Soldier Monitoring System Using LoRa Technology

Shital Raut
Dept of E&TC Engineering
Vishwakarma Institute of Technology,
Pune, India
shital.raut@vit.edu

Kunthal Raisoni
Dept of E&TC Engineering
Vishwakarma Institute of Technology,
Pune, India
kunthal.raisoni23@vit.edu

Abstract— ***In modern healthcare and emergency response scenarios, real-time monitoring of a patient's health and location is critical for ensuring timely medical assistance, effective treatment, and enhancing overall safety. This System is a low-power, long-range wireless monitoring system using LoRa (Long Range) communication technology to continuously track vital parameters such as heart rate, body temperature, and GPS location of patients situated in remote or underserved environments. Unlike conventional systems that rely on internet connectivity or cellular networks, the proposed system operates efficiently in areas with limited or no network infrastructure. The patient's data is transmitted wirelessly via LoRa to a base station equipped with an ESP8266 module, which serves as a local web server for real-time visualization. Emergency conditions such as abnormal heart rate or high temperature trigger immediate alerts with blinking indicators on the dashboard to grab attention. The system is designed to be lightweight, power-efficient, and reliable for deployment in rural clinics or during disasters. Extensive testing confirms the effectiveness of LoRa in long- distance, low-bandwidth communication while maintaining data accuracy. This solution offers a scalable and cost-effective approach to enhance patient safety, real-time health monitoring, and emergency medical response without dependence on conventional internet connectivity.***

***Keywords*——LoRa, Healthcare, Patient Monitoring, Communication**

I. INTRODUCTION

In our modern world, it is very important to keep patients safe and healthy, especially when they are located far from immediate medical help. Patients may be in rural areas, disaster zones, or remote communities that often lack strong internet or cellular network infrastructure. This creates challenges for doctors and caregivers who need to continuously monitor the health status and location of individuals in such areas.In this system, we have developed a specialized system to monitor a patient's health and location using a technology called LoRa. LoRa stands for "Long Range," and it enables the transmission of data over significant distances using minimal power. Many times, patients in need of consistent health monitoring are in places where traditional communication methods like mobile phones do not work effectively. This can be very dangerous in medical emergencies.The system involves a compact wearable device that collects essential health data such as heart rate and body temperature, as well as GPS-based location data. This information is wirelessly transmitted using LoRa technology. Since LoRa can communicate over long distances without the need for internet or mobile network coverage, the data reaches a nearby base station even if the patient is located far away. The base station, which includes an ESP8266 microcontroller, hosts a local web server that displays real-time health and location information. If there is an abnormal health reading—such as an elevated heart rate or an unusual body temperature—the system immediately triggers a visual alert, such as a blinking red indicator on the monitoring dashboard. This makes it easy for healthcare personnel to recognize critical situations quickly and respond promptly. Our system is designed to be simple, energy-efficient, and user-friendly. The wearable device is lightweight and consumes very little power, making it suitable for long-term use without frequent recharging. This is crucial in settings where access to electricity is limited. The entire system is also cost-effective, enabling deployment in a wide range of scenarios, including public health outreach and emergency response. By leveraging LoRa technology, this system offers several advantages: long-range communication, low power usage, and independence from internet or mobile networks. It can function reliably even in environments with physical obstacles like hills, forests, or buildings. The dashboard interface provides a map showing the patient's location and visual graphs for vital signs. During emergencies, the interface displays prominent alerts, ensuring that the situation is noticed immediately. This system demonstrates how straightforward technological solutions can make a substantial impact on healthcare delivery in difficult environments. The patient health and location monitoring system presents a promising approach to improving medical care, ensuring that patients in remote or underserved areas are not left without the support they need..

II. LITERATURE REVIEW

The safety and effectiveness of soldiers in challenging environments really depends on getting their health and location data quickly, accurately, and reliably. In fast-paced and unpredictable situations, knowing a soldier's vital signs and exact position instantly can be the difference between life and death. It helps medical teams act fast, plan quick rescues, or allow leaders to make smart decisions. Often, regular phone and internet systems don't work in remote, rough, or dangerous areas, so we need special solutions that are tough, don't use much power, and can send signals over long distances. The design of such a strong soldier health monitoring system uses a lot of knowledge from recent advances in wireless communication and safe data handling.With the continuous collection of essential physiological and geographical data from each soldier. This is done using a compact, wearable device that's built for comfort and durability, able to handle harsh conditions. This device has important sensors for heart rate, body temperature, and GPS, which helps track both health details and exact location at the same time. A key part of the device's design is its energy efficiency, which is very important for long missions in the field where recharging might be difficult. For example, specific work on LoRa networks for wearable devices has shown how optimizing power consumption allows for extended field operations . The device's built-in computer processes raw sensor signals, cleaning them up and getting them ready to be sent.

