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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,soitworkseven withoutaninternet 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,easytocarry,affordable,andperfectforreal-timemilitary use.Testsshowitworksreliably,sendsdataaccurately,andgives quick alerts in battlefield situations.

Index Terms—GPS Location Tracking, Real-Time Health Mon- itoring, GPS Location Tracking, ESP-NOW Wireless Communi- cation,IoT Cloud Monitoring

I. INTRODUCTION

The increasing demand for advanced defense technologies hascreatedtheneedforintelligentmonitoringsystemsthatcan improve soldier safety and battlefield awareness in real-time operational environments. Traditional battlefield communica- tion methods mainly rely on manual reporting and periodic updates, which are often unreliable during combat situations. Soldiers operating in harsh and remote environments mayface health issues such as fatigue, dehydration, injuries, or sudden medical emergencies, making continuous monitor-ing extremely important for timely assistance and decision- making.

Inmilitaryoperations,delaysinidentifyingasoldier'scriti- calconditionorexactlocationcanreducerescueefficiencyand increase operational risks. Existing systems mainly focus on communicationornavigationanddonotprovideanintegrated solution for health monitoring, GPS tracking, and emergency alertgeneration.Moreover,manymonitoringsolutionsdepend 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 reli- ably without internet dependency.

This paper introduces *Smart Battlefield Monitoring System*, an IoT-based defense monitoring solution designed to contin- uously track soldier health parameters and real-time location duringmilitarymissions.Theproposedsystemintegrates biomedical sensors, GPS technology, and ESP-NOW wireless communication to provide efficient real-time monitoring and emergency response support. The system measures heart rate, SpO, and body temperature, while also enabling instant SOS alerts using a panic button mechanism. The collected data is transmittedwirelesslytothecommandstationanduploadedto theThingSpeakIoT cloudforremotemonitoringandanalysis.

Themaincontributionsofthisworkareasfollows:

- AnIoT-basedreal-timebattlefieldmonitoringframework for continuous soldier health and location tracking.
- Integrationofbiomedicalsensors,GPSmodule,andESP- NOW communication for reliable wireless data transmis- sion without internet dependency.
- A compact and portable emergency monitoring system with panic-button-based SOS alert functionality for crit- ical situations.
- Asystematicevaluationincludingunittesting,integration testing, and system testing to validate communication reliability,monitoringaccuracy,andemergencyresponse efficiency.

Theremainderofthispaperisorganizedasfollows.Section II presents the literature survey related to IoT-based defense monitoring systems.

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Section III explains the proposed system architectureandmethodology.SectionIVdiscussesimplemen- tation 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 attentionduetotheincreasingneedforsoldiersafety,real-time health monitoring, and battlefield awareness. Several research worksfocusonintegratingIoTtechnologies,wirelesscommu- nication, 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 communica- tion 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 studiesproposedsensor-basedmonitoringframeworkscapable of tracking vital parameters in real time. Although these systemsimprovehealthvisibility,mostofthemfocusonly 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, Blue- tooth, and Wireless Sensor Networks (WSN) have also been used for transmitting soldier information to command centers. Severalresearchersproposedcommunication-basedsafetysys- tems for defense applications using wireless sensor networks and cloud platforms. While these systems support remote monitoring, they often suffer from high power consumption, communicationdelays,anddependenceonnetworkinfrastruc- ture, 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.

Despitetheavailabilityofthesetechnologies,severallimita- tionsstillexist,includingdependenceoninternetconnectivity, lack of integrated monitoring frameworks, limited emergency response support, and reduced reliability in remote battlefield conditions. Many existing systems do not combine real-time healthmonitoring,GPStracking,wirelesscommunication,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 com- munication, 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 re- moteaccessthroughThingSpeak,andinstantSOSalertgener- ation using a panic button. This integrated approach improves soldier safety, enhances situational awareness, and supports faster decision-making during critical battlefield operations.

III. METHODOLOGY

TheSmartBattlefieldMonitoringSystemisdesignedas an intelligent real-time defense monitoring framework that integratesbiomedicalsensing,GPStracking,wirelesscommu- nication, and IoT-based remote monitoring technologies. The methodology focuses on system architecture design, sensor integration, wireless data transmission, emergency alert han- dling,andastructureddevelopmentprocessusedtoimplement and evaluate the proposed system.

