Finished Vehicle Logistics

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1. Introduction

In an auto manufacturing plant, the efficient management of vehicle logistics is crucial for optimizing operations and minimizing resource wastage. However, the task of locating vehicles within a large holding presents a significant challenge, exacerbated by constant inventory movement and the absence of a systematic recording system. To address this core problem, the implementation of an Internet of Things (IoT) solution offers a viable solution. This report delineates the development and deployment of an IoT solution tailored to the specific needs of the auto manufacturing plant. By enabling employees to swiftly identify the general vicinity of vehicles, this solution aims to streamline operations and optimize resource utilization.

For our project, we researched various cutting-edge technologies currently utilized across industries. In our examination we explored various options to gain comprehensive understanding of their business applications, narrowed down our focus to two solutions, Bluetooth Low Energy and the integration of RFID (Radio Frequency Identification) and RTLS (Real-Time Location System). Through comparative evaluation across multiple parameters, we have opted for the RFID-RTLS solutions due to its superior range, readability and scalability compared to BLE.

This report is structured into five sections. Section 2 provides a Literature Review, while section 3 explores detailed insights into the Potential Solutions. In section 4, we provide an in-depth analysis of the Proposed System, covering its hardware components, cost model and communication protocols. Finally, section 5 presents the results of our analysis and section 6 concludes the report.

2. Literature Review

Implementing automated assert tracking systems can significantly improve efficiency and accuracy in large warehouses. Technologies such as RFID tags, barcode scanners, Bluetooth and IoT sensors enable real time tracking of asserts throughout the warehouse. RFID technology is used to track autonomous robots within closed environments. employing sensing surfaces divided into location units for precise localization. RFID tags on these units are read by RFID readers attached to entities with location IDs communicated wirelessly to a location manager mapping IDs [1]. Hey faced array antennas Constructed using 2 arpit reader antennas are employed for electronic beam steering to enhance the read range of our fit tax to address the degradation of RFID tag antenna performance in metallic environments a double slit antenna design with a ground plan is implemented. By varying the voltage to adjust the phase difference between consecutive antennas the main beam of our feedreader antenna is stayed in specific directions [2].

Different indoor localization methods were implemented and compared on Nexus 7 tablet including NFC, passive RFID, Wi-Fi, Bluetooth 2.0 and iBeacon technologies with varying levels of interaction and accuracy. iBeacon technology emerged as the most effective offering precise localization using smart devices n beacon signals[3]. Sustaining the needs of Industry 5.0 there are various types of RTLS readers including fixed readers, movement detection readers and high ceiling readers with precise geolocation capabilities. Energy harvesting tags were developed to exemplify Uwinloc's solution which enables the tags to gather and transmit energy for location tracking[4].

3. Potential Solutions

3.1 Bluetooth Low Energy

Bluetooth Low Energy (BLE), also referred to as Bluetooth Smart, is designed for wireless communication over short distances among devices. Its primary application is in energy efficient devices such as wearables, smart homes, gadgets, fitness monitors, and various IoT devices. In this setup, Bluetooth beacons are strategically positioned within parking spaces, while readers are deployed to capture data and relay it to a central server. This data is stored in a database for further processing and analysis.

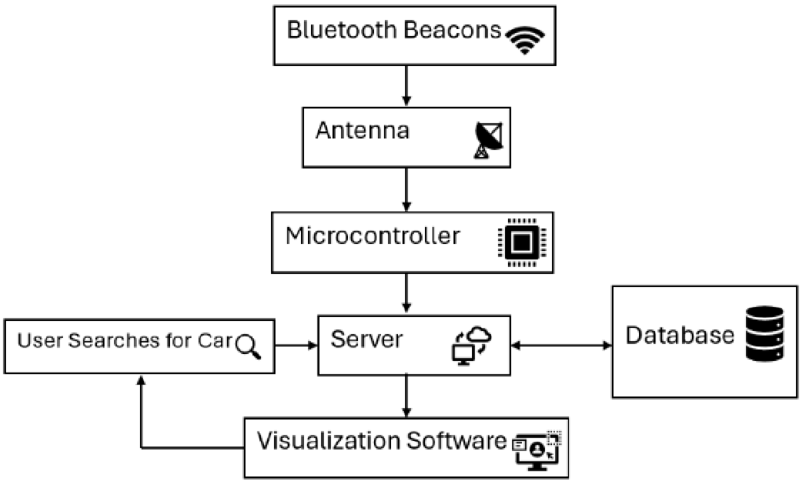


Figure 1: Block diagram of BLE.

