iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** VI **Month of publication:** June 2025

DOI: https://doi.org/10.22214/ijraset.2025.71881

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

Design and Implementation of a Smart Tracking System for People, Pets, and Assets Using LoRa and GPS

Nishi Shahnaj Haider[1], Afshan Hameed[2], Saptaparni Dey[3], Shashank Shreshtha[4], Vanisha Sahay[5]
[1]Assistant Professor, [2,3,4,5]Student, Department of Electronics and Instrumentation, Ramaiah Institute of Technology, India

Abstract: The growing demand for efficient tracking of personal belongings, pets, individuals, and vehicles across both indoor and outdoor environments has led to the advancement of smart, IoT-enabled monitoring systems. This paper presents a dual-mode real-time tracking solution that integrates embedded hardware with wireless and cloud-based technologies to ensure reliable location monitoring. The system consists of three specialized trackers: an Indoor Object Tracker, a Dual-Mode Personal Tracker, and a Vehicle GPS Tracker—each designed for different proximity and mobility use cases. ESP8266 microcontrollers paired with LoRa (RA-02) modules enable low-power, short-range communication, while GPS modules provide long-range positioning. A central receiver built using an ESP32 features a buzzer and LCD display for local feedback when the object is nearby. When the target moves beyond the defined range, GPS data is transmitted to the Blynk IoT platform via Wi-Fi. Within the Blynk app, users can manually select which tracker to locate, providing flexible control over the system's operation. The vehicle tracker operates independently, directly sending live GPS coordinates to the app, enhancing surveillance and anti-theft functionality. With its modular architecture, user interactivity, and seamless switching between tracking modes, the system offers a scalable, cost-effective, and practical solution for real-time location tracking in applications such as smart homes, personal safety, logistics, and intelligent transportation.
Keywords: IoT-based Tracking System, LoRa Communication, GPS Tracking, Real-Time Location Monitoring, ESP8266 Microcontroller, Dual-Mode Tracker, Blynk IoT Platform, Indoor and Outdoor Tracking, Asset and Personal Safety, Vehicle Tracking and Surveillance

I. INTRODUCTION

In today's fast-paced world, the problem of losing or misplacing valuable objects such as personal belongings, pets, and vehicles has become increasingly common. Traditional tracking systems are often expensive, offer limited range, and typically depend on either cellular networks or GPS alone. These limitations affect reliability, especially in indoor environments or remote areas with weak signals. Consequently, there is a growing demand for an efficient, affordable, and intelligent tracking system that can work seamlessly across different environments.

With the advent of the Internet of Things (IoT), real-time tracking and remote monitoring have become more feasible. Technologies like LoRa (Long Range) and GPS (Global Positioning System) have opened new possibilities for wide-area communication and accurate location detection. LoRa is known for its low-power, long-range data transmission capabilities, making it ideal for IoT-based tracking solutions. When integrated with GPS and microcontrollers like the ESP8266, these systems can provide an effective solution for object tracking with minimal cost and complexity.

This paper presents the design and implementation of a smart tracking system that leverages LoRa communication, GPS positioning, and IoT integration to locate and monitor the position of various objects in real-time. The system is designed to operate in multiple modes, prioritizing communication channels based on the object's proximity and availability of modules. It aims to be low-cost, compact, and user-friendly while providing efficient tracking capabilities for indoor and outdoor environments.

The proposed system introduces a hybrid tracking mechanism that includes three types of trackers: an indoor-only LoRa transmitter, a dual-mode personal tracker (LoRa + GPS), and a GPS-based vehicle tracker. A central receiver evaluates the signal availability and prioritizes which tracker to rely on. In addition, the system integrates with the Blynk IoT platform to provide users with a mobile-based interface for map visualization and alert notifications. The modular design and flexible operation make the system adaptable for various use cases with minimal infrastructure requirements.

II. LITERATURE REVIEW

Yagi et al. [1] proposed GO-Finder, a wearable system aimed at helping users locate lost objects without needing prior registration. The approach leveraged hand-held object discovery using embedded sensors, providing a unique wearable interaction model. While their system was innovative in design and user experience, it was mostly confined to localized object recognition and lacked long-range tracking capabilities or multi-environment adaptability.

