IoT Framework for Modern Battlefield : Implementation of Soldiers Health Integration for Enhanced Location Deployment (SHIELD) System

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***Abstract*— Battlefield awareness is the ability of military forces to collect, analyse, and comprehend real-time information of the battlefield and it enables commanders to make well-informed decisions. The soldier is the most critical element in the tactical battlefield. Their potential to fight and ability to provide valuable battlefield information needs to be enhanced. This paper presents an implementation of an Internet of Things (IoT) architecture designed for monitoring soldiers' health and acquiring real-time battlefield data. The system, named Soldiers Health Integration for Enhanced Location Deployment (SHIELD), integrates a comprehensive range of biometric and environmental sensors. These sensors monitor not only the physiological parameters of the soldiers but also critical aspects of the battlefield. Portable and designed for long-range functionality with low power consumption, the SHIELD system incorporates key IoT technologies and biometric sensors in a wearable device. This device facilitates seamless communication and data exchange between the soldier and a centralised command centre. Emphasis is placed on achieving low-latency and high-reliability data transmission to enable real-time monitoring and prompt decision-making.**

Keywords— Battlefield awareness, Internet of Things (IoT), SHIELD, Real-time monitoring.

I. INTRODUCTION

Battlefield awareness is a crucial aspect of all tactical military operations, demanding continuous acquisition, processing, and comprehension of real-time information. The ability to make informed decisions, adapt swiftly to evolving circumstances, and optimize resource utilization is paramount for military commanders. Recognizing the soldier as the linchpin in this dynamic environment, this paper introduces an innovative solution in the form of the Internet of Things (IoT) based portable soldier wearable system named 'Soldiers Health Integration for Enhanced Location Deployment' (SHIELD) System. Focused on augmenting real-time battlefield awareness, the system presented in this paper seamlessly integrates an extensive range of biometric and environmental sensors with the soldier making him a potent weapon in himself.

Beyond monitoring the physiological parameters of the soldier, the system extends its scope to encompass crucial aspects of the surrounding battlefield environment. This wearable device harnesses IoT technologies, facilitating seamless communication and data exchange between the soldier's wearable and a centralized command centre. Emphasizing the achievement of low-latency and high-reliability data transmission, the system is designed for real-time monitoring and decision-making, thereby ushering in a new era of enhanced military operational effectiveness.

The focus of this paper is to implement a novel architecture for a long-range low power portable system which can be worn by a soldier in the tactical battlefield. The system is expected to be robust and reliable and preferably have a very low latency for real time data accessibility. The system is designed using Military Internet of Things technologies which is a subset of IoT.

The Internet of Things (IoT) is a system of interlinked physical devices which can be any vehicle, appliance, and various other objects that are equipped with sensors, software, and network connectivity. This empowers them to gather and share data. The core idea of IoT is to establish a seamless and intelligent link between the information sensing and decision making, facilitating continuous and uniform data transmission among devices. This makes decision-making based on reliable data and knowledge.

Internet of Military Things (IoMT) takes IoT a notch further. The plethora of sensors and actuators that exist on the modern battlefield are integrated into a single system with IoT based technologies giving rise to IoMT. The integrated system now acts a force multiplier on the battlefield making battlefield awareness and soldier health monitoring easier than never before.

II. LITERATURE REVIEW

The inception of the Internet of Things (IoT) dates back to the early 1980s. First demonstration of an IoT based system was a modified beverage vending machine at a leading American University which emerged as one of the earliest instances of a network of smart devices. This vending machine, connected to a local network, transmitted data regarding its stock level and the condition of the stored products. However, the contemporary concept of IoT took shape in the early 1990s with leading researchers working on IoT based technologies. This idea gained traction in academic forums due to its potential for plethora of applications. Since then, IoT has undergone substantial development, giving rise to various subsets with their own applications in military, agriculture and medical fields.

Yokotani in his paper [1] has discussed the application and technical issues of IoT in 2012. His research introduces the concept and definition of IoT, as well as its architecture, key technologies, and challenges. The paper reviews some of the existing and potential uses of IoT in different areas, such as domestic, urban, smart grid, smart medicine, and smart industry. He also identifies some of the technical issues and research directions for IoT, such as standardization, interoperability, security, privacy, scalability, reliability, and energy efficiency.

