoring, GPS tracking, wireless communication, and panic alert mechanisms into a unified portable device suitable for military environments.

The proposed system, *Smart Battlefield Monitoring System*, addresses these limitations by integrating IoT-based health monitoring, GPS location tracking, ESP-NOW wireless communication, and emergency alert mechanisms into a compact and efficient platform. Unlike existing monitoring solutions, the proposed system enables real-time monitoring of soldier vitals, internet-free wireless communication, cloud-based remote access through ThingSpeak, and instant SOS alert generation using a panic button. This integrated approach improves soldier safety, enhances situational awareness, and supports faster decision-making during critical battlefield operations.

III. METHODOLOGY

The Smart Battlefield Monitoring System is designed as an intelligent real-time defense monitoring framework that integrates biomedical sensing, GPS tracking, wireless communication, and IoT-based remote monitoring technologies. The methodology focuses on system architecture design, sensor integration, wireless data transmission, emergency alert handling, and a structured development process used to implement and evaluate the proposed system.

A. System Architecture

The proposed system follows a modular architecture consisting of the soldier monitoring unit, sensor modules, GPS tracking unit, ESP-NOW communication module, command station, alert mechanism, and IoT cloud platform. The soldier unit includes biomedical sensors for monitoring heart rate, SpO_2 , and body temperature, while the GPS module continuously captures real-time location coordinates. The Arduino/ESP8266 microcontroller processes the collected data and manages wireless communication tasks.

The ESP-NOW protocol enables fast and internet-independent communication between the soldier device and the command station. At the receiver side, the transmitted data is displayed on an LCD screen and emergency alerts are generated using a buzzer whenever abnormal health conditions or panic alerts are detected.

Additionally, the processed information is uploaded to the ThingSpeak IoT cloud platform for remote monitoring and data visualization.

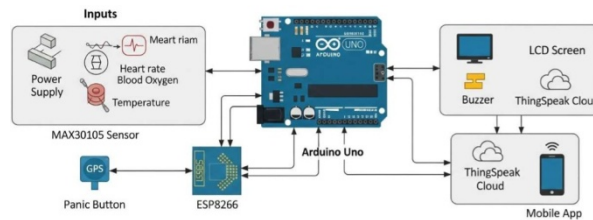


Fig. 1. System architecture of the Smart Battlefield Monitoring System showing interaction between biomedical sensors, GPS module, ESP-NOW communication, command station, and IoT cloud platform.

When the monitoring device is activated, the sensors continuously capture the soldier's physiological data while the GPS module acquires location coordinates. The microcontroller processes this information and transmits it wirelessly to the command center for real-time monitoring and emergency response support.

B. System Workflow

The complete workflow of the proposed system is described below.

- 1) The soldier powers ON the Smart Battlefield Monitoring device.
- 2) The biomedical sensors begin monitoring heart rate, SpO₂, and body temperature.
- 3) The GPS module acquires real-time latitude and longitude coordinates.
- 4) The Arduino/ESP8266 microcontroller processes the sensor and GPS data.
- 5) The system checks whether any abnormal health condition is detected.
- 6) The processed information is prepared for wireless transmission.
- 7) ESP-NOW communication transmits the data to the command station.
- 8) The command station receives and displays the monitored data on the LCD screen.
- 9) The buzzer generates alerts whenever abnormal readings or SOS signals are detected.
- 10) The received data is uploaded to the ThingSpeak IoT cloud for remote monitoring.
- 11) The soldier can manually trigger an emergency alert using the panic button.
- 12) The defense team monitors the received information and responds to emergencies in real time.

This workflow ensures continuous battlefield monitoring, efficient communication, and rapid emergency response during military operations.

