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BroadLoRa: Internet-Independent LoRa-Based Wearable Child Safety and Tracking System

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Abstract: Location-awareness and emergency-alert systems often rely on networks, Internet connectivity or cloud infrastructure. This dependency can cause problems in areas where network coverage's weak or unavailable. To solve this this study introduces BroadLoRa a system designed for location awareness and emergency alerts. It uses Global Navigation Satellite System (GNSS) for location tracking LoRa communication for long-range transmission Bluetooth Low Energy (BLE) for short-range data transfer and an Android app for user interface. The wearable device captures location data. Sends it along with emergency status as packets using a direct LoRa link to a receiver. The receiver checks the packets and sends the valid data to a paired Android app through BLE. The main communication path does not need Internet access. This setup ensures the system works in remote or disconnected areas. The research focuses on the design phase. Includes a methodology to evaluate key aspects: location accuracy, packet delivery, communication distance, end-to-end response time, battery life and how the system handles communication failures. Since the project is still in the design stage these performance metrics have not been tested in conditions yet. This study outlines the system architecture and sets up an evaluation framework. The goal is to support the development and testing of a portable safety device that operates offline. The framework can guide work, toward building a reliable network-independent wearable safety system.

Keywords: LoRa, GPS, GNSS, wearable safety, offline tracking, ESP32, Bluetooth Low Energy, emergency alerts.

I. INTRUDUCTION

Wearable location-aware systems can help responsible people keep track of a person's reported location and get alerts when an emergency starts. These features are useful for child safety, outdoor adventures and any situation where local communication matters.. The way a tracking system works depends on how its communication architecture is built. Systems that use networks, Internet services, or cloud servers can run into trouble when those services are down or unreliable.

BroadLoRa is a wearable system that provides location awareness and sends emergency alerts. It is built around satellite positioning, Long Range (LoRa) communication, Bluetooth Low Energy (BLE) and a native Android app. The BroadLoRa wearable contains an ESP32 controller, a GPS/GNSS module, and a LoRa transceiver that create location and status packets. A companion device, ReceiveLoRa, takes these packets. Sends the data to a nearby Android smartphone via BLE.

The design of the system keeps positioning and communication separate. GNSS supplies coordinates when a reliable position is found. LoRa then sends this information to the receiver. BLE connects the receiver to the smartphone. This core local communication path was built so that it can work even if there is no internet service or service.

The system still depends on good satellite reception, a long radio link and reliable packet delivery. It also needs BLE to be available.

The main goals of this work are to lay out the hardware and software architecture to describe how location and SOS data travel through the system and to set up a way to test the system. The key contributions of this design are: (1) a two-device system that uses GNSS for positioning and direct LoRa for location and SOS communication; (2) a receiver-to-smartphone BLE interface that shows location and alerts; and (3) a planned test plan that looks at packet delivery, latency, range and power usage. The project is still, in the design phase and building and testing the system is the step.

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II. RELATED WORK AND RESEARCH GAP

A. LoRa-Based Wearable Safety

Wu et al. presented WE-Safe, a wearable Internet of Things sensor network for safety applications using LoRa communication and energy harvesting [1]. Their work provides relevant background on wearable sensing and low-power wireless communication. A related conference publication describes the WE-Safe wearable sensor node [2].

These systems motivate the investigation of LoRa for safety-related applications, although their emphasis differs from BroadLoRa's proposed location and SOS workflow.

B. GPS and LoRa Safety Systems

GPS–LoRa safety-alert architectures are also relevant to this project [3]. Combining positioning with radio communication is not, by itself, a sufficient basis for claiming novelty. The original publications must be examined to establish how their hardware, communication paths, and evaluations compare with the proposed system.

C. Literature survey

Table I summarizes the reviewed approaches and the design questions motivating BroadLoRa. The research gap is treated as a design motivation rather than a claim that no similar system exists.