3.1.1 Working Scenario

- Radius Network RadBeacons known for their long battery life and remote configurability, are installed in each vehicle. These emits Bluetooth signals at regular intervals, uniquely identifying each parking space.
- Raspberry Pi board with Bluetooth 5.0 dongles offering a range up to 100 meters are used as readers. These are positioned strategically throughout the storage lot and can receive the signals from beacons within their range.
- Intel NUC featuring various connectivity options and compatible with both Linux and Windows operating systems is used as central server for receiving data from receivers across storage lot.
- All the components are connected with Ethernet cable and optionally to Wi-Fi.
- Using RSSI values and known locations of the receivers, trilateration is performed to estimate the approximate location of each Bluetooth beacon.
- A visualization software could be used to identify the location of the beacon. This provides a user-friendly interface to view the real-time location of vehicles.

3.1.2 Pros, Cons and Risks

Pros

- The primary advantage of the BLE is low power consumption, making it ideal for battery-operated devices.
- BLE supports a wide range of consumer devices making it easy to integrate BLE systems with existing technology.
- BLE hardware components are more cost-effective, making it budget friendly.

Cons

- BLE has shorter range, especially in environments with obstacles and interference.
- Implementation of a BLE-based system requires more complex setup and configuration.

Risks

- Susceptible to security vulnerabilities.
- Susceptible to operational disruptions.

3.2 RTLS-RFID

Real-Time Location Systems (RTLS) includes multiple automated identification technologies utilizing wireless signals to pinpoint exact location of the tagged assets or personnel. Radio Frequency Identification (RFID) technology utilizes radio waves to identify individuals or items. A reader can capture information stored in a wireless tag without the need for physical contact or direct line of sight.

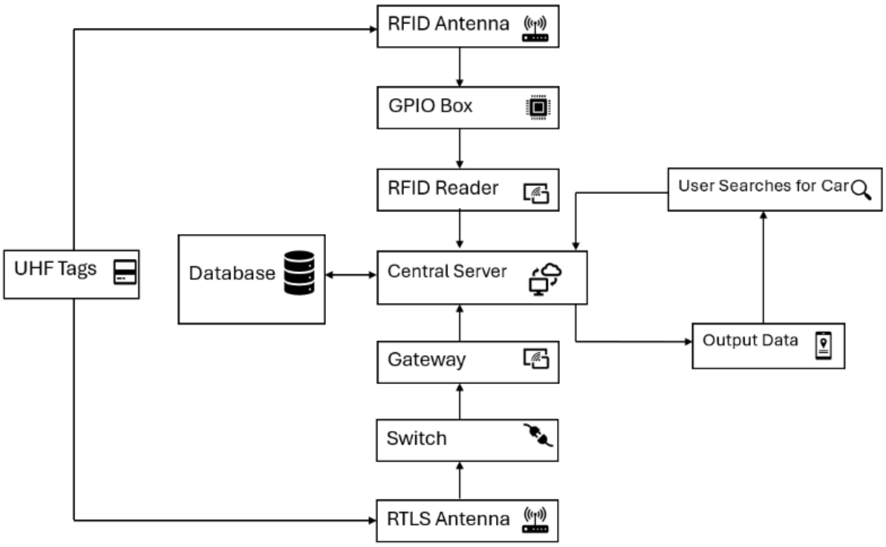


Figure 2: Block diagram of RTLS-RFID.

3.2.1 Working Principle

- RFID tags which contain unique id and other information are attached to each manufactured car during production.
- RFID readers are positioned at the entrance and exit of the storage to record the vehicle movement.
- The software monitors the availability of the parking spaces in the lot and assigns a free parking space for every incoming car.
- RTLS antennas are strategically installed throughout the storage lot which communicates with the tags attached to car.
- The location data collected by the antennas are transmitted to the central server which determines the location based on localization algorithm.
- All these data, including car information, entry/exit events and location data is stored in a database for analysis and references.