Yushi, Fei and Hui [2] in his paper explores the technical details and application modes pertaining to Military IoT (MIOT). The paper proposes a definition and an architecture of MIOT. The paper analyses three methods of MIOT, namely data detection, data communication, and data processing, and illustrates how they can be applied in various military domains, such as command and control, intelligence and reconnaissance, weapon control, logistics support, and training and simulation.

Jin, Gubbi et al. [3] have given an outline for forming an intelligent urban network using system of interconnected devices in 2014. They have given a comprehensive review of IoT technologies and proposed an architecture for an intelligent metropolitan using interconnected devices.

In 2018, Walker et al. [4] implemented a portable system for soldiers in the battlefield which could sense various physiological parameters, using wearable biosensors, wireless communication, and cloud computing. The system is based on BSN and aims to provide real-time information about the soldiers' vital signs, location, and environmental conditions, as well as to alert the base station and medical personnel in case of emergencies. Their research deliberates on the advantages and uses, such as enhancing the safety and performance of the soldiers, facilitating the medical decision making and intervention, and improving the command and control of the military operations.

Gondalic et al. [5] discuss a system that can detect the geographical position and sense the various parameters of the soldiers in real time with the help of positioning systems and various biometric sensors. Their paper also discusses the challenges and benefits of the system, such as enhancing the safety and performance of the soldiers, facilitating the medical decision making and intervention, and improving the command and control of the military operations. The paper presents a system architecture and a prototype implementation using Arduino, Node MCU, and various sensors.

In 2018, Mdhaffar et al. [6] in their paper presented a system in which various sensors were used as an interconnected system for tracking the soldier's parameters using LoRaWAN and secure wireless communication technology. Their paper proposes a system that can collect and transmit biosensor data from patients to a cloud-based analysis module, where algorithms are used to detect abnormal situations and provide feedback. The paper also discusses the challenges and benefits of the system, such as reducing the cost and complexity of health monitoring, improving the quality of care and patient satisfaction, and enabling remote and preventive healthcare. The paper presents a system architecture and a prototype implementation using Arduino, Node MCU, LoRaWAN, and various sensors.

III. Related Work

IoT and IoMT based technologies have seen rapid growth in the recent past owing to the plethora of applications they offer. There have been numerous implementations of IoT based systems in the field of defence and military applications. The aim of this research-based project is to propose and implement a novel framework architecture which may advance IoMT technology in a tangible way and contribute to further applications.

Manoje et al. [7] have presented a model for combatant tracking system that detects the different physiological parameters. It is implemented using a programmable microcontroller and associated sensors. They have used Zigbee technology for transmission and reception of data.

Another implementation of such system is done by Nikam et al. [8] in 2017. They have presented a system for the position tracking of a soldier and his navigation using GPS. The system has been implemented using an ARM based microcontroller.

IV. System Design and Framework

The presented system would comprise of an array of IoT based sensors which would capture the data of the soldier's physiological parameters like body temperature, heart rate and pulse rate as well as critical data about the battlefield like ambient temperature, presence of harmful gases or radiological agents.

The system is implemented in the form of a portable system in the form of a jacket which can be worn by the soldier. A constellation of such system will communicate to a gateway which can be vehicular or with the team leader. The information gets further communicated to the next processing node in channel. So broadly, the system consists of the soldier wearable system and the base station.

One critical component of this system is the geographical location data of the soldiers. This data is obtained by use of GPS based sensor which provides real time location of the soldiers. Another critical aspect is the communication of data from the combatants on the ground to the processing centre and back. To enable this communication of data, various technologies like Zigbee, LoRa WAN and GSM were examined based on parameters like range, power requirements, antenna size, latency and bandwidth. Based on the study and comparison of these technologies, LoRa WAN was selected as it optimally suited the requirements. [15,16]

V. System Architechure

The fundamental entity of battlefield is the soldier. In the SHIELD system, a wearable harness system is worn by the soldier. The system comprises of various sensors which capture soldier's physiological data and data from the surroundings. The graphical representation of the soldier with the SHIELD has been depicted in Figure 1.