TABLE I LITERATURE SURVEY OF LORA-BASED SAFETY SYSTEMS

Ref.	Objective	Method	Finding	Advantage	Limitation	Research Gap
[1] Wu et al., 2018	Wearable safety monitoring with low-power wireless communication.	Wearable sensors transmit data over LoRa.	Demonstrates LoRa-based wearable safety monitoring.	Low power, long range, wearable design.	Infrastructure-dependent; not focused on GPS tracking.	Evaluate direct location and SOS delivery.
[2] Wu et al., 2018	Compact wearable IoT node for safety monitoring.	Sensors send data through LoRa to a gateway.	Shows feasibility of wearable LoRa sensor nodes.	Low power and long-range communication.	Gateway/cloud dependence; no child tracking focus.	Evaluate direct wearable-to-receiver communication.
[3] Chitrakar et al., 2021	Long-range emergency location alerts.	GPS determines location; LoRa transmits alerts.	Combines GPS positioning with LoRa alerts.	Location awareness and long-range alerts.	Limited monitoring features; receiver required.	Integrate BLE and an Android interface.
[4] Smart-Child Track-ing, 2024	Child tracking with geofencing and safety features.	GPS/LoRa device communicates through a server.	Supports GPS and LoRa-Based child tracking.	Child-focused design and geofencing.	Server infrastructure; direct local link not emphasized.	Evaluate direct parent-side reception.
[5] Lo-RaWAN Anti-Kidnapping, 2024	Wearable tracking and distress alerts.	GPS/GNSS data sent through LoRaWAN and a gateway.	Demonstrates wearable tracking and alert delivery.	GPS, distress button, mobile application.	Requires gateway and network infrastructure.	Test standalone LoRa with BLE smartphone access.

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[6] Wearable Emergency System, 2020	Remote-area emergency monitoring.	GPS and sensors send emergency data through LoRa.	Supports remote safety monitoring without cellular coverage.	Low power and long-range communication.	Detailed quantitative performance is not provided in the survey.	Measure latency, reliability, range, and runtime.
[7] LoRaWAN GPS Tracker, 2023	Evaluate LoRaWAN-based GPS tracking.	ESP32, GPS, LoRaWAN, and indoor/outdoor RSSI testing.	Survey reports a maximum tested range of 5.67 km.	Long range and low-power tracking.	Infrastructure dependence; variable RSSI and indoor GPS accuracy.	Test direct-link performance in varied environments.
[8] SAR Safety Assessment, 2010	Assess RF exposure from body-worn antennas.	SAR measurements using body phantoms and probes.	Highlights the need to assess wearable RF exposure.	Measurement-based RF safety assessment.	Military antennas; not LoRa-specific.	Assess RF exposure for the proposed wearable.
[9] Portable Tele-ECG, 2020	Send wearable health data to smartphones.	Wearable sensors transmit data using BLE.	Demonstrates low-power wearable-to-phone communication.	Low power and smartphone integration.	Short range; health-monitoring focus.	Evaluate BLE location and SOS display in Android.
[10] LoRa LPWAN Study, 2017	Analyze LoRa communication performance.	Evaluates SF, BW, and CR effects on transmission.	Radio parameters affect data rate and transmission time.	Long range, low power, configurable parameters.	Low data rate; performance depends on configuration.	Optimize parameters for location and SOS messages.
BroadLoRa	Local child location awareness and SOS alerts.	GNSS wearable → LoRa → ESP32 receiver → BLE/Android.	Proposed architecture; testing pending.	Local communication without mandatory Internet.	Range, latency, reliability, and runtime unmeasured.	Validate the complete end-to-end prototype.

III. PROPOSED SYSTEM ARCHITECTURE

A. System Overview

BroadLoRa comprises a wearable transmitter, ReceiveLoRa receiver, and Android application. Fig. 1 illustrates the proposed data path and distinguishes the two wireless links.

B. Wearable Transmitter

The planned wearable includes an ESP32 controller, GPS/GNSS module, LoRa transceiver, SOS button, status indicator, and rechargeable power subsystem. The controller checks the location-fix validity and constructs packets containing a device identifier, sequence number, fix status, and coordinates when valid, as well as the SOS status.

The packet is transmitted through the LoRa transceiver. If a valid position is unavailable, the device should explicitly indicate that condition rather than represent invalid coordinates as a current location.

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C. Receiver and Mobile Application

ReceiveLoRa uses a planned ESP32 controller and a compatible LoRa transceiver to receive and validate the packets. The receiver forwarded the available information through a BLE service to an Android application developed using Kotlin and Jetpack. The application was designed to display the coordinates, last update timestamp, connection state, and SOS alerts. Stale information must be distinguished from recently received location data to avoid incorrect conclusions.

