Original Contribution

COMPARATIVE ANALYSIS OF REAL-TIME LOAD TRACKING TECHNOLOGIES

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ABSTRACT: *Real Time Locating Systems (RTLS) and Radio Frequency Identification (RFID) are key technologies in asset tracking and management. Although they may look similar at first glance, they have different characteristics, advantages and disadvantages that make them suitable for different applications.*

KEY WORDS: *Automation, GPS, Real-time tracking, RTLS, RFID, UWB, WLAN.*

A comparative analysis of real-time tracking systems (RTLS) and radio frequency identification (RFID) reveals their unique characteristics, strengths and weaknesses, and applications, especially in real-time cargo tracking. Real-time localization systems (RTLS) use a combination of wireless technologies such as Wi-Fi, Bluetooth, Ultra-Wideband, and GPS to provide real-time information about the location, movement, and status of tracked objects [1,4,6,9]. Individual objects, tools, machines, robots and vehicles can be identified by personal number and type, and information about their status can be visualized [2].

RTLS technologies utilize different communication methods and sensors to determine the real-time location of targets. These technologies empower businesses to enhance their operational efficiency, strengthen security measures, and optimize the allocation of resources. Through a thorough examination of the features, benefits, and limitations of each technology, we can acquire a comprehensive comprehension of its capabilities and potential applications [7].

A Comparison table of 8 types of RTLS Technologies [7]

TECHNOLOGY	REAL-TIME	ACCURACY	RANGE	POWER CONSUMPTION	INFRASTRUCTURE REQUIREMENTS	COST	APPLICATION
WB RTLS	Yes	High	Short to Medium	Moderate	Complex	High	Healthcare, Manufacturing, Asset Tracking
Bluetooth RTLS	Yes	Low to High	Short	Low	Simple	Low to Medium	Indoor Navigation, Proximity Marketing
WiFi RTLS	Yes	Medium	Medium to Long	Moderate	Simple	Medium	Retail, Logistics, Inventory Management
RFID RTLS	No	Low to High	Short to Medium	Low	Moderate to High	Low	Supply Chain, Asset Tracking, Inventory
Zigbee RTLS	Yes	Medium	Short	Low	Moderate	Medium	Smart Home Automation, Building Management
LoRa RTLS	No	Low to High	Medium to Long	Low	Moderate to High	Medium	Agriculture, Smart Cities, Outdoor Tracking
iBeacon RTLS	No	Low	Short	Low	Simple	Low to Medium	Indoor Navigation, Proximity Applications
Ultrasonic RTLS	Yes	High	Short	Moderate	Complex	High	Robotics, Security, Indoor Positioning

The applications of RTLS are virtually limitless, some of the common use cases and related applications are:

- Indoor and outdoor navigation
- Inventory and supply chain management
- Healthcare and monitoring of patients
- Production and warehouse management
- Smart cities and infrastructure monitoring
- Sports and recreation
- Security and access control.

Due to the variety of connectivity options for RTLS applications, RFID systems use radio waves for identification and tracking, with passive and active RFID tags [4]. In its general form, RFID needs two components. The first component is a Radio Signal Transponder, or this is a tag that attaches to the

object. The tag has an embedded chip that contains identification information about the object to which it is attached and an antenna to transmit that information via radio waves. The second component is a reader device that creates a radio frequency field that picks up radio waves. When the tag passes through the radio frequency field generated by the corresponding reader, the tag returns identification information about the object to which it is attached to the reader and thus identifies that object. Therefore, in an RFID system there is no requirement for visual access when identifying objects because RFID tags do not need to be visible to the scanner to be identified [5,9].

Due to the variety of RTLS connection options, comparisons of the two technologies reveal their characteristics, strengths and weaknesses, and applications, especially in real-time cargo tracking:

1. **Features**:
   - **Accuracy**: RTLS offers higher accuracy, pinpointing locations within a few centimeters or meters.
   - **Range**: RTLS systems have a longer range, up to 100 meters or more, compared to RFID.
   - **Real-time Tracking**: RTLS excels in providing real-time location updates, whereas RFID is better suited for identification and data capture [4].

2. **Strengths and Weaknesses**:
   - **Ease of Implementation**: RFID systems are easier and less expensive to implement.
   - **Power Consumption**: Passive RFID tags are low-maintenance and cost-effective, not requiring a power source. RTLS systems, however, need batteries.
   - **Scalability**: RFID systems are more easily scalable due to their simplicity and lower cost, while RTLS can be challenging to scale in large areas.
   - Interference caused by RFID antennas can be another problem, as it can affect other equipment and devices. In addition, the exciters needed to activate passive RFID tags are expensive and require a lot of power to activate the tags, which may not be ideal for hospital environments. [4,8]

3. **Applications**:
   - **RTLS**: Widely used in healthcare for tracking equipment and monitoring staff and patients. In manufacturing and warehousing, it optimizes workflows and inventory management. In logistics and transportation, RTLS enhances fleet management, route

optimization, and security through real-time tracking of vehicles, containers, or parcels [4, 6].

In conclusion, RTLS offers good accuracy and real-time tracking capabilities, while RFID is cheaper, more accessible and easier to implement. When choosing real-time tracking technologies, it is necessary to know the exact requirements of the tracked object, including the need for real-time information updates and object location accuracy.

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