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Design and Implementation of GPS-LoRa Tracking System with LCD Interface

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Abstract: *Traditional GPS tracking systems rely on cellular networks, limiting their utility in remote or rural areas and often incurring high data costs. This project report introduces an innovative GPS tracking system that leverages LoRa (Long Range) technology to overcome these limitations. The system combines a GPS module, which captures real-time geographical coordinates, with a LoRa module that facilitates long-range, low-power wireless data transmission. Utilizing Arduino-compatible hard ware and open-source software, the design comprises a transmitter unit that gathers and sends data, and a receiver unit that processes and displays the location information on various interfaces. This architecture not only ensures reliable tracking without cellular dependency but also offers significant benefits such as cost-effectiveness, energy efficiency, and customization potential. Applications of this system include wildlife monitoring, asset tracking, hiking safety, disaster management, and agricultural oversight. Overall, the report demonstrates the viability of a LoRa-basedGPSTrackerasarobustalternativeforIoTtrackinginareaswheretraditionalmethods are impractical.*

1. INTRODUCTION

In today's interconnected world, real-time monitoring and tracking of assets is crucial for many applications, ranging from fleet management to environmental monitoring. The rapid evolution of wireless communication technologies has paved the way for innovative solutions that combine different modules to achieve reliable and efficient data transfer over long distances. One such solution is a LoRa -based GPS tracking system, which leverages the long-range, low- power capabilities of LoRa (Long Range) communication alongside the precise positioning provided by GPS (Global Positioning System) technology. This project integrates multiple hardware components and software modules to create a system capable of sending location data from a remote device to a receiver. The sender module, built around an Adriano microcontroller, collects GPS data, processes it, and transmits the information using a LoRa module. The receiver, equipped with another LoRa module and an LCD display, decodes the incoming data and presents the information in a human-readable format. Although LEDs were originally included to indicate data validity on the sender side, they were omitted in the final hardware build, leading to reliance on serial output and the receiver's LCD form on it oring the system's performance. Tracking assets reliably over large geographical areas often presents significant challenges. Traditional tracking methods might rely on cellular networks, which can be expensive and limited by coverage in remote or rural areas. Additionally, the need for low power consumption and minimal hardware complexity makes many existing solutions less attractive for certain applications. The specific problem addressed in this project is how to develop a cost- effective, low-power tracking system that can operate over long distances and in areas with limited infrastructure. The lack of LED indicators on the sender side introduces another layer of complexity without visual feedback on the sender hardware, requiring debugging and verification of the system to rely on other signals such as serial outputs and its receiver's display. In medical imaging, histogram equalization enhances contrast to accurately define lesions or objects of interest, especially when structures overlap. In summary, this project aims to provide a comprehensive solution for remote asset tracking using a LoRa-based GPS tracking system with an LCD interface. By addressing challenges such as long-range communication, power efficiency, and user-friendly data presentation, the system is well-suited for a wide range of applications