A. SystemArchitecture

The proposed system follows a modular architecture con- sisting of the soldier monitoring unit, sensor modules, GPS tracking unit, ESP-NOW communication module, command station, alert mechanism, and IoT cloud platform. The sol-dier unit includes biomedical sensors for monitoring heartrate,SpO_2,andbodytemperature,whiletheGPSmodule continuously captures real-time location coordinates. The Ar- duino/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 transmitteddata is displayed on an LCD screen and emergency alerts are generatedusingabuzzerwheneverabnormalhealthconditions or panic alerts are detected.

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

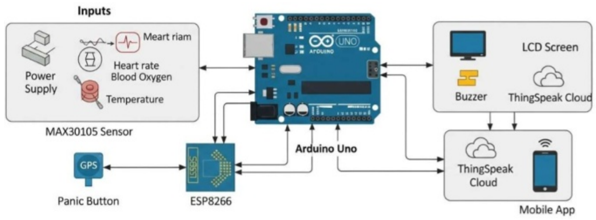

Fig. 1.System architecture of the Smart Battlefield Monitoring Systemshowing interaction between biomedical sensors, GPS module, ESP-NOWcommunication, command station, and IoT cloud platform.

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

B. SystemWorkflow

Thecompleteworkflowoftheproposedsystemisdescribed below.

1) ThesoldierpowersONtheSmartBattlefieldMonitoring device.
2) Thebiomedicalsensorsbeginmonitoringheartrate, SpO_2, and body temperature.
3) The GPS module acquires real-time latitude and longi- tude coordinates.
4) TheArduino/ESP8266microcontrollerprocessesthe sensor and GPS data.
5) The system checks whether any abnormal health condi- tion is detected.
6) Theprocessedinformationispreparedforwirelesstrans- mission.
7) ESP-NOWcommunicationtransmitsthedatatothe command station.
8) Thecommandstationreceivesanddisplaysthemoni- tored data on the LCD screen.
9) Thebuzzergeneratesalertswheneverabnormalreadings or SOS signals are detected.
*10)*ThereceiveddataisuploadedtotheThingSpeakIoT cloud for remote monitoring.
*11)*Thesoldiercanmanuallytriggeranemergencyalert using the panic button.
*12)*Thedefenseteammonitorsthereceivedinformationand responds to emergencies in real time.

This workflow ensures continuous battlefield monitoring, efficientcommunication,andrapidemergencyresponseduring military operations.

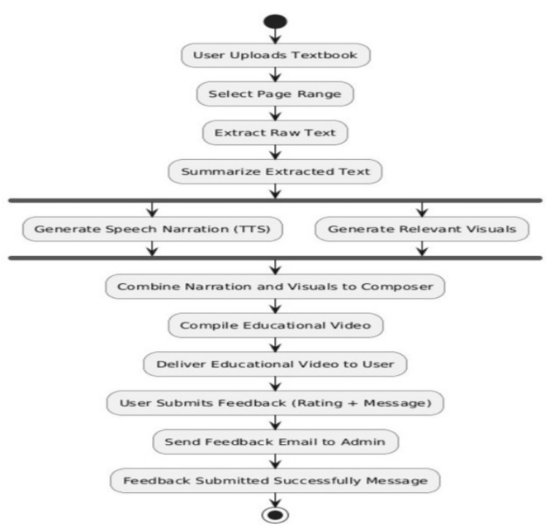

Fig. 2.Workflow of the Smart Battlefield Monitoring System illustratingsensor monitoring, GPS tracking, wireless communication, emergency alerts,and cloud monitoring.

C. MonitoringTechniquesandCommunicationMechanisms

The proposed system integrates multiple embedded andIoTtechnologiestoachievereliablebattlefieldmonitoringand communication.

HealthMonitoring:Biomedicalsensorscontinuouslymea- sure heart rate, SpO_2, and body temperature to monitor the soldier's physical condition in real time.

- GPS Tracking: The NEO-6M GPS module captures ac- curate location coordinates to support battlefield tracking and rescue operations.
- Wireless Communication: The ESP-NOW protocol en- ables low-latency and internet-free wireless data transmission between the soldier device and command station.
- Emergency Alert Mechanism: A panic button allows sol- dierstotriggerimmediateSOSalertsduringcriticalsituations, 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. DevelopmentApproach

TheprojectfollowstheWaterfalldevelopmentmethodology consisting of requirement analysis, system design, implemen- tation, testing, and evaluation phases. During the requirement analysis phase, essential functionalities such as health moni- toring,GPStracking,emergencyalertgeneration,andwireless communication were identified.

