STM JOURNALS

Journal of
Microcontroller Engineering and Applications

ISSN: 2455-197X
Volume 13, Issue 2, 2026
May—August
DOI (Journal): 10.37591/JoMEA

https://journals.stmjournals.com/jomea

Review JoMEA

Border Security Alert for Soldiers

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Abstract

Secure a nation by protecting its people and the country's borders. Soldiers guarding remote and hostile areas of the border experience very difficult situations when confronted with the possibility of arms and/or people crossing the border without permission and environmental conditions or obstacles that can impede communication. The proposed project titled, "Border Security Alert for Soldiers", is an attempt to assist soldiers in their border surveillance efforts by using an intelligent Internet of Things (IoT) border security alert system capable of providing real time alerts to both the soldiers and the control centre The system will use a network of sensors (PIR, ultrasonic, temperature) to detect if a person has entered an area and/or tried to cross the border illegally as well as identify if there are any abnormal environmental conditions (e.g. rising temperatures) within the borders. If any suspicious activity occurs, the system will automatically send an alert signal to the affected soldiers and the command centre via wireless communication technologies (e.g. RF, GSM, IoT (Wi-Fi/LoRa)) indicating that an unusual event has occurred. In addition, M8N GPS devices will be employed to provide the exact coordinates of the location where the incident occurred and facilitate quick response and coordination efforts. AI threat classification, camera integration, and solar-powered sensors can also be integrated into this system in order to provide continued functionality in remote locations.

Keywords: Border security, PS tracking, GSM communication, ESP32, IoT, soldier safety, emergency alert system

INTRODUCTION

National defense relies heavily on the protection of national borders and the safety of military personnel on duty in isolated and remote areas around the country. Soldiers assigned to perform border security or patrol to observe activity along the Canadian border often find themselves in extreme weather conditions, on severely rugged terrain, and without reliable means of communication to their Command Centres [1]. As a result of the conditions described above, it becomes quite difficult for Command Centers to constantly monitor all of their soldiers' locations or the well-being of their soldiers. There have been many instances where soldiers have unknowingly crossed the border line into Canada or encountered an emergency situation without any form of immediate assistance due to a lack of real-time monitoring and communication systems [2].

Identify applicable funding agency here. To help solve the challenges faced by soldiers when performing these duties, the Border Alert System for Soldiers was created using a combination of the latest Internet of Things (IoT) and Embedded System technologies to develop an innovative self-contained device that continuously monitors the

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Received Date: April 09, 2026
Accepted Date: June 12, 2026
Published Date: June 16,2026

Citation: J.J.Bandal, Snehal Sanjay Sawant, Maheshwari Jayvat Kharat, Nakshatra Anand Kharade. Border Security Alert for Soldiers. Journal of Microcontroller Engineering and Applications. 2026; 13(2): 24–31p.

activity and location of soldiers on duty along the border [3]. The main purpose is to enable real-time monitoring of soldiers and automatically alert the command center of a soldier's movement beyond a designated safe zone or the detection of an unusual pattern of movement that would indicate the possibility of danger or distress [4].

The center of the Border Alert System for Soldiers is the ESP32 microcontroller, which controls all the sensors and communication modules. The M8N GPS Module provides real-time geographic coordinates for the exact location of the soldier. The ESP32 microcontroller compares the real-time geographic coordinates obtained from the M8N GPS module against the pre-prioritized geo-boundary coordinates stored within the Device Co-ordinating Program (DCP) within the ESP32 microcontroller [5].

Project Aim

The goal of this project is to develop an all-in-one, smart, small-scale, efficient, and user-friendly Border Alert System for Soldiers, using multiple sensor types to collect data; real-time GPS functionality to monitor location; and a fully automated alert process whereby the system will automatically send an alert to the Soldier and Command Center when the Soldier exceeds the predefined geographical boundary set within the Soldier's ESP32 microcontroller. The objectives of the project are as follows:

1. Continuous tracking (GPS coordinates) of a soldier's location using the M8N GPS module and sending this location data for real-time evaluation and comparison against predefined boundaries to the ESP32 via Bluetooth [6].
2. To predefine "safe" geographical boundaries (within the ESP32) and send instant SMS alerts via the LTE 7670C GSM module-LTE 7670C to the Base Station, if a Soldier crosses those defined boundaries, with no reliance on the internet for sending the alert.
3. The ability to identify if a soldier is 'moving' (i.e., motion anomaly), has fallen, or has remained in a non-moving position for an extended time, using the MPU6050 accelerometer and gyroscope sensor, in order to provide early warning of a possible injury, unconsciousness, or risk to the soldier's safety.
4. The ability to provide real-time environmental data (altitude, atmospheric pressure, temperature) to the soldier and command center using the BMP280 barometric sensor for effective situational awareness when navigating through rough terrain and/or evaluating the safety of a given area [7].

