Demo: Real-Time Low-Latency Tracking for UWB Tags

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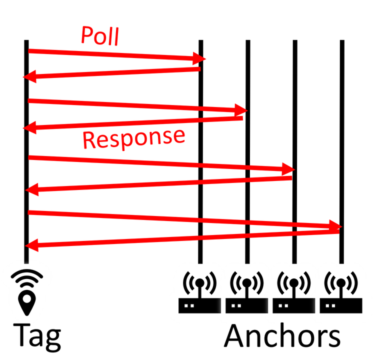
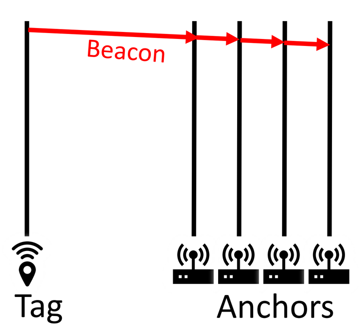
Link to Website

Motivation

- Adoption of VR/AR technologies demands limb tracking, which can be limited for visual sensors.
- UWB sensors provide pose for multiple tags in NLOS conditions.
- Final localization at infrastructure to reduce tag computation
- Popular two-way-ranging (TWR) too high latency. Angle-of-Arrival (AoA) methods superior with low latency.

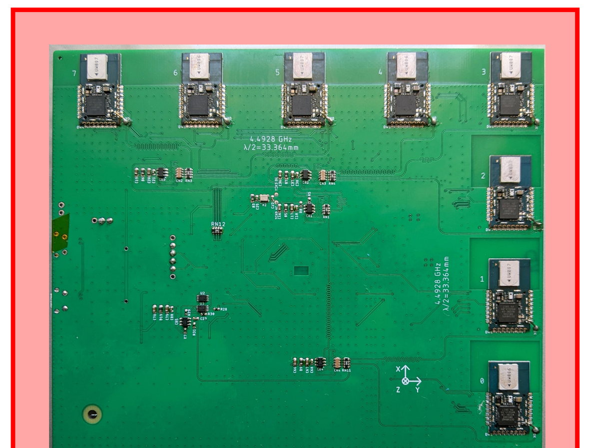


TWR: Multiple poll/response for single point

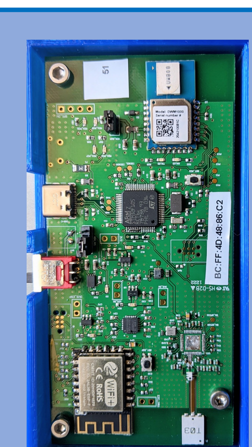


AoA: Single poll(beacon) for single point.

