Willow: Practical WiFi Backscatter Localization with Parallel Tags

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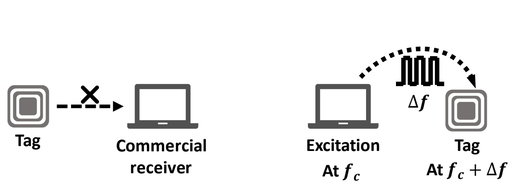
Introduction

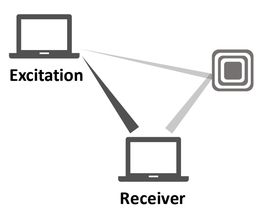
Motivation

Backscatter localization systems enable extremely low power sensing for wireless IoT devices, but it suffers from the following problems:

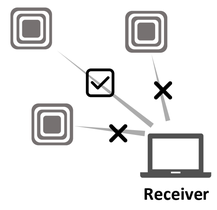


Dedicated device

Spectrum efficiency



Excitation interference



No parallel

1. Backscatter signal is hard to capture and process at commercial devices
2. Tags shift excitation signals out-of-band and waste spectrum waste
3. For in-band backscatter, there is severe excitation interference
4. Previous systems only apply for very few parallel tags

Willow System

The first **Wi**Fi **l**ocalization system for large-scale parallel **low**-power backscatter tags

Table 1: Comparison with existing WiFi backscatter localization systems.

	Low-power tag	Parallel localization	Low excitation interference	Compatible with COTS WiFi	Spectrum consumption
WiTag [6]	✗	✗	✓	✓	High
Batch Loc. [8]	✗	✓	✓	✗	Medium
TagFi [7]	✓	< 4 Tags[1]	✗	✓	Low
Willow	✓	✓**(> 50 Tags)**	✓	✓	**Low**

[1] The localization error significantly increases according to their evaluation.

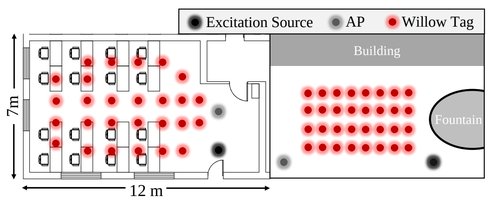
Simplicity Fully implemented on commercial WiFi devices

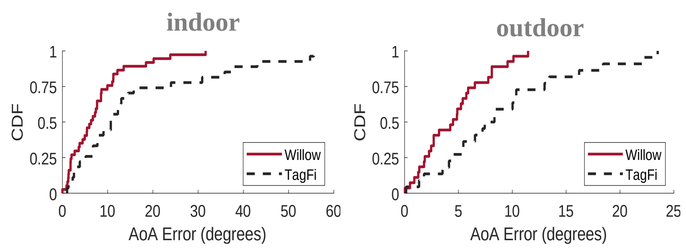
Scalability Locate 50+ in-band backscatter tags simultaneously

