Intelligent Safety Life Jacket Using LoRa Technology

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Abstract. The intelligent safety life jacket using long-range technology serves to enhance the safety of mountaineering by simultaneously providing real-time information and communication functionalities. This paper includes a modern new approach for tracking individuals in distress in mountainous regions by employing communication through LoRa, GPS, and biometric sensors. It is capable of providing long-range communication, energy efficiency, and reliability necessary for a proper outdoor environment. The system ensures effective long-range connectivity, energy efficiency, and reliability in extreme outdoor environments.

Keywords: Life jacket, LoRa, IoT, mountaineering safety, GPS, biometric monitoring.

1 Introduction

Mountaineering is associated with considerable risks due to sudden weather changes, bad terrains, and the lack of communication facilities. While traditional safety gear offers protection from harsh weather, it does not have smart monitoring features [1]. With the increasing number of mountaineering accidents, there is a growing demand for more sophisticated and all-inclusive safety solutions to provide warmth, flotation for alpine crossings, and real-time data for prompt rescue operations [2]. Hypothermia is a condition in which the body fails to regulate when exposed to cold weather. Hypothermia refers to a body temperature below 35 degrees Celsius [4]. The thermoneutral zone is that range where human beings would be comfortable between 36.5-37.5°C in which the human body can respond. There will be heat generation and heat loss according to temperature regulation that has got disturbed by the setting beyond the range.

The medical care of hypothermia holds special importance for climbers, especially when they will be put to subhuman temperatures. Hypothermia is common in climbing places and is due to the pristine extreme conditions of the settings, which include the cold exerted through high mountains in the form of air pressure, strong winds, wet clothes, and other such weird variables. Climbing safety principles, therefore, should be known by climbers to prevent the risk of hypothermia from the body [5]. The trouble is that most climbers don't know the first thing about climbing safety. Many climbers still climb for fun or as a hobby without sufficient knowledge of health and safety. Consequently, the treatment of hypothermic patients remains largely unscientific. If hypothermia

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victims are not adequately examined, the condition will often worsen, leading to unconsciousness or fainting, and a remote possibility of death from these stated conditions.

In view of all these challenges, this paper proposes an intelligent safety life jacket integrating LoRa communication, GPS tracking, and biometric monitoring [2]. Thanks to a continuous transmission of the user's location and vital signs, a timely detection of an emergency can be guaranteed, thus allowing a timely response from the rescue teams [3].

A long-range, low-power connectivity based LoRa communication was recently studied, enabling to use in outdoor rescue operation and severe conditions as well as mountain [6]. Moreover, the development of hybrid positioning systems that combine LoRa with Wi-Fi has boosted location real-world coverage (e.g., urban and rural areas) for local tracking applications [7]. LoRa technology has even been used in applications like automatic railway crossings, demonstrating the wide range of its use cases for remote communication [8]. The proposed safety life jacket is thereby highly advantageous on high-altitude mountains or in cold-water conditions, where rapid assistance in averting fatalities is required. This innovation could greatly lessen the death toll in the event of a mountaineering accident by providing greater real-time situational awareness and response capabilities [9].

2 Related Works

Different studies have contributed toward the development of smart safety systems for outdoor activities, especially in mountaineering. According to prior research on LoRa-based communication, it has been able to provide long-range connectivity with low-power consumption, making it an ideal choice for remote rescue operations in harsh environments [10]. As per studies, LoRa's application in outdoor rescue operations showcases the system as reliable in challenging conditions, which is crucial for mountaineering safety [13].

Biometric tracking systems used for health evaluation have gained significant attention, especially with recent work on the fusion of heart rate and temperature sensors with body-worn safety gear. Their studies place importance on real-time health monitoring in high-risk environments [11]. The integration of IoT and wearable technology has enabled the development of an intelligent safety life jacket that combines LoRa communication, GPS tracking, and biometric sensing into one unified, compact solution. This system aims to bring reassurance and enhanced real-time tracking, as well as emergency response efficiency for mountaineers [12].

