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A Survey on Next-Generation Internet of Military Things Wearable for Autonomous Soldier Monitoring

Nagarathna C[1], Sameeksha Patel[2], Reha Srikanta[3], Nadeem[4], Rishab N[5]
[1]*Assistant Professor, Dept. of CSE, Sapthagiri College of Engineering*
[2, 3, 4, 5] *Dept. of CSE, Sapthagiri College of Engineering*

Abstract: ***This project presents an advanced Internet of Military Things (IoMT)-based system designed for real-time soldier health monitoring and battlefield threat detection. It addresses the limitations of traditional systems such as manual surveillance, delayed communication, and lack of intelligent analysis in high-risk environments. The proposed solution integrates wearable sensor nodes with a distributed battlefield monitoring network to continuously track vital parameters like heart rate, body temperature, SpO_2 levels, motion, gas exposure, and location. The system utilizes ESP32-based embedded devices combined with multiple sensors to collect and transmit real-time data using MQTT and long-range communication technologies such as LoRa. To ensure reliability, the architecture incorporates both edge computing and cloud-based processing, enabling continuous monitoring even in communication-constrained scenarios. A key feature of the project is the integration of machine learning models, including TinyML for on-device inference and LSTM-based deep learning models in the cloud for accurate anomaly detection. The system detects critical conditions such as fatigue, heat stroke, falls, toxic gas exposure, and geofence violations, ensuring timely alerts to the command center. A mobile-based interface provides real-time visualization, enabling faster decision-making and improved coordination. Secure data transmission is ensured through encryption techniques, enhancing system reliability in military applications. Additionally, the project evaluates performance metrics such as latency, power consumption, and communication efficiency, demonstrating a balance between accuracy and resource utilization. Overall, the proposed IoMT framework offers a scalable, cost-effective, and intelligent solution for enhancing soldier safety, situational awareness, and operational efficiency in modern warfare environments.***

Keywords: Internet of Military Things (IoMT), Soldier Health Monitoring, Battlefield Threat Detection, Wearable Sensor Nodes, ESP32 Embedded System, Real-time Data Transmission, MQTT Communication Protocol, LoRa Long- Range Communication, Edge Computing, TinyML, LSTM Deep Learning Model, Anomaly Detection.

I. INTRODUCTION

The rapid evolution of connected technologies has significantly transformed modern military operations, particularly through the emergence of the Internet of Military Things (IoMT). IoMT extends the conventional Internet of Things (IoT) paradigm by enabling intelligent communication among battlefield devices, sensors, and personnel. In contemporary warfare, real-time situational awareness and rapid decision-making are critical for mission success and soldier survivability. However, traditional battlefield monitoring systems rely heavily on manual patrols, radio communication, and isolated sensing units, which are often inefficient. These systems suffer from limited communication range, delayed data transmission, and lack of real-time responsiveness. Moreover, the absence of intelligent data processing results in poor coordination and delayed medical assistance during emergencies.

Recent advancements in IoMT integrate wearable sensors, communication technologies, and artificial intelligence to enhance battlefield awareness. These systems enable continuous monitoring of soldier health parameters such as heart rate, temperature, and oxygen levels. Additionally, environmental sensing and location tracking provide a comprehensive understanding of battlefield conditions. Despite these improvements, many existing solutions remain dependent on centralized cloud infrastructure.

Such dependence leads to performance degradation in communication-constrained or hostile environments. Furthermore, conventional threshold-based alert mechanisms often produce inaccurate or delayed responses. To address these limitations, emerging research focuses on integrating edge computing with cloud-based intelligence. Edge devices enable local data processing, reducing latency and ensuring functionality even during network disruptions. At the same time, cloud-based models provide deeper analytical capabilities for complex pattern recognition. The combination of these approaches offers a hybrid architecture that improves reliability and accuracy.

