RESEARCH PAPER

IoT-Based Real-Time Soldier Health Monitoring with Smart Drug Delivery System Using Wireless Sensor Networks

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ABSTRACT: The integration of advanced healthcare technologies in military environments is essential for ensuring the safety and survival of soldiers in critical conditions. This paper presents the design and development of an IoT-based real-time soldier health monitoring system integrated with a smart drug delivery mechanism using wireless sensor networks (WSN). The proposed system employs wearable biosensors to continuously monitor vital physiological parameters such as heart rate, body temperature, and blood oxygen levels. These parameters are transmitted in real time to a central monitoring unit through a low-power wireless communication network.In emergency situations, the system utilizes an intelligent decision-making algorithm to analyze the collected data and detect abnormal health conditions. Upon identification of critical thresholds, an automated drug delivery module is triggered to administer predefined medication dosages to the soldier, ensuring timely medical intervention even in remote or battlefield environments. The integration of IoT with controlled drug delivery enhances responsiveness and reduces dependency on immediate human medical assistance.The system is designed to be energy-efficient, reliable, and scalable, making it suitable for deployment in harsh and inaccessible terrains. Experimental results demonstrate the effectiveness of the proposed framework in providing continuous health monitoring and accurate drug delivery with minimal latency. This approach significantly improves soldier survivability and operational efficiency by combining real-time monitoring with automated therapeutic response.

Keywords: Wireless Sensor Networks (WSN) , Soldier Health Monitoring ,Real-Time Monitoring, Smart Drug Delivery System , Automated Drug Administration, Wearable Sensors, Biomedical Monitoring

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1. INTRODUCTION:

Soldiers deployed in battlefield environments are frequently exposed to extreme physical exertion, harsh climatic conditions, and life-threatening situations. These factors significantly increase the risk of injuries, fatigue, and sudden medical emergencies. In such critical scenarios, continuous monitoring of vital physiological parameters becomes essential to ensure the safety and operational efficiency of soldiers. However, traditional health monitoring approaches rely on periodic medical checkups or manual observation, which are not suitable for real-time assessment in combat zones.

Recent advancements in the Internet of Things (IoT) and wearable sensor technologies have enabled the development of smart health monitoring systems capable of continuously tracking physiological parameters. Sensors such as heart rate monitors, temperature sensors, and motion sensors can be integrated into compact wearable devices to collect real-time health data. This data can be processed and transmitted wirelessly to remote monitoring centers, allowing medical teams to make timely decisions.

The proposed system focuses on developing an IoT-based soldier health monitoring device that integrates multiple sensors with an embedded microcontroller for real-time data acquisition and analysis. The system continuously monitors parameters such as heart rate, body temperature, and movement conditions, and transmits the data using wireless communication technologies such as GPS and GSM. In case of abnormal readings, automated alerts are generated to notify the control unit, enabling immediate medical response.

By providing continuous monitoring, rapid data transmission, and automated alert mechanisms, the proposed system enhances situational awareness and improves the overall safety and survivability of soldiers in battlefield environments.

2. LITERATURE REVIEW:

Recent advancements in biomedical engineering and Internet of Things (IoT) technologies have led to the development of various real-time health monitoring systems aimed at improving patient safety and early detection of medical conditions. Researchers have focused on integrating wearable sensors, wireless communication, and embedded systems to enable continuous monitoring of physiological parameters.

Madavarapu et al. (2024) introduced an IoT-based wearable health monitoring system that continuously tracks vital parameters and transmits data for remote analysis. Their work highlights the importance of real-time monitoring in improving healthcare outcomes. Similarly, Arun et al. (2025) developed an IoT-based patient monitoring system with fall detection capabilities, emphasizing the need for immediate alert mechanisms during emergencies.

Mnaathr (2023) proposed a remote health monitoring system using IoT, which enables real-time data transmission to healthcare professionals for continuous observation. This study demonstrated the effectiveness of wireless communication in improving patient care. Saini et al. (2024) presented an IoT-enabled health monitoring system that collects physiological data and uploads it to cloud platforms, enabling remote access and analysis.

Kommey et al. (2018) developed a medical emergency alert system capable of detecting abnormal conditions and notifying caregivers automatically. Their research emphasized the importance of automated alert systems in reducing response time during critical situations.