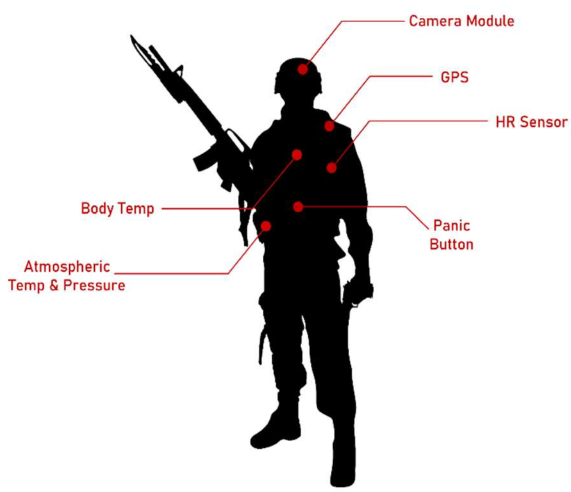

Fig. 1. System Architecture of the IoMT based System

The framework for the Soldier Wearable SHIELD device has been shown in Figure 2. It is based on three entities i.e. a Command-Relay Network, a Field Command Post and a Squad. [15]

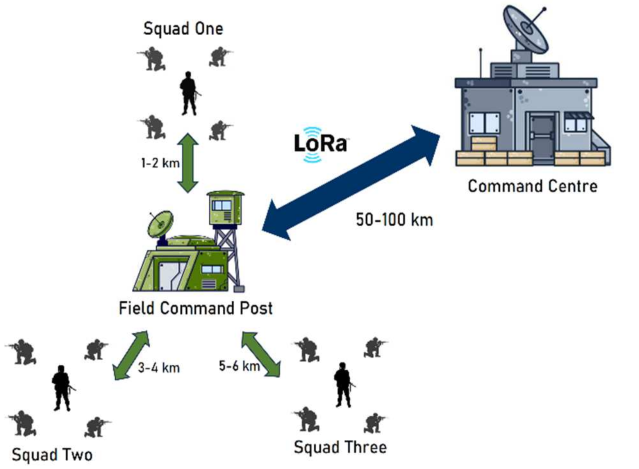

Fig. 2. System Architecture of the IoMT based SHIELD System

The system envisages the basic entity of a field unit as the Squad which consists of small team of 5 to 10 soldiers led by a team leader. The data from this squad flows to the Field Command Post. The collected data is collated and sorted here. It may be further sent to the Command Centre where higher computing resources are available for sorting and processing of data. Relevant decisions with respect to the battlefield are taken here and then are communicated down the chain.[18]

The consolidated architecture consists of the connection from each soldier to the Squad Leader and then further to the next command post or station. The Squad dynamics are illustrated in Fig. 3.

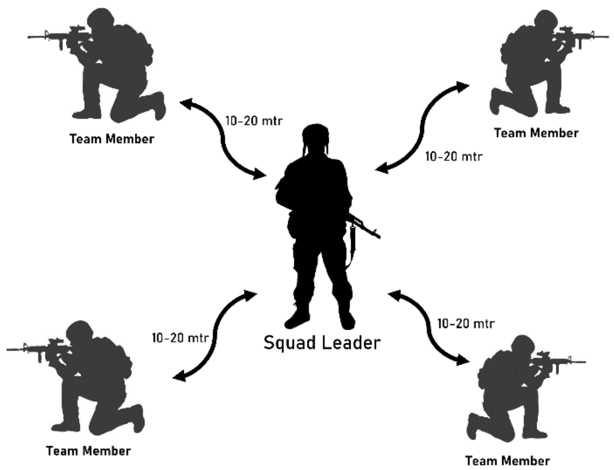

Fig. 3. Dynamics within a Squad

VI. Selection of Components

The system presented in this paper is based on a programmable microcontroller which is robust and reliable. The other components of this system are various sensors which will provide the data of the soldier and the surroundings. The next aspect is the communication technique. The comparison and selection of components is discussed in succeeding paragraphs.[20]

A. Microcontoller.

The system being based on IoT, the microcontroller for development of the system was chosen as the Arduino Nano for the transmitter and ESP 32 based integrated development board for the receiver. Fig. 4 and Fig. 5 show the Arduino nano and ESP 32 microcontrollers.

