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Health Threat-Aware Smart Soldier Monitoring System Using IoT

Shraddha, Shani Kumar Ray, Vivek Raj, Dr. Sazid
Dept. of Electronics and Communication Technology, Noida Institute of Engineering and Technology Greater Noida, India

***Abstract*—The safety, health, and situational awareness of the soldiers on missions must be guaranteed in the modern defense environment. It is essential to monitor the soldiers deployed to dangerous areas due to the presence of challenging environmental factors such as severe weather, physical exertion, and communication issues. This research paper will discuss the Health Threat-Aware Smart Soldier Monitoring System based on IoT technology that can be used to track the physiological status, environmental risks, and location information of the soldiers on missions.**

I. INTRODUCTION

In today's military operations, it is extremely important to ensure that the wellbeing of soldiers posted in difficult con-ditions is taken care of. Many times, soldiers are required to serve in extreme conditions, in which monitoring their physical fitness may prove important in preventing any health-related issues. Although current monitoring tools allow for monitoring of certain factors like heart rate and body temperature, their capabilities end there since they lack any analytical abilities. With the continuous development of IoT and embedded monitoring technologies, smarter and more reliable soldier safety systems can now be implemented for defense ap-plications. These technologies help in collecting important real-time information related to a soldier's health condition, environmental safety, and location tracking. However, many existing systems rely mainly on internet-based cloud platforms for processing and monitoring, which may cause communi-cation delays and reduced performance in remote or low-network battlefield regions. To overcome these limitations, the proposed Health Threat-Aware Smart Soldier Monitoring

System is developed using an ESP32 microcontroller with inte-grated local data processing capabilities. The system monitors important parameters such as heart rate, body temperature, harmful gas or smoke presence, and nearby metallic threats using multiple sensors. GPS and RFID modules are included for location tracking and soldier identification, while Wi-Fi communication supports remote monitoring functionality. In addition, a buzzer-based emergency alert mechanism is integrated to provide immediate warning during abnormal or dangerous situations. By processing sensor data directly on the embedded device, the proposed system reduces response time, improves reliability, and provides an efficient portable solution for real-time military monitoring applications.

II. LITERATURE REVIEW

A. Background

There is a pressing demand for efficient monitoring mech-anisms for soldiers as the environment of modern warfare becomes more complex and difficult. Continuous monitoring of various physiological parameters, including heart rate and body temperature, can help detect early onset of fatigue or any health issue. Early research on embedded systems and real-time computing stresses the necessity of predictability in timing and reliability in data processing, especially when working in critical systems that could pose threats to peo-ple's lives if there is even a minor delay in response. This notion is directly related to wearable monitoring devices, where data processing occurs promptly. Recently, IoT-enabled smart monitoring systems have been extensively considered for military and defense-related applications due to the efficiency and effectiveness with which sensor information is collected and transmitted in such systems. Smart monitoring systems make use of wireless technology to enable monitoring stations to monitor key health and environmental information from remote locations. However, there are some disadvantages with respect to the current monitoring schemes used in military settings in that they largely depend on internet connectivity and data processing through cloud computing systems, causing delay and inefficiency when internet connection is absent. One solution to this problem would be to implement the local data processing technique using microcontrollers, such as ESP32. In the case of Health Threat Aware Smart Soldier Monitoring System design, all data acquired by the sensors about the heartbeat, body temperature, harmful gases/smoke around the soldier, as well as the presence of metallic threats, are all processed locally. The inclusion of GPS and RFID devices fur-ther aids in the tracking and identification of soldiers involved in a military operation.The efficiency of energy consumption still needs to be considered when developing wearable devices because they should work non-stop with minimum amounts of available energy sources. In particular, power-aware ap-proaches in system design demonstrate that it is essential to balance energy consumption by implementing dynamic switching between activity periods and low-power modes. The described technique provides a continuous functioning cycle of devices without affecting their working capabilities.The application of monitoring systems depends not only on tech-nological issues but also on human factors. The development of signaling systems aimed at informing users about potential threats is another important element of wearable technology. Researchers prove that the proper visualization of warnings significantly affects reaction speed and the ability to assess situations correctly. At the same time, inappropriate signals can negatively impact users' decisions.On the whole, current studies prove that there is considerable success in fields such as IoT-based monitoring systems, edge computing, and intelligent devices. At the same time, many wearable devices do not integrate such innovations as predictive analytics, real-time edge computing, and secure communication. These elements are essential for the development of a reliable and effective defense system.

