



WHITE PAPER

LEVERAGING BLUETOOTH AOA RTLS FOR INDUSTRIAL
AND WAREHOUSING APPLICATIONS



How Hybrid AoA + RSSI
Tracking Improves
Accuracy, Efficiency,
and ROI.

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	The future of RTLS is hybrid – and it's available today

Executive Summary

Industrial and warehouse operators face mounting pressure to increase efficiency, improve safety, and reduce costs. **Real-Time Location Systems (RTLS)** are becoming essential in achieving these goals.

Bluetooth AoA RTLS, used in combination with RSSI as offered by **Sentrax**, provides a flexible, scalable, cost-effective, and accurate asset tracking solution for industrial and warehouse environments. This white paper outlines the technical foundations, technologies comparison, deployment best practices, and cost scenarios that demonstrate why **hybrid AoA + RSSI** is the optimal choice for modern industrial tracking.

Introduction – Why Location Intelligence Matters Today

Warehouses and industrial plants are under pressure to do more with less.

- **Labor shortages/cost drive the need for automation.**
- **Complex supply chains demand real-time visibility.**
- **Safety regulations require better monitoring of people and assets.**

RTLS technologies provide the foundation for smarter operations. Yet, the choice of technology — *BLE AoA, UWB, RFID, Wi-Fi, or LoRaWAN* — dramatically affects cost, accuracy, and scalability.

Sentrax's Hybrid AoA + RSSI RTLS combines the best of both worlds: high accuracy in challenging metal-heavy environments, and affordability that makes scaling realistic.

How AoA RTLS Works

- **Phase Differencing:** Estimates angle based on the phase shift between antennas.
- **Triangulation:** Multiple locators calculate position by combining angles.
- **Hybridization:** Sentrax integrates RSSI to strengthen accuracy under multipath and non-line-of-sight (NLOS) conditions.

Think of AoA like “digital ears”: just as humans locate a sound by comparing how it reaches each ear, AoA locators determine where a tag signal originates.

Advantages in Warehousing and Industrial Applications

High Information Accuracy

Provides real-time visibility and automatic event updates across the facility, ensuring reliable and data-driven decision-making.

Scalable Deployments

Thousands of assets can be tracked without overwhelming infrastructure.

Process & Operational Benefits

- More efficient automated workflows
- Improved accuracy and control of operations
- Enhanced traceability of the asset lifecycle
- Higher levels of automation

No Time Sync Required

Unlike UWB, AoA systems avoid expensive synchronization infrastructure.

Versatile Use Cases

- Pallet-level zoning
- Automated inventory checks
- Worker safety monitoring
- 3D shelf-level asset tracking
- Forklift tracking

Challenges in Metal-Frame Warehouses

Real-world deployments face obstacles:

- Multipath reflections cause angular errors.
- No-line-of-sight (NLOS) conditions degrade accuracy.
- Metal Interference and multipath propagation.

RTLS Technologies Comparison

Compares RTLS technologies by accuracy, range, and battery use factors that impact cost, maintenance, and deployment suitability.

Technology	Accuracy	Range	Battery Consumption	Indoor/Outdoor Suitability
BLE AoA	0.5–1 m	20–80 m, depending upon installation height	Low	Indoor, outdoor (yards level)
BLE RSSI	5 m – room level	30-80 meters (extended via external antenna)	Low	Indoor,outdoor (yard level, vehicle installation)
RFID (Active)	5 – 10 m (zone-based)	20-85 meters	Moderate-High	Indoor, outdoor (yards, gates)
RFID (Passive)	Portal only (no XY)	A few cm – 10 meters (depends upon the reader)	None	Indoor (portals & choke points), outdoor limited
UWB TDoA	10 – 50 cm	20-85 meters	High	Indoor, outdoor, limited
Wi-Fi	10 – 15 m	20-85 meters	Very High	Indoor, not ideal outdoor
LoRaWAN	20–200 m+ (outdoor), poor indoor	100 m – 10+ km (outdoor)	Low	Indoor weak (poor X, Y), outdoor wide area

Table -01 RTLS Technologies Comparison

Mitigation Strategies

- Use locator diversity (3+ per zone depending upon the environment).
- Mount arrays below metal trusses.
- Calibrate after installation (including tag transmission power in some cases).
- Hybridize with RSSI or Anchor Beacons in critical zones.

Technologies Cost Comparison

A cost-focused comparison of major RTLS (Real-Time Location System) technologies, highlighting accuracy, tag and infrastructure expenses, along with key deployment considerations.