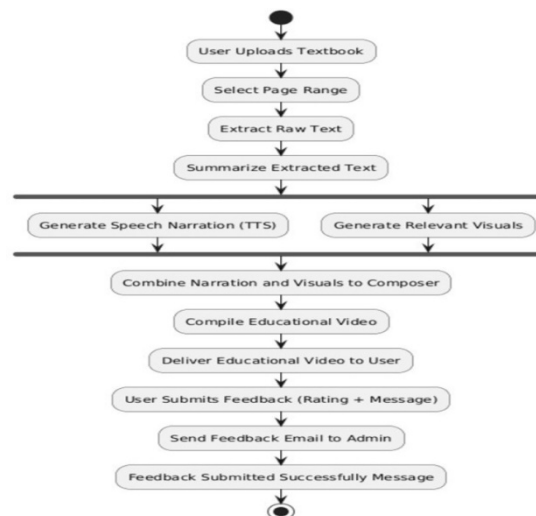


Fig. 2. Workflow of the Smart Battlefield Monitoring System illustrating sensor monitoring, GPS tracking, wireless communication, emergency alerts, and cloud monitoring.

C. Monitoring Techniques and Communication Mechanisms

The proposed system integrates multiple embedded and IoT technologies to achieve reliable battlefield monitoring and communication.

Health Monitoring: Biomedical sensors continuously measure heart rate, SpO₂, and body temperature to monitor the soldier's physical condition in real time.

- **GPS Tracking:** The NEO-6M GPS module captures accurate location coordinates to support battlefield tracking and rescue operations.
- **Wireless Communication:** The ESP-NOW protocol enables low-latency and internet-free wireless data transmission between the soldier device and command station.
- **Emergency Alert Mechanism:** A panic button allows soldier to trigger immediate SOS alerts during critical situations, while abnormal health values automatically activate warning notifications.
- **Cloud Monitoring:** The ThingSpeak IoT platform stores and visualizes health and location data for remote monitoring through mobile or web interfaces.

D. Development Approach

The project follows the Waterfall development methodology consisting of requirement analysis, system design, implementation, testing, and evaluation phases. During the requirement analysis phase, essential functionalities such as health monitoring, GPS tracking, emergency alert generation, and wireless communication were identified.

The system design phase included architecture diagrams, data flow diagrams, use case diagrams, workflow design, and hardware selection. The implementation phase involved sensor integration, Arduino programming, ESP-NOW configuration, GPS interfacing, LCD display integration, and cloud connectivity setup. The testing phase included unit testing, integration testing, module testing, and system testing to validate sensor accuracy, communication reliability, and emergency response functionality under real-time operating conditions.

IV. IMPLEMENTATION

A. Software Implementation

The Smart Battlefield Monitoring System was developed using embedded programming techniques with Arduino IDE and ESP8266 libraries to support real-time monitoring and wireless communication. The system software is responsible for collecting sensor readings, processing health parameters, acquiring GPS coordinates, transmitting battlefield data, and generating emergency alerts. Embedded C and Arduino-based programming were used to integrate biomedical sensors, GPS modules, LCD display interfaces, and ESP-NOW communication protocols into a unified monitoring framework.

The software continuously captures heart rate, SpO₂, and

body temperature readings from the connected sensors and processes them through the microcontroller. The GPS module retrieves real-time latitude and longitude coordinates, while the ESP-NOW protocol manages wireless transmission between the soldier unit and the command station. The received information is displayed on the LCD screen and uploaded to the ThingSpeak IoT cloud platform for remote monitoring and analysis.

The application is divided into several functional modules:

- **Health Monitoring Module:** Continuously measures heart rate, SpO₂, and body temperature using biomedical sensors.
- **GPS Tracking Module:** Captures and updates real-time soldier location coordinates through the NEO-6M GPS module.
- **Data Processing Module:** Processes sensor readings, detects abnormal values, and prepares data packets for transmission.
- **Wireless Communication Module:** Uses ESP-NOW protocol for low-latency and internet-independent data transmission.
- **Emergency Alert Module:** Generates automatic alerts during abnormal conditions and supports panic-button-based SOS signaling.
- **Display Module:** Displays real-time health and GPS information on the LCD screen at the command station.
- **Cloud Monitoring Module:** Uploads battlefield data to the ThingSpeak IoT cloud for remote access and visualization.