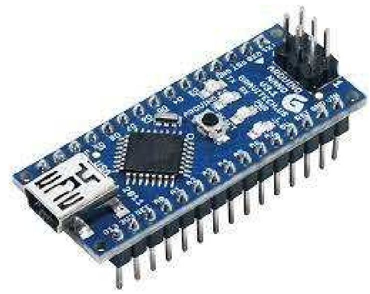

Fig. 4. Arduino Nano Microcontroller for Transmitter

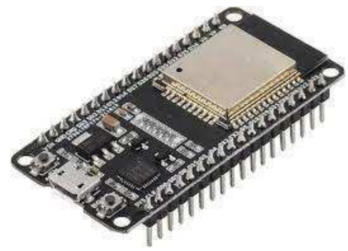

Fig. 5. ESP 32 Integrated IoT Development Microcontroller

B. Sensors

The SHIELD system consists of various sensors for data capture. These sensors include heart rate sensor, body temperature sensor, GPS module, ambient pressure sensor and gas sensor. These are as shown in figures below.

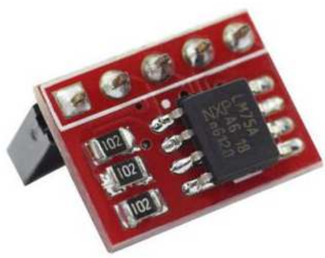

Fig. 6. LM 75 Temperature Sensor

Body temperature is one of the most crucial physiological parameters of the human body. In active combat, detecting and tracking soldier's body temperature helps us to understand the current status of the soldier. In SHIELD system, the temperature sensor used is LM-75. It is interfaced to a microcontroller. It continuously senses temperature data and sends to the microcontroller.

Fig. 7. MQ 135 Gas Sensor

In active combat scenarios, the soldiers have to face many situations where they may encounter harmful gases. These gases may be a result of explosions, chemical warfare or radiological warfare. Detecting these harmful gases forms an important part of SHIELD system. To detect the presence of various gases on the battlefield, MQ-135 gas sensor is interfaced with the microcontroller of the SHIELD system. The gas sensor alerts microcontroller whenever it encounters any harmful gas.

Fig. 8. MAX 30102 Heart Rate Sensor

Another important physiological parameter is the heart rate and oxygen saturation in the blood. In the SHIELD system, MAX-30102 sensor is used to detect the heart rate and oxygen saturation. It is interfaced with the microcontroller and provides continuous data.

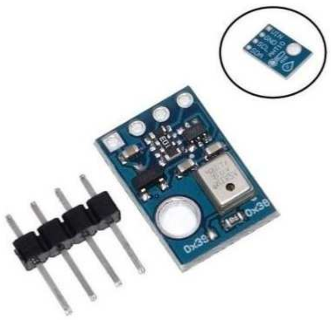

Fig. 9. AHT 10 Digital Temperature and Humidity Sensor

Battlefield awareness necessitates precise detection of the tactical battlefield environment. One critical aspect of the battlefield is the ambient temperature and humidity. The temperature and humidity data are crucial for accurate use of many weapon systems. In SHIELD, this data is provided by AHT-10 sensor, which is interfaced to the microcontroller and provides continuous data. This data precisely alters weapon parameters.

Fig. 10. SX1276 LoRa Transmitter and Receiver

An indispensable component of the SHIELD system is the data transmission between various entities. Many viable options are commercially available for use in the system. However, one technology which stands out is LoRa communication. Based on LoRa, the communication protocol used in this system is LoRaWAN. For communication, SX1276 is used which provides the needed range for the application envisaged.