Several researchers have focused on GPS-enabled IoT solutions for enhancing safety and real-time location tracking. Boomika et al. [2] developed a women's safety system using GPS and IoT modules to monitor location and alert in emergencies. Jeevan et al. [3] presented a real-time vehicle tracking system with two-factor authentication over IoT platforms, ensuring both position accuracy and secure access. These systems, although functional, rely heavily on GPS and cellular communication, which limits usability in GPS-denied zones or areas with poor signal reception.

To overcome GPS limitations, researchers have explored LoRa-based localization. Fargas and Petersen [4] proposed a GPS-free geolocation model using LoRa, suitable for low-power wide-area networks. Rahman et al. [5] provided a comprehensive review of LoRaWAN's protocol stack, challenges, and its potential for scalable IoT deployments. Centenaro et al. [6] and Augustin et al. [7] further emphasized LoRa's relevance in unlicensed bands and smart city applications due to its range and power efficiency. These studies clearly highlight the viability of LoRa for low-power, long-range communication, yet most works focus on network-level analysis rather than concrete tracking implementations.

Open-source implementations of LoRa for IoT purposes have also been explored. Zhou et al. [8] designed Open LoRa, focusing on the open architecture for IoT communications. Though flexible and well-integrated with cloud solutions, their implementation emphasized data management over practical tracking mechanisms. Meanwhile, Rao et al. [9] combined GPS, GSM, and image recognition via OpenCV for object localization, which, while innovative, increased hardware complexity and cost. Muchtar et al. [10] applied GPS tracking in augmented reality environments for asset visualization, demonstrating novel use cases but requiring AR-specific hardware support.

While existing works successfully address various aspects of object tracking—ranging from safety applications and GPS monitoring to LoRa-based communication—a hybrid tracking system capable of intelligently switching between different tracking modes (indoor LoRa, outdoor GPS + LoRa, and GPS-only for vehicles) remains underexplored. Furthermore, many solutions are either too specific, expensive, or require constant connectivity. This motivates the design of a cost-effective, energy-efficient, and multi-modal IoT tracking solution, capable of adapting to environmental conditions while providing real-time feedback to users via a mobile platform.

III. SYSTEM DESIGN

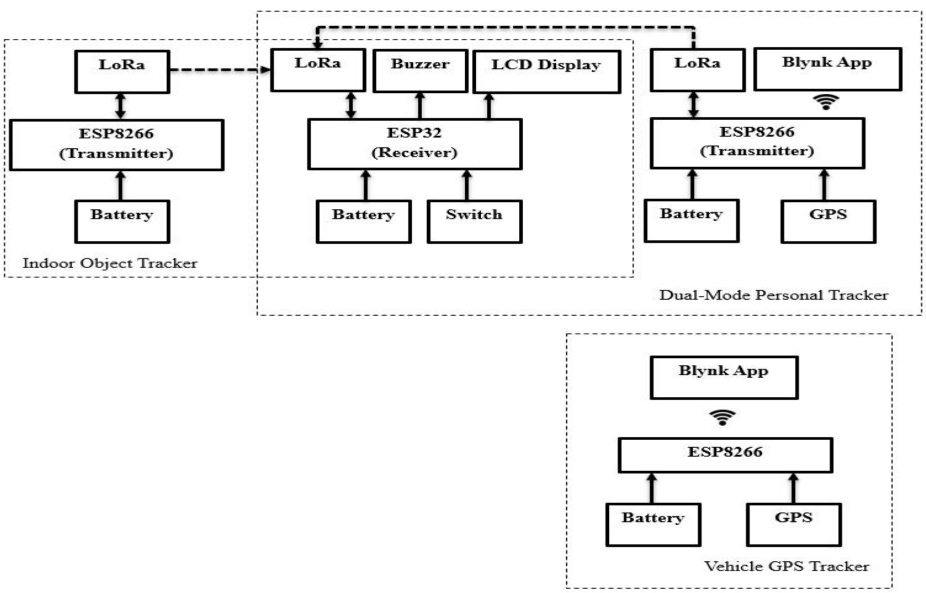

Fig. 1 Block Diagram of the Smart Tracking System

The proposed smart tracking system is designed to provide a multi-mode tracking mechanism that adapts based on environmental context—supporting indoor, outdoor, and vehicular object location tracking. The system architecture is modular and consists of four key units: the Receiver Unit, the Indoor Object Tracker, the Dual-Mode Personal Tracker, and the Vehicle GPS Tracker. Fig. 1 illustrates the block diagram representing the interconnections between the various modules.

