



Dynamic-MUSIC: Accurate **Device-Free** Indoor Localization

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2016-09-14

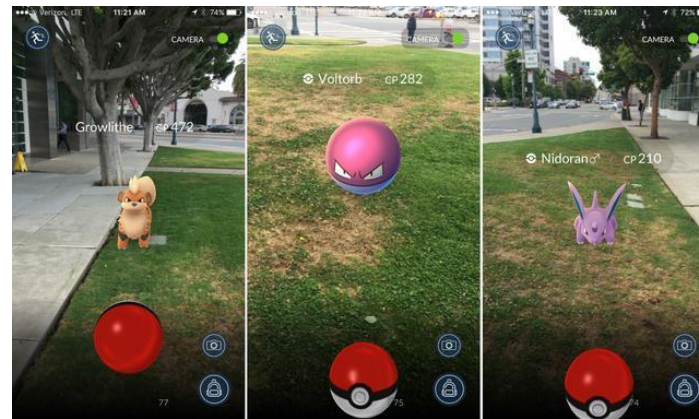
Why localization?



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Google Map



Pokemon Go



Navigation



Unmanned Aerial Vehicle

Indoor Localization is still Missing!



Outdoor

Drawbacks of indoor GPS:

1. Low accuracy
2. Too weak

Indoor



Device-free Localization is Required!

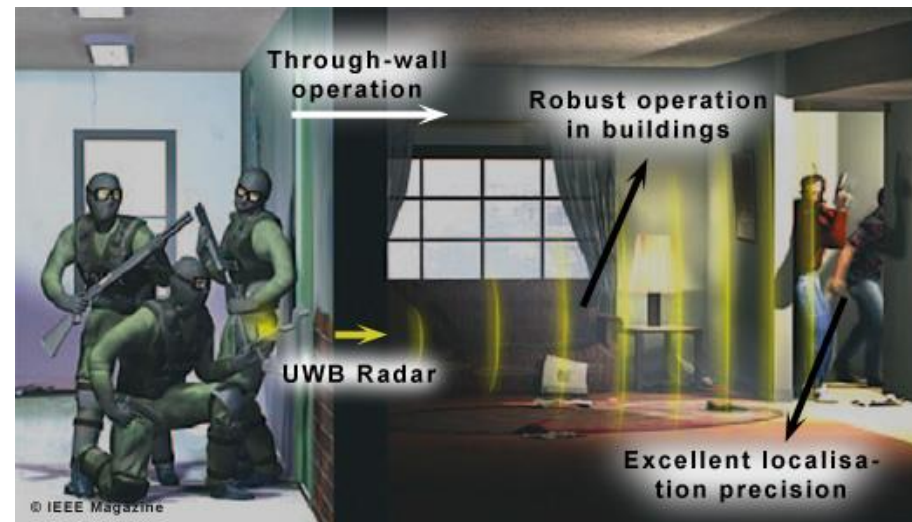


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Elderly Care

Terrorist tracking



WiFi is a Better Choice



- WiFi-based device-free localization
 - Ubiquitous
 - Work in dark & less intrusive
 - Penetrate walls
 - Larger coverage