3.2.2 Pros, Cons and Risks

Pros

- RTLS-RFID systems can offer extended range coverage allowing for tracking and locating assets over larger areas.

- Provides high reliability in accurately identifying and tracking assets, ensures consistent performance, minimizing errors or inaccuracies.
- Highly scalable, capable of accommodating a large number of tags and readers, similarly, allows for seamless expansion or customization of the system to evolve business needs.
- RTLS-RFID systems provide quick and real-time tracking of assets, providing up-to-date information and enabling timely decision-making.

Cons

- Implementing RTLS-RFID is expensive for large scale deployments initially.
- Involves complex hardware and software components. Designing, deploying, and managing are challenging.

Risks

- Interference can reduce signal strength and leads to inaccuracies.
- Data may be vulnerable to interception, unauthorized access, or manipulation, posing risks to data privacy and security.

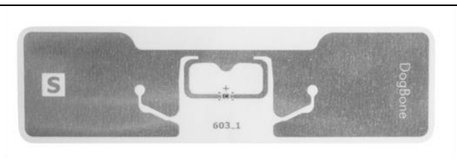
Table 1: Comparison of BLE and RTLS-RFID

Parameters	**BLE**	**RFID-RTLS**
Battery Life	Good	Medium
Cost	Efficient	Efficient for small scale
Latency	Medium	Low
Data Accuracy	Medium	Good
Response Time	Medium	Good

4. Proposed System

4.1 Hardware and Cost Model

For our proposed system, hardware elements such as UHF RFID passive tags, RFID antennas, RFID readers, RTLS smart antennas and POE/POE+ switches are utilized. The combined cost of these components for a single section is approximately $17,000.

Components	**Specifications**
 Avery Dennison Smartrac DogBone M750	Operating Frequency: UHF 860 – 940 MHZ Memory: EPC 96 Bits, TID 96/48 Bits, User 32 Bits. Max Read Distance: Up to 20 meters Integrated Circuit (IC): Impinj M750 Operating Temperature: - 40 to +85 °C (-40 to +185°F) Dimensions: 97 x 27 mm Weight: 1 g Cost: $0.14
 Impinj Speedway Revolution R420	Antenna Ports: 4 Up to 1100 tag reads per second Receive Sensitivity: -84 dBm Network Connectivity: 10/100BASE-T Ethernet Operating Temperature: -20 to +50°C (-4 to +122°F) Dimensions: 7.5 x 6.9 x 1.2 in Weight: 1.5 lbs (0.7 kg) Cost: $1905

 Vulcan RFID™ S9028PCR	Operating Frequency: 902-928 MHz Gain: 8.5 dBic Elevation Beamwidth: 70° Maximum Input Power: 10 Watts Operating Temperature: -25° to +70°C (-13° to +158°F) Dimensions: 10.2 x 10.2 x 1.32 in Weight: 2.3 lbs (1 kg) Cost: $172
 S3400-24T4FP, 24-Port	Ports: 24 x 4 Switching Capacity: 56 Gbps Flash Memory: 16MB Max Power Consumption: 20W (370W with PoE) Operating Temperature: 0 to +45ºC (+32 to +113°F) Dimensions: 1.77 x 17.32 x 8.19 in Weight: 7.7 lbs (3.5 kg) Cost: $439
 RFC CS-490	Tag Read Period: 8 ms Tag Read Distance: 90 ft (27 m) Tag Location Accuracy: 1.5 - 3 ft (0.45 - 0.91 m) Mounting Height: 25 - 50 ft (7.6 - 15.2 m) Operating Temperature: -30 to +45°C (-22 to +113°F) Dimensions: 23.75 x 46 x 4 in Weight: 26 lbs (12 kg) Cost: $500 (approx.)

4.2 Communication Protocol

To simulate a real-time data stream, Python scripts were employed to interact with the RFID reader, RTLS antenna, and simulate the data transmission. Message Queuing Telemetry Transport (MQTT) serves as communication protocol for transmitting simulated data from the gateway devices to central server. MQTT is designed to facilitate effective communication among devices within IoT applications. MQTT offers three levels of QoS to ensure reliable delivery by eliminating duplicates or loss of information.

The JSON serves as versatile data structure for representing RFID and RTLS data. It encapsulates essential information search as tag ID timestamp location coordinates and sensor metadata. JSON's simplicity and flexibility facilitate effortless interpreting, manipulating and exchange of data making it ideal for real time transmission over networks and storage.