A. Materials Used

1) *ESP32 Development Board:* The ESP32 is a powerful microcontroller with dual-core processing, integrated Wi-Fi, and Bluetooth capabilities, making it ideal for IoT applications. It offers more GPIO pins and better processing speed compared to the ESP8266, which makes it suitable for the receiver unit that needs to handle both LoRa communication and peripheral interfaces such as LCD, buzzer, and Blynk connectivity. Its low power consumption and versatile connectivity options make it a robust choice for smart tracking systems.
2) *ESP8266 NodeMCU Board:* The ESP8266 is a cost-effective microcontroller with built-in Wi-Fi, widely used in IoT projects. It was chosen for the transmitter and tracker units due to its simplicity, availability, and compatibility with the Blynk IoT platform. While it is less powerful than the ESP32, it is sufficient for handling GPS data, sending LoRa packets, and connecting to cloud services when required.
3) *RA-02 LoRa Module (SX1278):* The RA-02 LoRa module, based on the Semtech SX1278 chipset, supports long-range, low-power wireless communication in the 433 MHz band. It is ideal for environments where Wi-Fi or GSM signals may be weak or unavailable. It was chosen for its extended range (up to 10 km in open areas), high interference resistance, and low current consumption — all of which are essential for energy-efficient, long-range tracking applications.
4) *NEO-6M GPS Module:* The NEO-6M is a GPS receiver module that provides accurate and real-time geographic positioning data. It was selected for its high sensitivity, fast acquisition, and low power consumption. The module supports standard NMEA protocols and interfaces easily with both ESP8266 and ESP32, making it a reliable choice for outdoor location tracking in the proposed system.
5) *16x2 LCD Display:* A standard 16x2 character LCD is used to display short-range location information, system status, and alerts on the receiver device. It was chosen for its simplicity, low cost, and ease of integration with microcontrollers. It provides a user-friendly visual output without requiring smartphone access.
6) *Buzzer:* The buzzer provides an audible alert when the tracked object is within range, enhancing the user experience through immediate feedback. It is a low-cost and low-power component that supports the proximity alert functionality of the system.
7) *Rocker Switch:* A simple rocker switch is used to turn the device on or off manually. It ensures safe handling of power, especially when switching between test modes or conserving battery during standby.
8) *Li-ion Cell (Battery):* Lithium-ion cells were selected for their high energy density, rechargeable capability, and compact size. They are well-suited for portable IoT devices where reliable power supply and mobility are essential.
9) *Resistors:* Various resistors are used throughout the circuit to ensure proper voltage levels, current limiting, and safe operation of the components. Though passive, they are essential for stable circuit behavior.
10) *Jumper Wires:* Jumper wires are used for prototyping and establishing temporary or semi-permanent connections between components on the breadboard or PCB. They offer flexibility during testing and debugging stages of hardware development.

B. System Architecture

The Receiver and Interface Unit is the central control hub of the entire system and is built using an ESP32 development board. It integrates a LoRa module to receive data from transmitters, a 16x2 LCD display for visual feedback, a buzzer for audible alerts, and a rocker switch to control tracking initiation. This unit serves as the user interface and notification system. It is powered by a rechargeable Li-ion battery, and the switch allows users to initiate a scan for nearby devices, triggering a response if the object is within range.

The Indoor Tracking Unit is designed using an ESP8266 microcontroller connected to an RA-02 LoRa (SX1278) module. This transmitter unit is battery-powered and periodically sends data to the receiver using LoRa technology. It is optimized for short-range, indoor object tracking where GPS signals are not accessible or necessary. Its minimalistic design ensures portability and low power consumption.

The Dual-Mode Personal Tracker extends the functionality by integrating GPS with LoRa. It uses an ESP8266 NodeMCU, RA-02 LoRa module, and the NEO-6M GPS module. This unit can be used for tracking pets, people, or valuable items both indoors and outdoors.

When within LoRa range, it communicates directly with the receiver. If out of LoRa range, it sends GPS coordinates to the Blynk IoT platform via Wi-Fi, allowing remote tracking via a smartphone app. The inclusion of both technologies ensures redundancy and wide coverage.

