LORA MESH-BASED DECENTRALIZED DISTRESS SIGNALING FOR EMERGENCIES IN NETWORK DEAD AREAS

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Keywords:

LoRa Mesh Network, Decentralized Communication, Distress Signaling, Emergency Alert System, Network Dead Zones, IoT Based Safety System.

Introduction:

The rise of gender-based violence and security issues in society is a warning to the community that there is a lack of knowledge and security measures. In the present rapidly changing society, where the population is constantly increasing along with the daily commute, safety regulations are no longer a priority. Safety concerns should not be defined in terms of gender. An ideal situation for all, including men-women, transgender and other at-risk minorities, should be one where there is equality, safety, and justice. Technological interventions are the only means to break through the walls of the existing safety systems to achieve the world objectives. A system that will function in the regions where there are no networks, and the emergency signal should be sent in any case has to be developed. It has to be very easy to use and trigger within a few seconds during a crisis, and it must be capable of constantly monitoring the situation and making an automatic response to prevent a danger issue. It should not be simply about responding to accidents but rather about preventing their occurrence. There are already several ways out there, but majority of them depend on Internet connection which restricts their application in remote or low network coverage areas. The proposed LoRa-based safety device utilizes long range, low-power wireless communication to communicate distress signals to relevant contacts or authorities in areas that are not connected to the network as a solution to such issues.

Objectives:

1. To design a system that sends distress signals during emergencies encountered in daily life.
2. To integrate the proposed system with a LoRa mesh network topology to enhance communication between peers enabling greater outreach in difficult situations and even in areas with poor network coverage.
3. To ensure network security for the established system to protect it against malicious attacks and planned intrusions.

Methodology:

The proposed system uses a LoRa-based decentralized mesh network as seen in Figure 1 and Figure 2 to ensure emergency communication even in areas with weak or no cellular coverage. Each wearable node equipped with an ESP32, LoRa transceiver, GPS, panic button, and Wi-Fi subsystem can send, receive, and relay alerts based on its connectivity. If internet is available, the alert is sent directly to the server; otherwise, it's broadcast across the LoRa mesh as a multi-hop packet. When this broadcast happens, all neighbouring nodes are immediately notified, ensuring people/devices nearby also become aware of the distress situation. Intermediate nodes add their GPS coordinates while relaying the packet toward any node with internet access, forming a route trace. Smart firmware prevents loops and redundant transmissions using duplicate detection and adaptive TTL, which adjusts based on network density to improve reliability without flooding the mesh.