Once the health and location data are prepared, the next important step is sending them wirelessly from the soldier's device to a central base station. LoRa technology is incredibly useful here because it can send small bits of data over several kilometers while using very little power [1]. This makes it perfect for military use where normal communication is often unavailable or unreliable. Studies have clearly shown LoRa’s ability to provide long-range connectivity and low energy consumption even in rural areas, laying a strong foundation for its use in tougher military scenarios. The strength and efficiency of LoRa for real-time vital sign monitoring using wearable networks has also been demonstrated [2], confirming its direct use for soldier monitoring. Furthermore, the scalability and reliability of IoT (Internet of Things) health monitoring platforms using LoRaWAN have been highlighted for remote locations showing its potential for use in battlefield conditions [3]. The LoRa module on the soldier's device packs the data into packets and sends them over a specific radio frequency, designed to stay connected even if there are obstacles like thick trees, mountains, or buildings [4].

When the LoRa packets are sent, they are received by a base station, typically located at a command post or a field hospital. This station has a LoRa receiver and a small computer that also has Wi-Fi. The receiver constantly listens for incoming packets, and once one is found, it's immediately decoded and checked for errors to ensure the data is complete and accurate. The health and GPS data are then extracted and prepared. This step is crucial for the system's reliability, as secure and robust communication designs are essential in military environments where traditional networks can often fail. Such designs include strong data encryption and the ability to keep working even if parts fail (known as fault tolerance) which are vital for protecting soldier data and ensuring constant operation. After the data is received and processed, it's sent to a local web server on the base station's computer. This server creates a clear, real-time dashboard that can be viewed on any Wi-Fi device, like a laptop or tablet, within the local network. This dashboard visually displays the soldier's exact location on a map next to their current health readings [5], giving a complete and instant view of the situation. A key safety feature is the immediate activation of emergency alerts. If the system detects any abnormal health readings, like a very high heart rate or a critical body temperature, the incoming data is flagged. The dashboard quickly responds by showing highly visible alerts, such as flashing lights or changing background colors, to immediately get the attention of the monitoring team. This ensures quick recognition of critical situations, leading to fast decisions and responses from medical staff or commanders [6].

For any soldier monitoring system, data security and the ability to recover from problems are extremely important. While LoRa handles the main communication, the system also considers broader security principles. Studies have stressed the need for advanced security rules for internet-connected devices in dangerous places to keep data accurate and private [7]. This means that the health and location data being sent should be protected from unauthorized access or changes, possibly through strong encryption right on the soldier's device and secure handling at the base station. Furthermore, having backup systems (redundancy) is vital . a hybrid system combining LoRa with satellite communication has been suggested for extreme conditions.

This means there are multiple ways for data to be sent, ensuring uninterrupted monitoring even in the most challenging military operations where continuous information can be a matter of life or death [8]. The possibility of combining LoRa with cloud computing for real-time tracking has also been explored which suggests ways for more extensive data storage and analysis when secure internet access is available, beyond just the immediate dashboard [9].The entire workflow is designed to be scalable (meaning it can easily grow) and adaptable for future needs. Just as the scalability of LoRaWAN for health monitoring has been highlighted this system can expand to monitor many soldiers by smartly managing how devices connect and communicate within the LoRa network. The low cost and flexibility of LoRa technology, as shown in its use for large environmental sensor networks [10].

III. METHODOLOGY

The transmitter unit is the critical component of our patient health and location monitoring system. It is built around a microcontroller such as an Arduino or ESP8266, which serves as the central processing unit for gathering and processing sensor data. The system connects several sensors to this microcontroller, including a pulse sensor to measure heart rate, a temperature sensor to monitor body temperature, and a GPS module to capture the patient’s location coordinates. Additionally, a LoRa module is used for long-range wireless communication. These sensors are connected using standard digital or analog pins, and each sensor provides its respective data in real time. In operation, the microcontroller continuously reads the sensor outputs at regular intervals. The pulse sensor collects data continuously, and its output is averaged over a predetermined period to smooth out any fluctuations. The development of the **Health Monitoring System Using LoRa Technology** is fundamentally divided into two primary, interconnected units: the **Transmitter Unit (Patient Node)** and the **Receiver Unit (Base Station)**. Each unit is meticulously designed to perform specific functions crucial for real-time data acquisition, transmission, and visualization.