D. Packet Design and Offline Boundaries

The proposed packet contains a protocol version, device identifier, sequence number, fix status, coordinates, SOS flag, and optional status fields. The field sizes, coordinate encoding, timestamps, and security mechanisms will be finalized during implementation. GNSS receives satellite signals; LoRa carries data only within its usable radio range; and BLE connects the receiver to the paired smartphone.

IV. COMMUNICATION ARCHITECTURE AND PROTOCOL

BroadLoRa uses a two-stage wireless communication system. The first stage uses Long Range (LoRa) to send data from the transmitter to the receiver. The second stage uses Bluetooth Low Energy (BLE) to send data from the receiver

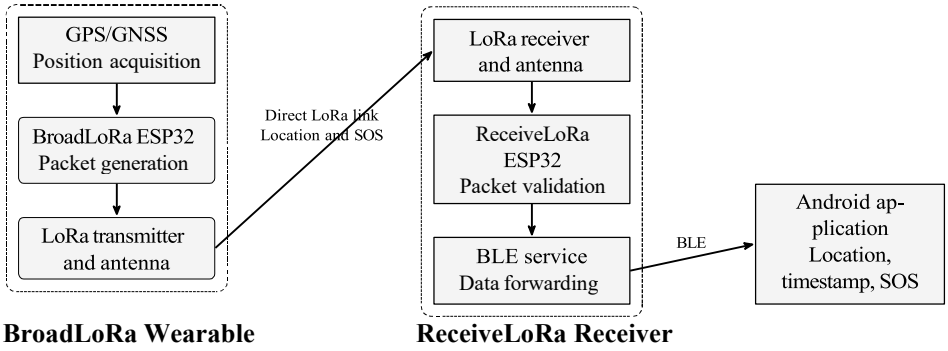


Fig. 1 Proposed BroadLoRa architecture showing direct LoRa communication between the wearable and receiver, followed by BLE data forwarding to the Android application.

to the Android application. This setup allows for location tracking and emergency alerts without needing cellular service or Internet access for the main data path.

A. LoRa-Based Communication

The BroadLoRa wearable has an ESP32-based controller connected to a GNSS module and a LoRa transceiver. The GNSS module gets coordinates at regular intervals. The controller processes this data. Puts it into a data packet. The packet includes the device identifier, a sequence number, the location coordinates, GPS-fix status, a timestamp and the emergency status.

Once the packet is ready it is sent wirelessly via the LoRa transceiver to the ReceiveLoRa unit. The receiver checks the packet for validity and then forwards the information. LoRa creates a link between the wearable and the receiver. This means no cellular networks or Internet infrastructure are needed within the radio range.

B. Bluetooth Low Energy Communication

The ReceiveLoRa unit serves as a point between the LoRa wearable and the Android application. After receiving and checking a packet the ESP32 controller in the receiver makes the data available to a paired smartphone using Bluetooth Low Energy (BLE).

The Android application connects to the receiver via BLE. Receives location updates, device status and emergency alerts. BLE offers a power, short-range connection. This allows the smartphone to show the recent coordinates, connection status, timestamp and SOS alerts.

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C. Communication Workflow

The overall communication process follows these stages:

1. The GNSS module gets the wearables location when it has a satellite fix.
2. The wearable controller builds a data packet with location and device-status details.
3. The LoRa transceiver sends the packet to the ReceiveLoRa unit.
4. The receiver checks the packet. Pulls out the needed information.
5. The receiver passes the data to the paired Android application using BLE.
6. The application updates the location and status or sends an SOS alert if an emergency packet is received.

This communication architecture separates long-range This communication design keeps long-range device-to-device communication separate from short-range smartphone connectivity. As a result the system can function without networks or Internet services, for local monitoring. This works long as both wireless connections are active and the wearable has a valid GNSS fix.

V. DESIGN AND EVALUATION METHODOLOGY

A. Development Process

The project follows the iterative prototyping model. The planned stages are as follows:

1. Validate hardware and the LoRa communication link.
2. Develop GNSS and SOS firmware.
3. Implement receiver packet handling and BLE communication.
4. Develop the Android application interface.
5. Integrate the complete end-to-end data path.
6. Refine the prototype using measured test results.