In addition to personal and indoor object tracking, the system includes a Vehicle GPS Tracker unit to monitor assets like bikes or cars. This module is built around the ESP8266 NodeMCU and a NEO-6M GPS module. It operates independently, without a LoRa interface, and sends real-time location data directly to the Blynk IoT platform over Wi-Fi. This GPS-only approach ensures continuous outdoor tracking even when the vehicle moves beyond the LoRa communication range. It is compact, battery-powered, and transmits coordinates periodically for the user to view on the mobile application.

IV. METHODOLOGY

The methodology outlines the step-by-step procedures and technical processes employed to implement the system effectively. It details the initialization and configuration of hardware modules including ESP8266 microcontrollers, LoRa transceivers, GPS sensors, and the integration with the Blynk IoT platform. The methodology also covers data acquisition from GPS, encoding and transmitting location and identification data via LoRa, and signal reception and processing at the receiver end to determine object proximity and status. Emphasis is placed on the timing mechanisms for periodic data transmission, the use of RSSI for distance estimation, and the logic for prioritizing multiple tracking modes to ensure accurate and reliable object tracking in various environments.

A. Operational Workflow

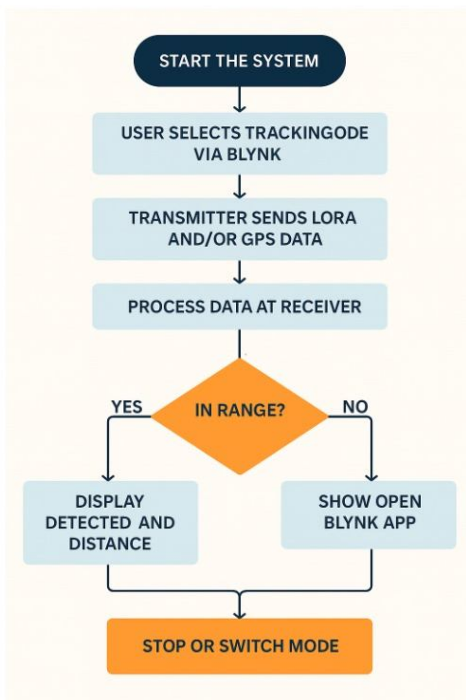

Fig. 2 Operational Workflow of the Smart Tracking System

The operational workflow begins with system initialization, where all microcontrollers, LoRa modules, and GPS sensors are powered up and configured. Once the system is ready, the user selects the desired tracking mode (object, human, or vehicle) via the Blynk IoT mobile application. This selection configures the receiver node to expect specific types of incoming data.

The corresponding transmitter device then starts sending location or identification data, depending on the selected mode. If it is an object tracker (indoor), it sends only a LoRa ID signal. If it is a human or vehicle tracker, it transmits GPS coordinates through LoRa and/or sends the same to Blynk via Wi-Fi.

The receiver node listens for LoRa signals, decodes the payload, and checks for GPS data if available. Using RSSI (Received Signal Strength Indicator), the system estimates the proximity of the transmitter. If the signal strength indicates that the device is within range, the receiver triggers a buzzer alert and displays relevant information like distance estimate and detection status on an LCD screen. If no LoRa signal is received or the RSSI is too low, the system assumes the device is out of range, and prompts the user to open the Blynk app to view the last known GPS location on Google Maps. This dual-path decision ensures robust tracking in both indoor and outdoor environments.

Finally, the user may either stop the tracking session or switch to another mode, returning the system to a new initialization loop. This structured operational flow ensures seamless switching between multiple tracking environments with minimum user intervention.

B. Communication Process

The communication process in the system is a hybrid, multi-channel architecture combining low-power, long-range LoRa radio frequency communication with Wi-Fi-enabled cloud interactions via the Blynk IoT platform. This hybrid communication design optimizes system responsiveness, range, power efficiency, and data reliability across diverse operational environments (indoor, outdoor, vehicular).