5. Results

Figure 3 and Figure 4 illustrate the layout of the storage lot from both side and top perspectives.

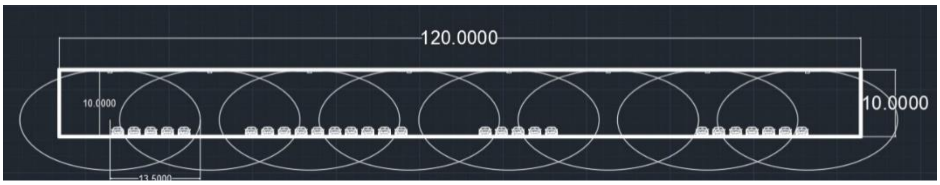


Figure 3: Side view of storage lot.

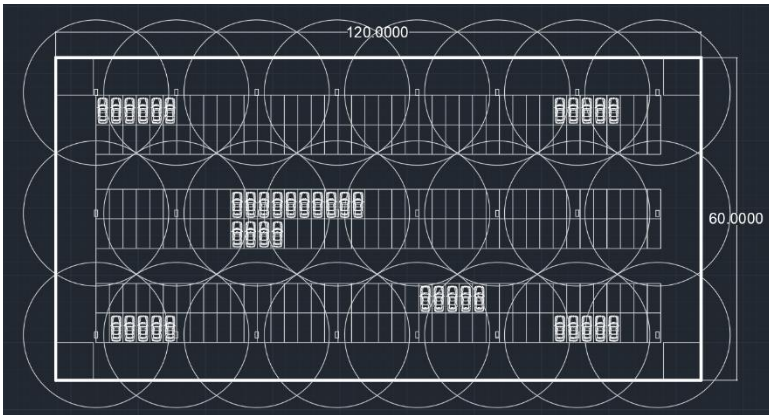


Figure 4: Top view of storage lot.

When a vehicle enters the storage lot, the RFID reader at the entrance captures the data from RFID tag, as depicted in Figure 5. Subsequently, Figure 6 displays the parking space assigned to the vehicle.

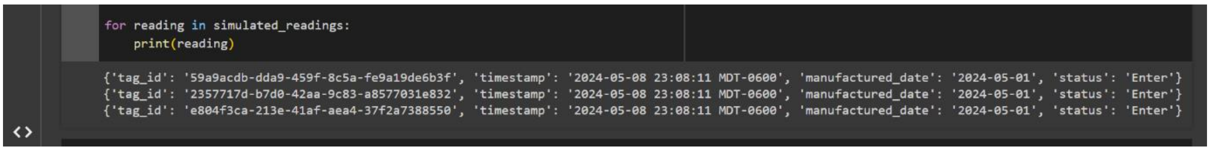


Figure 5: RFID reader data at storage lot entrance.

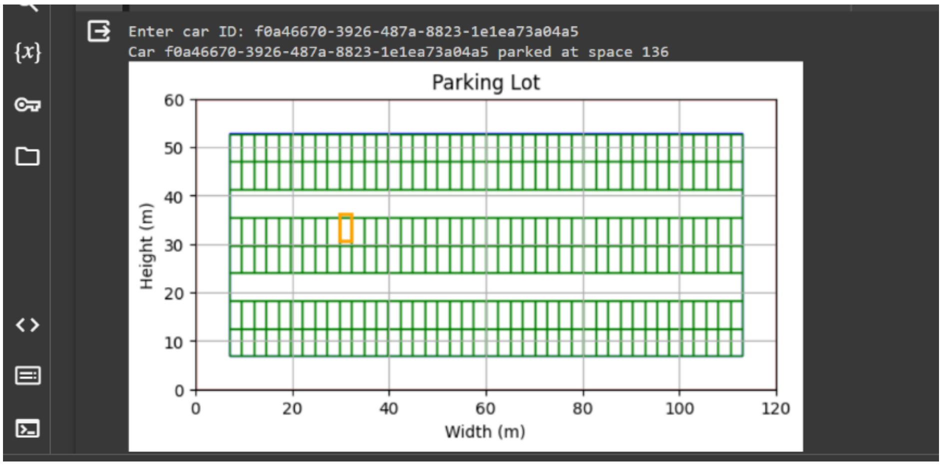


Figure 6: Layout of storage parking lot locating the parking space for vehicle.

