Poster: SALT: Shelf Asset Localization Using a 6TiSCH Industrial IoT Network

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ABSTRACT

Low-cost asset localization is increasingly important for warehouse management in the Industrial Internet of Things (IIoT). Existing approaches, such as ultra-wideband, angle-of-arrival systems, and automated vehicles, often require costly dedicated infrastructure. This paper presents **SALT**, a shelf asset localization system integrated into a 6TiSCH industrial IoT network. In a reserved slot, asset tags broadcast minimum-power beacons that nearby anchors detect and report to the DAG root through normal-power 6TiSCH links. The root estimates each asset's shelf position from the known locations of the receiving anchors. SALT thereby combines monitoring and localization within the same low-power infrastructure and supports tags with hardware costs potentially at the tens-of-cents level. Experiments in a warehouse deployment show an average localization error of 0.66 m, with most tags localized within 1 m of their ground-truth positions. The results demonstrate practical shelf-level tracking without dedicated ranging radios, antenna arrays, or direction-finding hardware.

CCS CONCEPTS

• **Networks** → **Location based services**; *Ad hoc networks*; • **Computer systems organization** → **Sensor networks**.

KEYWORDS

Asset Tracking, Localization, 6TiSCH, Low-Power

1 INTRODUCTION

The rapid adoption of the Industrial Internet of Things (IIoT) has increased the demand for low-cost warehouse asset tracking [2]. In shelf-based storage environments, approximate asset locations can improve inventory visibility, retrieval efficiency, and operational automation. However, dedicated localization infrastructure is often uneconomical for large numbers of low-value assets. A practical system should therefore provide monitoring and shelf-level localization with minimal additional hardware and deployment effort.

The IPv6 over Time-Slotted Channel Hopping (6TiSCH) architecture is well suited to industrial monitoring [4]. Its TSCH layer combines scheduled communication with channel hopping to provide reliable and energy-efficient operation in challenging industrial environments. IPv6 further enables interoperability with Internet services and existing warehouse-management systems. Nevertheless, conventional 6TiSCH networks collect sensor data without directly providing asset locations.

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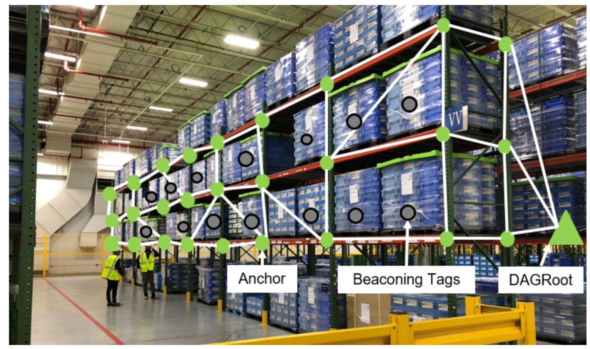

Figure 1: SALT warehouse deployment: shelf anchors form a 6TiSCH mesh, forwarding tag observations to the DAG root.

Existing warehouse localization technologies, including ultra-wideband (UWB) [1], automated guided vehicles, and angle-of-arrival (AoA) systems, can provide accurate positioning but often require dedicated anchors, antenna arrays, mobile platforms, or additional radios [3]. Their infrastructure costs, calibration requirements, and deployment complexity limit their suitability for tracking large numbers of inexpensive shelf assets.

To address this gap, we present **SALT**, a shelf asset localization system built directly on a 6TiSCH network. As shown in Fig. 1, SALT infers an asset's shelf region from connectivity observed during controlled low-power beacon transmissions. It thus integrates asset monitoring and localization within the same wireless infrastructure without dedicated ranging or direction-finding hardware. This design supports tags with hardware costs potentially at the tens-of-cents level, making large-scale shelf deployments economically practical.

2 SALT: 6TISCH NETWORK-BASED ASSET TRACKING

2.1 Deployment and Localization Mechanism

Fig. 2 illustrates the SALT deployment and localization mechanism. Fixed anchors are installed at known shelf positions, while low-cost beaconing tags are attached to stored assets. The anchors form a full-power 6TiSCH mesh, shown by green links, and forward data toward the DAG root. The red links represent reduced-power communication between tags and nearby anchors. Beacon reception therefore indicates that the tag is close to the corresponding anchor.