Fig. 11. NEO 6M GPS Module

The geographical location of the soldier is of vital importance in the tactical battlefield and is detected using global positioning system. For providing the location data, Neo-6M sensor. This sensor provides data in the form of latitude and longitude. The sensor is interfaced with the SHIELD system and provides continuous location data. There is an integrated antenna with the sensor. The sensor is fast and provides quick latch-on on the satellites.

VII. Implementation Details

The main objective of SHIELD device is to improve the accuracy of actions of the soldiers on the tactical battlefield. It comprises of various components, like biometric and bio-mechanic sensors and other sensors which detect other environmental parameters. Temperature and humidity of the surroundings is detected with an AHT-10 sensor, providing the reading in degrees and humidity in percentage.

The system also includes a hazardous gas sensor which detects the presence of harmful gases which can be used in chemical or radiological warfare. For soldier tracking, the system integrates the GPS sensor, offering accurate position data. The global positioning system sensor is employed to access the satellites signals, determining the soldier's position information, which are then sent to the microcontroller.[19]

The programmable controller, equipped with integrated program for an IoT module on a programmable microcontroller, is designed to monitor and capture the physiological parameters of the soldiers. The in-built SHIELD device activates an alarm if the body parameters surpasses or declines as compared to a benchmark value, and it triggers various other mechanisms which can help the soldier to maintain their body parameters. Through a serial connection, the IoT module transmits and receives temperature, heart rate, and location data.

The results are displayed in the base station. In emergency situations, an alert can be sent to the field command post or to the other unit by pressing an emergency switch. The receiver module continually monitors the status, presenting relevant information on an LCD display. The figures below show the actual system implementation.

Fig. 12 shows the transmitter module and Fig. 13 shows the receiver module. There can be many transmitter modules connected to a central receiver module.

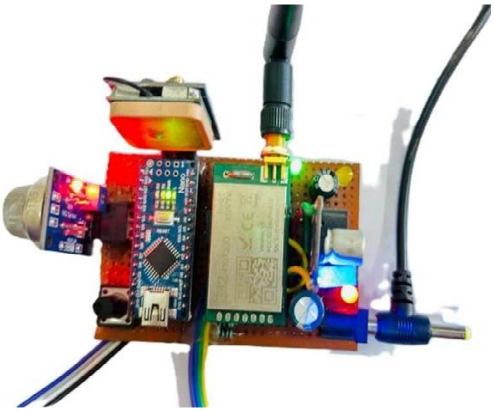

Fig. 12. SHIELD Transmitter Module

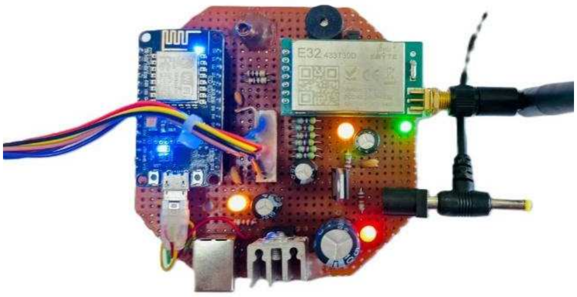

Fig. 13. SHIELD Receiver Module at Base Station

VIII. Results and Discussion

The system was rigorously tested in various environments and in varying weather conditions to simulate the battlefield environment.

A. *Ranges Achieved*

Typical range achieved was approximately 7 km. The range achieved remained unaffected by the presence of building and other structures.

B. *Transmission and Reception of Data*

The data from the sensors is constantly monitored, captured and transmitted to the base station by the SHIELD transmitter. Parameter threshold can be set to alert the base station for various emergencies.

Upon successful transmission, a data frame containing GPS position information is dispatched to the command node or the nearest data processing node capable of taking decisions. In case of the soldier's vital signs deviating from the set benchmarks, the command node promptly is alerted by the transmitter of the soldier and provides the accurate location. This allows for the collection and assessment of crucial physiological parameters and position of soldier.

There is provision of a ‘panic’ switch which can be manually activated by the soldier or automatically triggered in an event like the soldier taking a hit on the body. Upon activation, an emergency alert is sent to the command node including the position. This could be used to request for emergency backup or for evacuation.