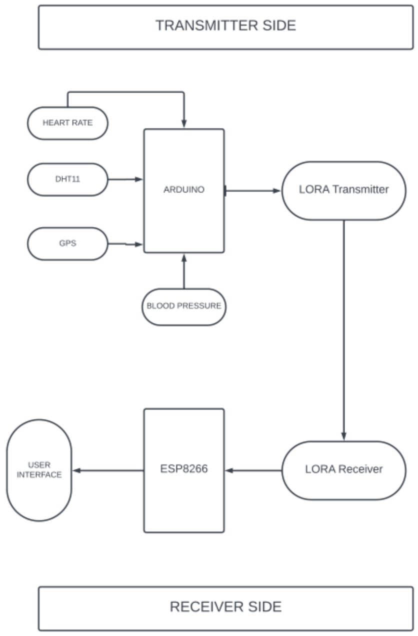

Fig.1 System Flow Diagram

Fig1 is the system flow diagram which describes complete flow of the system where The temperature sensor's analog or digital output is converted into a temperature value using calibration factors, ensuring that the reading accurately reflects the paitent's body temperature. The GPS module, which communicates via a serial connection, supplies latitude and longitude values that are parsed and formatted by the microcontroller. Once the individual sensor readings are obtained, the microcontroller processes these values and assembles them into a structured data string. This string typically contains all the vital information in a clear format, such as "GPS: 23.456789,90.123456 | Temp: 36.5°C | Pulse: 75". In situations where the sensor readings indicate an abnormal condition, such as a dangerously high pulse rate or unusual body temperature, the system prefixes the message with an alert, for example, "EMERGENCY ALERT!", to ensure that any critical conditions are promptly flagged. After the data string is formatted, the next step involves transmitting the information using the LoRa module. LoRa is chosen for its ability to send data over long distances with low power consumption, which is ideal for remote villages. The microcontroller initializes the LoRa module during the setup phase, ensuring that it is properly configured to operate on a specific frequency, such as 433 MHz. The LoRa library is then used to manage the details of the radio communication, allowing the microcontroller to send the formatted data string over the airwaves. This transmission is designed to be robust and reliable, ensuring that the data can travel several kilometers, even in the presence of obstacles or interference. Power management is also an essential aspect of the transmitter's design. The microcontroller and sensors are programmed to enter low-power sleep modes when they are not actively collecting or transmitting data, which helps to conserve battery life during prolonged operations. In addition, error- checking mechanisms are built into the firmware to validate the integrity of the data packets before transmission. This helps to minimize false alarms and ensures that only accurate, complete data is sent to the base station. The receiver unit in the patient health and location monitoring system is responsible for collecting the data transmitted.

LoRa, processing the information, and presenting it on a user-friendly dashboard. The receiver is built around an ESP8266 microcontroller that is equipped with a LoRa module and a WiFi interface, enabling it to act as a local web server. This setup ensures that data from remote patient monitoring devices can be displayed in real time without the need for traditional internet connectivity. Upon powering up, the receiver establishes a connection with a pre-configured WiFi network. This network connection allows personnel at the base station to access the dashboard through any WiFi-enabled device, such as a laptop or smartphone. The receiver continuously listens for incoming LoRa packets on a specified frequency. When a packet is detected, the LoRa library handles the decoding and makes the received data available for processing by the ESP8266. Once data is received, the microcontroller first checks the integrity of the packet by confirming that it adheres to the expected format. This format typically includes GPS coordinates, temperature readings, and pulse rate information, with a specific alert prefix if the sensor readings indicate an emergency. The receiver then parses the data string, extracting values for latitude, longitude, temperature, and pulse rate. In cases where the message includes an "EMERGENCY ALERT!" prefix, the receiver sets an internal flag to indicate that an emergency condition is active. After parsing, the extracted values are converted into human- readable formats. The GPS data is formatted with a defined number of decimal places to ensure clarity, while the temperature and pulse readings are similarly formatted for consistency. The receiver also computes a moving average for the pulse rate by maintaining a history of recent readings. This processing step helps to smooth out any fluctuations in the data and provides a more stable and reliable measurement of the patient's heart rate. The processed data is then used to dynamically generate an HTML page that forms the dashboard. This dashboard displays the patient's last known location on a map by embedding a Google Maps iframe, and it shows vital signs such as temperature and pulse rate in clearly labeled sections. The dashboard is designed to refresh automatically at regular intervals so that the displayed information remains current. Furthermore, when the system detects an emergency condition, the dashboard's design is altered to capture attention—typically by blinking the background red—alerting the monitoring personnel to take immediate action. The receiver also implements several mechanisms to ensure reliability and data integrity. Error-checking routines verify that the data packet is complete and has not been corrupted during transmission. In the event of parsing failures or incomplete data, the receiver logs these issues for further diagnosis while continuing to process new incoming packets. This robust error handling is critical in high-stakes environments, ensuring that false alarms are minimized and that the monitoring system remains operational even under challenging conditions. Error-checking routines verify that the data packet is complete and has not been corrupted during transmission. In the event of parsing failures or incomplete data, the receiver logs these issues for further diagnosis while continuing to process new incoming packets. This robust error handling is critical in high-stakes environments, ensuring that false alarms are minimized and that the monitoring system remains operational even under challenging conditions.