SALT estimates a tag's position from the known locations of its receiving anchors, as shown on the right of Fig. 2. Four surrounding anchors strongly constrain the feasible region, whereas fewer

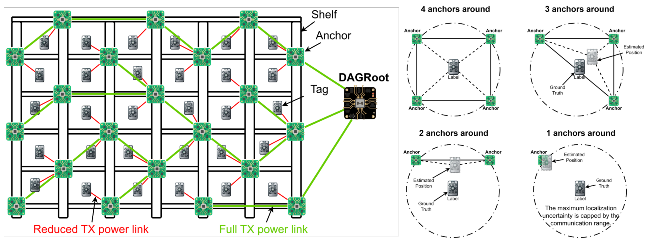

Figure 2: SALT deployment and localization using full-power mesh links and reduced-power tag–anchor links.

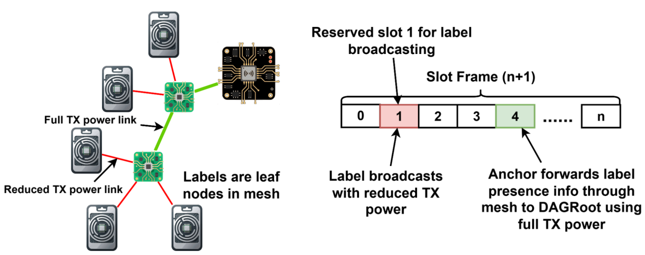

Figure 3: SALT schedule: slot 1 supports reduced-power discovery, and a later uplink cell forwards presence information at full power.

anchors produce a larger region. With only one receiving anchor, the tag can only be placed within that anchor's reduced-power communication range. Localization accuracy therefore depends on anchor density, placement, and beacon range.

2.2 SALT Protocol and 6TiSCH Schedule

Fig. 3 presents the SALT protocol and schedule. Asset tags operate as leaf nodes and periodically broadcast their identifiers at reduced power. Nearby anchors listen for these beacons and record the identifiers of tags within their reduced-power communication range. Each detected tag identifier and receiving anchor identifier form a tag–anchor presence observation.

SALT reserves one cell in every 6TiSCH slotframe for localization. In the illustrated $n + 1$-cell slotframe, slot 1 handles reduced-power tag broadcasting and anchor listening, while the remaining cells support normal 6TiSCH traffic. This fixed slot synchronizes proximity discovery without requiring a separate localization network.

After receiving a beacon, an anchor forwards the tag identifier and its own identity toward the DAG root over full-power 6TiSCH links. In Fig. 3, the observation collected in slot 1 is forwarded through the uplink cell in slot 4. The report allows the DAG root to associate the tag with the known location of the receiving anchor. The root then combines reports from multiple anchors to estimate the tag's shelf location. SALT thus separates short-range proximity detection from reliable full-power multi-hop delivery while reusing the existing 6TiSCH network.

3 EVALUATION

We implemented SALT and evaluated it in the warehouse deployment shown in Fig. 1. Fig. 4 reports the localization error of each

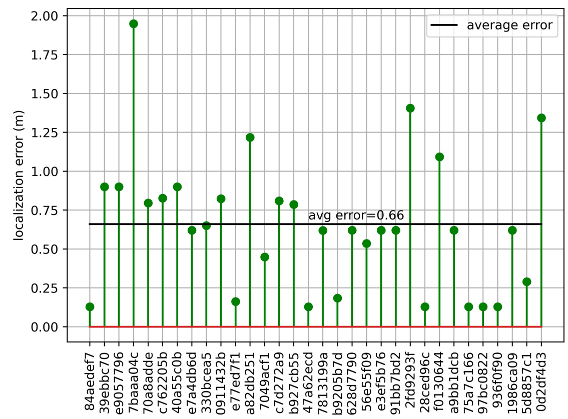

Figure 4: Localization error of each deployed tag; the black line shows the average error of 0.66 **m.**

deployed tag, measured as the distance between its estimated and ground-truth positions. The horizontal axis identifies the tags by their unique IDs, the blue markers represent individual errors, and the black line shows the average error of 0.66 m.

Most tags are localized within 1 m, several achieve errors below 0.2 m, and the largest error is approximately 1.95 m. The variation may result from differences in tag positions relative to nearby anchors, especially near coverage boundaries or where few anchors receive a beacon. Overall, SALT provides sub-meter average shelf localization without dedicated ranging or direction-finding hardware.

4 CONCLUSION AND FUTURE WORK

This paper presented SALT, which reuses a 6TiSCH network for low-cost shelf asset monitoring and localization. Minimum-power beacons provide tag–anchor proximity observations, while normal-power links deliver them reliably to the DAG root. By reusing the same hardware and network infrastructure, SALT avoids a dedicated localization network. The warehouse evaluation achieved an average localization error of 0.66 m, demonstrating the feasibility of connectivity-based shelf tracking. Future work will use reliably localized tags as virtual anchors to reduce the number of fixed anchors while maintaining accuracy.

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