METHODOLOGY

The new system aims to improve the safety of soldiers by including real-time data collection, location tracking, and a system for sending alerts in an emergency; this will all be accomplished through an IoT-based system.

System Architecture

The architecture will be composed of sensors that will be connected to an ESP32 microcontroller to process real-time data and communicate emergencies and locations to a remote monitoring center using a GSM network. Figure 1 shows the border security alerts for soldiers.

Data Acquisition

Data acquisition refers to obtaining real-time data through various sensors that are part of a system that collects the conditions of a soldier and their surroundings. The Border Security Alert for Soldiers System uses many types of sensors and modules as part of its data acquisition process, which will connect to the ESP32 Microcontroller.

SOC Estimation Method

SOC estimation using voltage. Therefore, I decided to use voltage-based SOC estimation for my project, as no current sensor was used. To determine the battery voltage, the ESP32 uses the ADC readings to obtain a corresponding estimate of the battery SOC as a percentage.

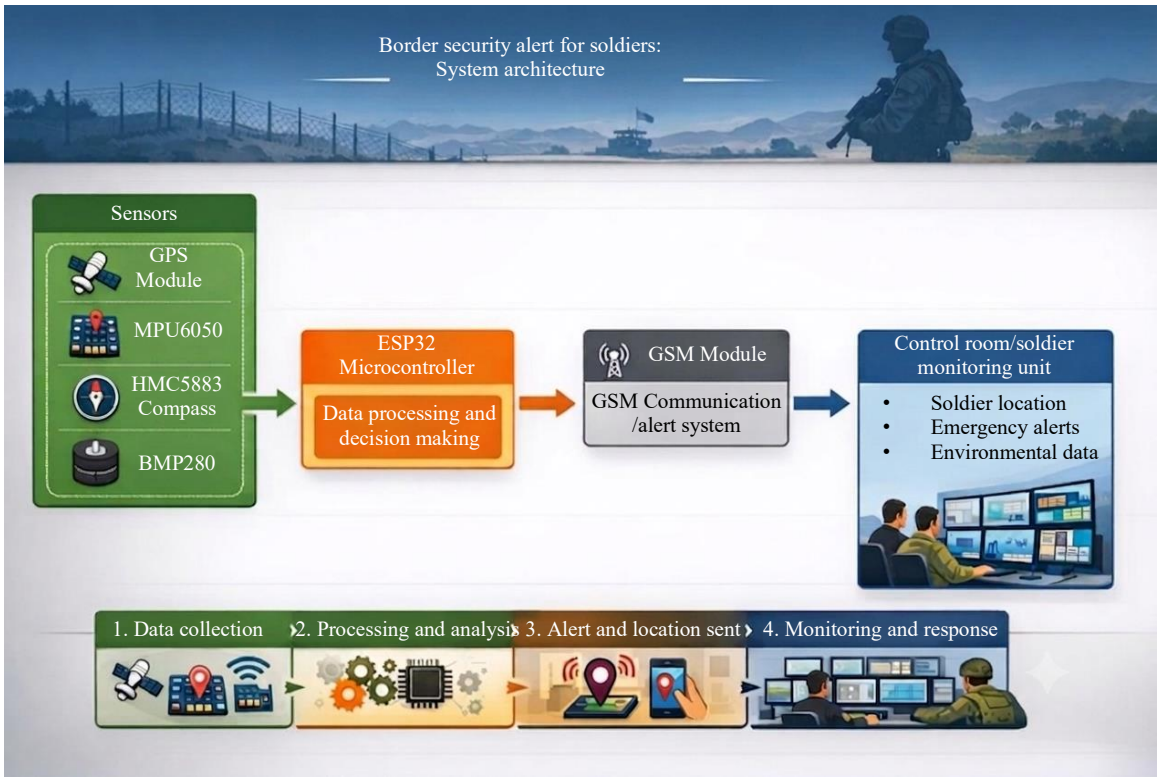

Figure 1. Border security alert for soldiers.

SOH Estimation Method

We estimated the State of Health (SOH) of a battery by comparing its present capacity with its rated capacity. For our project, the SOH was calculated using a conventional simplified voltage-based method. The ESP32 microcontroller we are using, as well as the very basic sensors used in conjunction with the ESP32 (rather than via an advanced battery monitoring integrated circuit) allow us to use the conventional voltage-based SOH estimation method.