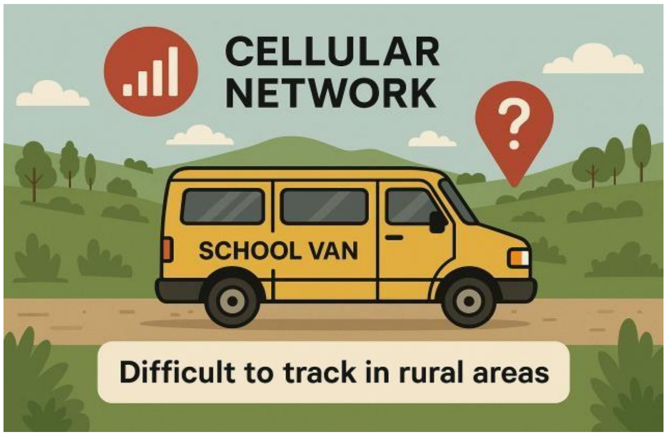


FIGURE 1: Using Cellular Network

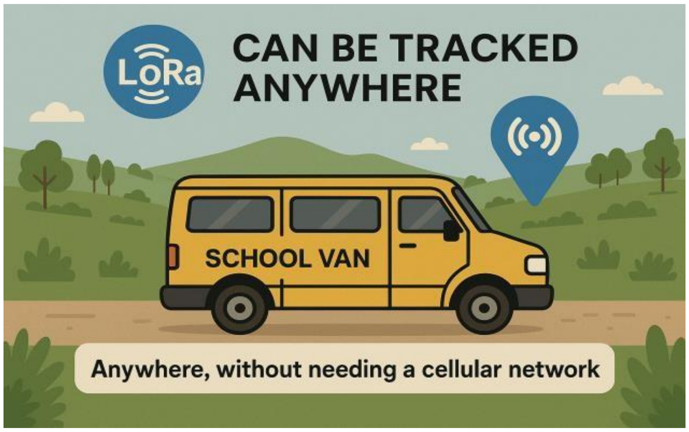


FIGURE 2: Using LoRa Communication

This project aims to provide a comprehensive solution for remote asset tracking using a LoRa-based GPS tracking system with an LCD interface. By addressing challenges such as long-range communication, power efficiency, and user-friendly data presentation, the system is well-suited for a wide range of applications. The integration of hardware components with robust software routines ensures that the system can handle varying operational conditions while delivering reliable performance

2. LITERATURESURVEY

Gu et al. [1] presented an analysis of LoRa-based localization, highlighting the opportunities and challenges in its implementation. Their work focused on the physical layer of LoRa and emphasized aspects such as coverage and localization error. While their study provided foundational insights into the technology, they pointed out the need for significant accuracy improvements for broader application. Muppala [2] investigated a GNSS-free localization system leveraging TDOA techniques. The approach introduced an additional stationary node to improve geolocation capabilities. While it addressed the challenges of synchronization and latency, time-based errors in geolocation still posed significant limitations. Fraunhofer FIT [3] developed a personal tracker using GPS and LoRa mesh networks, capable of operating without traditional mobile networks. This method focused on data transmission range and offered a solution for remote tracking. However, the deployment faced challenges in scalability for large-scale use. Anjum et al. [4] proposed a machine learning-based positioning approach using RSSI fingerprinting in LoRa networks. They implemented SVM and Decision Tree models to predict location based on signal patterns. While improvements were noted in localization accuracy and power efficiency, the study highlighted the continued need for precision enhancement. Mackey et al. [5] explored the development of a LoRa-based localization system designed for emergency services in GPS-deprived environments. Using RSSI-based localization, the study evaluated power efficiency and signal strength as critical parameters. Their results demonstrated the system's usefulness, although challenges related to GPS inaccessibility in certain areas remained. Fernandez-Garcia et al. [6] proposed a wearable GPS tracking system based on Low-Power Wide-Area Networks, particularly LoRa and SIGFOX. Their focus was on power consumption and user comfort. The study offered promising results, with the added benefit of integration with smart textiles, making it viable for wearable tech applications. Lee & Kim [7] explored real-time display interfaces for tracking systems, emphasizing LCD integration with LoRa-based trackers. Their findings suggested that high refresh rates and minimal power consumption are crucial for ensuring effective real-time tracking visualization. Hassan et al. [8] developed a hybrid GPS-LoRa tracking system for urban and remote environments. Their study evaluated signal propagation challenges in different terrains and proposed an adaptive transmission algorithm to improve localization accuracy. However, signal interference in dense urban areas remained a limitation. Patel & Sharma [9] introduced a low-power LoRa tracking system with an LCD interface for real-time location display. Their research focused on optimizing LCD refresh rates to minimize energy consumption while maintaining accurate and responsive tracking updates. Tan et al. [10] proposed an IoT-based GPS-LoRa tracker with cloud integration for data logging and remote monitoring. The system allowed real-time tracking visualization on a mobile app, with LoRa handling long-range communication. However, network congestion affected data transmission speed in high-traffic environments. Singh & Verma [11] explored energy-efficient LoRa tracking solutions using adaptive duty cycling to extend battery life. They tested various power-saving algorithms and concluded that dynamic transmission scheduling significantly enhances device longevity without compromising tracking precision.