Infrared



Camera

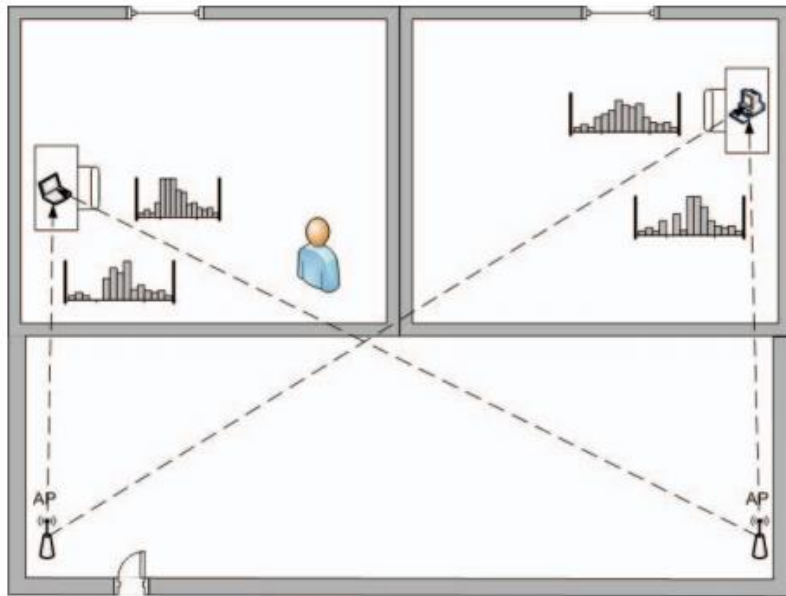


Sound

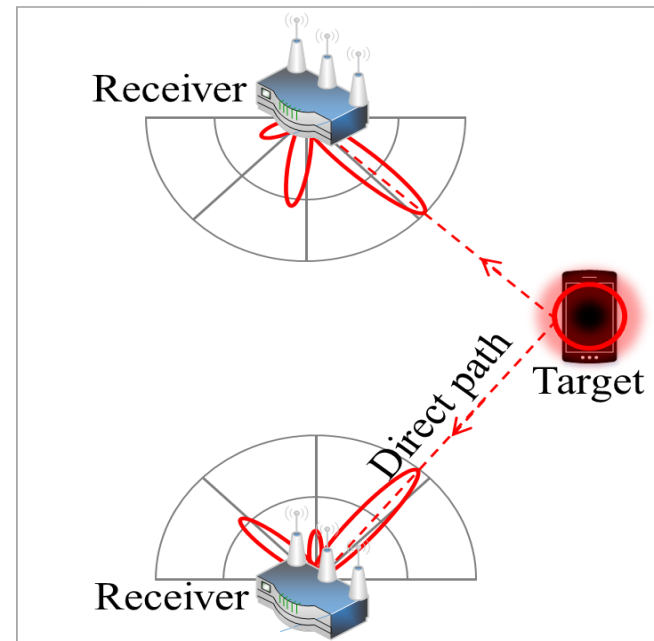


Visible Light

- Fingerprint vs Angle-of-Arrival (AoA)



Fingerprinting based



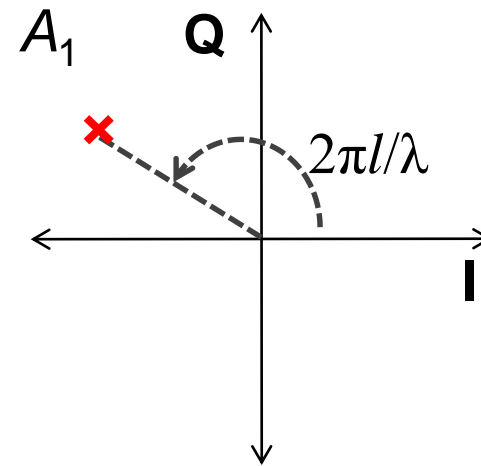
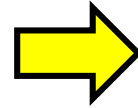
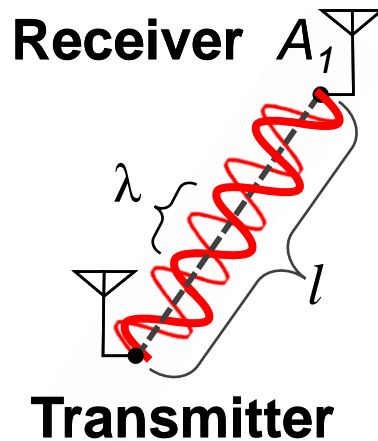
AoA-based

Drawbacks:

- Labor-intensive offline training to build fingerprint database
- Coarse accuracy