Algorithm Design

With a purpose of consistently assessing soldiers' physical and positional state, in addition to assessing data input from sensors, to create an alert when the soldier has an issue, this algorithm allows for the capability of real-time tracking, immediate notification, and rapid decision-making, all key factors in keeping a soldier safe. If no indication of an issue is detected, monitoring continues at routine intervals. This cycle guarantees real-time location, a quick response, and a dependable communication method for soldiers in need of help. Figure 2 shows a flowchart of the border security alerts for soldiers.

IMPLEMENTATION

Dataset Construction

The proposed Border Security Alert for Soldiers system dataset was created using real-time data from several sensors integrated with the ESP32 microcontroller. The system gathers multiple types of data that show the soldier's physical state, position, and motion, as well as their environment at all times. The most significant data type is the coordinates of the soldier (latitude/longitude) provided by the GPS, which allows the system to continuously track the location of the soldier. Another significant data type is the data recorded by the MPU6050 (Motion Processing Unit 6050) sensor, which can capture the acceleration and angular velocity. Some specific types of physical activities can be determined from this data, including types of activities, such as running, walking, or falling. The soldier's orientation (or direction) can be established using the HMC5883 digital compass to determine the direction in which the soldier is heading. The BMP280 sensor measures atmospheric pressure and altitude, which allows

the system to assess low and high terrains and the related altitude variations along the border. In addition, the system records the battery life of the soldier to monitor whether there are any power interruptions during the soldier's operation. Periodically, all sensor data is collected, and each data collection is assigned a time-stamp so that data can be sequenced and analyzed according to the timeliness of the event for each soldier. Data are stored in their raw form using multiple sources for input. Table 1 shows the sensor dataset sample.