Among other things, it proposed a smart vest designed with temperature and heart rate sensors for high-altitude trekkers, demonstrating the advantages of real-time biometric monitoring in the extreme climatic conditions in which they find themselves. The study also highlighted the need for energy-efficient solutions that would increase the lifetime of these safety systems [12]. Further research was performed by Siaka et al. (2025), developing a LoRa-based alert system integrating AI-driven anomaly detection, confirming the feasibility of automatic distress alerts in rugged terrains [10]. These findings helped ground the development of the smart safety life jacket, interweaving several technologies to ensure the safety of climbers [11].

3 Methodology

3.1 System Design

- LoRa Module: Provides long-distance, low-power communication between climbers and base stations.
- GPS Module: Enables real-time tracking of climber locations.
- Biometric Sensors: Measurements of vital parameters such as heart rate, body temperature, and oxygen levels that can detect early symptoms of hypothermia or distress.
- Microcontroller Unit (MCUs): These are used to process data from the above sensors and transmit information through the LoRa network.
- Battery and Power Management System: To make sure energy consumption is low and operating time is prolonged in extreme conditions.

3.2 Data Transmission and Monitoring

The Intelligent Safety Life Jacket consists of various Data Transmissions from different components. This process includes:

- Sensor Data Collection: Continuous monitoring of user health indicators and ambient conditions by both biometric and environmental sensors
- Data Processing: The collected data will be processed by the MCU and prepared for communication.
- LoRa Transmission: Transmission of the processed data is executed through LoRa to either a base station or a cloud platform.
- Constant Surveillance: Dashboard views pertaining to the collected information are made available to the various rescue teams.
- Data Logging: The system keeps a health data record for post-event evaluation and enhancement of performance.

4 System Architecture

4.1 Sensor Layer

This includes biometric sensors such as heart rate and body temperature, as well as environmental sensors, including temperature, humidity, and atmospheric pressure. It gathers real-time information about the climber's health and environmental conditions and allows for continuous monitoring of his or her condition. Fig 1 shows the connection of the Controller to GPS Module, pulse sensor, power supply, I2C LCD, LoRa, etc. This is the systematic outline of the connections.

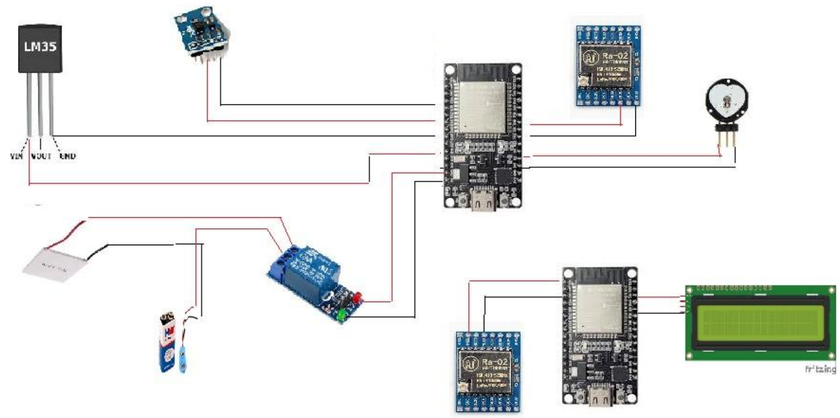

Fig. 1. Schematic Flow of Theoretical Structure.

4.2 Processing Unit

The data collected by the sensors are processed and analyzed by the Microcontroller Unit (MCU). The data is filtered and processed to identify abnormal conditions such as hypothermia or altitude sickness. Finally, based on preliminary decision-making, the system raises an alarm in case of emergencies and further communication.

4.3 Communication Layer

The LoRa module connects the life jacket with the base station via long-range, low-power two-way communication, enabling emergency response operations and ongoing status updates, particularly in areas without connectivity. The life jacket keeps updating the rescue stations, thereby tracking it for real-time information and condition monitoring.