1) LoRa Communication Protocol:

At the core of the local wireless communication layer lies the LoRa (Long Range) modulation protocol, operating on the 433 MHz ISM band. Each transmitter node (Indoor Object Transmitter and Dual-Mode Personal Tracker) utilizes a Semtech SX1278 transceiver controlled by the microcontroller's SPI interface. The LoRa protocol employs chirp spread spectrum (CSS) modulation, which provides high sensitivity (~-137 dBm) and robust interference immunity suitable for long-distance, low-data-rate transmissions in noisy environments. The transmitters initiate communication by constructing packets containing identification data and, where applicable, GPS coordinates formatted as ASCII strings. The payload format follows a lightweight scheme: a numeric identifier denoting device type (e.g., "1" for object, "3" for human tracker), followed by comma-separated latitude and longitude values if GPS data is available. These packets are transmitted approximately every 1.5 to 3 seconds, depending on the device.

The Receiver node continuously listens on the LoRa channel, synchronizing to preamble signals and decoding incoming packets. Upon reception, the node extracts payloads, and analyses metadata, including RSSI (Received Signal Strength Indicator) and SNR (Signal-to-Noise Ratio). RSSI is crucial for distance estimation, enabling proximity-based triggering of alerts.

2) Wi-Fi and Blynk Cloud Communication:

Complementing the local LoRa network is the cloud communication channel established via Wi-Fi connectivity. All nodes that require internet access (Dual-Mode Personal Tracker and Vehicle Tracker) connect to a configured Wi-Fi Access Point using the ESP8266's built-in Wi-Fi module. After network association and IP acquisition, the nodes establish a TCP connection to the Blynk cloud server on port 80, using the Blynk library's simplified API.

Through Blynk, nodes log GPS coordinates as virtual events and send periodic heartbeat signals to designated virtual pins. These events enable real-time visualization of tracking data on the Blynk mobile app and facilitate remote monitoring. The cloud serves as a redundant communication layer when LoRa coverage is unavailable or for vehicle trackers without LoRa hardware.

3) Integration and Data Fusion:

The system's communication stack effectively fuses the local LoRa radio data with cloud-based Blynk telemetry. The Receiver node acts as a gateway, bridging wireless sensor data with cloud interfaces. By continuously scanning and decoding LoRa packets, it maintains up-to-date knowledge of indoor and personal tracker positions via RSSI and GPS data relayed over LoRa. Simultaneously, it queries or receives updates from Blynk to track vehicle GPS and heartbeat status.

4) Timing, Synchronization, and Error Handling:

Each transmitter operates on asynchronous timers to schedule transmissions, balancing network congestion and power consumption. The Receiver uses non-blocking LoRa listening routines coupled with event-driven Blynk callbacks to manage concurrent data streams efficiently. Error handling is implemented through payload validation, RSSI threshold checks, and retransmission on failed or corrupted packets. GPS data validity is verified by ensuring coordinates are non-zero and within feasible ranges before transmission or logging.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

C. User Interaction

The interaction between the user and the tracking system is primarily facilitated through the Blynk IoT mobile application, which acts as the central interface for controlling and monitoring the trackers. Upon initiating the system, the user selects the desired tracking mode—Object, Human, or Vehicle—via predefined buttons on the Blynk dashboard. This selection configures the receiver to process only the relevant LoRa transmissions based on unique identifier codes. For indoor tracking (Object mode), the user receives real-time proximity feedback on an LCD display, along with buzzer alerts whose frequency varies with distance, providing intuitive directional guidance. In outdoor tracking scenarios (Human or Vehicle mode), the associated tracker units transmit GPS coordinates to the Blynk cloud platform and via LoRa to the receiver. If the target is within LoRa communication range, the receiver displays the estimated distance locally. When the target moves out of range, the system instructs the user to open the Blynk app, where a Google Maps link—automatically generated and logged through Blynk event notifications—provides precise live location information. The system autonomously handles protocol switching and data prioritization, requiring minimal technical intervention from the user. Thus, the interface design emphasizes ease of use, offering dual-level interaction—local feedback via hardware components and remote monitoring through the Blynk mobile application—ensuring a seamless and intuitive user experience.

V. RESULTS

A. LoRa Communication Performance

TABLE I
RSSI VALUES AT VARYING DISTANCES FOR INDOOR AND OUTDOOR LORA COMMUNICATION

Distance (m)	RSSI Indoor (dBm)	RSSI Outdoor (dBm)
0	-53	-48
5	-70	-60
10	-82	-72
15	-92	-83
20	-110	-90
30	-	-97
40	-	-104
50	-	-111

The RSSI (Received Signal Strength Indicator) values were analyzed under both indoor and outdoor environments to evaluate the effective range and reliability of LoRa communication. The results show that LoRa signals degrade more rapidly indoors due to obstructions such as walls, ceilings, and furniture. In contrast, in open outdoor environments, the signal attenuates gradually due to free-space path loss, maintaining higher strength over longer distances. At 20 meters indoors, RSSI drops to around -110 dBm, rendering packet transmission unreliable. Outdoors, the signal remains above -100 dBm up to 30 meters and continues to be detectable up to 50 meters. These findings justify the architectural decision to utilize LoRa for indoor tracking within confined areas and switch to GPS with Blynk IoT integration for broader outdoor coverage.