In addition, studies on wearable sensor systems and wireless sensor networks have demonstrated the feasibility of integrating multiple sensors for accurate physiological monitoring. These systems provide advantages such as portability, low power consumption, and continuous data acquisition. However, most existing solutions are designed for general healthcare applications and do not specifically address the challenges faced by soldiers in battlefield environments, such as extreme conditions, limited connectivity, and the need for rapid emergency response.

The findings from these studies provide a strong foundation for developing a specialized soldier health monitoring system that combines multi-sensor integration, real-time data transmission, and automated alert mechanisms to enhance safety and operational efficiency in critical environments.

3. PROPOSED SYSTEM:

The proposed system presents a compact, wearable, and IoT-enabled solution for real-time monitoring of soldiers' health conditions in battlefield environments. The system integrates multiple physiological sensors with an embedded microcontroller to continuously acquire, process, and transmit health data. It is designed to operate efficiently in harsh and remote conditions while ensuring reliability and quick response during emergencies.

The device monitors vital parameters such as heart rate, body temperature, and motion status. These parameters are processed in real time and transmitted wirelessly to a central monitoring unit using communication technologies such as GPS and GSM. In case of abnormal readings, the system automatically generates alerts, enabling immediate medical assistance and improving the survivability of soldiers.

3.1 System Design and Components

The system is designed by integrating sensing, processing, communication, and alert mechanisms into a single wearable unit. Sensors continuously collect physiological data from the soldier's body. The microcontroller processes this data and determines whether the values fall within normal limits. The processed data is then transmitted to a remote monitoring station, where it can be analyzed by medical personnel.

The system also includes an alert mechanism that activates when abnormal conditions such as high temperature, irregular heart rate, or unusual motion are detected. This ensures timely intervention in critical situations.

A. Hardware Components

The proposed system is built using a set of integrated hardware components that work together to ensure efficient real-time monitoring and response. The Arduino Nano functions as the central processing unit, coordinating all operations and managing data from various sensors. A heart rate sensor is used to continuously measure the soldier's pulse rate, while a temperature sensor and thermocouple provide accurate body temperature readings even under extreme environmental conditions. The MPU6050 sensor detects motion and orientation, enabling the system to identify falls or abnormal movements. For location tracking, a GPS module is incorporated to provide real-time positioning of the soldier. Communication is facilitated through a GSM module, which transmits health data and emergency alerts to remote monitoring stations. An LCD display is used to show real-time health parameters locally, while a buzzer generates immediate audible alerts during critical situations. Additionally, a push button allows the soldier to manually trigger an emergency signal when required. All components are powered by a reliable power supply, ensuring continuous and uninterrupted operation of the system.

B. Software Components

The system is implemented using embedded programming techniques to manage data acquisition, processing, and communication efficiently. Embedded C programming is used to configure and control the Arduino Nano, enabling it to interface with sensors and execute the overall system logic. The acquired sensor data is processed using data processing algorithms that filter noise and ensure accurate measurement of physiological parameters such as heart rate and body temperature. A threshold-based analysis approach is employed to continuously compare the sensed values with predefined limits, allowing the system to detect abnormal health conditions in real time. For communication, wireless communication protocols are utilized to transmit data through the GSM and GPS modules to remote monitoring stations. Additionally, an alert system logic is incorporated to automatically trigger notifications, alarms, and emergency responses whenever critical health conditions are identified, ensuring timely intervention and improved safety.

3.2 System Architecture

The system architecture as shown in Figure 1. consists of multiple layers including sensing, processing, communication, and monitoring.Sensors continuously collect physiological data → Arduino Nano processes and analyzes the data → Processed data is transmitted via GSM/GPS → Central monitoring unit receives and displays data → Alerts are generated if abnormal conditions are detected.This architecture ensures seamless data flow and real-time monitoring of soldiers' health status.

