



A Survey on IoT-Based Emergency Navigation and Tracking Device

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Abstract: Personal safety and emergency navigation are major concerns in remote and low-network environments. Existing safety systems mainly depend on smartphones, internet connectivity, and GSM communication, making them unreliable during emergencies. This survey paper reviews various IoT-based emergency navigation and personal safety systems using GPS, GSM, and LoRa communication technologies. The paper also proposes TRAX, a Smart Emergency Navigation and Tracking Device that integrates breadcrumb-based navigation, LoRa emergency communication, and multi-mode safety functionality into a portable embedded system. The proposed system aims to improve emergency communication, navigation support, and reliability in both urban and remote environments.

Keywords: IoT, GPS Navigation, LoRa, Emergency Alert System, Breadcrumb Navigation, Embedded Systems, Personal Safety

I. INTRODUCTION

Personal safety and emergency navigation have become important concerns in modern society due to the rapid increase in outdoor activities, adventure tourism, travel, and urban mobility. Individuals travelling through forests, trekking routes, mountainous terrains, isolated areas, or unfamiliar locations often encounter navigation difficulties caused by poor visibility, lack of route markings, environmental conditions, and absence of communication infrastructure. During such situations, users may become lost and may not be able to communicate their location to rescue teams or nearby authorities.

Modern navigation systems primarily depend on smartphones and internet-based communication applications. Although smartphones provide GPS navigation and emergency communication support, they suffer from several practical limitations. Most mobile navigation applications require continuous internet connectivity and cloud access for proper operation. In remote environments such as forests, trekking routes, and disaster-affected regions, cellular communication may become unavailable, making smartphone-based systems unreliable.

Another major issue with smartphone-based systems is battery dependency. Continuous operation of GPS, internet communication, and location-sharing services rapidly drains battery power, reducing reliability during emergencies. Additionally, smartphone interfaces may become difficult to use during panic situations where immediate communication and navigation support are required.

This survey paper reviews various IoT-based emergency navigation and personal safety systems and analyzes their advantages and limitations. The paper also proposes TRAX, a Smart Emergency Navigation and Tracking Device designed to integrate breadcrumb-based navigation, LoRa-based emergency communication, and multi-mode safety functionality into a compact portable system.

A. RESEARCH CONTRIBUTIONS

The major contributions of this survey paper include:

- Analysis of existing IoT-based emergency navigation and safety systems.
- Comparative study of GPS, GSM, and LoRa-based communication technologies.
- Identification of limitations in current emergency tracking systems.
- Proposal of a multi-mode emergency navigation and tracking device.
- Introduction of breadcrumb-based backtracking navigation for user guidance.



II. RELEVANT LITERATURE

A. Paper 1: A Wearable IoT-Based Rescue System Using LoRa Mesh Network and Physiological Monitoring for Mountain Emergency Response (Ming-Ying Chung et al., 2025)

Ming-Ying Chung et al. [1] proposed a wearable IoT-based rescue system designed for mountain emergency response applications by integrating LoRa mesh communication, GPS tracking, physiological monitoring sensors, and embedded communication systems. The proposed architecture combined real-time location tracking, long-range wireless communication, and health monitoring functionalities to improve emergency rescue operations in remote mountainous environments.

The framework utilized wearable sensor devices connected through LoRa mesh networking, where nearby devices functioned as relay nodes for forwarding communication packets to rescue stations. The system continuously monitored user physiological parameters along with GPS coordinates and transmitted emergency information through low-power long-range communication channels.

Experimental evaluation demonstrated reliable communication performance and effective GPS tracking in remote environments. The use of LoRa communication improved long-range wireless communication while maintaining low power consumption suitable for outdoor rescue applications.

Although the framework significantly improved emergency communication capability, the proposed approach mainly focused on rescue coordination and physiological monitoring rather than independent user navigation. The system also depended heavily on nearby relay nodes for mesh communication and lacked breadcrumb-based backtracking support for users who become lost in remote environments.

B. Paper 2: A LoRa-Based GPS Tracking and Emergency Alert System for Remote Exploration (Dr. Usha Choudhary et al., 2025)

Dr. Usha Choudhary et al. [2] proposed a LoRa-based emergency communication and GPS tracking system designed for individuals travelling or working in remote and isolated environments. The proposed framework integrated ESP32 microcontroller, REYAX RYLR998 LoRa communication module, and NEO-M8N GPS receiver to provide reliable emergency communication without depending on cellular communication networks.