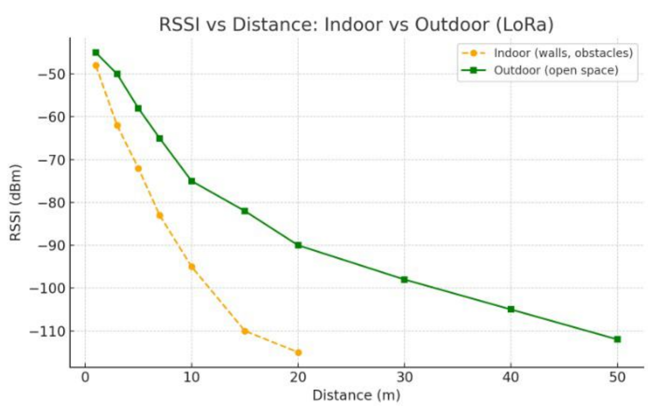

Fig. 3 Characteristic Plot of RSSI vs Distance: Indoor vs Outdoor Environments

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

B. GPS Accuracy Test

The NEO-6M GPS module was tested in an open-sky environment for accuracy and reliability. The module successfully acquired a satellite fix within 30 to 45 seconds after powering on. Over a 10-minute test period, the module delivered consistent latitude and longitude readings with an average accuracy deviation of less than ±3 meters. Sample coordinates recorded during the test include:

TABLE III
SAMPLE GPS COORDINATES LOGGED DURING TEST

Reading Number	Latitude (°)	Longitude (°)
1	13°02'05.3"N	77°34'01.2"E
2	13°01'59.8"N	77°33'45.6"E
3	13°01'40.6"N	77°33'29.3"E
4	13°01'51.7"N	77°33'10.5"E

These readings demonstrate the module's suitability for real-time outdoor tracking, particularly when the device moves across urban or suburban areas.

C. Receiver Unit Display Output:

The receiver unit effectively identifies and differentiates between object types—Indoor Object, Human (Dual-Mode), and Vehicle—based on predefined device IDs embedded in incoming LoRa packets. When an indoor object is tracked, the receiver displays "Tracking Object Scanning…" followed by "Object Detected" if within range, and an estimated distance calculated from RSSI values. If the object is not detected, the display reads "Object Not Detected."

For the dual-mode human tracker, the receiver initiates with "Tracking Human Scanning…" and shows "Human Detected at X meters" if the device is nearby. If not detected via LoRa, the receiver updates to "Human Not Near – Open Blynk App," indicating the need to transition to GPS-based tracking.

The vehicle tracker, which operates exclusively on GPS, triggers the display message "Tracking Vehicle Scanning…" followed by "Vehicle Not Detected" if there is no signal. Once a GPS heartbeat is received, the message updates to "Tracking Vehicle – Open Blynk App." For all detection events, an audible buzzer alert accompanies the visual feedback, ensuring immediate user awareness.

The receiver's intuitive interface and real-time alerts provide a seamless user experience, ensuring quick response and efficient tracking. By combining multiple tracking technologies and intelligent signal processing, the system adapts to various environments and scenarios. This versatility makes it ideal for monitoring valuable assets, loved ones, or vehicles with high reliability. Future updates may include enhanced multi-device support and improved accuracy for even better performance.