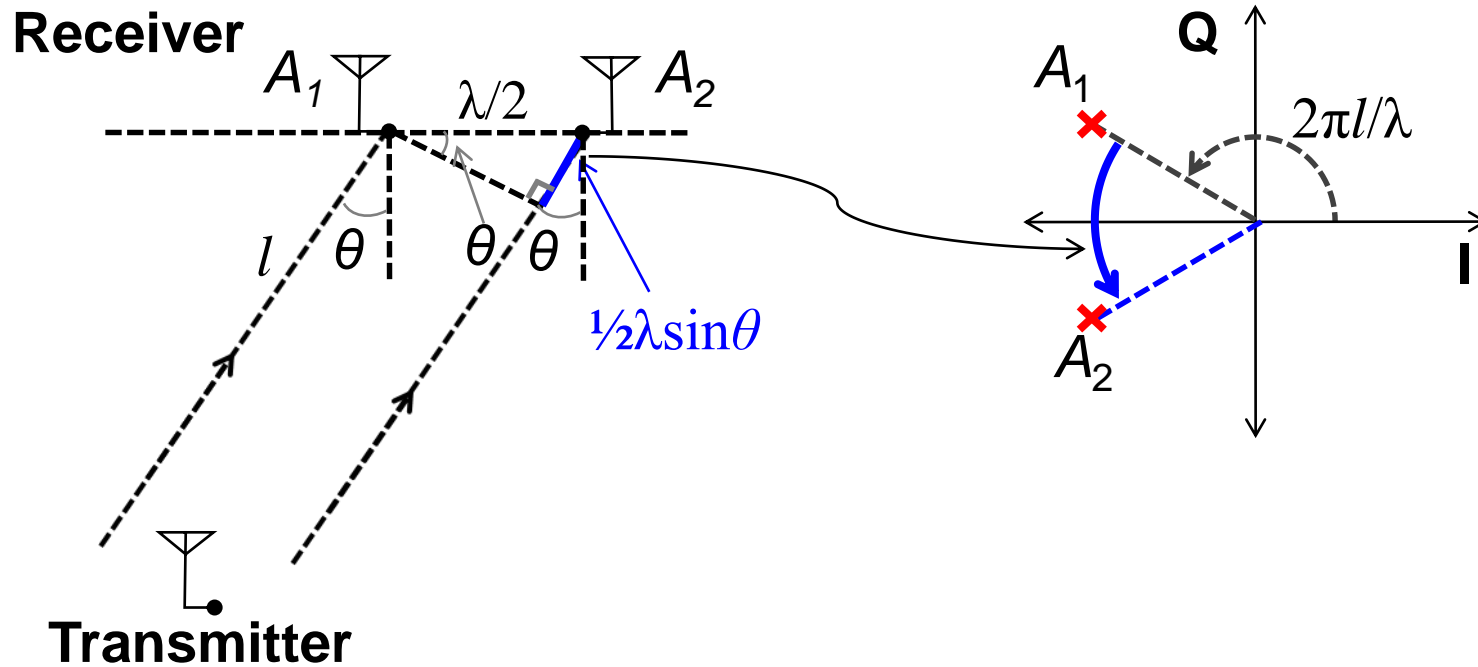
1. Can achieve AoA-based device-free localization?
2. Can we achieve high accuracy with only 3 antennas?

Angle-of-Arrival (AoA)



Measured baseband signal
at receiver (Channel State
Information (CSI))

