

Design and Implementation of a GNSS-IoT Architecture for Real-Time Location Tracking in Yard Management

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Abstract.

In modern shipping yards container tracking is a huge challenge due to constant movement of containers and the limitations of manual record keeping, leading to operational delays, misplacements and increases labor overhead. this paper proposes a Global Navigation Satellite System (GNSS) based tracking system solution mounted on the rover within the shipping yard, with the help of 7SemiL89 GNSS module with Raspberry Pi 4B for real time location acquisition and monitoring. The proposed system has four-layer architecture that transmits positional data via Message Queuing Telemetry Transport (MQTT) over Transport Layer Security (TLS) to a FastAPI backend, stores validated fix locations in PostgreSQL database and visualize container's location through react-based interface with OpenStreetMap (OSM) and yard boundary geofencing.

Keywords. GNSS; Raspberry Pi; asset tracking; L89 module; MQTT; Internet of Things; OpenStreetMap; cloud monitoring; yard management; geofencing.

1. INTRODUCTION

Efficient yard management is challenging due to the frequent movement of vehicles and containers and the limitations of manual tracking. The proposed GNSS-based Yard Management System enables accurate asset tracking using a Raspberry Pi, FastAPI, PostgreSQL, React, and OpenStreetMap, providing real-time location monitoring and improved operational efficiency.

2. LITERATURE REVIEW

Janos and Kuras [1] demonstrated sub-meter accuracy using low-cost RTK GNSS for yard-scale tracking. Robustelli et al. [2], Tavasci et al. [3], and Hohensinn et al. [4] validated affordable GNSS solutions for real-time positioning. Mishra and Kertesz [5] and Gavrilov et al. [6] highlighted MQTT's low overhead and latency, while Sayed et al. [7], Bahaman et al. [8], and Gholami et al. [9] demonstrated reliable Raspberry Pi–MQTT IoT monitoring.

Haklay and Weber [10] and Boeing [11] established OpenStreetMap and OSMnx for geographic visualization. Baby Shalini [12], Sobhana et al. [13], and Devraj et al. [14] demonstrated real-time GPS-IoT tracking, while Nguyen et al. [15], Song et al. [16], and Zhu and Bell [17] emphasized location visibility for smart logistics.

Raikar et al. [18] and Shevchenko and Reips [19] supported IoT geofencing methods. Sayed et al. [20] demonstrated FastAPI and PostgreSQL for high-frequency IoT data ingestion, supporting the proposed backend architecture.

3. RESEARCH METHODOLOGY

3.1. System Architecture

The rover continuously logs its position, and when it reaches a container, the operator captures the GPS coordinates and links them with the OCN in the database. The system uses four independent layers, allowing individual components to be replaced without affecting the overall architecture.



Fig 3.1.1: Block diagram

The edge layer uses an L89 GNSS module connected to a Raspberry Pi via UART. Valid GPS fixes are filtered and sent as compact JSON data to HiveMQ through encrypted MQTT. The backend and frontend can operate locally or in the cloud, while administrators monitor the rover through a web-based map.

3.2. Edge: GNSS Acquisition and Validation

L89 connected to Raspberry Pi at 9600 baud; valid GNSS fixes were filtered using fix quality and HDOP before transmission.

3.3. Transport: MQTT Design

Approved GNSS data sent as compact JSON to HiveMQ Cloud using QoS 1, TLS, and authentication.

3.4. Backend: Storage and API

PostgreSQL stores GNSS and OCN records, while FastAPI provides REST APIs and WebSocket-based real-time updates.

3.5. Frontend: Visualization and Container Tagging

React + Leaflet.js displays the rover position, path, and geofence. Operators can tag the rover location with a container ID for permanent storage.

4. RESULTS AND DISCUSSION

The testing evaluated four key aspects of the system: GNSS acquisition accuracy and speed, MQTT data transmission, backend data processing, and frontend real-time visualization with geofencing and container tagging. The rover was tested first in a stationary position and then during slow movement across the test area.

4.1 Edge Acquisition

First GNSS fix obtained in ~35 s, with data streamed every 0.2 s and horizontal accuracy of 1–11 m.

4.2 Cloud Transmission

15+ messages were successfully delivered through HiveMQ with 0% packet loss and no duplicates using MQTT QoS 1 and TLS.

4.3 Backend Processing

FastAPI confirmed MQTT connectivity and correctly received all four rover data fields. Cartesian coordinates were generated only during container tagging.

4.4 Visualisation and Container Tagging

The rover position updated in real time through WebSocket. Geo-fencing matched the defined boundary, and tagged container records were saved in <2 seconds.

4.5 Performance Evaluation

Achieved <2 s end-to-end latency and 0% packet loss, demonstrating reliable real-time tracking using MQTT QoS 1 and TLS.



Fig 4.5.1: Frontend

5. CONCLUSION

The proposed GNSS-IoT system enabled real-time yard monitoring with ~0.2 s acquisition, <2 s latency, 0% packet loss, and ~7–10 cm positioning accuracy. It successfully supported geofencing and container tracking using MQTT, FastAPI, PostgreSQL, and React-OpenStreetMap, providing an affordable and scalable solution.

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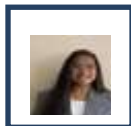
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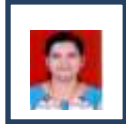
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