Technology	Accuracy	Tag Cost	Infra Cost	Comments
BLE AoA	0.5–1 m	€8–20	€400–1,500	Medium-cost solution that provides high accuracy. It offers sub-meter accuracy at a significantly lower cost than UWB.
BLE RSSI	3–5 m	€8–20	€100–800	A low-cost solution that leverages existing Bluetooth-enabled devices, making it a very affordable option for proximity-level tracking. The low hardware and implementation costs make it ideal for simpler, scalable tracking applications.
RFID Portals	Portal only	€0.10–0.50	€2–8k	Inexpensive tags with higher infrastructure costs, making it a valuable solution for high-volume tracking at fixed points like entry/exit.
UWB TDoA	10–30 cm	€35–70	€2000–5,000	The most expensive technology with the highest accuracy, which requires a significant investment in both tags and infrastructure.
Wi-Fi FTM	1–5 m	€15–40	Variable	Can reduce initial deployment costs by leveraging existing Wi-Fi networks, but its effectiveness is dependent on the network quality and the complexity of the environment.
LoRaWAN TDoA	20–200 m	€15–30	€300–800	Wide-area coverage; poor XY accuracy. Offers wide-area coverage at a relatively low infrastructure cost, but with limited indoor accuracy. It's a lowest-cost solution, especially for long-range, battery-powered use cases.

Table -02 Technologies Cost Comparison

Cost Scenarios

Cost scenarios compare the estimated deployment costs of BLE AoA and UWB TDoA RTLS. Scenario A covers **BLE AoA for a 20,000 m² site with 1,000 assets**, while Scenario B applies UWB TDoA to the same site.

Scenario - A & B	Scenario A - BLE AoA	Scenario B - UWB TDoA
Infrastructure	~€48k	~€90k
Installation	€15–30k	€25–50k
Tags	~€12k	€25–50k
Total	€100–150k	€190–265k
Scenario - A & B	~€48k	~€90k
Infrastructure	€15–30k	€25–50k

Table -03 Cost Scenarios

ROI for BLE AoA RTLS

The table below outlines the return on investment (ROI) for deploying a BLE AoA real-time location system in a **20,000 m² warehouse with ~1,000 assets**. It includes capital and operational expenses along with estimated payback time and long-term financial benefits.

Typical Investment	(20,000 m ² warehouse, ~1,000 assets)
CAPEX	€100–150k (infrastructure, tags, software, install)
OPEX	€6–9k/year (tag batteries, maintenance, updates)
Payback in	~2 years
5-Year Net Benefit	€180k–220k
Typical Investment	(20,000 m ² warehouse, ~1,000 assets)

Table -04 ROI for BLE AoA RTLS

The investment in BLE AoA RTLS typically breaks even within two years and delivers a net financial benefit of **up to €220k over five years**, making it a cost-effective solution for large-scale asset tracking.

How BLE AoA Gains an Edge Over UWB in Warehousing?

BLE AoA stands out as a more practical and scalable solution for warehouse environments. It combines sufficient accuracy with lower operating costs, longer battery life, and deployment flexibility, making it well-suited for day-to-day asset tracking and safety monitoring. **Unlike UWB**, which demands higher investment and specialized infrastructure.

BLE AoA provides a balance of cost-effectiveness, reliability, and future readiness through hybrid integration.

50% lower CAPEX: Less infrastructure investment.

Cheaper Tags: €8–20 (BLE) vs €35–70, enabling scalability.

Accuracy: 0.5–1.5 m (BLE AoA), enough for most workflows.

Lower OPEX: ~2 years (BLE) vs ~3.5 years (UWB).

Longer Battery Life: Reduced replacement costs.

Hybrid Ready: Combines with RSSI for flexible tracking.

BLE AoA offers reliable accuracy with lower costs, longer battery life, and reduced maintenance. Unlike UWB, which requires higher investment and complex infrastructure, **BLE AoA** delivers a cost-effective, flexible system. With hybrid RSSI integration, it ensures future-ready tracking for assets, workflows, and safety monitoring.

Breakdown of Expected Savings

Reduced Asset Search Time	- Warehouse workers spend up to 30–40% of time locating pallets, tools, or equipment. - With RTLS: cut that time by 70–90%. - Savings: Less wasted labor hours → €25–35k/year per site.
Inventory Accuracy & Shrinkage Reduction	- Misplaced or lost items cause production delays and write-offs. - Reduced shrinkage by 20–30%. - Savings: €10–15k/year.
Operational Efficiency & Automation	- Automatic check-in/out of assets at zones → fewer manual scans. - Faster stock counts (real-time instead of weekly/monthly manual audits). - Savings: €10–20k/year (labor + reduced downtime).
Improved Equipment Utilization	- Forklifts, trolleys, and tools often underutilized or hoarded. - RTLS data shows true utilization rates → enables right-sizing fleet. - Savings: €10–15k/year by avoiding unnecessary purchases or rentals.
Safety & Compliance (hard to quantify but real)	Indirect savings: avoids incidents that cost €50k+ per occurrence.