III. PROPOSED METHODOLOGY

The Health Threat Aware Smart Soldier Monitoring System that we have designed is an embedded device that is compact and easily portable for military safety. It uses the ESP32 microcontroller as its central processing and communication module. Various sensors have been used in our prototype design, such as a pulse sensor that measures heart rate, temperature sensor that detects the body's temperature, gas sensor (MQ-2) that senses the presence of smoke and other dangerous gases, and finally inductive proximity sensor that senses any nearby metallic threat. Apart from the mentioned sensors, we have also incorporated GPS and RFID modules that help us track and identify the soldier during military operations. The entire system functions via continuous monitoring and localized data processing performed by the ESP32 control board. Real-time sensor readings can be viewed on the LCD/OLED display screen. Once there is an occurrence of an abnormal heartbeat, high temperature, gas leakage, and/or metallic objects, the alert system will automatically activate to inform the user or authorities of such incidents. With the Wi-Fi capability of the ESP32, remote monitoring becomes possible even without physically being near the device as long as there is an active Internet connection. The use of rechargeable batteries allows for energy conservation and portable use of the system.

IV. SYSTEM DESIGN

A. System Architecture

This paper discusses the Health Threat-Aware Smart Soldier Monitoring System which is designed as a holistic embedded system that monitors the safety of soldiers, detects environmental threats, and tracks their locations. The central unit of the proposed system is the ESP32 microcontroller. Different sensors are attached to the ESP32 microcontroller that monitor critical variables associated with the soldier's health and environment. The heartbeat of the soldier is mon-itored through a pulse sensor, while the body temperature is measured through a temperature sensor. Moreover, an MQ-2 gas sensor is used to detect any smoke or toxic gases, and an inductive proximity sensor is used to detect metallic threats. It is meant to analyze the data gathered from sensors in the local ESP32 system in order to provide timely action without being fully dependent on the availability of an internet connection. This data is also shown on the LCD/OLED screen for instant review. In addition to that, a buzzer and LED lights are used for emergency alerts. The WiFi communication capabilities of the ESP32 allow us to monitor this system remotely in case there is any network availability. The entire design aims to keep things compact and portable for use in battlefields.

B. Hardware Design

In this case, the hardware design will be based on three important aspects that include mobility, energy consumption efficiency, and reliable real-time performance. The main con-troller that will be used is the ESP32 microcontroller since it comes with integrated Wi-Fi capabilities, high-speed pro-cessing power, and multiple interface communication options. Pulse sensor will be utilized to measure the soldier's heartbeats rate at any moment, whereas the temperature sensor will be used for measuring body temperature for health analysis purposes. MQ-2 gas sensor will help identify smoke and other harmful gases within the environment, while the inductive proximity sensor will be used to detect metallic materials around the soldier. The outdoor GPS module to be used is the Neo-6M GPS module, which will be connected via serial com-munication link. The RC522 RFID module will be used for soldier recognition purposes, as well as indoor soldier tracking. LCD/OLED will be used as a display device to indicate sensor data measurements in real-time fashion. Finally, a buzzer and LED devices will be used for generating emergency alarms

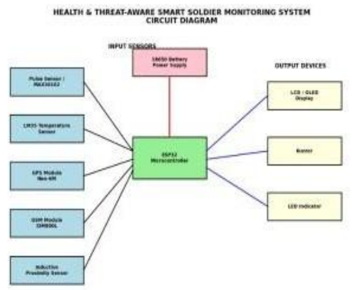

Fig. 1. Software Architecture

whenever there are any dangerous situations. The system will run with the aid of a rechargeable battery together with the appropriate voltage regulation circuitry.