The signal received by the RTLS antenna is transmitted to the server, whose location coordinates are computed using localization technique as illustrated in Figure 7 when providing the tag ID.

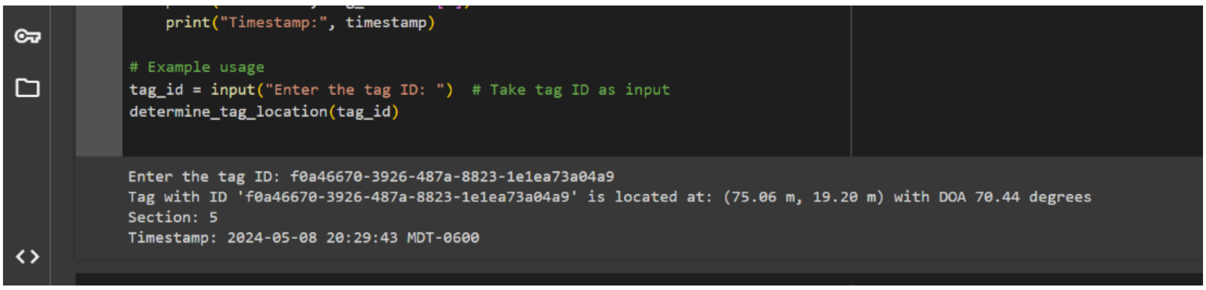
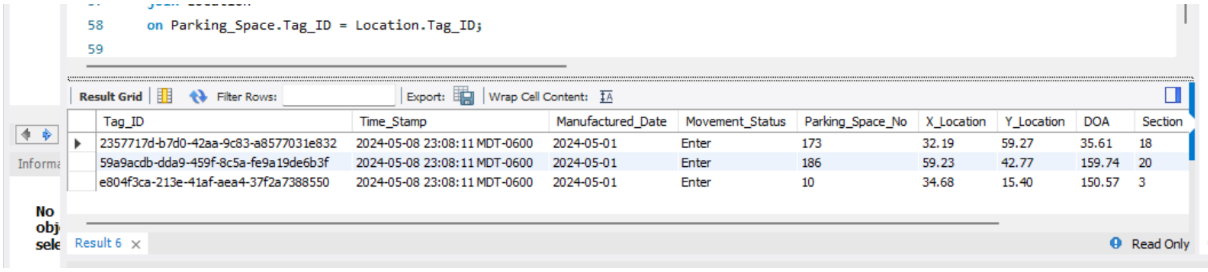


Figure 7: Location information sensed by RTLS system.

Finally, Figure 8 presents the complete data of three different vehicles stored in the MySQL database, upon providing the tag ID as input.



```
58    on Parking_Space.Tag_ID = Location.Tag_ID;
59
```

Tag_ID	Time_Stamp	Manufactured_Date	Movement_Status	Parking_Space_No	X_Location	Y_Location	DOA	Section
2357717d-b7d0-42aa-9c83-a8577031e832	2024-05-08 23:08:11 MDT-0600	2024-05-01	Enter	173	32.19	59.27	35.61	18
59a9acdb-dda9-459f-8c5a-fe9a19de6b3f	2024-05-08 23:08:11 MDT-0600	2024-05-01	Enter	186	59.23	42.77	159.74	20
e804f3ca-213e-41af-aea4-37f2a7388550	2024-05-08 23:08:11 MDT-0600	2024-05-01	Enter	10	34.68	15.40	150.57	3

Figure 8: Data from MySQL database.

6. Conclusion and Future Scope

In conclusion, the implementation of enhanced asset visibility and streamlined operations, alongside improved safety and security measures, marks a significant progress in optimizing organizational efficiency. The scalability and flexibility inherent in this system not only addresses the current needs but also pave the way for future growth and adaptability.

Looking ahead, the potential for integrating all modules with software presents opportunities for seamless data management and process optimization. Furthermore, the prospect of incorporating AI techniques holds promise for even greater efficiency gains and decision-making capabilities. As the technology evolve, embrace these advancements ensure that organizations remain at the forefront of innovation, equipped to meet the challenges and opportunities of future.

References

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