3. EXISTING SYSTEM

The block diagram of the Existing diagram is shown in Figure 1. The system consists of two parts which are LoRa transmitter and receiver. LoRa/GPS shield was stacked onto Arduino at transmitter part before location data being transmitted on the LoRa network. At receiver part, LoRa shield was stacked onto Yun shield for data collection and then onto Arduino. Hardware and software component LoRa or global positioning system (GPS) shield with the part number of SX1276/SX1278 was used in the project. In this project, Arduino Mega was chosen as the microcontroller as it has more pins that can be used as an input or output compared to other version of Arduino. Yun shield was stacked between LoRa and Arduino, where the purpose of Yun shield is to solve the storage issue for Arduino board as this project require more storage to store GPS data. The transmitter and receiver parts were shown as Figures 2 and 3. Arduino IDE was used to develop the project.

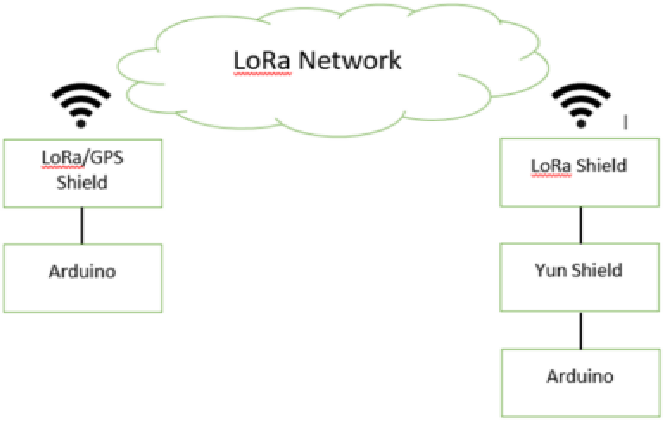


FIGURE 3: Block Diagram

FIGURE 4: Transmitter

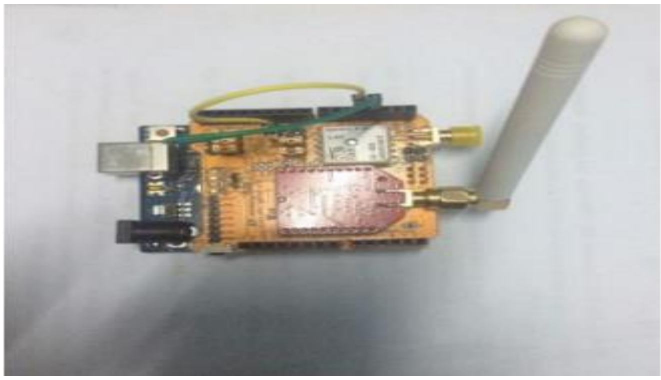
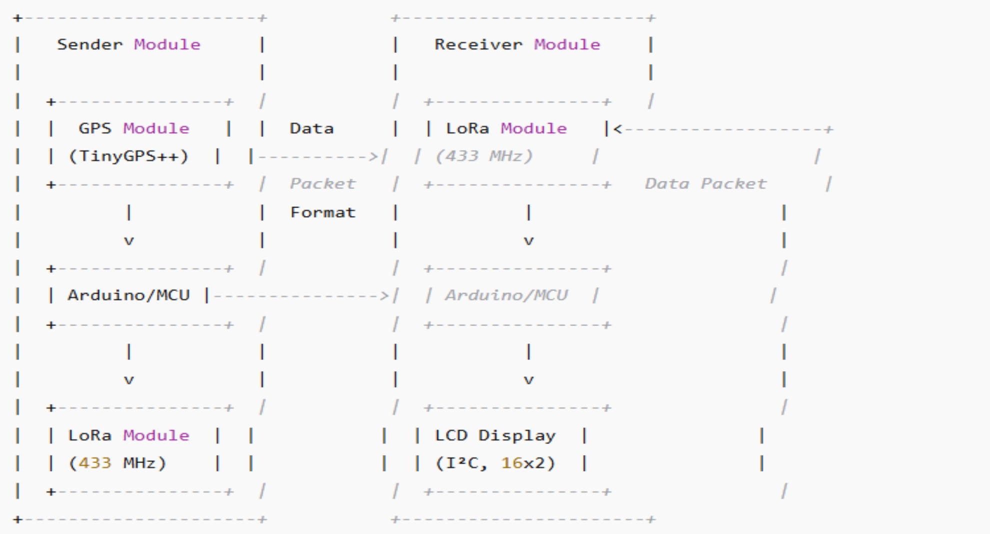