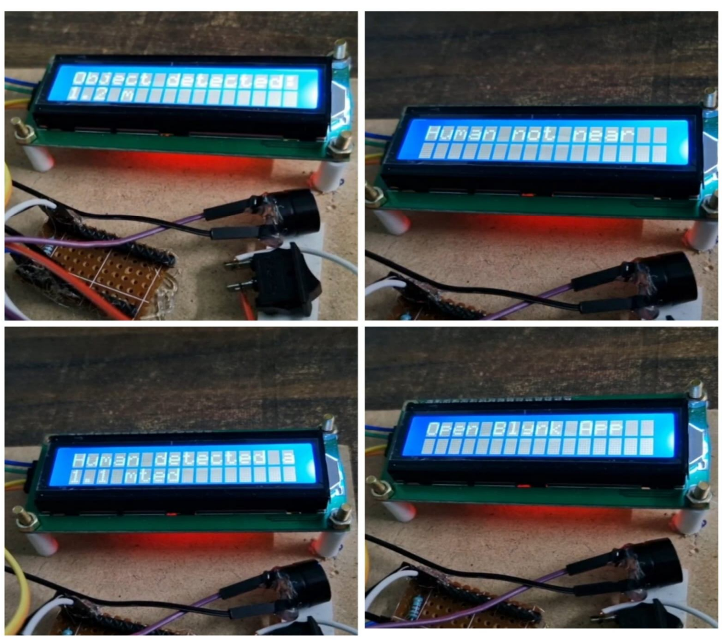

Fig. 4 LCD Output Display for Different Tracker Modes

D. Blynk App Integration Results

The Blynk application acts as the primary user interface for real-time tracking. It features a dropdown menu to choose between Object, Human, and Vehicle tracking. Upon selection, the respective tracker activates, and real-time data is transmitted. When operating in outdoor conditions or when LoRa fails, GPS coordinates are sent to the Blynk cloud and displayed as clickable Google Maps links within the app.

Additionally, the system includes an automated email notification feature that sends GPS coordinates and tracker type details to the user's registered email. This ensures continuous awareness even if the app is closed or not actively monitored, making the system reliable, intuitive, and accessible.