The system continuously collected GPS coordinates and transmitted emergency location data using LoRa wireless communication. The ESP32 controller managed communication and processing operations while the GPS module provided real-time geographical positioning. The architecture additionally supported multi-hop communication where nearby devices functioned as relay nodes to improve communication reliability and coverage in remote regions.

Experimental analysis demonstrated reliable GPS positioning, low communication latency, and stable LoRa communication over distances of approximately 2.5 kilometers under outdoor conditions. The framework also demonstrated low power consumption suitable for portable outdoor safety applications.

Although the proposed system improved emergency communication capability in remote environments, the framework mainly focused on location transmission and emergency alerts rather than independent user navigation. The architecture also experienced communication degradation in dense forest environments and lacked breadcrumb-based backtracking support for users who become lost during outdoor activities.

C. Paper 3: Rakshak: An AI-Powered SOS System with Offline and Indoor Emergency Response Capabilities (Sorbojit Mondal et al., 2025)

Sorbojit Mondal et al. [3] proposed Rakshak, an AI-powered personal safety system developed using Internet of Things architecture for emergency response applications. The proposed framework integrated cellular communication systems, GPS hardware, automated emergency alert generation, and compact embedded hardware to improve personal safety during dangerous situations.

The system continuously monitored emergency conditions and automatically transmitted emergency notifications and location coordinates using GSM communication infrastructure. The architecture enabled rapid distress communication and emergency coordination without requiring manual intervention after activation.

The proposed framework focused mainly on improving emergency response efficiency through automated communication and quick location sharing during emergencies. The compact architecture additionally improved portability and usability for daily safety applications.

However, the proposed system depended heavily on GSM communication networks, making it ineffective in low-network environments such as forests, remote regions, and mountainous terrains. The framework also lacked breadcrumb-based navigation support and independent route guidance functionality during navigation emergencies.

The proposed TRAX system improves this approach by integrating LoRa communication for operation in low-network environments along with breadcrumb-based backtracking navigation to provide both emergency communication and navigation support within a single portable system.

***D. Paper 4: Design and Implementation of an IoT-Based Emergency Alert and GPS Tracking System using MQTT and GSM/GPS Module (P. Chinnasamy et al., 2025)***

P. Chinnasamy et al. [4] proposed an IoT-based emergency alert and GPS tracking system designed for personal safety applications using MQTT communication and GSM/GPS modules. The proposed framework integrated location tracking, emergency communication, and mobile-based alert systems into a compact portable safety device.

The system continuously monitored user location using GPS technology and transmitted emergency alerts and location coordinates through GSM communication networks. MQTT communication protocols were additionally used for cloud-based message handling and emergency coordination.

The proposed architecture improved rapid emergency communication capability and supported portable safety applications suitable for urban environments. The compact design additionally improved portability and ease of operation during emergency situations.

However, the framework depended heavily on GSM communication and internet-based infrastructure, limiting operation in remote or low-network environments. The proposed system also lacked outdoor navigation support and breadcrumb-based backtracking functionality.

The proposed TRAX system improves this approach by integrating LoRa-based emergency communication, breadcrumb navigation, and multi-mode safety functionality capable of operating in both urban and remote environments.

E. Paper 5: LoRa Mesh-Based IoT GPS Tracking System for Mountain Climbers (Muladi et al., 2025)

Muladi et al. [5] proposed a LoRa mesh-based IoT GPS tracking system designed for mountain climbers and outdoor navigation applications. The framework utilized GPS receivers, embedded controllers, and LoRa communication modules for tracking movement and transmitting location information during outdoor activities.

The proposed architecture continuously tracked user location and transmitted GPS coordinates to rescue stations and monitoring systems. The framework demonstrated effective communication and positioning support in trekking and mountainous environments where traditional communication infrastructure may be unavailable.

Experimental analysis showed reliable GPS tracking performance in open outdoor environments and improved rescue coordination capability during emergency situations. The architecture also supported continuous location monitoring for outdoor safety management.

However, the framework mainly focused on movement tracking and rescue coordination rather than direct navigation support for users. The system lacked breadcrumb-based backtracking functionality and independent route retracing support for users who become lost during outdoor activities.