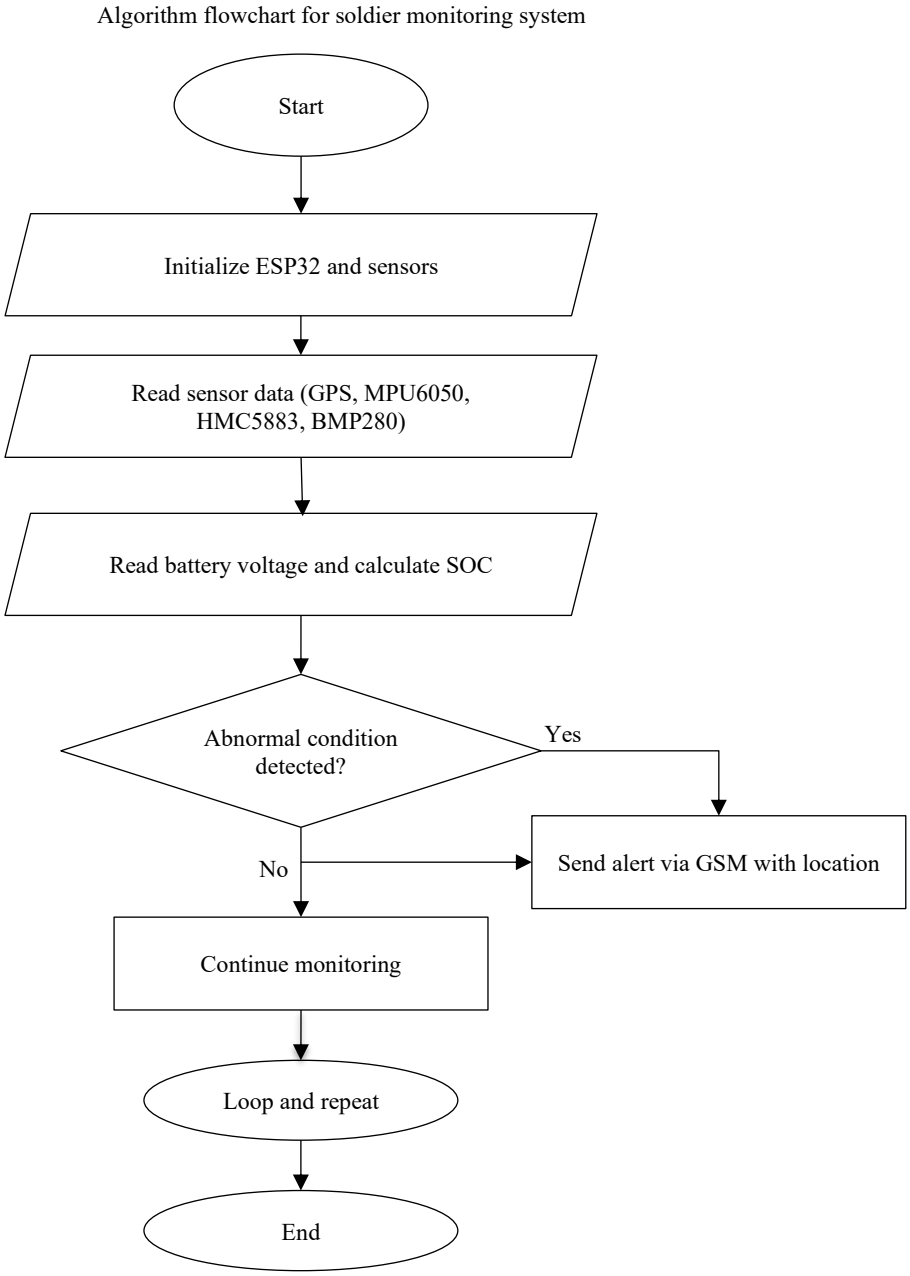

Figure 2. Flowchart of border security alert for soldiers.

Table 1. Sensor dataset sample.

Timestamp	Latitude	Longitude	Acceleration	Direction	Pressure	Altitude	Voltage	Status
10:01	17.38	78.48	Normal	North	1012	210	3.9V	Normal
10:02	17.38	78.49	High	East	1011	212	3.8V	Moving
10:03	17.38	78.50	Drop	West	1010	215	3.7V	Alert

Table 2. Quantitative performance analysis.

Parameter	Value/range	Performance
GPS accuracy	3–10 m	Good
Fall detection	90–95%	High
Direction accuracy	±2° to ±5°	Good
Pressure accuracy	±1 hPa	High
Response time	2–5 sec	Fast
GSM success rate	85–95%	Reliable
Battery voltage	3.0–4.2V	Stable

Table 3. Comparison with traditional methods.

Feature	Traditional methods	Proposed system
Monitoring	Manual	Automatic
Location tracking	Not accurate	Real-time GPS
Emergency detection	Manual	Automatic
Response time	High	Low (2–5 sec)
Communication	Radio	GSM
Environmental data	Not available	Available
Accuracy	Moderate	High
Reliability	Human dependent	High

Software Integration

The integration of software plays an important part in enabling the various hardware components and functional modules included in the proposed Border Security Alert for Soldiers System, to function together in a smooth and coordinated manner. Various hardware components were designed around the ESP32 microcontroller, and all embedded firmware programming was developed using the Arduino Integrated Development Environment (IDE) [8]. The software is responsible for interfacing with several different sensor types, processing the real-time data taken from the sensors, making intelligent decisions, and managing the communications with the remote monitoring station that monitors the alert system. Initially, the hardware components were initialized using the correct libraries and associated communication protocols. The GPS module was interfaced with the ESP32 via a Universal Asynchronous Receiver/Transmitter (UART) communication protocol to receive real-time update location coordinates (latitude and longitude) [9]. The MPU6050 motion sensor and BMP280 environmental sensor were interfaced with the ESP32 via the Inter-Integrated Circuit (I2C) Communication Protocol for the efficient transfer of motion data and environmental sensor readings. The HMC5883 Digital Compass was also interfaced with the ESP32 via the I2C Communication Protocol to provide directional information to the Alert System. The GSM Module was connected so that the Alert System could transmit alerts/messages via Serial Communication. The ESP32 has a defined software execution flow that continuously reads the sensor data from all the sensor devices in a circular fashion. Once the sensor data are acquired from all sensors, the respective data are processed through user-defined algorithms to interpret the soldier's condition [9]. An example of the processing method for the soldier's condition is to use the acceleration data from

RESULT AND DISCUSSION

Quantitative Performance

Quantitative analyses of the effectiveness of the Border Security Alert for Soldiers will use measurable parameters and numerical results. The effectiveness of each proposed solution will be evaluated based on its accuracy, response time, reliability, and efficiency under various operational conditions. Quantitative performance will be evaluated by means of the following: real-time sensor data obtained from the GPS, MPU6050, HMC5883, and BMP280 sensors (GPS module); GSM module (communication); and network access equipment (Raspberry Pi 4 device) [10]. One of the primary areas for evaluating performance is the accuracy of the soldier's location, measured in terms of latitude and