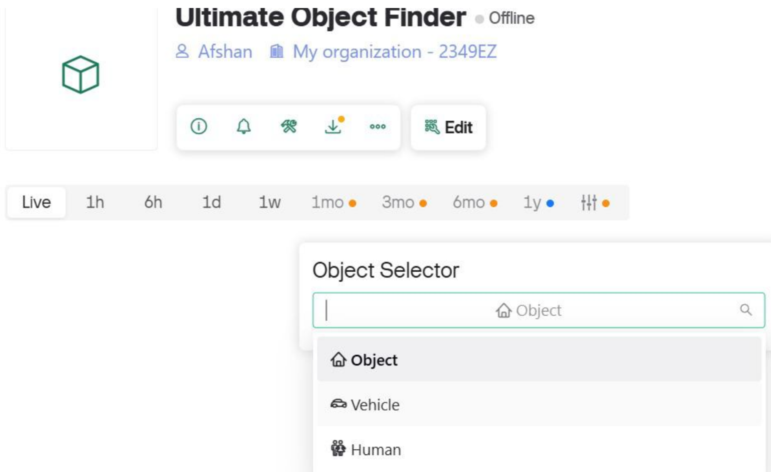

Fig. 5 Blynk App Dashboard Showing Tracker Selection Menu

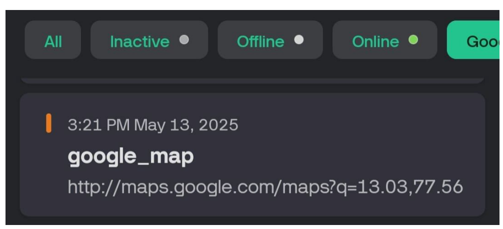

Fig. 6 Real-Time Google Maps Link Generated in Blynk App

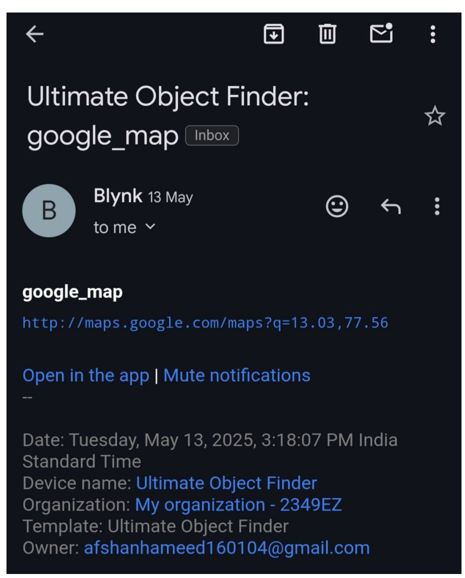

Fig. 7 Email Notification with GPS Coordinates from Blynk

VI. CONCLUSION AND FUTURE SCOPE

This project successfully delivers a low-cost, efficient, and scalable real-time tracking solution tailored for people, pets, objects, and vehicles. By utilizing a hybrid communication architecture—combining LoRa for short-range communication and GPS for long-range tracking—the system intelligently adapts to proximity conditions to ensure reliable performance both indoors and outdoors. The receiver unit accurately differentiates between object, human, and vehicle signals using predefined device IDs and displays real-time feedback through an LCD interface and buzzer alerts. In indoor scenarios, LoRa signal strength is used to estimate distance via RSSI values, while in outdoor conditions, GPS coordinates are transmitted to the Blynk cloud and visualized through the mobile app. The seamless integration with the Blynk platform also enables automated notifications via email, enhancing usability. Experimental results confirm that LoRa is ideal for close-range, low-power communication, while GPS offers stable and precise positioning in open environments.

Future enhancements may include integrating Wi-Fi-based location tracking to improve indoor accuracy where LoRa performance is limited by walls and interference. Incorporating low-power wake-up modules or energy-harvesting mechanisms could extend battery life in portable trackers. Adding a mobile app with built-in controls, real-time alerts, and a geofencing feature could significantly improve the user experience. Expanding the system to support multi-device tracking and AI-driven analytics for movement prediction or anomaly detection would further increase its potential in security, logistics, and personal safety applications.

REFERENCES

[1] T. Yagi, T. Nishiyasu, K. Kawasaki, M. Matsuki, and Y. Sato, “GO-Finder: A Registration-Free Wearable System for Assisting Users in Finding Lost Objects via Hand-Held Object Discovery,” in Proceedings of the Conference on Ubiquitous Computing, College Station, TX, USA, 2021, pp. 139–149.

[2] Boomika A, Divyapriya E, Vidhya N, P. Ramesh, Vanathi K, and Bhuvaneswari P. T. V, “Empowering Women Safety: A GPS-Enabled IoT Tracking System,” in Conference on Emerging Trends in Networks and Computer Communications, India, 2024, pp. 29–34.

[3] S. Jeevan, K. Karthik, Mohana, M. Moharir, J. Sharma, and A. Kumar, “GPS Based Efficient Real-Time Vehicle Tracking and Monitoring System Using Two- Factor Authentication and Internet of Things (IoT),” in Conference on Intelligent Cyber Physical Systems and Internet of Things, India, 2024, pp. 473–478.

[4] B. C. Fargas and M. N. Petersen, “GPS-Free Geolocation Using LoRa in Low- Power WANs,” IEEE Internet of Things Journal, Denmark, 2017.

[5] H. U. Rahman, H. Ahmad, M. Ahmad, and M. A. Habib, “LoRaWAN: State of the Art, Challenges, Protocols and Research Issues,” in IEEE 23rd International Multitopic Conference, Pakistan, 2020.

[6] M. Centenaro, L. Vangelista, A. Zanella, and M. Zorzi, “Long-Range Communications in Unlicensed Bands: The Rising Stars in the IoT and Smart City Scenarios,” IEEE Wireless Communications, vol. 23, no. 5, pp. 60–67, Oct. 2015.

[7] A. Augustin, J. Yi, T. Clausen, and W. M. Townsley, “A Study of LoRa: Long Range & Low Power Networks for the Internet of Things,” Sensors, vol. 16, no. 9, p. 1466, Sep. 2016.

[8] Q. Zhou, K. Zheng, L. Hou, J. Xing, and R. Xu, “Design and Implementation of Open LoRa for IoT,” IEEE Access, vol. 7, pp. 100649–100657, Aug. 2019.

[9] N. P. Rao, G. Bhavana, and M. L. R. Teja, “RTOS Based Image Recognition & Location Finder Using GPS, GSM and OpenCV,” Science, Engineering and Technology, vol. 2, pp. 85–88, Dec. 2015.

[10] M. A. Muchtar, M. F. Syahputra, N. Syahputra, S. Ashrafia, and R. F. Rahmat, “Augmented Reality for Searching Potential Assets in Medan Using GPS Based Tracking,” in International Conference on Computing and Applied Informatics, Netherlands, 2016.