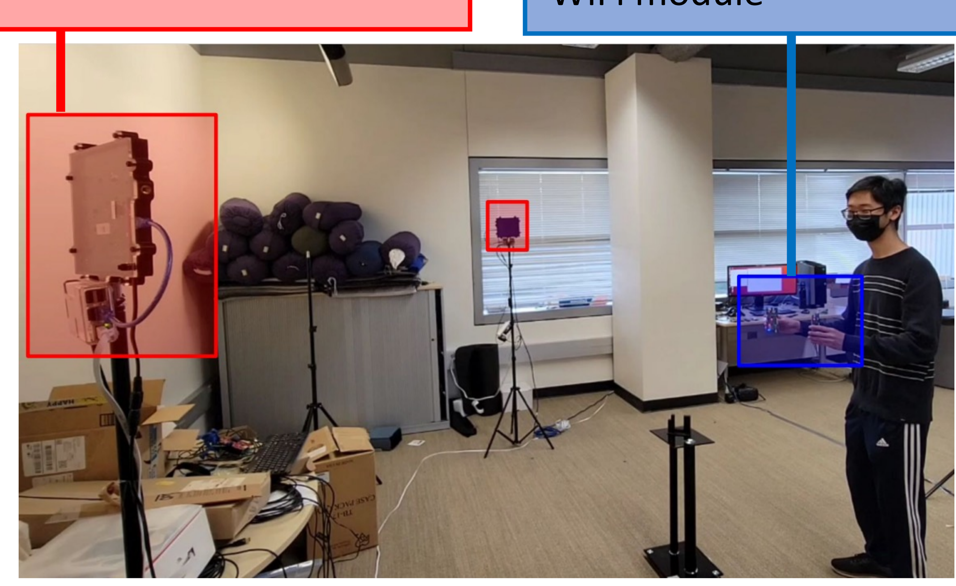
System and Environment



Uloc AP:
Board mounted with 8 DW1000 UWB antennas [1]

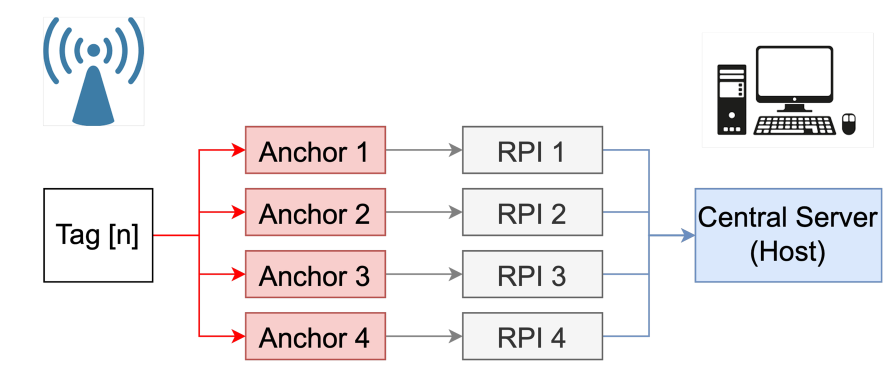


Uloc Tag:
Tag mounted with single DW1000 UWB antenna [1], MPU 6050 IMU, and ESP8266 WiFi module

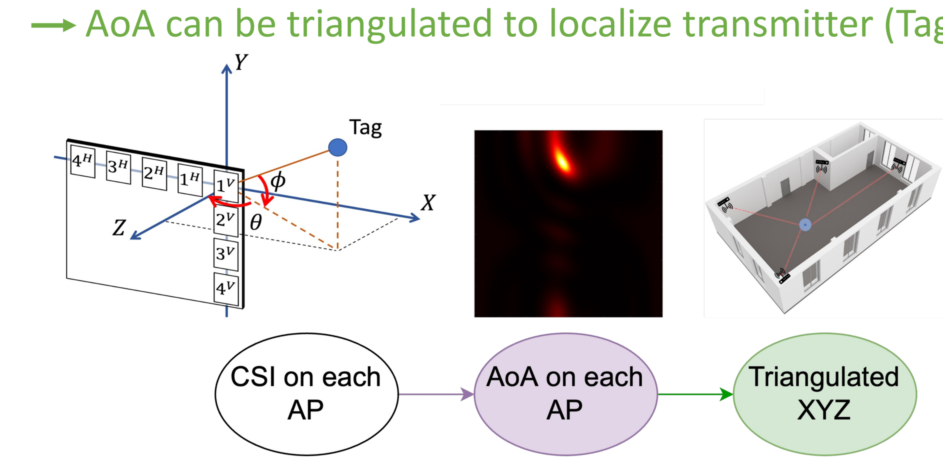


System Design

Data Transmission:
- UWB Beacon transmitted to Anchors
- Signal sent to RPI by serial line, USB 2.0
- Signal per AP sent to Host by ethernet LAN