The system design phase included architecture diagrams, data flow diagrams, use case diagrams, workflow design, and hardwareselection.Theimplementationphaseinvolvedsensor integration, Arduino programming, ESP-NOW configuration, GPS interfacing, LCD display integration, and cloud connec- tivitysetup.Thetestingphaseincludedunittesting,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. SoftwareImplementation

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 communi- cation protocols into a unified monitoring framework.

Thesoftwarecontinuouslycapturesheartrate,SpO_2,and

body temperature readings from the connected sensors and processes them through the microcontroller. The GPS module retrievesreal-timelatitudeandlongitudecoordinates,whilethe ESP-NOW protocol manages wireless transmission between the soldier unit and the command station. The received infor- mation is displayed on the LCD screen and uploaded to the ThingSpeak IoT cloud platform for remote monitoring and analysis.

Theapplicationisdividedintoseveralfunctionalmodules:

- Health Monitoring Module: Continuously measures heart rate, SpO_2, 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.
- CloudMonitoringModule:Uploadsbattlefielddata to the ThingSpeak IoT cloud for remote access and visualization.

B. HardwareImplementation

ThehardwareimplementationoftheSmartBattlefieldMon- itoringSystemconsistsofbiomedicalsensors,GPStrack- ing components, wireless communication modules, display interfaces,andemergencyalertmechanismsintegratedinto a compact embedded platform.

The Arduino/ESP8266 mi- crocontroller acts as the central processing unit responsibleformanagingsensoracquisition, wirelesscommunication,and system control operations.

The MAX30102 sensor is used to measure heart rate and SpO_2levels, while the temperature sensor continuously mon- itors body temperature. The NEO-6M GPS module provides accurategeographiccoordinatesfortrackingsoldiermovement 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 locationdata,whileabuzzergeneratesemergencyalertsduring 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 mon- itoring device suitable for battlefield deployment. Its modular hardware structure allows efficient integration, low power consumption,andreliableoperationunderharshenvironmental conditions.

C. ToolsandTechnologies

The development and implementation of the Smart Bat- tlefield Monitoring System utilized the following tools and technologies:

- ArduinoIDE:Usedforembeddedprogramming,code compilation, debugging, and firmware uploading.
- EmbeddedC/ArduinoProgramming:Usedforsensor interfacing, data processing, and communication control.
- ESP8266 Libraries: Used for ESP-NOW wireless com- munication and Wi-Fi module configuration.
- MAX30102Sensor:Usedformeasuringheartrateand SpO_2values.
- TemperatureSensor(LM35/DS18B20):Usedfor monitoring body temperature.
- NEO-6MGPSModule:Usedforcapturingreal-time latitude and longitude coordinates.
- TinyGPS++Library:UsedforparsingGPSdatainto readable location information.
- ThingSpeakIoTCloudPlatform:Usedforremote monitoring, data storage, and visualization.
- 16x2 LCD Display:Usedfordisplayingreal-timesensor and location data at the command station.
- ESP-NOWProtocol:Usedforlow-power,internet-free wireless communication between devices.

V. RESULTS AND DISCUSSION

A. Testing Strategy

TheSmartBattlefieldMonitoringSystemwasevaluated throughunittesting,moduletesting,integrationtesting,and systemtestingto ensureaccurate monitoring,reliablecom- munication, and stable system operation under real-time con- ditions. Unittestingfocusedonvalidatingindividualfunc- tionalitiessuchasheartratemeasurement,SpO_2sensing, temperaturemonitoring, GPS dataacquisition, panicbutton operation, LCD display updates, and buzzer alert generation. Moduletestingverifiedthecorrectoperationofmajorfunctionalmodulesincludingthehealthmonitoringmodule, GPS tracking module, wireless communication module, alert module, display module, and cloud monitoring module. Each modulewastestedindependentlytoensureproperfunctional- itybeforefullsystemintegration.

Integration testing examined communication and interac- tion between connected modules, including sensor data trans- fer 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.

Systemtestingevaluatedthecompletebattlefieldmonitoring workflow, including real-time monitoring of soldier health parameters,GPSlocationtracking,wirelesscommunication, emergency alert transmission, and cloud-based monitoring. Thesystemwasalsotestedforrepeatedoperationcycles,com- munication reliability, and response during abnormal health conditions and panic-button activation.

Across all testing scenarios, the system performed suc- cessfully 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.