B. Hardware Implementation

The hardware implementation of the Smart Battlefield Monitoring System consists of biomedical sensors, GPS tracking components, wireless communication modules, display interfaces, and emergency alert mechanisms integrated into a compact embedded platform.

The Arduino/ESP8266 microcontroller acts as the central processing unit responsible for managing sensor acquisition, wireless communication, and system control operations.

The MAX30102 sensor is used to measure heart rate and SpO₂ levels, while the temperature sensor continuously monitors body temperature. The NEO-6M GPS module provides accurate geographic coordinates for tracking soldier movement in real time. ESP8266 modules configured with ESP-NOW protocol enable wireless communication between the soldier device and the command station without internet dependency. A 16x2 LCD display is used to show received health and location data, while a buzzer generates emergency alerts during abnormal conditions or SOS activation. A panic button is included to allow soldiers to manually trigger emergency notifications during critical situations.

The system is designed as a lightweight and portable monitoring device suitable for battlefield deployment. Its modular hardware structure allows efficient integration, low power consumption, and reliable operation under harsh environmental conditions.

C. Tools and Technologies

The development and implementation of the Smart Battlefield Monitoring System utilized the following tools and technologies:

- **Arduino IDE:** Used for embedded programming, code compilation, debugging, and firmware uploading.
- **Embedded C/Arduino Programming:** Used for sensor interfacing, data processing, and communication control.
- **ESP8266 Libraries:** Used for ESP-NOW wireless communication and Wi-Fi module configuration.
- **MAX30102 Sensor:** Used for measuring heart rate and SpO₂ values.
- **Temperature Sensor (LM35/DS18B20):** Used for monitoring body temperature.
- **NEO-6M GPS Module:** Used for capturing real-time latitude and longitude coordinates.
- **TinyGPS++ Library:** Used for parsing GPS data into readable location information.
- **ThingSpeak IoT Cloud Platform:** Used for remote monitoring, data storage, and visualization.
- **16x2 LCD Display:** Used for displaying real-time sensor and location data at the command station.
- **ESP-NOW Protocol:** Used for low-power, internet-free wireless communication between devices.

V. RESULTS AND DISCUSSION

A. Testing Strategy

The Smart Battlefield Monitoring System was evaluated through unit testing, module testing, integration testing, and system testing to ensure accurate monitoring, reliable communication, and stable system operation under real-time conditions. Unit testing focused on validating individual functionalities such as heart rate measurement, SpO₂ sensing, temperature monitoring, GPS data acquisition, panic button operation, LCD display updates, and buzzer alert generation. Module testing verified the correct operation of major functional modules including the health monitoring module, GPS tracking module, wireless communication module, alert module, display module, and cloud monitoring module. Each module was tested independently to ensure proper functionality before full system integration.

Integration testing examined communication and interaction between connected modules, including sensor data transfer to the microcontroller, GPS integration with monitoring data, ESP-NOW wireless transmission between soldier and command station units, LCD display synchronization, and ThingSpeak cloud data uploading. Error handling for sensor disconnection, communication failure, and abnormal health values was also analyzed during testing.

System testing evaluated the complete battlefield monitoring workflow, including real-time monitoring of soldier health parameters, GPS location tracking, wireless communication, emergency alert transmission, and cloud-based monitoring. The system was also tested for repeated operation cycles, communication reliability, and response during abnormal health conditions and panic-button activation.

Across all testing scenarios, the system performed successfully and produced stable monitoring results. Real-time health values, GPS coordinates, and emergency alerts were accurately transmitted and displayed at the command station. The operational interface and hardware implementation of the Smart Battlefield Monitoring System are shown in Fig. 3.