Robustness Accurate localization results with real WiFi traffic

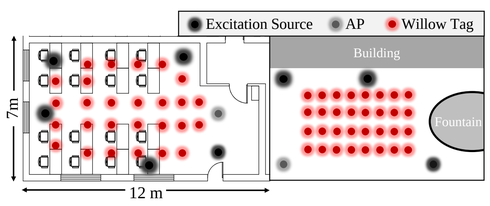
Evaluations

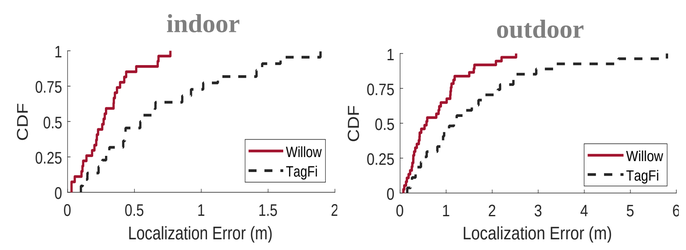
AoA Estimation Error



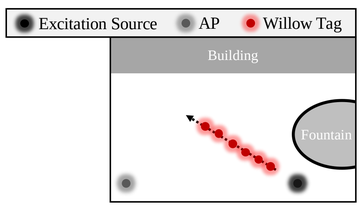


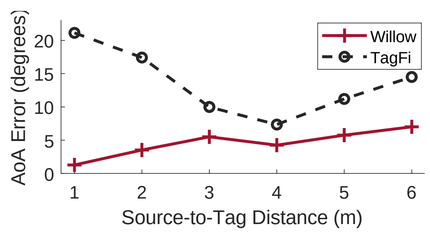
Localization Error



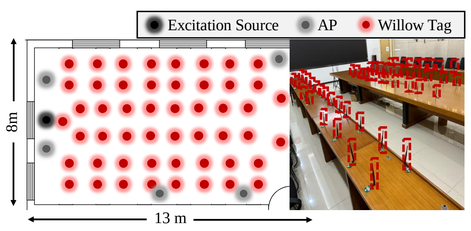


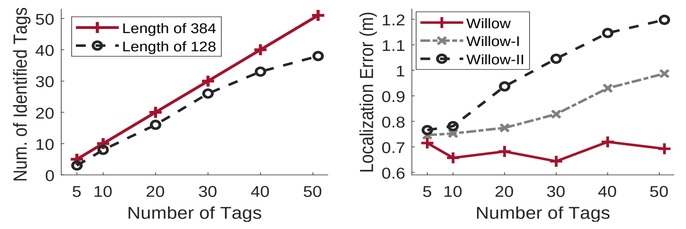
Excitation Interference





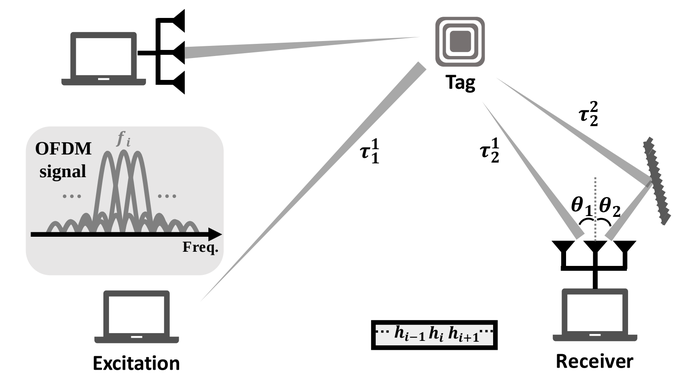
Parallel Localization

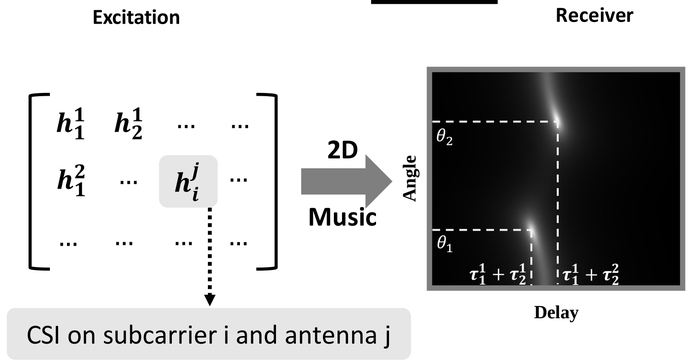


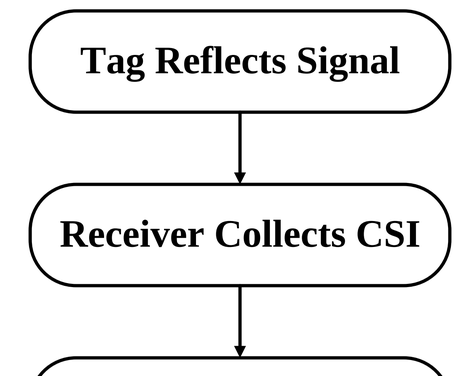


System Design

Localization Model

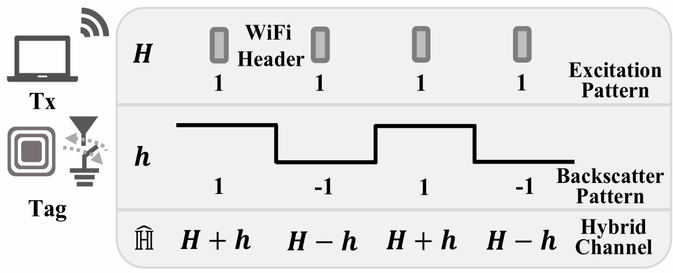


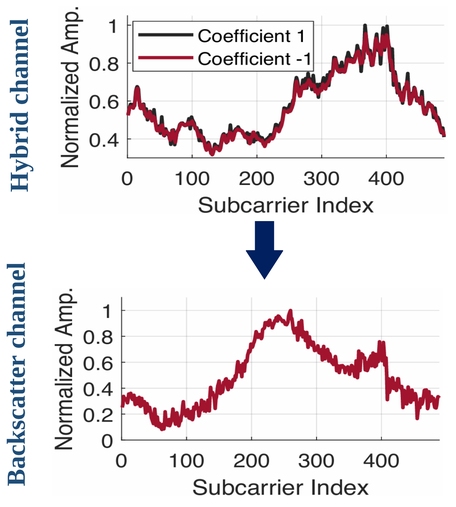




Extract Backscatter Channel

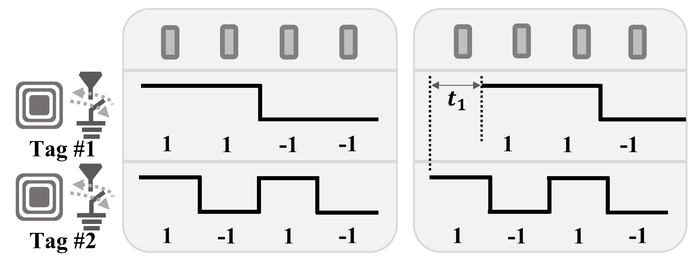
How to extract backscatter signals under strong in-band interference of excitation signals?





Parallel Localization

How to enable parallel localization for Sync/Unsync tags?



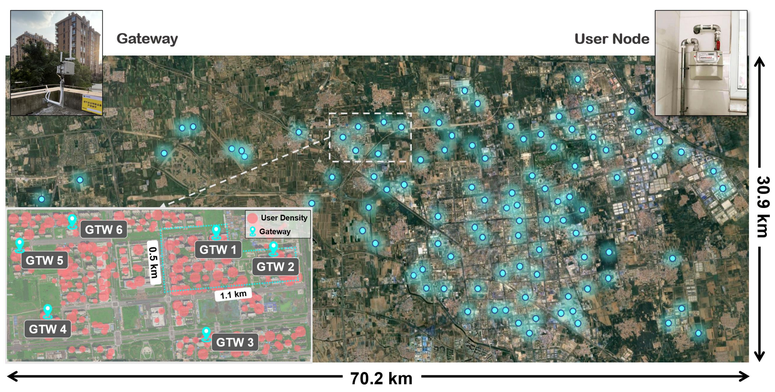
- **Synchronized Tags -> Orthogonality**
- **Unsynchronized Tags -> Leaked signal/interference**
- **Interference cancellation**

For (a): $CP_B^1 \cdot CP_B^2 = [1, 1, -1, -1] \cdot [1, -1, 1, -1] = 0$

For (b): $CP_B^1 \cdot CP_B^2 = [0, 1, 1, -1] \cdot [1, -1, 1, -1] = 1$

Future Work

Extending wireless sensing to other IoT protocols, e.g., LoRa.