B. Experimental Setup

The proposed evaluation used a selected wearable device, receiver, and Android smartphone. The tests documented the hardware and firmware versions, antenna placement, radio parameters, distance, environment, packet counts, and timestamps. Open-area and obstructed-environment trials were considered. The numerical acceptance thresholds, trial counts, and test distances were finalized before the formal evaluation. No measurements were assumed in this design-stage study.

C. Evaluation Metrics

Packet delivery ratio (PDR) will be calculated as

$$\mathrm{PDR}(\%) = \frac{N_{\mathrm{received}}}{N_{\mathrm{sent}}} \times 100. \tag{1}$$

Packet loss rate will be calculated as

$$\mathrm{Loss}(\%) = \frac{N^{\mathrm{sent}} - N^{\mathrm{received}}}{N_{\mathrm{sent}}} \times 100. \tag{2}$$

For n latency observations, mean latency i

$$\overline{T} = \frac{1}{n}\sum_{i=1}^{n} T_i, \tag{3}$$

where Ti is the measured delay between event generation and its availability in the application. Timestamping limitations will be documented.

An idealized battery-runtime estimate is

$$T_{\mathrm{ideal}} = \frac{C_{\mathrm{battery}}}{I_{\mathrm{average}}}, \tag{4}$$

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where capacity is measured in mAh and the average current is measured in mA. This estimate neglects conversion losses and variable load behavior; the actual runtime must be measured.

The test plan includes GNSS acquisition, packet delivery, communication range, SOS latency, BLE reconnection, stale data handling, battery runtime, and fault recovery. The actual results will be added only after the experiments are completed.

VI. PLANNED EVALUATION AND DISCUSSION

The evaluation will investigate packet delivery under different distances and environmental conditions. The measured range applies only to the tested radio configuration, antenna placement, and environment. It will not establish a universal operating distance.

The end-to-end latency was measured for routine location updates and SOS events. The delay may include GNSS update timing, firmware processing, LoRa transmission, receiver validation, BLE transfer, and application processing times. The GNSS acquisition time was recorded separately because satellite visibility affected the availability of coordinates.

Power testing will examine the relationship between transmission interval, current consumption, and battery runtime. More frequent updates may improve timeliness but increase radio activity. Tests will also examine packet loss,

GNSS nofix conditions, receiver power interruption, and BLE disconnection.

BroadLoRa is designed to provide a local communication path without cellular or Internet dependency in the core workflow. Its practical usefulness remains dependent on measured radio performance, GNSS availability, BLE connectivity, and power behavior. As testing has not been completed, no quantitative performance or successful end-to-end operation is claimed. Comparisons with published work will require sufficiently comparable experimental conditions.

VII. SECURITY AND PRACTICAL CONSIDERATIONS

Device identifiers and packet validation can support basic filtering; however, they do not independently authenticate the sender. The implementation should consider message authentication, replay protection, sequence validation, and duplicate-packet handling. A checksum alone does not provide authentication.

BLE pairing and access controls should limit unintended access, where supported. If location history is implemented, its storage and deletion policies should be documented. Unnecessary personal information should not be transmitted to the user.

The selected radio modules and antennas must comply with applicable Indian frequency and transmit-power requirements. Battery protection, charging circuitry, and electrical safety must also be evaluated. BroadLoRa is an experimental safety aid, not a certified emergency system. Alert delivery cannot be guaranteed when either the wireless link, receiver, or smartphone is unavailable.

VIII. CONCLUSION AND FUTURE WORK

This paper presents the design of BroadLoRa, a proposed offline wearable location-awareness and emergency-alert system integrating GNSS positioning, direct LoRa communication, a receiver-side BLE interface, and an Android application. The design separates positioning, wearable-to-receiver radio transmission, and receiver-to-smartphone communication to support local operation without cellular or Internet connectivity in the core path.

This study defines the proposed architecture, packet information, development process, and evaluation methodology. The project remains at the design stage, and the practical range, packet delivery, latency, battery runtime, and end-to-end behavior remain to be experimentally established.

Future work will implement and integrate the hardware and software, measure performance under documented conditions, test failure recovery, and refine power management and packet security based on the observed results.

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