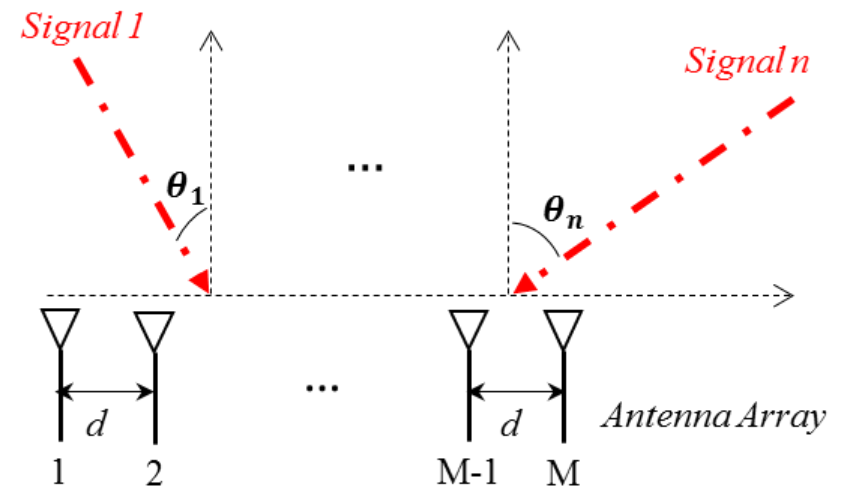
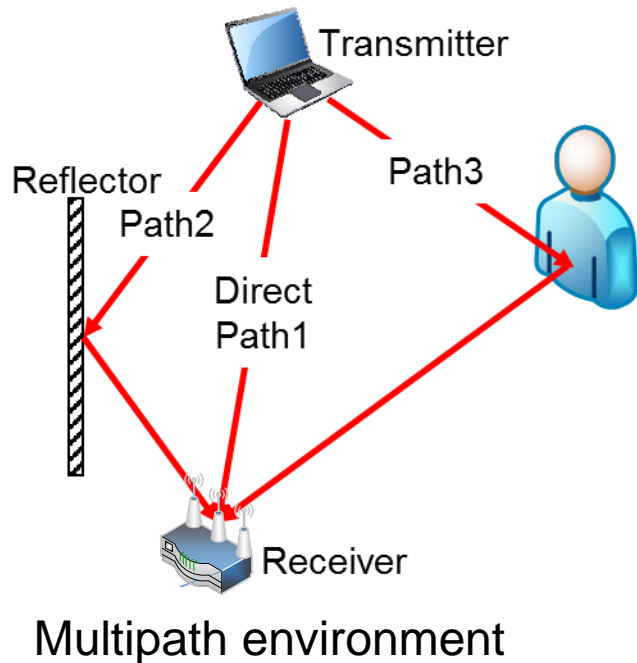
Angle-of-Arrival (AoA)



If only one incident signal, phase measurements give the signal's bearing to receiver θ .

$$\theta = \arcsin \frac{\angle A_2 - \angle A_1}{\pi}$$

Angle-of-Arrival (AoA)



With enough antennas, each signals' AoA can be estimated according to the Multiple Signal Classification (MUSIC) algorithm.

AoA-Based Device-Free Localization



The AoA of the target reflection path signal gives the bearing to receiver .

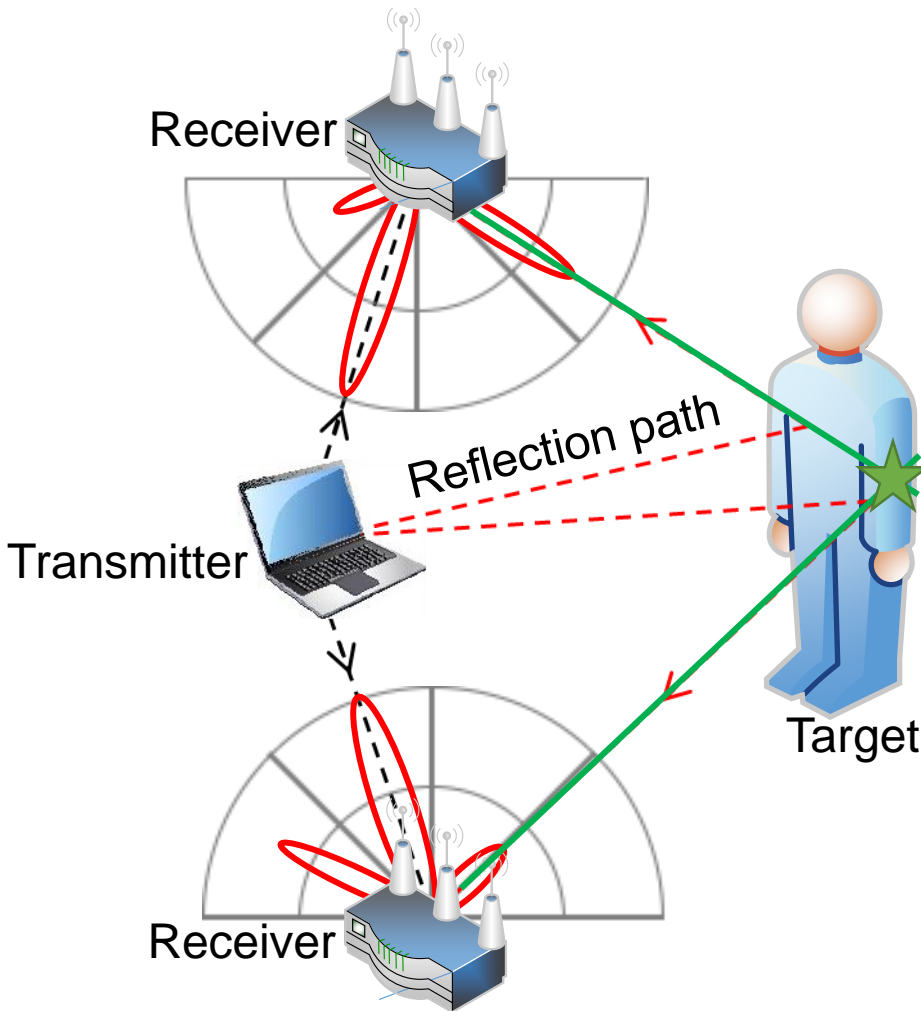
Step 1: Estimate the AoA of each path signal.