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In parallel, communication technologies such as MQTT and LoRa have been widely adopted for efficient and long- range data transmission. Security mechanisms including encryption protocols further ensure safe data exchange in sensitive military environments. These technological advancements collectively contribute to the development of scalable and robust IoMT systems.
This survey paper presents a comprehensive review of IoMT-based soldier monitoring systems, focusing on recent developments in sensing, communication, and intelligent data processing. It critically analyzes existing approaches, identifies their limitations, and highlights the role of edge–cloud integration in enhancing system performance. The paper also explores emerging trends such as TinyML, deep learning-based anomaly detection, and secure distributed architectures. Finally, it outlines future research directions for developing efficient, reliable, and intelligent IoMT solutions for next-generation military applications.

II. LITERATURE SURVEY

1) HEAL System Researchers (2026): This paper introduces an AI-based IoMT system using LoRa for long-range communication. It enables real-time monitoring and predictive analysis of soldier health conditions. The system improves energy efficiency and communication reliability. It integrates machine learning for intelligent alert generation. However, real-time deployment in complex battlefield scenarios requires further validation.

2) S. Mishra and R. Pande (2025): This research focuses on deep learning-based anomaly detection in IoMT environments. The authors use LSTM autoencoders to analyze time-series physiological data. The model achieves high accuracy in detecting abnormal health conditions. It improves early detection of medical emergencies. However, the approach requires significant computational resources and cloud support.

3) H. Li, W. Zhang, and Y. Chen (2025): The authors present a comprehensive survey on TinyML applications for biometric recognition. It discusses techniques such as model pruning and quantization for resource- constrained devices. The study covers applications like heart rate monitoring and fall detection. It emphasizes the importance of efficient models for embedded systems. However, challenges remain in maintaining accuracy under strict hardware limitations.

4) A. Patel, M. Singh, and K. Reddy (2025): This work presents an integrated wearable system combining IoT and artificial intelligence for soldier monitoring. The system collects biometric and environmental data to provide real-time situational awareness. Cloud-based machine learning models are used for anomaly detection with improved accuracy. However, the system depends heavily on continuous internet connectivity. It lacks edge processing, which reduces reliability in communication-disrupted environments.

5) D. Verma, N. Shah, and S. Agrawal (2024): This paper explores TinyML techniques for deploying machine learning models on low-power IoT devices. It demonstrates that compressed models can run efficiently on microcontrollers with low latency. The study highlights benefits such as reduced power consumption and faster decision-making. However, accuracy trade-offs exist due to model compression. The work is significant for enabling edge intelligence in IoMT systems.

6) F. Sattler, S. Wiedemann, K. Müller, and W. Samek (2024): The authors explore federated learning for distributed IoT systems. This approach allows multiple devices to collaboratively train models without sharing raw data. It enhances data privacy and reduces communication overhead. The method is suitable for military environments with strict data security requirements. However, synchronization and model convergence remain challenging.

7) DARPA IoBT Collaborative Research (2023): This work outlines the vision for the Internet of Battlefield Things (IoBT) in modern warfare. It emphasizes interconnected devices, real-time intelligence, and adaptive communication systems. The study identifies key challenges such as interoperability and security. It promotes edge- based AI for faster and decentralized decision-making. However, large-scale implementation remains complex and resource-intensive.

8) P. Nair and B. Sharma (2022): This paper discusses the design and implementation of wearable multi-sensor systems for military applications. It highlights practical challenges such as sensor calibration and power management. The system integrates multiple sensors for comprehensive monitoring. It improves reliability in data collection under field conditions. However, it lacks advanced analytics for intelligent decision-making.

9) T. Ramesh and V. Krishnamurthy (2022): The authors developed a real-time soldier monitoring system using IoT and GPS tracking. The system transmits data using MQTT protocol for efficient communication. It enhances coordination between soldiers and command centers. However, it suffers from high dependency on centralized systems. The absence of local intelligence limits performance during network failures.

10) R. Kumar, S. Sharma, and P. Gupta (2018): The authors proposed an IoT-based system for monitoring soldier health parameters such as heart rate, body temperature, and location. The system uses wearable sensors and GSM communication to transmit data to a central monitoring station. It improves basic tracking and emergency response capabilities in battlefield conditions.