The proposed TRAX system improves this approach by integrating breadcrumb navigation and directional guidance to assist users in independently navigating back to safe locations without depending entirely on external rescue support.

F. Paper 6: ANGEL: Automated Navigation Giving Emergency Location – A Robust Tracking System Leveraging Communication and Networking (Nirupama Balasubramanian et al., 2025)

Nirupama Balasubramanian et al. [6] proposed ANGEL, an IoT-based emergency tracking and alert system using ESP32C3 microcontroller, A9G GSM/GPS module, GPS tracking, and GSM communication for personal safety applications.

The system continuously monitored user location and enabled emergency communication through a dedicated SOS button. Upon activation, the framework retrieved GPS coordinates and transmitted emergency alerts using GSM communication by sending SMS messages containing location information and initiating emergency calls to predefined contacts. The architecture mainly focused on providing rapid emergency response support and improving user safety during dangerous situations.

The proposed system demonstrated reliable GPS tracking and successful emergency communication under different environmental conditions. The compact embedded architecture and low-power operation improved portability and suitability for daily safety applications. The framework additionally emphasized simple user interaction and quick emergency activation during panic situations.

However, the proposed system depended heavily on GSM communication infrastructure, making it less reliable in forests, isolated regions, and low-network environments where cellular communication may become unavailable. The framework also lacked breadcrumb-based backtracking navigation and independent route guidance functionality for users who become lost during outdoor activities.

The proposed TRAX system improves this approach by integrating LoRa-based emergency communication for operation in low-network environments along with breadcrumb-based navigation and directional guidance support within a unified multi-mode portable safety system.



III. COMPARATIVE ANALYSIS OF EXISTING SYSTEMS

Table 1 presents a structured comparison of the reviewed IoT-based emergency navigation and personal safety systems based on communication technology, navigation support, emergency communication capability, and major limitations.

TABLE I. COMPARISON OF EXISTING EMERGENCY NAVIGATION AND SAFETY SYSTEMS

Ref.	Year	Technology Used	Route Navigation	Real-Time Tracking	Key Limitation
[1] Chung et al.	2025	LoRa Mesh + GPS	No	Yes	Relay node dependency
[2] Choudhary et al.	2025	ESP32 + LoRa + GPS	No	Yes	No backtracking support
[3] Mondal et al.	2025	GSM + GPS + IoT	No	Limited	GSM dependency
[4] Chinnasamy et al.	2025	MQTT + GSM/GPS	No	Yes	Internet dependency
[5] Muladi et al.	2025	LoRa Mesh + GPS	Partial	Yes	No user guidance
[6] Balasubramanian et al.	2025	ESP32C3 + GSM/GPS	No	Yes	No offline navigation

IV. GAP ANALYSIS

Based on the review of the six studies, the following critical gaps are identified in the existing literature.

A. Lack of Unified Safety Systems

Existing systems mainly focus on single-purpose functionalities such as tracking, emergency alerts, or women safety applications. Very few systems combine navigation assistance and emergency communication into one integrated platform.

B. Absence of Breadcrumb Navigation

Most systems track user location but do not help users independently navigate back to safe locations. Breadcrumb-based navigation support is missing in many existing systems.

C. Dependence on Cellular Networks

Several emergency communication systems rely completely on GSM communication. These systems become ineffective in forests, mountains, and remote regions where mobile network coverage is unavailable.

D. Limited Offline Operation

Most smartphone-based systems require internet connectivity and cloud support for proper operation. This limits their reliability during emergencies.

E. Lack of User-Level Guidance

Existing systems mainly assist rescue teams rather than directly helping users safely navigate during emergencies.

V. PROPOSED SYSTEM DESIGN

A. System Overview

The proposed system, TRAX: Smart Emergency Navigation and Tracking Device, is designed as a portable IoT-based safety device capable of functioning in both outdoor navigation and personal safety scenarios.

The system integrates GPS-based location tracking, breadcrumb path recording, LoRa emergency communication, OLED display interface, and multi-mode safety functionality into a compact embedded architecture.

The device continuously records user movement paths using GPS coordinates. During navigation emergencies, the breadcrumb navigation system helps users safely retrace their path back to the starting location.