Step 2: Identify target reflection path signals on the spectrum.



Step 3: Use the AoA of target reflection path signals for localization.

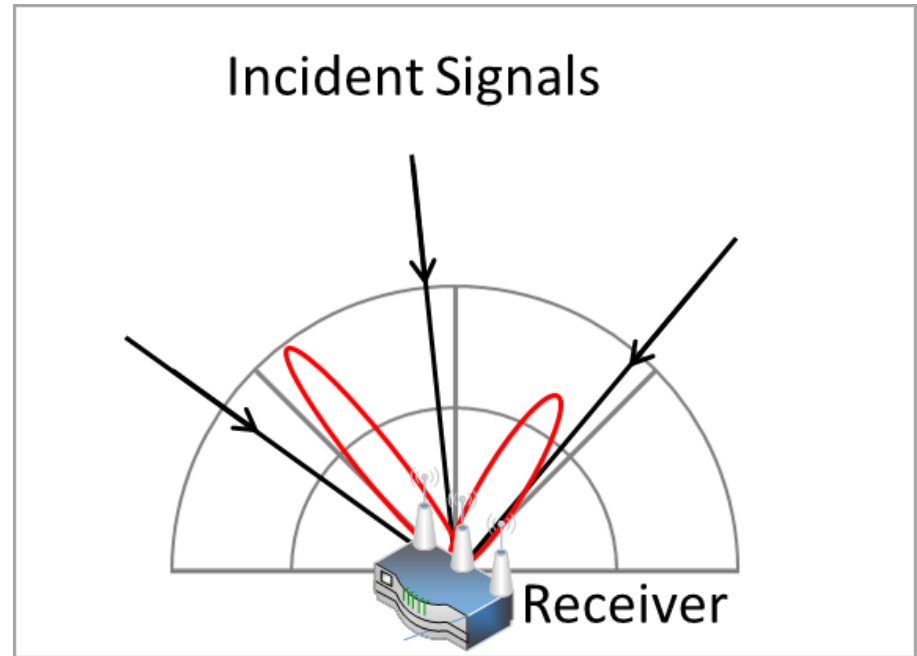
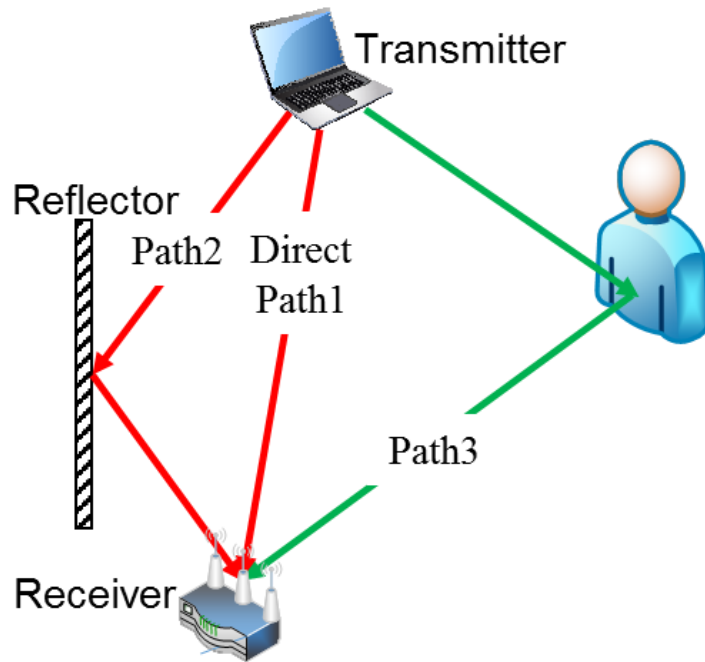