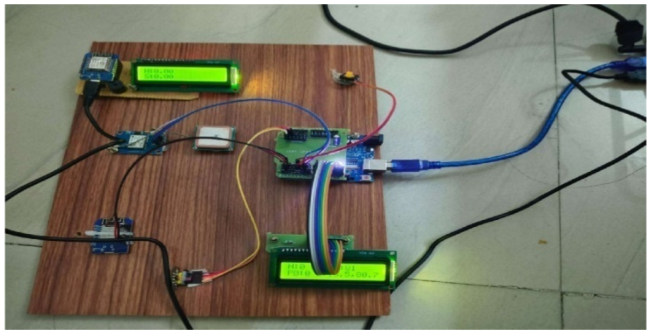

Fig. 3.Hardware implementation and monitoring interface of the SmartBattlefield Monitoring System showing real-time health and GPS data trans-mission.

B. PerformanceAnalysis

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 onmanualcommunicationandperiodicstatusreporting,which may lead to delayed emergency response during combat situ- ations. 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 andSpO_2readings under normal operating conditions, while the temperature sensor accurately monitored body temperature variations.TheGPSmodulesuccessfullyacquiredandupdated soldierlocationcoordinatesinrealtime.Wirelesscommunica- tion through ESP-NOW maintained low-latency and internet-independent transmission with reliable performance across multipletestruns.TheThingSpeakcloudplatformconsistently stored and visualized battlefield data for remote monitoring purposes.

C. Discussion

The experimental results demonstrate that the Smart Battle- field Monitoring System successfully achieves its objective of providingcontinuoussoldierhealthmonitoring,real-timeGPS tracking, wireless communication, and emergency alert sup- port 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 cre-atesareliableandcost-effectivedefensemonitoringsolution

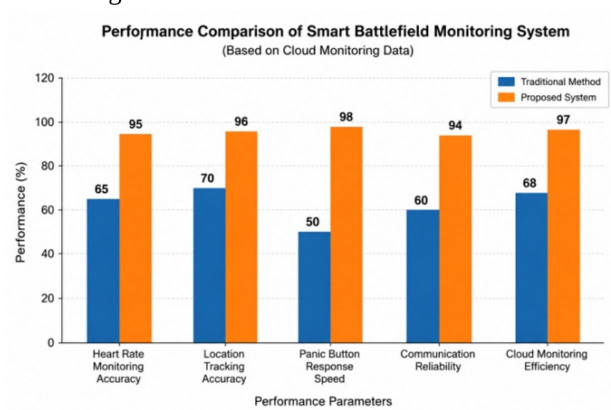

Fig. 4.Performance comparison between traditional battlefield monitoringmethods and the proposed Smart Battlefield Monitoring System.

suitable for military operations. The proposed system reduces dependency on internet connectivity while maintaining stable wirelesscommunicationandaccuratemonitoringperformance in remote environments.

Certain limitations still exist in the current implemen-tation. 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 se- curity 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.

TABLEI
PERFORMANCECOMPARISONBETWEENTRADITIONALMONITORINGAND PROPOSED SYSTEM

Metric	Traditional Methods	Proposed System
HealthMonitoring	Manual	Automated
LocationTracking	Limited	Real-TimeGPS
Communication	Internet Dependent	ESP-NOWBased
EmergencyAlerts	Delayed	Instant SOS Alerts
MonitoringAccuracy	Moderate	High
UserEffort	High	Minimal

VI. FUTURE WORK

Future enhancements to the Smart Battlefield Monitoring System will focus on improving communication range, moni- toring capabilities, security, and operational efficiency in real- worldmilitaryenvironments.Advancedlong-rangecommuni- cation technologies such as LoRa, GSM, or satellite commu- nicationcanbeintegratedtoprovidereliableconnectivityover larger battlefield areas.

The system can also be extended to support multi-soldier monitoring,enablingcommandcenterstotrackandman- age multiple soldiers simultaneously through a centralized monitoring platform. Additional biomedical sensors such as ECG,bloodpressure,hydrationmonitoring,andstressanalysis sensors may be incorporated to improve health assessment accuracy and early risk detection.

Future versions of the system may include AI-based pre- dictive analysis to identify abnormal health conditions be-fore critical situations occur. Integration of machine learning techniquescansupportintelligentdecision-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 militarysurveillanceplatformsmayfurtherimprovebattlefield 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 Sys- tem*, an IoT-based defense monitoring framework developedto improve soldier safety, real-time health tracking, and bat- tlefield 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 embed- ded platform. By continuously monitoring heart rate, SpO_2, body temperature, and real-time location, the system enables command centers to receive critical battlefield information instantly and respond quickly during emergencies.