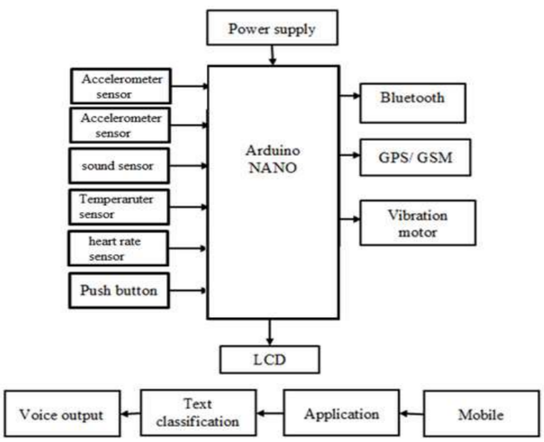

Figure 1. system architecture

A. Hardware Design

The hardware design focuses on creating a compact and wearable system by integrating all components into a single unit. Sensors are placed strategically to ensure accurate measurement of physiological parameters. The Arduino Nano serves as the central controller, interfacing with all sensors and communication modules.

The GPS and GSM modules are connected to enable location tracking and data transmission. The LCD display provides local visualization of health data, while the buzzer acts as an immediate alert mechanism. The entire system is powered by a portable power supply, ensuring uninterrupted operation in remote areas.

B. Software Design

The software design involves continuous data acquisition, processing, and decision-making.

Initially, sensor data is collected and filtered to remove noise and inaccuracies. The system then calculates parameters such as heart rate and temperature values. These values are compared against predefined thresholds to determine whether they are within normal limits.

If abnormal conditions are detected, the system activates the alert mechanism and transmits the data to the monitoring unit. The software ensures real-time performance, efficient data handling, and reliable communication, making the system suitable for critical applications.

Shock Index Diagnosis and Interpretation

In the context of soldier health monitoring, a derived parameter similar to the Shock Index can be used to assess the physiological condition of the soldier by correlating heart rate and body temperature variations. Continuous monitoring of these parameters helps in identifying abnormal physiological states such as stress, fatigue, or potential medical emergencies.

The system categorizes the health condition into different levels based on predefined threshold values:

- **Normal Condition:** Vital parameters remain within the safe range, indicating stable health status.
- **Moderate Risk:** Slight deviations from normal values suggest early signs of stress or fatigue, requiring observation.
- **Abnormal Condition:** Significant variation in parameters indicates potential health risks, requiring immediate attention.
- **Critical Condition:** Extreme values signal life-threatening situations, triggering instant alerts and emergency response.

This classification helps in early detection and timely medical intervention, improving the overall safety of soldiers.

3.3. Basic Workflow of the Project

The system operates through a continuous and automated workflow to ensure real-time monitoring:

- Sensors continuously collect physiological data such as heart rate, body temperature, and motion.
- The collected data is transmitted to the Arduino Nano for processing.
- The system filters and analyzes the data to obtain accurate parameter values.
- These values are compared with predefined threshold limits.
- If the values remain within normal range, the system continues monitoring.
- If abnormal conditions are detected, alerts are generated using a buzzer and transmitted via GSM.
- Simultaneously, GPS provides the location of the soldier for quick response.

This workflow ensures uninterrupted monitoring and rapid response in emergency situations.

Functional Features

The proposed system provides several functional advantages:

- Continuous real-time monitoring of multiple physiological parameters
- Automatic detection of abnormal health conditions
- Instant alert generation for emergency situations
- Wireless transmission of data for remote monitoring
- Integration of location tracking for quick medical response
- Compact and wearable design for ease of use in battlefield conditions

Benefits

- Enables proactive health monitoring instead of reactive treatment
- Reduces response time during medical emergencies
- Enhances soldier safety and survivability
- Provides reliable and accurate health data
- Cost-effective solution using low-power embedded systems
- Suitable for operation in remote and harsh environments

Applications

The system can be applied in multiple real-world scenarios:

- Monitoring soldier health in battlefield environments
- Tracking health conditions in remote military operations
- Disaster management and rescue team monitoring
- Monitoring personnel in hazardous environments such as mining or firefighting
- Remote healthcare monitoring in rural or inaccessible areas

Evaluation and Verification

The performance of the proposed system was evaluated based on several parameters to ensure reliability and effectiveness:

- **Accuracy Testing:** Sensor readings such as heart rate and temperature were compared with standard measurement devices to verify accuracy.
- **Real-Time Performance:** The system was tested for its ability to process and transmit data without delay.
- **Emergency Detection:** The system's capability to detect abnormal conditions and trigger alerts was verified.
- **Communication Reliability:** GSM and GPS modules were tested for consistent data transmission and location tracking.
- **Power Efficiency:** The system was evaluated for continuous operation under battery-powered conditions.