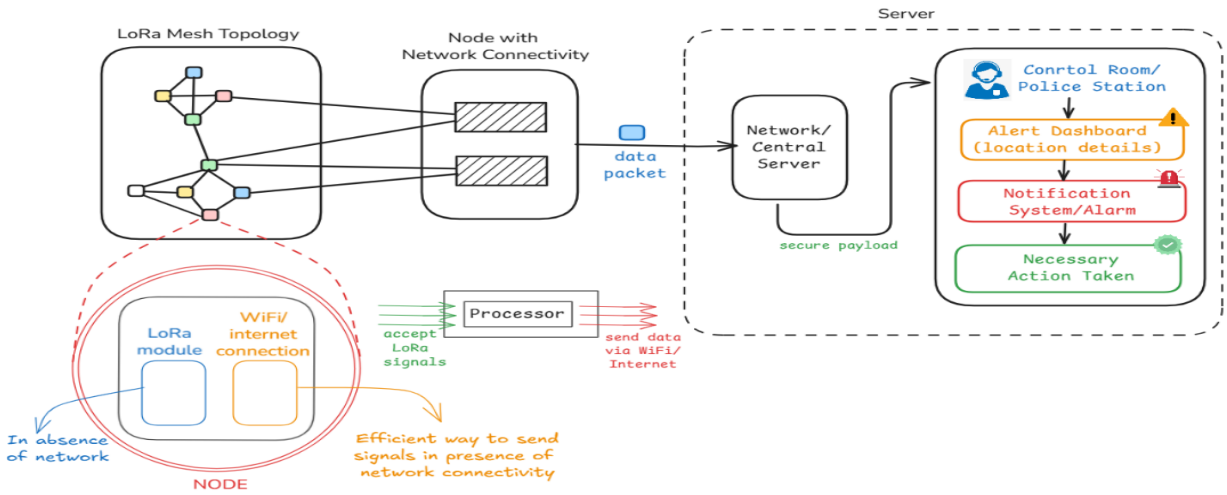

Figure 1: Functional Architecture of Proposed LoRa-Based Safety System

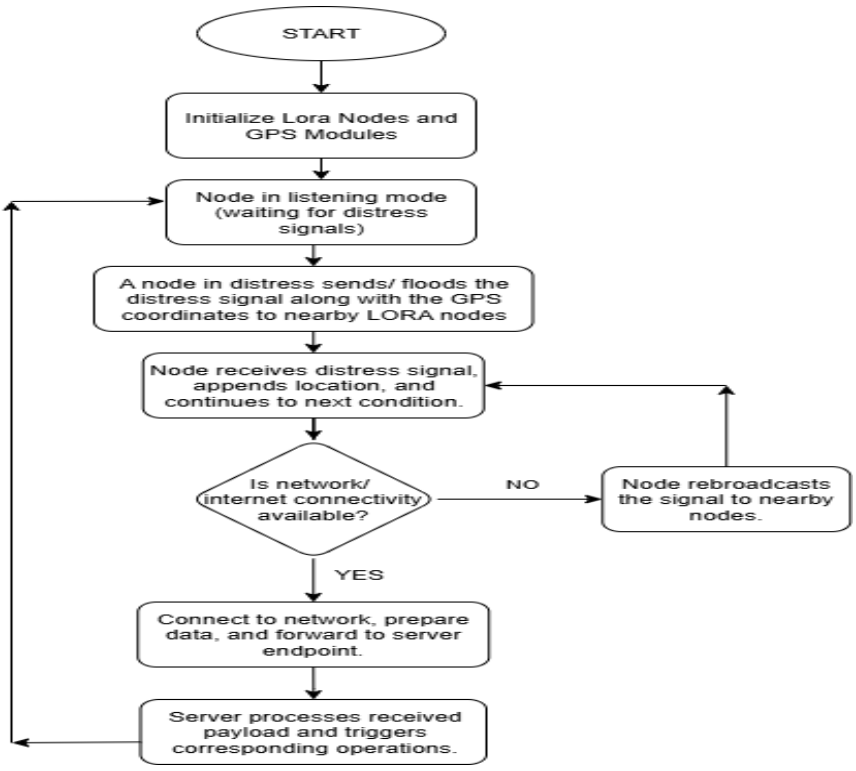

Figure 2: Flow Chart of the Distress System

The pin diagram as shown in Figure 3 shows how different parts of the LoRa-based distress signalling node are connected. Each wearable device combines an ESP32 microcontroller, a LoRa transceiver, a GPS module, a panic button, and optionally a Wi-Fi interface. The ESP32 acts as central controller of the system, handling signals from the panic button, collecting GPS data, communicating with the LoRa module and switching between Lora and Wi-Fi Communication.