TheSmartBattlefieldMonitoringSystemplaysanimportant 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 sys- tem analysis, architecture design, hardware integration, em- bedded programming, and comprehensive testing. Unit test- ing, integration testing, module testing, and system testing demonstrated that the system operates reliably under differ-ent monitoring scenarios. Experimental evaluation confirmed accurate sensor readings, stable wireless communication, real-timeGPStracking,andefficientemergencyalerthandling.The lightweight and cost-effective design also makes the system practical for deployment in military operations and related defense applications.

Theproposedframeworkdemonstratestheeffectiveness of combining IoT technologies, biomedical sensing, GPS tracking, and wireless communication to create an intelligent battlefieldmonitoringsolution.Byprovidingcontinuoussitua-tionalawarenessandautomatedemergencysupport,thesystem 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 integra- tionwithautonomousdefensesystemscanfurtherincreasethe 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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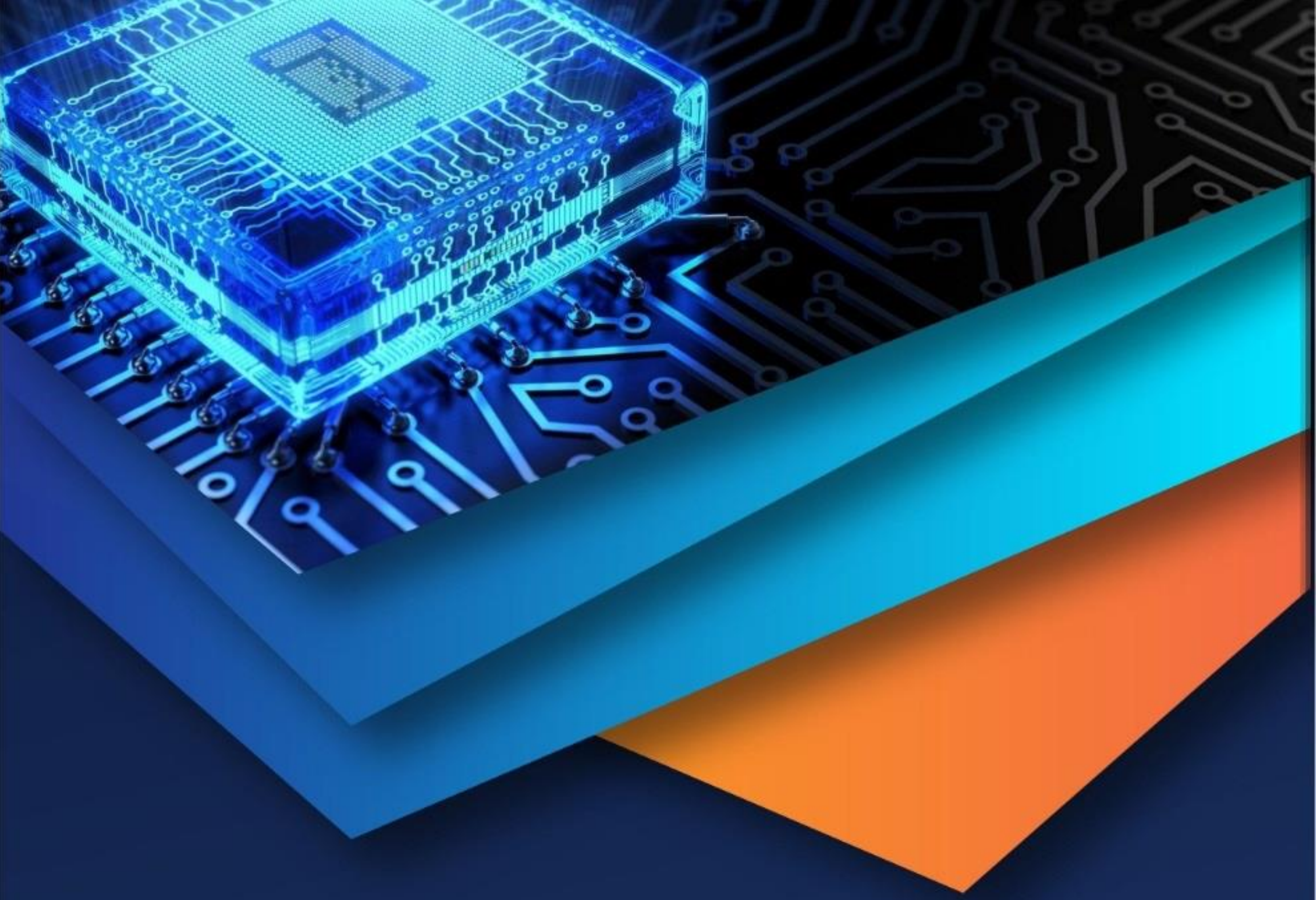

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