longitude, based on the GPS module, whose operating characteristics under open skies will yield an accuracy range of approximately 3–10 m. The second measurable performance characteristic to evaluate is motion detection accuracy, which will be accomplished using the MPU6050 sensor to distinguish between normal movement and abnormal conditions (i.e., when the soldier abruptly falls) at a high sensitivity level [11]. The third measurable performance characteristic to evaluate is direction accuracy, where the HMC5883 compass is used to determine the soldier's correct direction orientation, with a very small calibration error. Finally, the fourth measurable performance characteristic is the environmental sensor pressure and altimeter accuracy as measured by the BMP280 sensor [12]. The final area for evaluating performance is the system's response time, which is comprised of the time it takes the system to detect an abnormal condition and then to issue an alert using the GSM module. The overall response time of the entire system is a matter of seconds, assuring timely notification/communication in emergency situations. The overall communication reliability was assessed by evaluating the frequency and accuracy with which alerts were successfully transmitted via the GSM module [13].

Comparison with Traditional Methods

The Soldier Border Security Alert System Program provides superior capabilities compared to traditional border security monitoring systems. Traditional border security systems primarily depend on the manual supervision of border security personnel, periodic radio communication, and limited tracking devices [14]. As a result, these sensors take a significant amount of time to respond and do not provide real-time feedback. However, the proposed program significantly improves soldier location tracking, soldier movement monitoring, and soldier environmental monitoring by using multiple types of advanced sensors and embedded technologies to provide up-to-the-moment soldier information in real time. Unlike traditional monitoring systems that do not automatically detect falls or notify of health issues, the proposed system includes MPU6050 sensors that can detect unusual motion patterns that could signal a soldier's fall or unexpected motions [17]. Whereas most traditional systems do not provide location information, the proposed program reliability utilizes GPS for location tracking. Traditional systems also require manual reporting of incidents, leading to long reporting times. In contrast, the proposed program uses GSM technology to send alerts to the control room for an immediate response and significantly shorter reporting times than manual systems [18]. In addition to the superior performance of the Soldier Border Security Alert System compared to traditional border security monitoring, the proposed system provides real-time monitoring of battery status; current traditional border security systems do not meet operational continuity and reliability requirements owing to the absence of battery monitoring capabilities. Table 3 shows a comparison with traditional methods [19]. Although traditional systems are typically simpler and less reliant upon electronic components, they do not provide the reliability, accuracy, or efficiency associated with the proposed Soldier Border Security Alert System. Table 2 shows the quantitative performance analysis.

CONCLUSION AND FUTURE SCOPE

Conclusion

Soldiers' safety and well-being when deployed in remote and high-risk locations is addressed effectively by the Border Security Alert for Soldiers system; an effective and reliable real-time soldier monitoring solution. The Border Security Alert for Soldiers is composed of multiple sensors (GPS, MPU6050, HMC5883, and BMP280) integrated with the ESP32 microcontroller, continuously providing ongoing positional, motion, azimuthal orientation, and any adverse environmental conditions of the soldier [15]. Alerts are transmitted to the control room via GSM to ensure that the appropriate personnel respond rapidly during an emergency. Battery monitoring is implemented to ensure the reliable operation of the system. Based on experimental results and quantitative analysis, the performance of the system in these environments meets expectations with regards to automation, real-time data acquisition, and enhanced situational awareness and decision making compared to existing methods [16]. Overall, thef Border Security Alert for Soldiers has been proven to be cost-effective, scalable, and a practical solution that enhances border security while providing increased safety for our soldiers [20].

Future Scope

Improvements to the proposed system can include the implementation of new technologies and features that enhance its functionality or performance. For example, an improvement for future implementations of this system could be adding more accurate positioning systems (e.g., multi-GNSS) or even using satellite-based augmentation systems, which would allow the system to work in areas where GPS signals are too weak to function correctly. One way to extend the capabilities of the system would be to add additional sensor technologies such as heart rate and temperature sensors which would provide a complete picture of the health of a soldier. This can also be accomplished by utilizing new IoT platforms and cloud storage technologies to allow for real-time logging of data, remote access to data, and advanced analytics capabilities. The application of machine learning algorithms can greatly enhance the ability of the system to detect anomalies or false alerts by using historical data to improve performance. In addition, low-power communication technologies, such as LoRa, can enhance the communication range and reliance on the GSM network. Additionally, improvements to the battery management system can improve efficiency and extend operational time. In addition, the system can be miniaturized or ruggedized, which will allow for more durability in extreme environments. These improvements will not only make this system more intelligent and robust but will also allow it to be feasible for use in large-scale deployment in new military applications.

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