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However, the approach relies on threshold-based alerts without intelligent data analysis. The lack of AI integration limits its ability to detect complex health anomalies.

III. METHODOLOGY

The proposed IoMT-based soldier monitoring system is developed to enable continuous tracking of soldier's physiological conditions and battlefield environment in real time. The system is organized into multiple functional layers that work together to collect, process, transmit, and analyze data efficiently.

A. System Design and Architecture

The overall system is built on a wearable IoMT framework, where each soldier carries a compact sensing unit. This unit is centered around an ESP32 microcontroller that connects various biomedical and environmental sensors. All individual units form a connected network that communicates with a central monitoring station for supervision and control.

B. Sensor Data Collection

The wearable module gathers real-time data using integrated sensors, including:

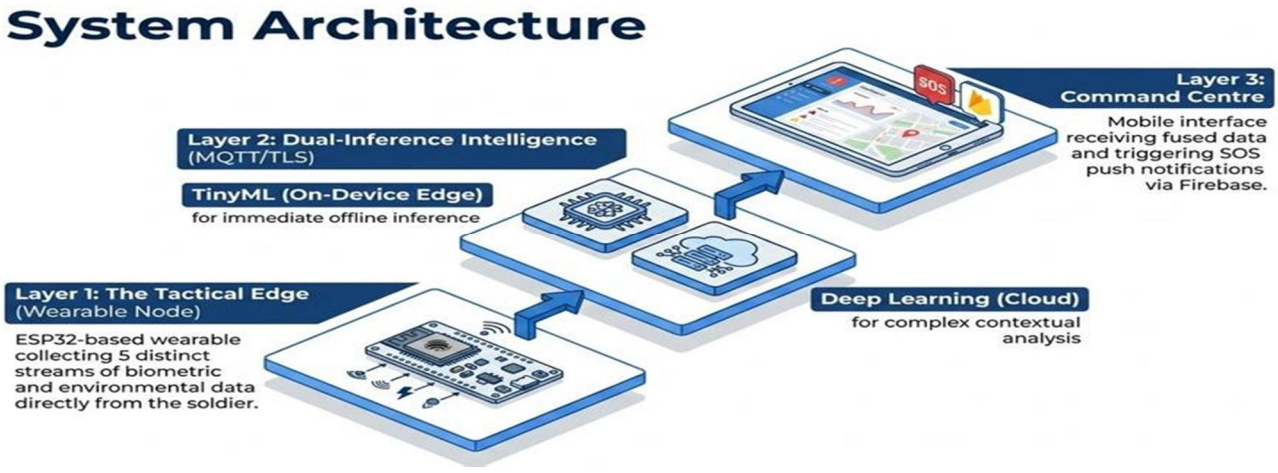
- Heart rate sensor for pulse monitoring
- Temperature sensor for body temperature
- SpO_2 sensor for oxygen level measurement
- Gas sensor for detecting harmful environmental exposure
- GPS module for live location tracking

These sensors ensure continuous acquisition of critical health and environmental parameters.

C. Local Processing Unit

The ESP32 performs initial processing of sensor data at the edge level. This includes:

- Filtering and refining raw sensor inputs
- Removing noise and inconsistent readings
- Identifying abnormal values using predefined thresholds
- Generating instant local alerts during emergency conditions
- Storing temporary data when connectivity is weak or unavailable This reduces delay and improves system responsiveness.



D. Communication System

Processed information is transmitted to the central monitoring station through multiple communication channels such as:

- Wi-Fi for short-range communication
- GSM/LTE networks for long-distance data transfer
- Mesh networking to maintain connectivity in difficult terrains This ensures continuous and reliable data flow from the battlefield.