FIGURE 5: Receiver

4. PROPOSEDSYSTEM



```
+---------------------+           +----------------------+
|   Sender Module     |           |   Receiver Module    |
|                     |           |                      |
|  +---------------+  /           /  +---------------+   /
|  |  GPS Module   |  |  Data     |  | LoRa Module   |<-------------------+
|  | (TinyGPS++)   |  |---------->/ / (433 MHz)      /                   /
|  +---------------+  /  Packet   /  +---------------+  Data Packet      /
|         |           |  Format   |          |                        |
|         v           |           |          v                        |
|  +---------------+  /           /  +---------------+                /
|  | Arduino/MCU |--------------->/  | Arduino/MCU   /               /
|  +---------------+  /           /  +---------------+                /
|         |           |           |          |                        |
|         v           |           |          v                        |
|  +---------------+  /           /  +---------------+                /
|  | LoRa Module  |  |          |  | LCD Display  |                |
|  | (433 MHz)    |  |          |  | (I²C, 16x2)  |                |
|  +---------------+  /           /  +---------------+                /
+---------------------+           +----------------------+
```

FIGURE 6. Block Diagram of the Proposed System

The system is designed to monitor and track asset locations remotely using GPS data, which is transmitted via LoRa communication. The architecture comprises two primary modules: the sender (transmitter) module and the receiver module. On the sender side, the GPS module captures real-time location data such as coordinates and timestamps. This raw data is forwarded to a microcontroller unit (MCU), such as an Arduino, where it is processed using GPS libraries to parse and format it into a readable packet. The processed data is then wirelessly transmitted through a LoRa module. On the receiver side, the LoRa module continuously listens for incoming packets. Once received, these packets are sent to its connected MCU, which parses the data and extracts the location information. This information is then displayed on an LCD screen for real-time user monitoring. Additionally, the receiver module supports serial output for data logging or debugging purposes. This setup demonstrates a seamless flow of data from acquisition to transmission and finally to user-friendly display making it well-suited for tracking applications in areas with limited or no cellular coverage.