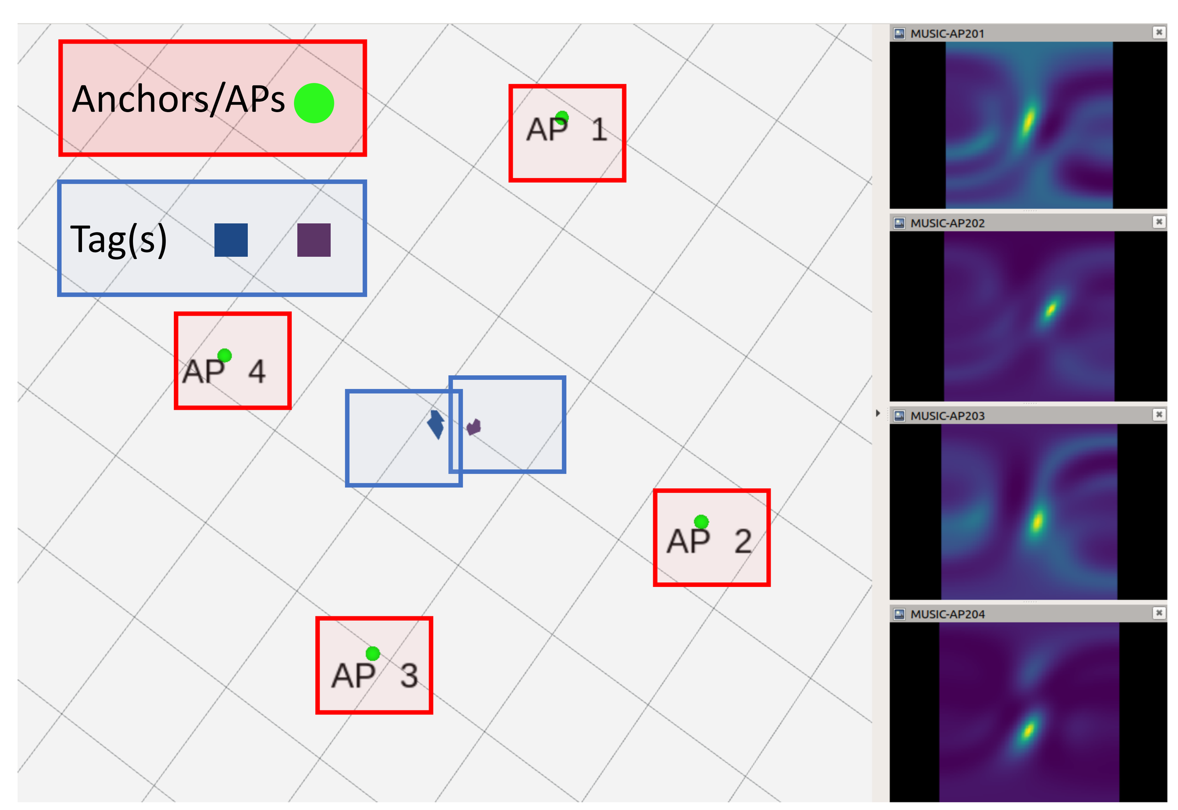


Data Transmission:
- Phase differences of signal on each antenna used to estimate AoA
- AoA can be triangulated to localize transmitter (Tag)



GUI

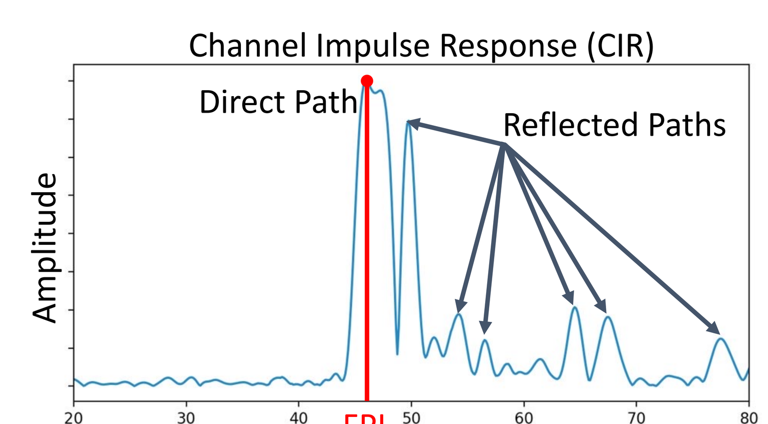
Localization:
3D locations of each of our Anchors and Tags as they move in real-time.