E. Central Monitoring Platform

A centralized dashboard or cloud system receives and manages incoming data from all soldiers. It provides:

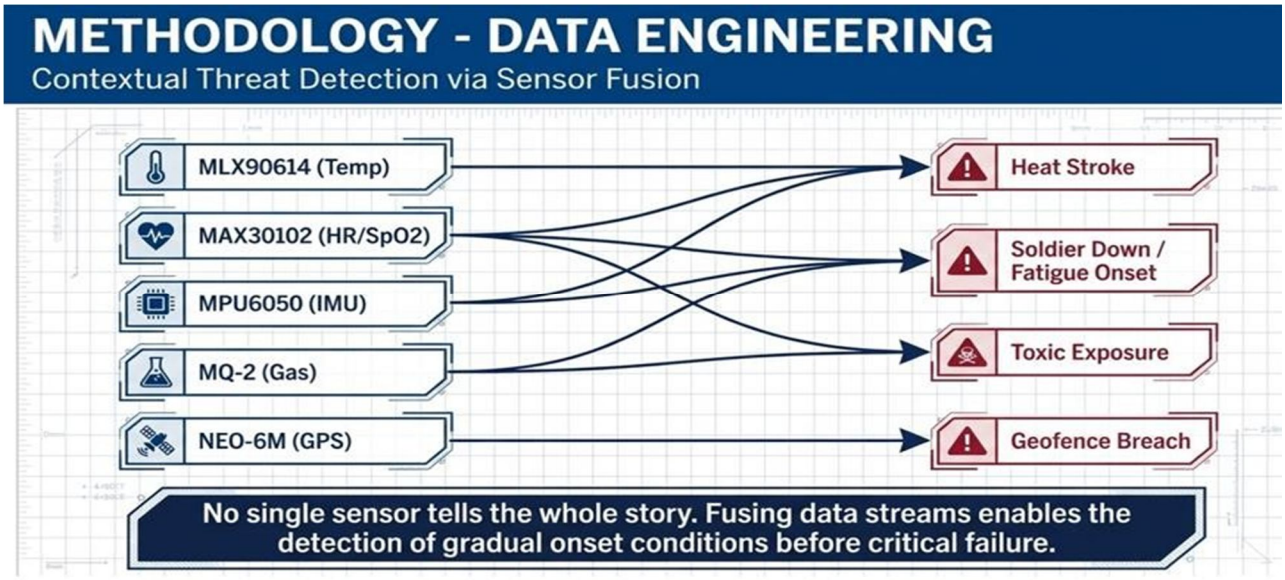
- Real-time health and status monitoring
- Live GPS-based battlefield tracking
- Data storage for future analysis
- Visual representation of soldier conditions for commanders

F. Alert and Decision Mechanism

The system continuously evaluates incoming data to detect abnormal situations such as:

- Sudden changes in vital signs
- Falls or prolonged inactivity
- Exposure to toxic gases
- Emergency physiological conditions

Once detected, the system immediately generates alerts, sends SOS signals with location details, and informs command authorities.



G. Advantages of the System

- Enables continuous real-time monitoring of soldier health and location
- Improves emergency response time through instant alerts
- Enhances battlefield safety by detecting hazardous conditions
- Provides reliable communication in remote and hostile environments

H. Result Outcomes

The implemented system demonstrates effective performance in real-time monitoring scenarios. The key outcomes include:

- Accurate and continuous tracking of soldier vital health parameters and position
- Successful identification of abnormal conditions such as irregular heart rate, oxygen drop, and temperature variations
- Immediate generation of alerts during emergency situations with minimal delay
- Reliable transmission of data between wearable devices and the central monitoring system

IV. DISCUSSION

The survey highlights the rapid evolution of Internet of Military Things (IoMT) systems for soldier health and battlefield monitoring, emphasizing the transition from conventional systems to intelligent, connected frameworks. Existing literature indicates that early systems primarily relied on threshold-based monitoring techniques, which lacked contextual understanding and resulted in high false alarm rates.

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These systems were limited in their ability to analyse temporal variations in physiological data, making them unsuitable for detecting gradual health deterioration. Recent advancements have introduced machine learning and deep learning approaches, significantly improving anomaly detection accuracy in IoMT applications.

Cloud-based models such as LSTM and autoencoders have demonstrated high performance in analyzing time-series biomedical data. However, dependence on continuous connectivity remains a major limitation in such systems, particularly in communication-constrained battlefield environments.To address this, researchers have explored edge computing and TinyML techniques for deploying intelligence directly on embedded devices.