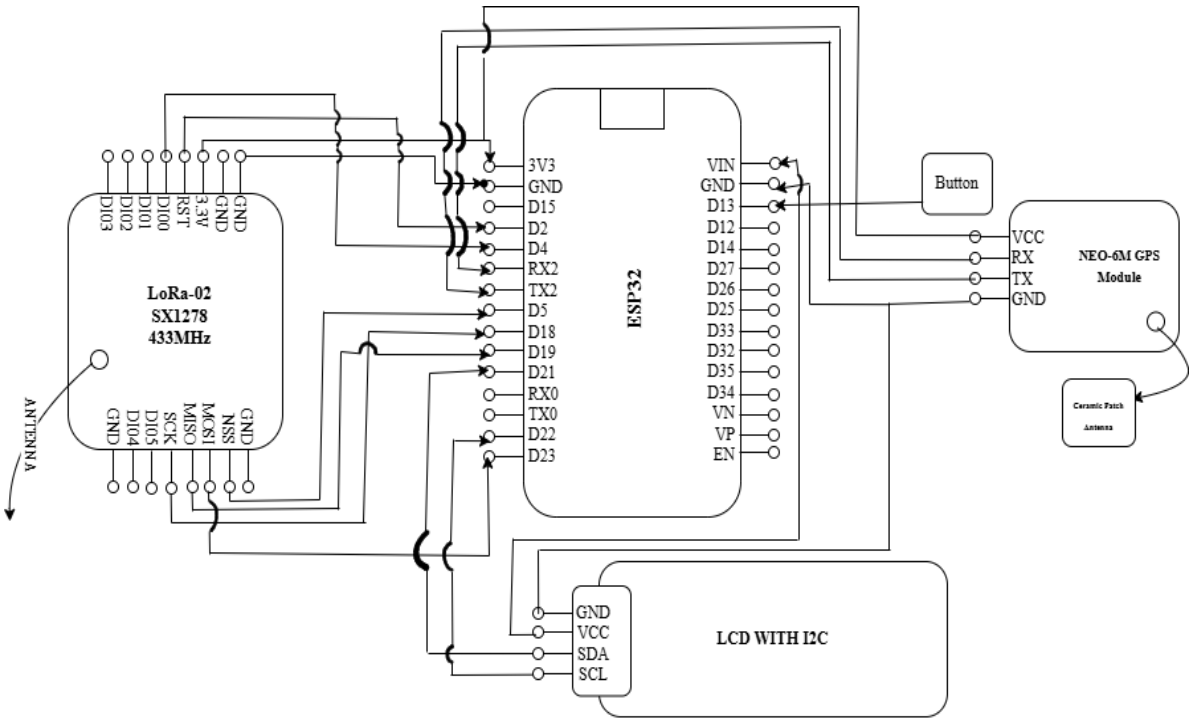

Figure 3: in Diagram Illustrating the Hardware Connections

Result and Conclusion:

This work develops a LoRa-based safety wearable by implementing a self-organizing mesh network that offers a decentralized and reliable emergency communication.

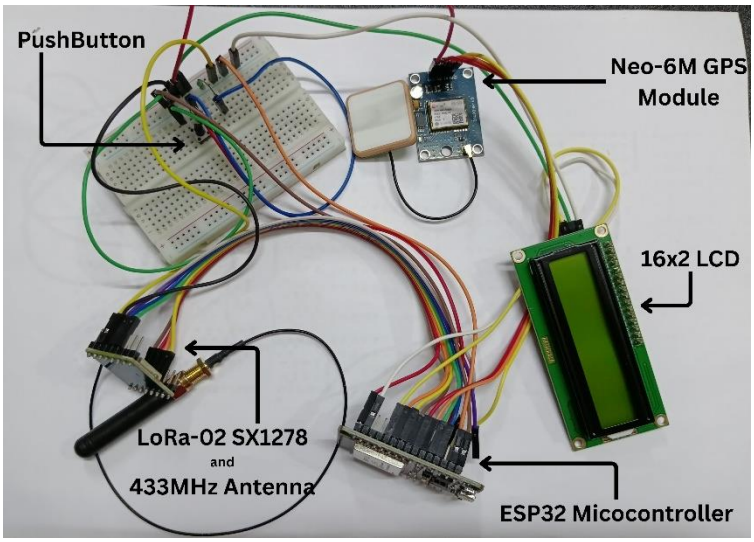

Figure 4: Hardware working prototype (Node) of the LoRa-based safety wearable, including ESP32 controller, LoRa transceiver, GPS module, emergency trigger button, and status LCD.