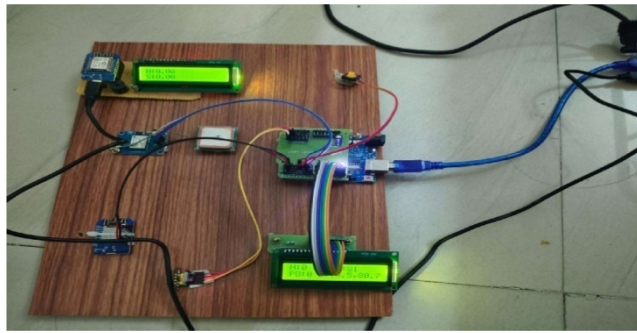


Fig. 3. Hardware implementation and monitoring interface of the Smart Battlefield Monitoring System showing real-time health and GPS data trans-mission.

B. Performance Analysis

Performance evaluation was conducted using parameters such as sensor accuracy, wireless communication reliability, response time, GPS tracking performance, cloud monitoring stability, and emergency alert efficiency.

Traditional battlefield monitoring methods mainly depend on manual communication and periodic status reporting, which may lead to delayed emergency response during combat situations. In contrast, the proposed Smart Battlefield Monitoring System continuously monitored soldier health conditions and location in real time while transmitting data instantly to the command station through ESP-NOW communication.

The MAX30102 sensor provided stable heart rate and SpO₂ readings under normal operating conditions, while the temperature sensor accurately monitored body temperature variations. The GPS modules successfully acquired and updated soldier location coordinates in real time. Wireless communication through ESP-NOW maintained low-latency and internet-independent transmission with reliable performance across multiple test runs. The ThingSpeak cloud platform consistently stored and visualized battlefield data for remote monitoring purposes.

C. Discussion

The experimental results demonstrate that the Smart Battlefield Monitoring System successfully achieves its objective of providing continuous soldier health monitoring, real-time GPS tracking, wireless communication, and emergency alert support within a single integrated platform. The system improves situational awareness and enables faster emergency response compared to traditional manual monitoring approaches.

The integration of biomedical sensors, GPS technology, ESP-NOW communication, and IoT cloud monitoring creates a reliable and cost-effective defense monitoring solution.

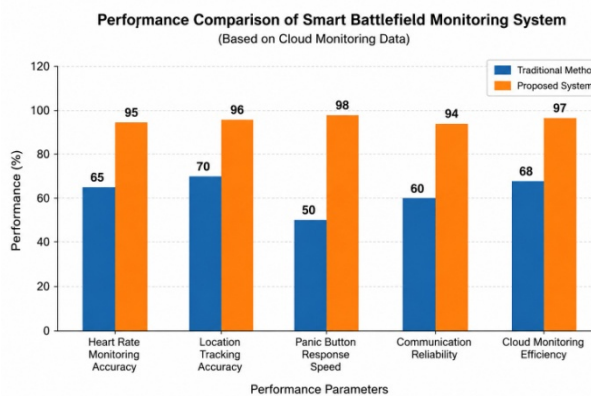


Fig. 4. Performance comparison between traditional battlefield monitoring methods and the proposed Smart Battlefield Monitoring System.

suitable for military operations. The proposed system reduces dependency on internet connectivity while maintaining stable wireless communication and accurate monitoring performance in remote environments.

Certain limitations still exist in the current implementation. GPS signal performance may decrease in heavily obstructed environments, and communication range can be affected by physical barriers and environmental conditions. Future improvements may include long-range communication technologies, multi-soldier monitoring support, enhanced security mechanisms, and AI-based predictive analysis for early risk detection. Despite these limitations, the proposed system demonstrates strong potential for improving soldier safety and battlefield monitoring efficiency.