TinyML-based approaches offer reduced latency, lower power consumption, and offline operational capability, making them suitable for real-time military applications. Despite these advantages, edge models often face challenges related to limited computational resources and reduced accuracy compared to cloud models. The survey also reveals the importance of multi-sensor data fusion in improving system reliability and detection capability.

Combining biometric and environmental data enables comprehensive monitoring of both physiological and external threat conditions. Communication technologies such as MQTT and LoRa have been widely adopted for their efficiency in low-power and long-range data transmission. Security remains a critical concern in IoMT systems, as sensitive military data must be protected against interception and cyber threats.

Encryption techniques and secure communication protocols are essential components in modern implementations. Another key observation is the lack of integration in many existing systems, where monitoring, analysis, and visualization are handled separately. This fragmentation reduces operational efficiency and delays decision-making during critical situations.

Modern architectures aim to provide unified platforms integrating sensing, processing, communication, and visualization. Scalability is another challenge identified in the literature, especially in large-scale deployments involving multiple nodes. Energy efficiency plays a vital role in wearable IoMT devices, as battery limitations directly impact system usability in the field.

Research efforts are increasingly focused on optimizing power consumption without compromising performance. The survey also highlights the growing role of real-time data analytics in enhancing situational awareness.

Immediate alerts and predictive insights can significantly reduce response time during emergencies. Furthermore, the integration of mobile and web-based dashboards has improved accessibility for command centers.

Visualization tools enable better interpretation of complex battlefield data. Despite significant progress, there is still a gap in achieving fully autonomous and adaptive IoMT systems. Most current systems require predefined configurations and lack dynamic learning capabilities. Emerging technologies such as federated learning offer promising solutions for distributed model training while preserving data privacy. Interoperability among heterogeneous devices is another open research issue in IoMT ecosystems.

Standardization of protocols and architectures is necessary for seamless integration. The survey also identifies the need for robust testing under real-world conditions. Many proposed systems are validated only in simulated environments, limiting their practical applicability. Future research should focus on hybrid architectures combining edge and cloud intelligence for optimal performance.

Such systems can leverage the strengths of both approaches while mitigating their individual limitations. Overall, the discussion emphasizes that IoMT-based soldier monitoring systems have strong potential to revolutionize battlefield healthcare and safety. However, addressing challenges related to scalability, security, energy efficiency, and real-world deployment remains essential for practical adoption.

V. CONCLUSION

This project presents a comprehensive IoMT-based solution for real-time soldier health and threat monitoring in challenging battlefield environments. The system successfully integrates multiple sensors, embedded hardware, and intelligent data processing to ensure continuous monitoring of critical parameters. By combining biometric and environmental sensing, the proposed model enhances situational awareness and improves decision-making capabilities. The use of ESP32-based wearable nodes ensures a compact, cost-effective, and energy-efficient implementation. The adoption of MQTT protocol enables reliable and low-latency communication between devices and the command center.

A key contribution of this project is the integration of both edge-based TinyML and cloud-based deep learning models. This hybrid approach ensures system functionality even in communication-constrained scenarios. The TinyML model provides fast, real-time inference at the device level, supporting offline operations. The cloud-based LSTM and autoencoder model improves detection accuracy through advanced temporal analysis. The developed Flutter application offers an intuitive interface for real-time monitoring and alert management.