The results indicate that the system performs efficiently in real-time monitoring and provides reliable alerts during abnormal conditions.

Future Enhancements

The proposed system can be further improved by incorporating advanced technologies:

- Integration of cloud-based platforms for centralized data storage and remote access
- Development of a mobile application for real-time monitoring by medical teams
- Implementation of machine learning algorithms for predictive health analysis
- Enhancement of battery efficiency for longer operational duration
- Miniaturization of hardware components for improved comfort and wearability

Testing operation parameters:

Test Parameter	**Testing Description**	**Observed Value**
Heart Rate Monitoring	Accuracy of heart rate sensor compared with standard device	98%

Test Parameter	Testing Description	Observed Value
Body Temperature Monitoring	Measurement accuracy under different environmental conditions	97%
Motion Detection (MPU6050)	Detection of movement and fall conditions	95%
Data Transmission	Reliability of GSM communication for sending data	96%
GPS Accuracy	Precision of location tracking	94%
Alert System Response	Time taken to trigger alerts during abnormal conditions	Instant (<2 sec)
System Processing Speed	Time taken for data acquisition and processing	Real-time
Battery Life	Continuous operation duration under normal conditions	10–12 hours

4. Results and Discussion:

The proposed IoT-based real-time soldier health monitoring system integrated with a smart drug delivery mechanism using wireless sensor networks was successfully designed and tested under simulated conditions. The system demonstrated reliable acquisition and transmission of physiological parameters such as heart rate, body temperature, and motion data. The sensor outputs were continuously monitored and processed using embedded algorithms, which effectively filtered noise and ensured accurate readings. The integration of the GPS module enabled precise real-time location tracking, while the GSM module ensured seamless communication of health data and alerts to remote monitoring units.The performance evaluation showed that the system could detect abnormal health conditions based on predefined threshold values with minimal delay. In critical scenarios, such as elevated body temperature or abnormal heart rate, the alert system was triggered instantly, activating both local (buzzer and LCD display) and remote notifications. Furthermore, the smart drug delivery mechanism responded efficiently by administering predefined medication dosages when emergency conditions were identified. This automated response significantly reduced the time required for medical intervention, which is crucial in battlefield environments.The system exhibited low latency in data transmission and high reliability in continuous monitoring, even in dynamic conditions involving movement and environmental variations. The MPU6050 sensor effectively identified unusual movements and fall detection, enhancing the system's capability to respond to physical emergencies. Additionally, the power consumption of the system was optimized to support prolonged operation, making it suitable for deployment in remote and resource-constrained environments.Overall, the results confirm that the proposed system provides an efficient and scalable solution for real-time health monitoring and automated drug delivery for soldiers. The integration of IoT, wireless sensor networks, and intelligent decision-making improves response time, enhances situational awareness, and increases the survivability of soldiers in critical conditions. However, further improvements can be made by incorporating advanced machine learning techniques for predictive analysis and enhancing the precision of drug delivery mechanisms for personalized treatment.

5. CONCLUSION:

This paper presented the design and development of an IoT-based real-time soldier health monitoring system integrated with a smart drug delivery mechanism using wireless sensor networks. The proposed system effectively combines wearable sensors, embedded processing, and wireless communication to continuously monitor vital physiological parameters such as heart rate, body temperature, and motion. The integration of GPS and GSM modules enables real-time location tracking and seamless transmission of health data and emergency alerts to remote monitoring units.The implementation of a threshold-based decision system allows for the early detection of abnormal health conditions, while the inclusion of an automated drug delivery mechanism ensures timely medical intervention without the need for immediate human assistance. Experimental results demonstrate that the system is reliable, energy-efficient, and capable of operating in dynamic and harsh environments, making it highly suitable for military applications.Overall, the proposed system enhances soldier safety, reduces response time during critical situations, and improves the efficiency of healthcare delivery in remote or battlefield scenarios. Future work can focus on incorporating advanced machine learning techniques for predictive health analysis, improving the precision and adaptability of drug delivery systems, and enhancing system security to ensure safe and reliable data transmission.

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