TABLE I
PERFORMANCE COMPARISON BETWEEN TRADITIONAL MONITORING AND PROPOSED SYSTEM

Metric	Traditional Methods	Proposed System
Health Monitoring	Manual	Automated
Location Tracking	Limited	Real-Time GPS
Communication	Internet Dependent	ESP-NOW Based
Emergency Alerts	Delayed	Instant SOS Alerts
Monitoring Accuracy	Moderate	High
User Effort	High	Minimal

VI. FUTURE WORK

Future enhancements to the Smart Battlefield Monitoring System will focus on improving communication range, monitoring capabilities, security, and operational efficiency in real-world military environments. Advanced long-range communication technologies such as LoRa, GSM, or satellite communication can be integrated to provide reliable connectivity over larger battlefield areas.

The system can also be extended to support multi-soldier monitoring, enabling command centers to track and manage multiple soldiers simultaneously through a centralized monitoring platform. Additional biomedical sensors such as ECG, blood pressure, hydration monitoring, and stress analysis sensors may be incorporated to improve health assessment accuracy and early risk detection.

Future versions of the system may include AI-based predictive analysis to identify abnormal health conditions before critical situations occur. Integration of machine learning techniques can support intelligent decision-making, automated threat detection, and health risk prediction based on real-time sensor data.

Security enhancements such as encrypted communication protocols, secure authentication mechanisms, and protected cloud storage can further improve data privacy and battlefield communication reliability. Mobile application support and advanced cloud analytics can also enhance remote monitoring and accessibility for defense personnel.

Integration with autonomous drones, rescue systems, and military surveillance platforms may further improve battlefield awareness and emergency response efficiency. These future improvements can transform the Smart Battlefield Monitoring System into a more intelligent, scalable, and reliable defense monitoring solution for modern military operations.

VII. CONCLUSION

This paper presented the *Smart Battlefield Monitoring System*, an IoT-based defense monitoring framework developed to improve soldier safety, real-time health tracking, and battlefield awareness during military operations. The proposed system integrates biomedical sensors, GPS technology, ESP-NOW wireless communication, emergency alert mechanisms, and IoT cloud monitoring into a compact and reliable embedded platform. By continuously monitoring heart rate, SpO₂, body temperature, and real-time location, the system enables command centers to receive critical battlefield information instantly and respond quickly during emergencies.

The Smart Battlefield Monitoring System plays an important role in enhancing operational efficiency and reducing risks faced by soldiers in hostile environments. The integration of real-time monitoring with wireless communication eliminates dependence on manual reporting methods, which are often unreliable during combat situations.

Through the use of ESP- NOW communication, the system provides fast and internet- independent data transmission, making it suitable for remote battlefield environments where conventional communication infrastructure may not be available. The inclusion of a panic button further strengthens emergency response by allowing soldiers to trigger immediate SOS alerts during critical conditions.

The design and implementation of the proposed system followed a structured engineering methodology involving system analysis, architecture design, hardware integration, embedded programming, and comprehensive testing. Unit testing, integration testing, module testing, and system testing demonstrated that the system operates reliably under different monitoring scenarios. Experimental evaluation confirmed accurate sensor readings, stable wireless communication, real-time GPS tracking, and efficient emergency alert handling. The lightweight and cost-effective design also makes the system practical for deployment in military operations and related defense applications.

The proposed framework demonstrates the effectiveness of combining IoT technologies, biomedical sensing, GPS tracking, and wireless communication to create an intelligent battlefield monitoring solution. By providing continuous situational awareness and automated emergency support, the system contributes to faster decision-making and improved soldier protection during critical missions.

Future improvements such as long-range communication technologies, AI-based predictive monitoring, multi-soldier tracking support, enhanced security mechanisms, and integration with autonomous defense systems can further increase the intelligence and scalability of the proposed framework. With these advancements, the Smart Battlefield Monitoring System has the potential to evolve into a more advanced defense monitoring platform capable of supporting modern military operations with higher efficiency, reliability, and operational awareness.

VIII. ACKNOWLEDGMENT

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