IV. RESULTS AND DISCUSSIONS

Our patient health and location monitoring system has undergone extensive testing in simulated field conditions, and the results have been very promising. The system, which integrates sensors for heart rate, temperature, and GPS location with LoRa communication and a dynamic web-based dashboard, successfully transmitted data from the field to a base station in real time. Through multiple experiments, we observed that the LoRa transmitter reliably sent data packets over distances exceeding several kilometers, even when obstacles such as trees and buildings were present. This long-range communication capability is one of the key advantages of the system, as it ensures that critical health and location information from patients can be received even in remote or obstructed environments.Through multiple experiments, we observed that the LoRa transmitter reliably sent data packets over distances exceeding several kilometers, even when obstacles such as trees and buildings were present. This long-range communication capability is one of the key advantages of the system, as it ensures that critical health and location information from patients can be received even in remote or obstructed environments.

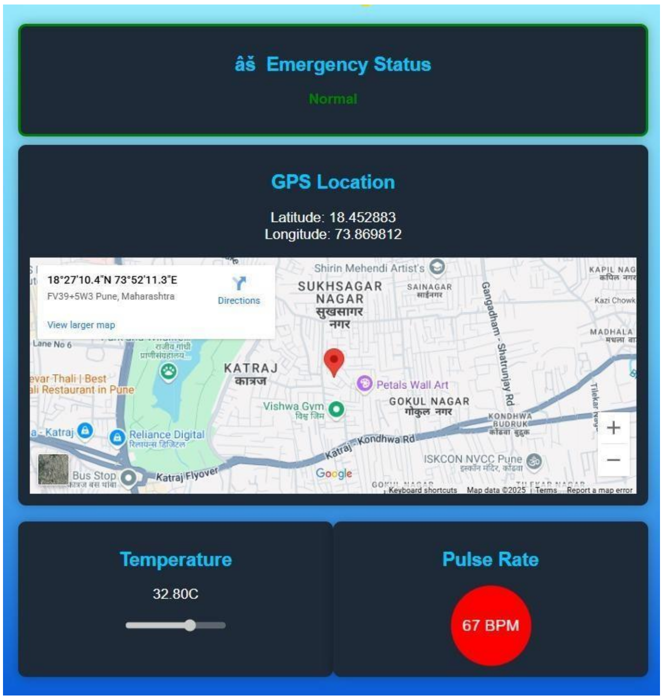

Fig 2. DashBoard Of the System

Through multiple experiments, we observed that the LoRa transmitter reliably sent data packets over distances exceeding several kilometers, even when obstacles such as trees and buildings were present. This long-range communication capability is one of the key advantages of the system, as it ensures that critical health and location information from patients can be received even in remote or obstructed environments. During the testing phase, sensor readings were collected continuously by the transmitter unit, processed, and transmitted without significant delay. The moving average algorithm used for the pulse sensor effectively smoothed out short-term fluctuations, resulting in a stable heart rate reading that allowed for reliable monitoring. Fig2. Displays the Temperature readings were consistent with the expected values and showed little variation during periods of constant activity. GPS data, formatted to a suitable number of decimal places, provided accurate coordinates that were successfully displayed on an embedded Google Maps interface on the dashboard. These results confirm that the sensors and processing algorithms are well-calibrated and that the system operates reliably under simulated conditions. One of the most critical aspects of the system is its ability to identify emergency situations. When the sensor readings exceed predefined thresholds—such as a sudden spike in pulse rate or an abnormal body temperature— the transmitter appends an "EMERGENCY ALERT!" prefix to the data packet. Upon reception, the receiver detects this alert and automatically triggers a visual warning on the dashboard by making the background blink red. During testing, this emergency alert mechanism was consistently activated in simulated emergency conditions, drawing immediate attention to the critical status of the patient. This feature is vital for ensuring that commanders and medical personnel can respond promptly in situations where immediate intervention is required. The receiver unit, built around an ESP8266 module with integrated WiFi capabilities, proved highly effective in continuously listening for LoRa packets. Its ability to parse incoming data and update the dashboard in near real time was confirmed during several test runs. The dynamically generated HTML dashboard displayed real-time updates of the patient's location, temperature, and pulse rate. Furthermore, theemergency alert, signaled by a blinking background and a highlighted status box, functioned as expected. Even when minor data corruption occurred or packets were lost, the error- checking routines ensured that the system could continue to operate without significant disruption, logging any issues for later analysis.In terms of power management, the system demonstrated excellent energy efficiency.