The system also provides emergency communication support using LoRa wireless technology. Users can activate an SOS feature to transmit emergency alerts and location information during dangerous situations.



B. System Workflow

The proposed system workflow includes the following stages:

- Device initialization
- GPS coordinate acquisition
- Breadcrumb path recording
- Outdoor navigation mode activation
- Directional guidance generation
- Emergency SOS transmission
- LoRa communication
- OLED display notification

The system continuously monitors user location and stores breadcrumb coordinates for navigation support.

C. System Components

The proposed TRAX architecture includes the following hardware modules:

- ESP32 Microcontroller
- GPS Module
- LoRa Communication Module
- OLED Display
- Push Buttons
- Rechargeable Battery System

The ESP32 microcontroller acts as the central processing unit responsible for navigation processing, communication handling, and display control.

D. Key Features

- Breadcrumb-based backtracking navigation
- Long-range emergency communication
- Real-time GPS tracking
- Portable and lightweight design
- Low power consumption
- Multi-mode safety operation
- Standalone operation without internet dependency

VI. EXPECTED OUTCOMES AND BENEFITS

A. Improved Emergency Navigation

The breadcrumb navigation system is expected to help users independently retrace their movement path and safely return to their original location during navigation emergencies.

B. Better Communication in Remote Areas

LoRa communication technology is expected to improve emergency communication capability in forests, mountainous regions, and low-network environments.

C. Reduced Smartphone Dependency

The proposed standalone device reduces dependency on smartphones, internet connectivity, and cloud services during emergencies.

D. Improved User Safety

Quick SOS communication and navigation guidance are expected to improve emergency response efficiency and user safety during dangerous situations.

E. Energy-Efficient Operation

The use of low-power embedded system components and LoRa communication technology is expected to improve battery efficiency and support long-duration operation.



VII. CONCLUSION AND FUTURE WORK

This survey paper analyzed various IoT-based emergency navigation and personal safety systems using technologies such as GPS tracking, GSM communication, LoRa communication, and wearable rescue devices.

The study identified several limitations in existing systems including GSM dependency, lack of navigation assistance, absence of integrated multi-mode functionality, and overdependence on internet-based services.

The proposed TRAX system addresses these limitations by integrating breadcrumb-based navigation, LoRa emergency communication, and personal safety support into a compact portable device. The proposed system is intended to improve emergency response capability, independent navigation support, and operation in low-network environments.

Future enhancements such as AI-based route optimization, voice-guided navigation, cloud connectivity, satellite communication, and physiological monitoring sensors can further improve system capability and reliability.

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REFERENCES

- [1]. M. Chung, Y. Lu, C. Lee, S. Kuo, and L. Chen, "A Wearable IoT-Based Rescue System Using LoRa Mesh Network and Physiological Monitoring for Mountain Emergency Response," in *IEEE Access*, 2025.
- [2]. U. Choudhary, L. Upreti, and S. Singhal, "A LoRa-Based GPS Tracking and Emergency Alert System for Remote Exploration," in *International Journal of Innovative Research in Technology (IJIRT)*, 2025.
- [3]. S. Mondal, P. Goneka, R. Dey, N. Das, R. Saha, and B. Sadhukha, "Rakshak: An AI-Powered SOS System with Offline and Indoor Emergency Response Capabilities," in *International Journal of Scientific Research in Engineering and Management (IJSREM)*, 2025.
- [4]. P. Chinnasamy, P. S. Chintha, S. Sivakrishnaiah, T. Sathiya, I. Alam, and D. P. Degala, "Design and Implementation of an IoT-Based Emergency Alert and GPS Tracking System using MQTT and GSM/GPS Module," in *International Journal for Research in Applied Science and Engineering Technology (IJRASET)*, 2025.
- [5]. Muladi, H. Wijaya, S. D. Prasetyo, S. A. Hamzah, and A. K. Mahamad, "LoRa Mesh-Based IoT GPS Tracking System for Mountain Climbers," in *Journal of Embedded Systems and Wireless Communication*, 2025.
- [6]. N. Balasubramanian, B. V, and S. Reddy, "ANGEL: Automated Navigation Giving Emergency Location – A Robust Tracking System Leveraging Communication and Networking," in *International Journal of Advanced Research in Science, Communication and Technology (IJARST)*, 2025.