Profiles:
MUSIC likelihood profile of the AoA to Tag 1 (Blue) for each Anchor. The horizontal axis gives the azimuthal angle, while the vertical axis gives the elevation angle.

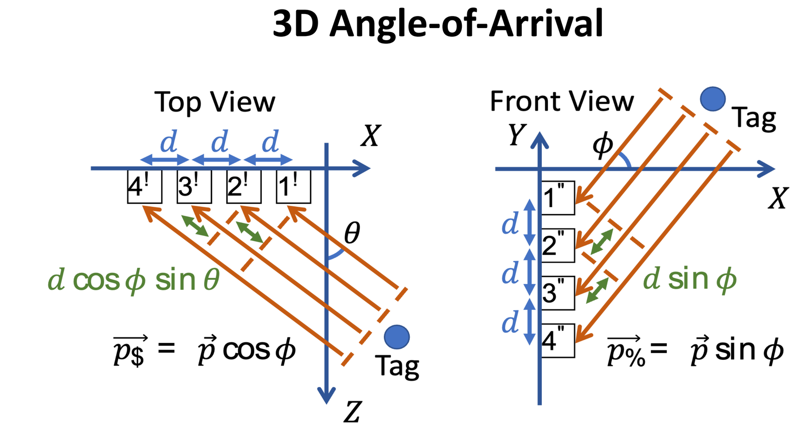
3D AoA Measurements

UWB Multipath Separation



- A reflected path will have a longer time of flight (ToF) than a direct path.
- High bandwidth of 500MHz allows 1ns ToF or 1ft spatial resolution.
- Reflected paths arriving beyond 1ns of the direct path can be resolved by using FPI.
- Phase at the FPI is then used to estimate AoA.

3D Angle-of-Arrival



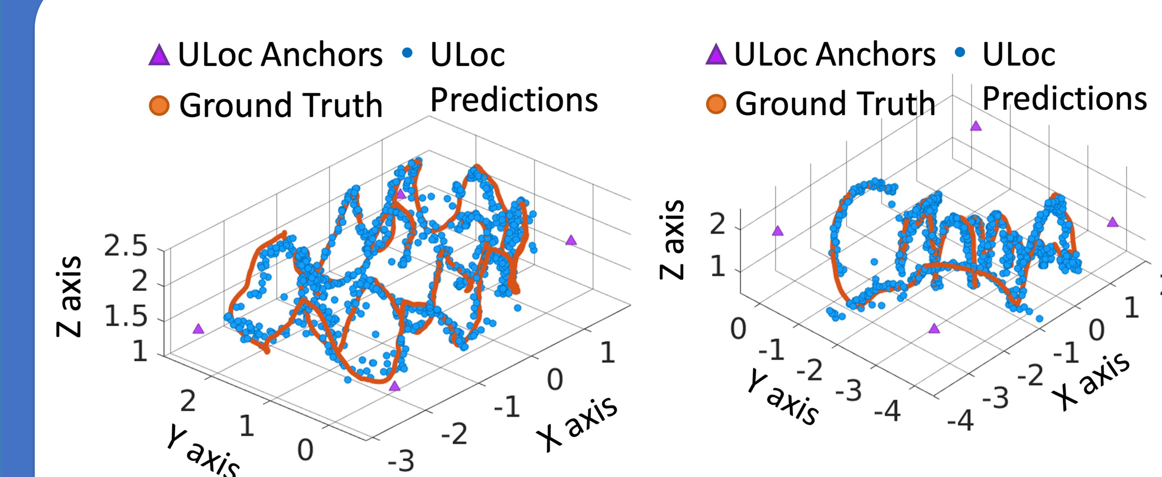
- The azimuthal (θ) and elevation (ϕ) angles must be jointly estimated as above for an L shaped array [5]
- These can be estimated by finding the θ, ϕ that maximize the dot product of our steering vectors below with the onset signal for antennas:
  - 1'-4' : $\left[1,\ e^{\frac{2\pi d\sin(\theta)\cos(\phi)}{\lambda}},\ e^{\frac{2\pi 2d\sin(\theta)\cos(\phi)}{\lambda}},\ e^{\frac{2\pi 3d\sin(\theta)\cos(\phi)}{\lambda}}\right]$
  - 1"-4" : $\left[1,\ e^{\frac{2\pi d\sin(\phi)}{\lambda}},\ e^{\frac{2\pi 2d\sin(\phi)}{\lambda}},\ e^{\frac{2\pi 3d\sin(\phi)}{\lambda}}\right]$