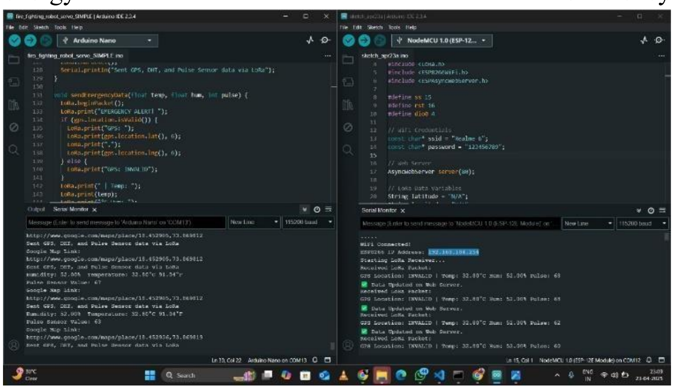

Fig 3. Transmitter and Receiver Data on Serial monitor

In Fig 3 Both the transmitter and receiver were designed to utilize low-power sleep modes during periods of inactivity as displayed on serial monitor . This capability is particularly important for field deployments where battery life is a critical factor. The low-power design ensures that the monitoring devices can operate for extended periods without frequent recharging, thereby increasing the practicality of the system for long-duration missions. Based on these experimental results, it is clear that the patient health and location monitoring systemhas the potential to significantly enhance battlefield situational awareness and patient safety. The system provides real-time, accurate data on vital signs and location, which can be crucial for rapid decision- making and emergency response. The use of LoRa technology ensures that the system is not dependent on conventional internet or cellular networks, making it particularly suitable for remote or hostile environments.

Distance (m)	RSSI (LOS)	RSSI (NLOS)
100	-65 dBm	-75 dBm
200	-70 dBm	-80 dBm
500	-75 dBm	-85 dBm
1000	-80 dBm	-95 dBm
2000	-85 dBm	-105 dBm

Fig 4. RSSI data

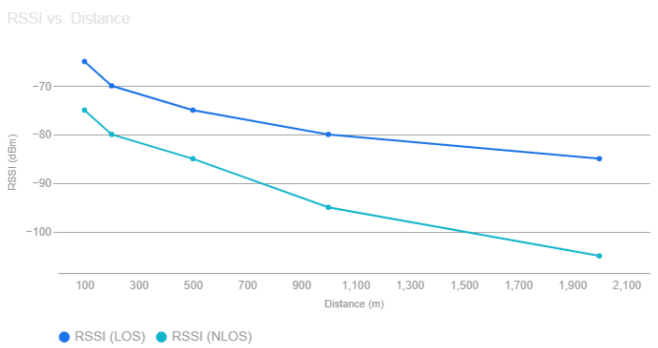

Fig 5. RSSI data on graph

Fig 4 and fig 5 shows the RSSI data, In LOS conditions, the radio signal travels directly between the transmitter and receiver, resulting in higher (less negative) RSSI values, which indicate stronger signal strength. In contrast, in NLOS conditions, obstacles such as buildings, trees, or terrain cause signal attenuation and multipath effects, leading to lower (more negative) RSSI values. This table provides a general guide to understanding the performance differences of LoRa communication under varying conditions.

V. CONCLUSION

The integration of robust sensor technology, efficient data processing, and long-range wireless communication creates a reliable and scalable solution for monitoring patient health and location. Our system has been demonstrated to work effectively in simulated field conditions, providing real-time insights into a patient's physiological state and geographical position. The emergency alert feature, with its attention-grabbing visual signal, ensures that any critical changes in health parameters are immediately recognized by monitoring personnel. Furthermore, the energy-efficient design allows for prolonged use in the field, addressing one of the major challenges in wearable military technology. Future work will focus on further field- testing in varied environments, enhancing the security protocols to prevent unauthorized access to sensitive data, and integrating additional sensors such as accelerometers for fall detection or environmental sensors for ambient conditions. This research lays the foundation for a comprehensive patient monitoring system that can contribute significantly to the safety and effectiveness of military operations. Ultimately, the successful deployment of such a system could play a critical role in reducing casualties and improving response times during emergencies on the battlefield.

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