- We build a LoRa network, name CityWAN, consisting of 100 gateways and 19,821 LoRa end nodes, covering an area of 130 km^2 for 12 applications.
- We perform in-depth measurement on CityWAN. Many devices, such as nodes in traffic tracking, require low-power and high-accuracy localization capabilities.

Conclusion

We present Willow: a WiFi based localization system for large-scale parallel low-power backscatter tags. Willow works with real-world WiFi traffic and devices, and can extract the pure backscatter channel for parallel localization. We implement Willow on customized backscatter tags and commercial WiFi devices.

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Reference

[1] Jinyan Jiang, Zhenqiang Xu, Fan Dang, Jiliang Wang. Long-Range Ambient LoRa Backscatter with Parallel Decoding. In Proceedings of ACM Mobicom, 2021.
[2] Jinyan Jiang, Jiliang Wang, Yijie Chen, Yihao Liu, Yunhao Liu. LocRa: Enable Practical Long-Range Backscatter Localization for Low-Cost Tags. In Proceedings of ACM MobiSys, 2023.
[3] Shuai Tong, Zilin Shen, Yunhao Liu, and Jiliang Wang. Combating link dynamics for reliable lora connection in urban settings. In Proceedings of ACM MobiCom, New York, NY, USA, 2021.
[4] Shuai Tong, Jiliang Wang, Jing Yang, Yunhao Liu, Jun Zhang. "Citywide LoRa Network Deployment and Operation: Measurements, Analysis, and Implications", In Proceeding of ACM SenSys 2023.