LoRa uses spread spectrum at its physical layer which gives built-in prevention strategy to protect data from jamming attacks. collision recovery and parallel decoding are some potential protection solutions used in the LoRa to protect a Gateway against jamming attacks. Additionally, the combatant is in a surrounding which is having adverse weather and the parameters fall below or go above the benchmarks, there is a provision for inclusion of heating or cooling system which can be switched on. Any abnormal pulse rate triggers an alert to the command node or squad leader as the case may be, providing the precise position. The device, affixed to the soldier’s tactical harness or harness utilizes location sensor for tracking both health status and current position.

C. *Interface for Data Reception*

The system status interface is available in dual mode. It is implemented as part of the receiver module as LCD screen. This is aimed to facilitate handheld usage in field conditions by the squad leader or field command post. In a more sophisticated setting, the data can also be captured and represented on a computer display in terms of body temperature, heart rate of the soldier and temperature, humidity and hazardous gases on the battlefield. If the Soldier presses the panic button, then it will be displayed in the field of backup requirement. With the help of the GPS module, the location of the soldier is recorded at the centre of the display on the map.

In this system, the data is displayed remotely using Adafruit utility.

Fig. 14. LCD display of SHIELD Receiver Module

Fig. 15. System interface on Adafruit IO

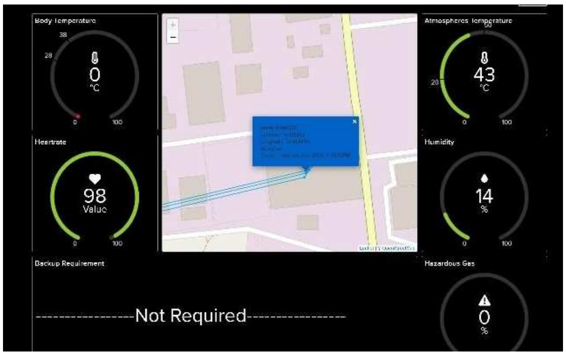

Fig. 16. Data received and displayed on System Interface

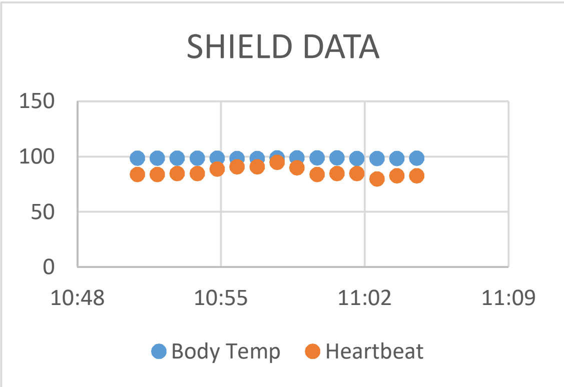

Fig. 17. SHIELD Data of HR and Body Temp against Time

Above graph shows the data captured for a sample unit time period for the SHIELD system. The parameters are shown as mapped against time.

IX. Conclusion and Future Scope

The objective of this paper has been to disseminate data about successful employment of SHIELD system in the simulated combat scenario. SHIELD has been proven to be successful in capturing and transmitting various parameters of the solider and more importantly capture battlefield data using sensors like gas sensors, pressure and ambient temperature sensor. In future, we envision enhancing the system by incorporating a solar panel for continued power accumulation during the day.

SHIELD system employs an innovative data transmission method for transmitting accurate sensor data. The seamless and rapid flow of information is achieved over large range using LoRaWAN communication technology. This allows the command node or another squad to assist in critical situations by tracking the sensor values, the surrounding battlefield situation, and the soldier's location. The system proves highly advantageous in wartime and rescue operations, offering unrestricted use, ensuring the protection of combatants in battle, and exhibiting high effectiveness due to integrated systems and sensors.

SHIELD is capable of effortless attachment to a soldier's hand or harness and can be made more potent by implementing improved communication protocols to boost robustness and scalability. The Mic and camera can also be added at the receiver end to transmit the audio and video stream which is capable of transferring more information regarding soldier and battlefield.

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