The software design of the Health Threat-Aware Smart Soldier Monitoring System is created through embedded C coding in the Arduino Integrated Development Environment (IDE). The software is divided into several functional modules such as sensor data acquisition, local processing of data, display control, communications, and alerts among others. Prior to entering the operational phase, the ESP32 initiates the sensors, communication ports, and display devices.

The code constantly acquires the sensor readings from the heartbeat sensor, temperature sensor, gas sensor, and proximity sensors. The processed data is checked against pre-established safe threshold values in order to determine abnormal conditions. The processed data is then presented on the LCD/OLED display. Upon detecting an unsafe condition such as an abnormal heartbeat, high temperature, presence of smoke or metal threats, the code triggers the buzzer and LED alerts. Additionally, functions for Wi-Fi communications are included but not implemented in order to accommodate future upgrades to cloud connectivity.

C. Software Design

The software design of the Health Threat-Aware Smart Soldier Monitoring System is created through embedded C coding in the Arduino Integrated Development Environment (IDE). The software is divided into several functional modules such as sensor data acquisition, local processing of data, dis-play control, communications, and alerts among others.Prior to entering the operational phase, the ESP32 initiates the sensors, communication ports, and display devices.

D. Algorithm and Flow of Operation

The proposed system works through a systematic process of monitoring, processing, and sending alerts. First, the ESP32 initializes the system by setting up all sensors, display units, communication devices, and alerting systems. Subsequently, the ESP32 continues gathering real-time data from the heart rate monitor, the temperature sensor, the MQ-2 gas sensor, and inductive proximity sensors.

Once collected, the raw data is subjected to a local com-putation and comparison process against preset safety limits in the system. In case the values fall within the acceptable limit, the system displays the values on the LCD/OLED unit

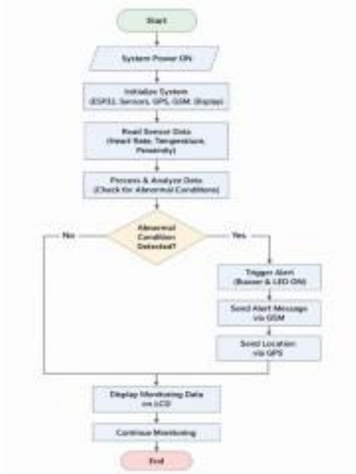

Fig. 2. Flow Chart

continuously. However, in case of abnormal values such as abnormal heartbeat, high temperatures, smoke detection, or metal presence, then the alarm will be triggered through the buzzer and the LEDs. GPS and soldier data may also be transmitted wirelessly for further analysis.

V. RESULTS AND DISCUSSION

A Health Threat-Aware Smart Soldier Monitoring System that had been suggested was analyzed and tested to establish how well it performs, how reliable it is, how well it monitors, and how efficient it responds depending on the conditions under which it operates. The Health Threat Aware Smart Sol-dier Monitoring System was subjected to testing by inputting information about heart rate, body heat, smoky and gaseous el-ements, metallic objects, and the position coordinates through GPS sensors.

A. System Functionality

The implemented system ran smoothly during real-time testing without experiencing any delay or problem in commu-nication. The ESP32 controller effectively collected the sensor information, processed it locally, displayed it on the LCD screen, and generated alert messages in real time. The pulse sensor consistently monitored the heartbeat values, and the temperature sensor continuously recorded body temperature. The gas sensor was capable of detecting smoke and toxic gases, and the proximity sensor sensed metallic objects around its vicinity.

As soon as an unusual condition related to high temperature, heartbeat, gas leakage, and metallic presence happened, the buzzer and LEDs immediately triggered alert messages. The GPS sensor consistently tracked the device's location, and the RFID sensor facilitated identification features. All the sensors were displayed simultaneously on the LCD screen.