5. CIRCUITDIAGRAMOVERVIEW

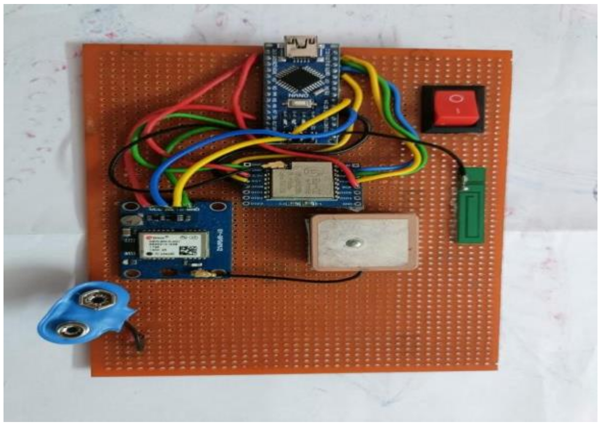


FIGURE 7: Transmitter

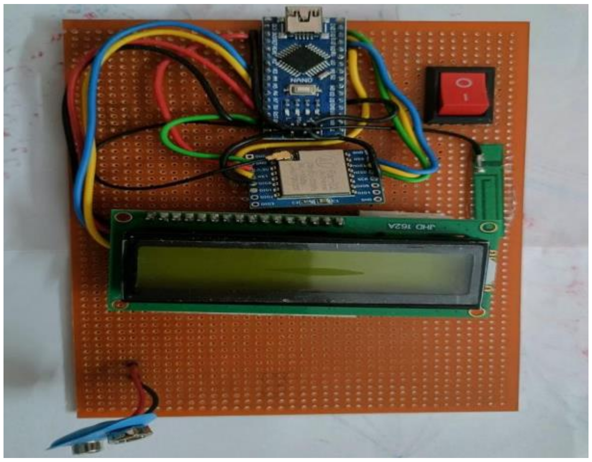


FIGURE 8: Receiver

The circuit diagram is thoughtfully segmented into key functional blocks to ensure efficiency, modularity, and expandability. The power section is designed to deliver a regulated and stable voltage supply of either 5V or 3.3V, depending on the operating requirements of the connected modules. A voltage regulator such as the AMS1117 or LM317 ensures steady output. To enhance stability, decoupling capacitors (typically 0.1 µF and 10 µF) are placed close to the power pins of critical ICs to filter out noise and voltage spikes. Moving to the microcontroller section, an Arduino (commonly Uno, Nano, or Mega, based on project scale) serves as the core processing unit. It offers: Digital I/O pins for controlling peripherals, Analog inputs for sensor integration, and Serial communication interfaces such as UART, SPI, and I²C to seamlessly interface with other modules. The Arduino can be powered via USB or an external power source, providing flexibility for various deployment environments. In the communication modules block, a GPS module (such as the NEO-

6M) is interfaced using Software Serial to free up the main hardware UART for debugging purposes. Proper voltage level shifting is implemented, especially when interfacing 3.3V GPS modules with a 5V Arduino to prevent damage and ensure compatibility. The LoRa module (e.g., SX1278) communicates over the SPI interface, with well-defined connections to the CS, MOSI, MISO, and SCK pins. Care is taken to avoid conflicts with other SPI devices, and antennas are properly mounted to maximize transmission range and signal quality. For the user interface, an I²C LCD display (typically 16x2 or 20x4) is connected via the SDA and SCL lines. Pull-up resistors (usually 4.7 kΩ) are included if the module does not integrate them by default, ensuring reliable communication on the I²C bus. This display provides real-time feedback such as GPS coordinates, system status, or signal strength. Optional indicators, such as LEDs, can be connected to designated digital pins through current-limiting resistors to provide visual feedback during operation. The entire design emphasizes future scalability, allowing seamless integration of additional sensors or modules without requiring significant circuit redesign thanks to the availability of unused I/O channels and modular wiring practices.

6. CONCLUSION

The challenges and limitations of the LoRa-based GPS tracking system are multifaceted, encompassing hardware constraints, environmental factors, software complexities, deployment issues, and regulatory considerations. Each of these challenges requires careful attention and innovative solutions to ensure that the system remains reliable, accurate, and scalable. While the current prototype demonstrates the fundamental viability of using LoRa and GPS for remote tracking, addressing these challenges is essential for transitioning from a proof-of-concept to a robust, field-deployable system. Future developments must focus on: Enhanced hardware integration, Advanced software algorithms, Improved user interfaces, Adherence to regulatory compliance. These improvements are critical to overcoming the system’s limitations and fully realizing the potential of this technology in a wide range of real-world applications.

REFERENCES

1. Gu et al. (2018): Discusses opportunities and challenges in LoRa-based localization. The study analyzes LoRa’s physical layer and highlights issues like localization error and the need for accuracy improvement.
2. Mackey et al. (2019): Proposes a GPS-less LoRa localization system tailored for emergency services. It utilizes RSSI for positioning, focusing on power efficiency and signal strength under GPS-inaccessible environments.
3. Anjum et al. (2020): Introduces an RSSI fingerprinting-based localization approach using machine learning (SVM and Decision Trees) in LoRa networks to improve positioning accuracy, although further precision enhancement is suggested.
4. Fraunhofer FIT (2022): Develops a GPS/LoRa-based personal tracker that functions without mobile networks, utilizing a LoRa mesh network to extend coverage. It highlights large-scale deployment issues and network scalability.
5. Hassan et al. (2021): Designs a hybrid GPS-LoRa tracking solution optimized for mixed terrains. The system uses adaptive transmission to counter signal loss in dense areas but faces challenges in urban interference handling