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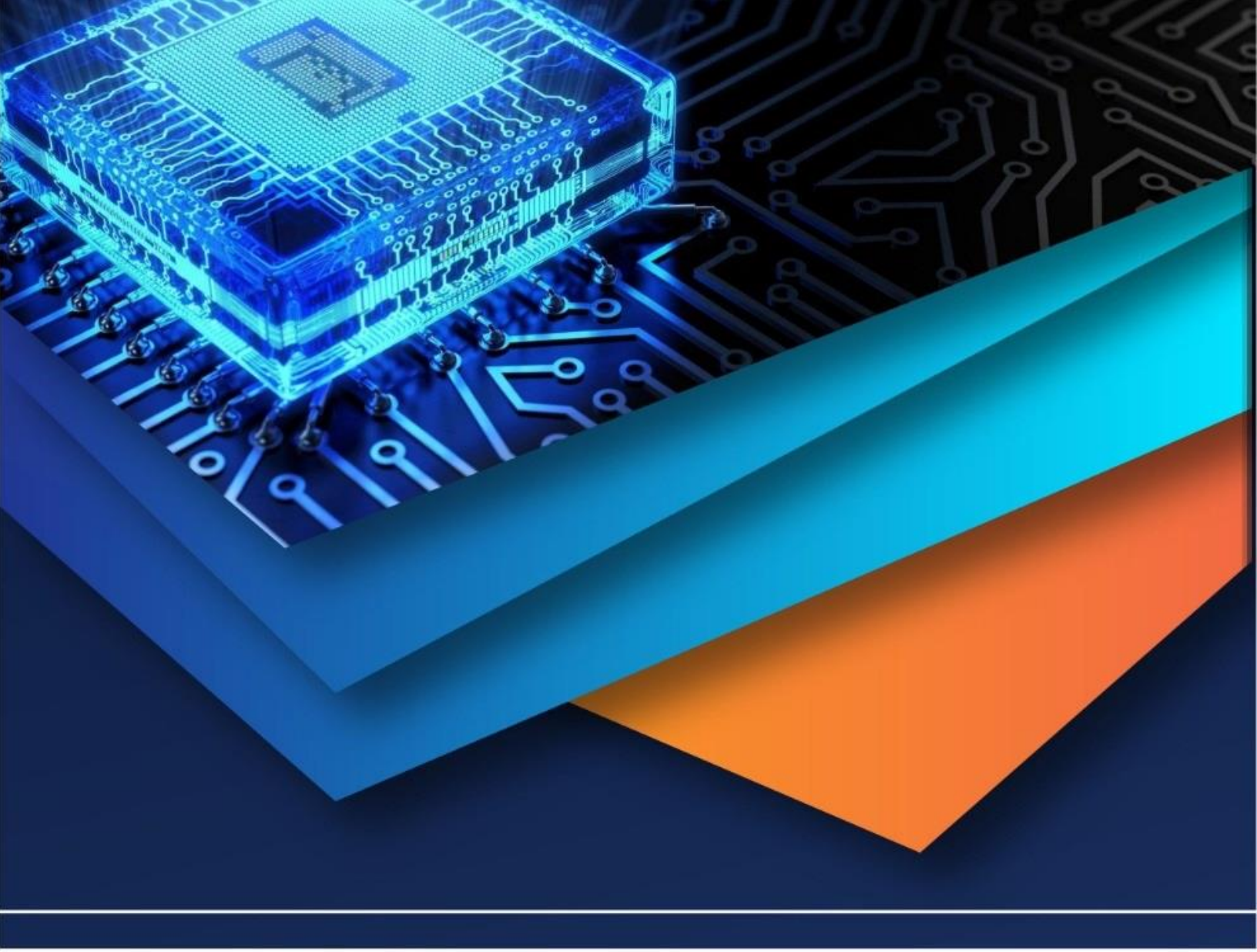
This enhances the ability of commanding officers to respond quickly to emergency situations. The system also demonstrates the effectiveness of multi-sensor data fusion in identifying complex health conditions. Experimental results indicate improvements in latency, reliability, and detection efficiency compared to traditional systems. The project successfully addresses major limitations of existing approaches, such as high false positives and lack of real- time intelligence.

Additionally, the prototype remains economically feasible, making it suitable for scalable deployment. Despite these advantages, further improvements can be made in terms of large-scale testing and rugged hardware design. Future work can explore federated learning and enhanced security mechanisms for better data privacy and system robustness. Integration with advanced communication technologies like LoRa can further improve range and reliability. Overall, the proposed system demonstrates a significant step toward intelligent and resilient military IoMT solutions

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