Test Case	*Input Time*	*Expected Output*	*Observed Output*	*Result*
TC1	Normal Condition	No Alert	No Alert	Pass
TC2	High Temperature	Alert Activated	Ale	Pass
TC3	High Heart	Risk Detected	Risk Detectd	Pass
TC4	GPS Tracking	Accurate Location	Accurate Location	Pass
TC5	Long Operation	Stable Performance	Stable operation	Pass

Fig. 3. Data Table

B. Accuracy and Performance Analysis

The system performed satisfactorily during the real-time implementation without any communication delay. The ESP32 controlled the process of collecting data from the sensors, processing the data, displaying it on the LCD and also generated alert messages in real-time mode. The pulse sensor kept on monitoring the heartbeat data while the temperature sensor kept on recording the temperature data. The gas sensor detected the occurrence of smoke and other toxic gases while the proximity sensor detected metal objects near it.

Immediately after the detection of an unusual condition due to the occurrence of high temperature, heartbeat rate, gas leakage, and metallic presence, the alarm signals were produced by the buzzer and LEDs. The GPS sensor monitored the position of the device whereas the RFID sensor provided identification capabilities to the sensors.

C. Power Consumption and Efficiency

Power efficiency was an essential criterion for portable mon-itoring equipment since portable monitoring tools are expected to function non-stop under field conditions. The developed monitoring system exhibited low power consumption as a result of efficient power management of the ESP32 microcon-troller and efficient work of sensors. Power consumption is low during routine work of the system, while communication and alarming functions become operative only if necessary.

Rechargeable 18650 lithium batteries were used for provid-ing stable portable power supply during the testing process. Efficient power regulation was implemented in order to protect system components from voltage fluctuations. Thus, the de-veloped monitoring tool showed a good compromise between monitoring quality and power consumption.

D. Test Case Analysis

From the results of experiments, it is possible to conclude that the Health Threat-Aware Smart Soldier Monitoring Sys-tem suggested in this study presents an effective and reliable system designed for real-time applications in military safety monitoring. It outperforms other similar monitoring systems because of its improved capabilities, which are implemented due to such features as multi-sensor usage, embedded local processing, environmental threat recognition, GPS localiza-tion, RFID identification, and alerts.

E. Discussion

From the results of experiments, it is possible to conclude that the Health Threat-Aware Smart

Soldier Monitoring System suggested in this study presents an effective and reliable system designed for real-time applications in military safety monitoring. It outperforms other similar monitoring systems because of its improved capabilities, which are implemented due to such features as multi-sensor usage, embedded local processing, environmental threat recognition, GPS localiza-tion, RFID identification, and alerts. Thanks to the ESP32 microcontroller, the system proved effective for implementing the required features. Its low power consumption, wireless communication capability, and efficient integration of sensors were beneficial for this system. Besides,it can be improved further using the possibility of connecting to cloud services and adding new sensors. At the same time, there are several issues associated with limitations in communication in highly obstructed areas and sensor calibration. In terms of further research, the next steps would be to apply artificial intelligence to health prediction, improve wireless communication features, and develop a mobile application for the system as well as to implement additional sensors. In general, the proposed system proves to be an effective and scalable solution for monitoring soldier

F. CONCLUSION

The developed system proves to be a working example of successful implementation of embedded technology in health and threat awareness in smart soldier monitoring. The system includes a range of sensors, which detect soldier heart rate, body temperature, smokes and other gases, metallic objects, and determine GPS coordinates as well as track soldier movements using RFID technology. ESP32 microcontroller is capable of handling all data from sensors, its local pro-cessing, transmission over wireless networks, and generating alerts. The system created is an excellent example of a good integration of the use of embedded technology in health and threat awareness for monitoring smart soldiers. This system contains various sensors that will help monitor the heart rate of soldiers, their body temperature, smokes, and other gases, metallic items, as well as GPS coordinates, among other things. The ESP32 microcontroller can process all information from sensors and transmit them wirelessly via Wi-Fi. This system has been tested under several environments, and its efficiency has been observed to be quite impressive. The ability of this system to process information locally, display on LCD/OLED screens, have alarms such as buzzers, and use wireless technologies such as Wi-Fi makes this system more efficient compared to previous ones.

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