Related Works

Many other UWB systems employ either TWR, Concurrent Ranging/AoA, or time-difference-of-arrival (TDoA) when localizing tags.

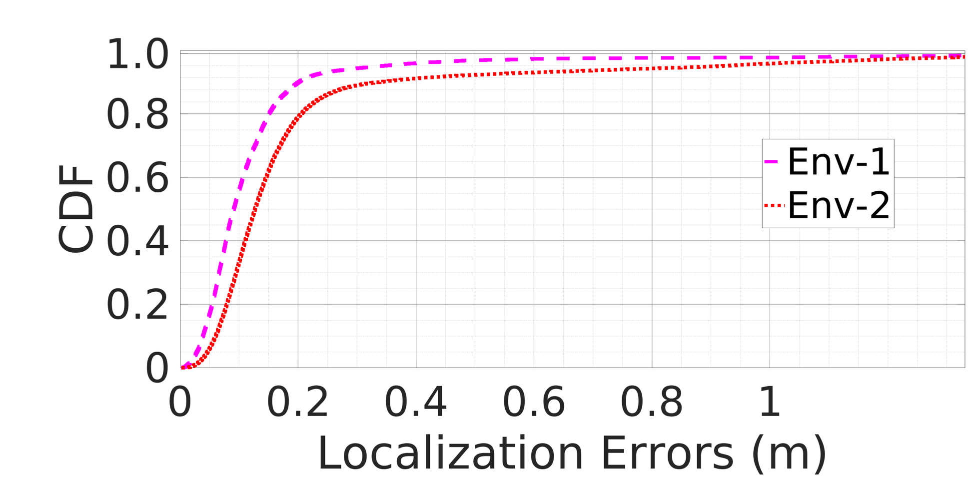
- TWR suffers from high-latency due to multiple transmissions for a single localization estimate [2].
- Concurrent AoA/Ranging methods suffer from high power consumption due to tag receiving from multiple APs [3,4]
- TDoA requires extremely accurate time syncing across APs [4].

Results



Env1 – Office Environment
- Many reflected paths
- Median Error: 9cm
- 90th Percentile: 20cm

Env2 – Open Environment
- Few reflected paths
- Median Error: 13cm
- 90th Percentile: 33cm



References
[1] Decawave Antenna Datasheet. https://www.decawave.com/product/dwm1000-module/.
[2] Pozyx. pozyx.io.
[3] Milad Heydariaan, Hossein Dabirian, and Omprakash Gnawali. 2020. AnguLoc: Concurrent angle of arrival estimation for indoor localization with UWB radios. In 2020 16th International Conference on Distributed Computing in Sensor Systems (DCOSS). IEEE, 112–119.
[4] B. Groβwindhager, M. Stocker, M. Rath, C. A. Boano, and K. Römer. Snaploc: An ultra-fast uwb-based indoor localization system for an un-limited number of tags. In 2019 18th ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN), pages 61–72. IEEE, 2019.
[5] M. Zhao, T. Chang, A. Arun, R. Ayyalasomayajula, C. Zhang, and D. Bharadia. Uloc: Low-power, scalable and cm-accurate uwb-tag localization and tracking for indoor applications. Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies, 5(3):1–31, 2021.