4.4 Location Tracking System

The GPS module offers real-time information to allow for precise location tracking of the climber. Integrated with cloud-based monitoring for remote access by rescue teams and concerned authorities. It uses geofencing alerts that notify the system to ensure that no climber has moved out of the designated safe zone.

5 Result

5.1 Real-Time Monitoring

There was a ±2% accuracy of the system that monitored biometric parameters, such as heart rate and body temperature. Environmental parameters were monitored continuously, with temperature and humidity data being displayed in real time. Early detection of hypothermia risks was possible via real-time temperature tracking.

5.2 Effective Long-Range Communication

LoRa communication provided stable transmission ranges of up to 10 km in open environments and 5 km in obstructed terrain. Data transmission reliability was maintained above 95%, with minimal packet loss. Multi-node communication guarantees seamless connectivity between the climbers and rescue teams.

5.3 GPS Accuracy and Response Time

The GPS tracking system transmitted location data with an accuracy of ±5 meters. Emergency geofencing alerts were successfully triggered when users moved beyond designated safety zones. Real-time movement tracking evaluated risk by predicting climbers' movement patterns. Offline location logging assured recognition of the last known locations in the event of signal loss, as shown in Fig 2.

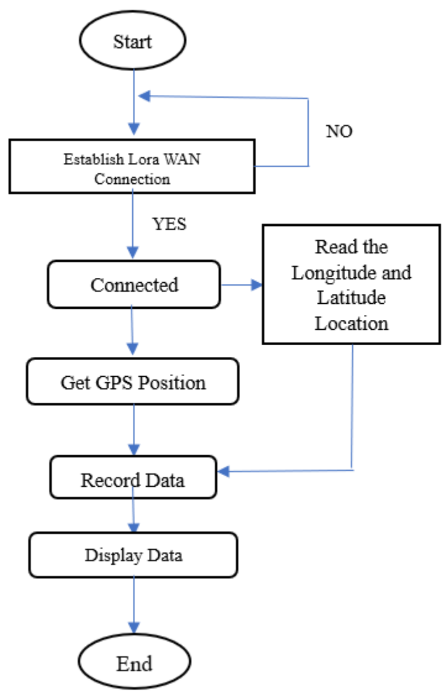

Fig.2. GPS Tracking Algorithm.

5.4 Power Efficiency

Optimized power management strategies extended the battery life of the system up to 48 hours on the SAM-51. Solar charging has helped improve operational durations by an additional 20% in outdoor environments. Dynamic power adjustments based on activity levels substantially contribute to battery conservation when the user is known to be stationary.

5.5 Environmental Adaptability

The system functioned well under different weather conditions, such as low temperatures and high altitudes. Waterproofing and wind-resistant casing helps ensure hardware durability under very extreme conditions. The entire device was tested under differing terrain conditions to validate constant performance. The GPS module offers real-time information to allow for precise location tracking of the climber. Integrated with cloud-based monitoring for remote access by rescue teams and concerned authorities. It uses geofencing alerts that notify the system to ensure that no climber has moved out of the designated safe zone.

6 Conclusion

A safety life jacket intended to detect climbers' signs of hypothermia is introduced by the suggested system. The device will transmit a command to activate the Peltier sensor, which will raise the climber's jacket's temperature if hypothermia symptoms appear. Through an Android app, climbers will get advice on how to handle their current circumstances in light of their unique health concerns. When linked to the climbing group, they can also see each other's locations and physical states. Climbers can monitor their body temperature, heart rate, and other health metrics with an Android smartphone. Long-range communication is used by the system, enabling seamless connectivity. It makes it possible to send messages to groups of mountaineers and offers insights into the medical parameters of climbers. The technology is used in real-time monitoring and health applications, which enhance safety and wellbeing when climbing.

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