ROI Timeline: BLE Hybrid vs UWB RTLS

compares the return on investment (ROI) between a BLE AoA + RSSI hybrid RTLS and a UWB TDoA RTLS deployment.

Factor	BLE AoA + RSSI Hybrid	UWB TDoA
CAPEX	€100–150k	€190–265k
OPEX/year	€6–9k	€25–30k
Payback	~2 years	~3.5 years
Accuracy	0.5–2 m	0.1–0.3 m
Scalability	Easy, flexible	Complex

Table -05 ROI Timeline: BLE Hybrid vs UWB RTLS

- **Improved Accuracy** in multipath and metal-heavy zones.
- **Flexible Deployment** across different warehouse layouts.
- **Dual Accuracy Modes:** proximity (RSSI) and sub-meter precision (AoA).

Sentrax Hybrid AoA + RSSI System

Sentrax combines **AoA and RSSI** into a **hybrid solution** that ensures robust performance in demanding warehouse and industrial environments. This approach delivers flexibility by supporting both low-accuracy proximity tracking and high-accuracy sub-meter positioning within the same system. It also enables seamless integration of passive RFID tags for entry/exit checkpoints or zone-based monitoring, creating a comprehensive and cost-efficient tracking ecosystem.

- **Passive RFID support** for portal-based or zone-level tracking.
- **Real-time analytics** for asset flow and utilization.
- **Integration-ready** with IoT platforms, WMS, and ERP systems.

Why AoA ROI is Stronger than UWB

- **Lower CAPEX** 50% less infrastructure cost.
- **Lower OPEX** no sync infra, fewer calibration requirements.
- **Adequate accuracy** 0.5–2 m is “good enough” for 95% of warehouse workflows.
- **Scalability:** Tags are cheaper (€8–20 vs €35–70 for UWB).

The ROI figures, cost estimates, and savings examples provided in this white paper are based on industry benchmarks, reference deployments, and modeled scenarios. Actual results may vary depending on facility layout, asset mix, workforce size, operational processes, and integration requirements.

Deployment Recommendations

- **RF Site Survey:** Understand the environment, required accuracy levels in each areas, and list possible challenges.
- **Strategic Placement:** Position locators for maximum coverage (Sentrax's exclusive support in deployment planning).
- **Calibration:** In some cases, tag transmission power may need to be calibrated depending on the environment. Supports bulk programming via the mobile app.
- **Pilot Program:** Validate before scaling to full deployment.

Omlox Integration for Industrial & Warehousing Systems

Omlox is particularly important for industrial and warehousing environments, where multiple systems and applications must work together. By adopting this open standard, **Sentrax** ensures that its **Hybrid BLE RTLS systems** can integrate smoothly with higher application platforms such as ERP, MES, and WMS.

This integration enables enterprises to:

- **Standardize location data** for consistent use in enterprise workflows.
- **Connect real-time visibility** from Sentrax's BLE systems into broader operational processes.
- **Scale seamlessly** from small pilot deployments to enterprise-wide rollouts without re-architecting.
- **Simplify integration efforts** by leveraging Omlox APIs and middleware rather than building custom connectors.
- **Protect long-term investments** by aligning with an open, future-proof ecosystem recognized across industries.
- **Accelerate time-to-value**, ensuring faster deployment and ROI for industrial and warehouse operations.

Through **Omlox**, **Sentrax** delivers not just BLE-based positioning, but also enterprise-ready interoperability, ensuring efficiency, scalability, and reliability in even the most complex industrial and warehousing scenarios.

Conclusion

Bluetooth Hybrid RTLS Systems provide the ideal balance of cost, accuracy, and scalability for industrial and warehousing environments.

While UWB offers ultra-precision, its higher cost limits ROI due to extensive maintenance and time sync. By contrast, [Sentrax's Hybrid \(AoA + RSSI\) systems](#) enable companies to achieve:

- Real-time visibility across thousands of assets.
- Faster workflows and improved safety.
- ROI within months, not years.
- Easy to maintain and scalable system.
- Flexible accuracy levels in different zones in the same building, saving unnecessary costs.

The future of RTLS is hybrid – and it's available today

Check our website for details on Hybrid BLE (AoA + RSSI) RTLS System

<https://sentrax.com/solutions/hybrid-tracking/>

Contact Sentrax to explore a pilot program and calculate your facility's ROI potential.

Email us at info@sentrax.com



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