Every node as seen in Figure 4 works both as a transmitter and as a relay, and thus allows an emergency message to spread even without network coverage in the area. A root node is used to forward an alert outside the network if an opening into the Internet is available. The proposed architecture will support the key functionality of distress signaling and location sharing while keeping power consumption low to provide long usability. Considering the overall scalability and practicality for emergency response, the solution deals with the problems of current limitations of safety devices and is flexible for real-world deployments, both at the individual and community levels, towards safety enhancement. For businesses, society, and organisations that rely on dependable emergency communication in low-connectivity settings, the proposed project is extremely pertinent. Security services, disaster management teams, rural development authorities, and departments like the Karnataka Forest Department, NDRF, and local law enforcement are all catered to. The system contributes to the 17 Sustainable Development Goals (SDGs) established by the United Nations, with this project mapping specifically to the following goals. It supports SDG 5 by improving safety for women and vulnerable groups, SDG 9 through innovative and resilient communication infrastructure, SDG 11 by strengthening community-level emergency response, and SDG 16 by promoting accountability and timely intervention through traceable, verifiable alerts.

The project involved the development of a physical working prototype, where LoRa modules were implemented to establish real-time multi-hop communication. The system is being tested under practical conditions to validate its performance, reliability, and scalability. Through the process of designing, implementing, and analysing the system, practical insights into low-power wide-area network design, packet structuring, handling transmission constraints and communication in resource-limited environments were gained.

References:

1. [1] Kommineni, Kiran Kumar, et al. "A review on IoT-based defensive devices for women security." *2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS)*. Vol. 1. IEEE, 2023.
2. [2] Sonia, R., et al. "Empowering Safety: Designing of an IoT based Women Protective System using Artificial Intelligence enabled Smart Sensors." *2024 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI)*. IEEE, 2024.
3. [3] Suthagar, S., et al. "Performance Analysis of Velostat, Conductive Fabric and Force Sensing Resistor for Incorporating Safety in Women's Jacket." *2024 International Conference on Emerging Smart Computing and Informatics (ESCI)*. IEEE, 2024.
4. [4] Tayeh, G. B., et al. "A Wearable LoRa-Based Emergency System for Remote Safety Monitoring. 2020 International Wireless Communications and Mobile Computing, IWCMC 2020, 120–125." 2020,
5. [5] Ebi, Christian, et al. "Synchronous LoRa mesh network to monitor processes in underground infrastructure." *IEEE access* 7 (2019): 57663-57677.
6. [6] Alagumeenaakshi, M., et al. "Monitoring and controlling of solar photovoltaic cells using LoRa technology." *2021 International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA)*. IEEE, 2021.

7. [7] Lee, Huang-Chen, and Kai-Hsiang Ke. "Monitoring of large-area IoT sensors using a LoRa wireless mesh network system: Design and evaluation." *IEEE Transactions on Instrumentation and Measurement* 67.9 (2018): 2177-2187.
8. [8] Huh, Heon, and Jeong Yeol Kim. "LoRa-based mesh network for IoT applications." *2019 IEEE 5th World Forum on Internet of Things (WF-IoT)*. IEEE, 2019.
9. [9] Pan, Miaoxin, et al. "UAV-aided emergency environmental monitoring in infrastructure-less areas: LoRa mesh networking approach." *IEEE Internet of Things Journal* 9.4 (2021): 2918-2932.
10. [10] Yi, Yunhui, Hailang Zhao, and Yisu Wang. "LoRa Signal Monitoring System of Multi-Node Software Define Radio." *2020 IEEE Wireless Communications and Networking Conference Workshops (WCNCW)*. IEEE, 2020.

Future Scope:

The future scope of this project includes:

1. Optimization of packet structure by transitioning from JSON-based encoding to a compact binary format, which can reduce payload size and improve transmission efficiency.
2. Developing intelligent routing mechanisms, where relay nodes dynamically select the best transmission paths based on parameters such as signal strength, hop count, and node availability. Though this would add complexity but it would improve network reliability and reduce data loss in challenging environments.
3. Techniques such as collision avoidance, time synchronization, and channel allocation strategies can be explored to manage network traffic as the system can be extended to support a larger number of nodes while maintaining efficient communication.