Challenges & Solutions



Step 1: Estimate AoA of each path signal.

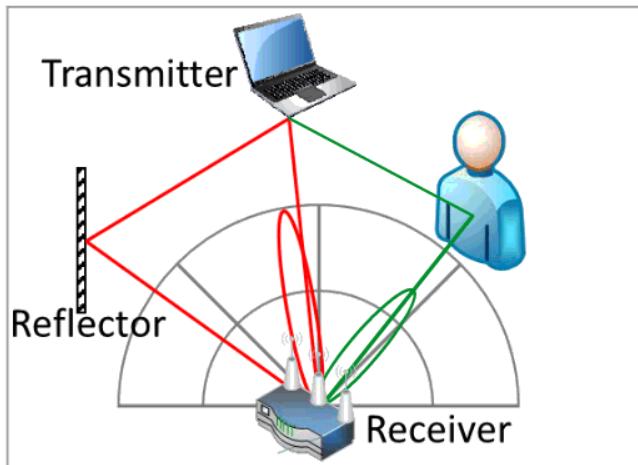
- **Challenge:** Limited number of antennas on commodity Wi-Fi card.



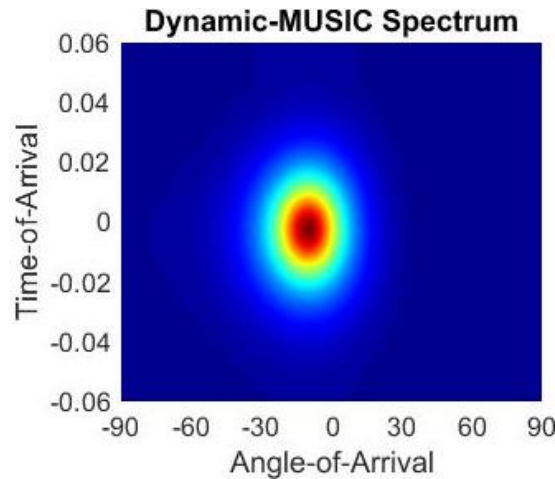
Which path can be estimated?

Solution 1.1: Let the target move

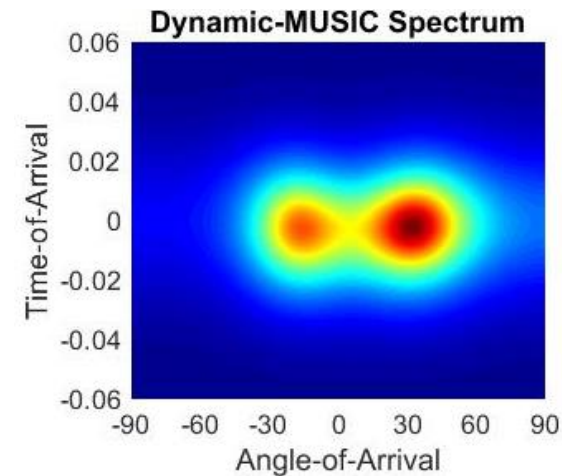
- **Key Insight:** Static path signals are coherent with each other, but they are incoherent with mobile path signals.



Typical indoor scenario

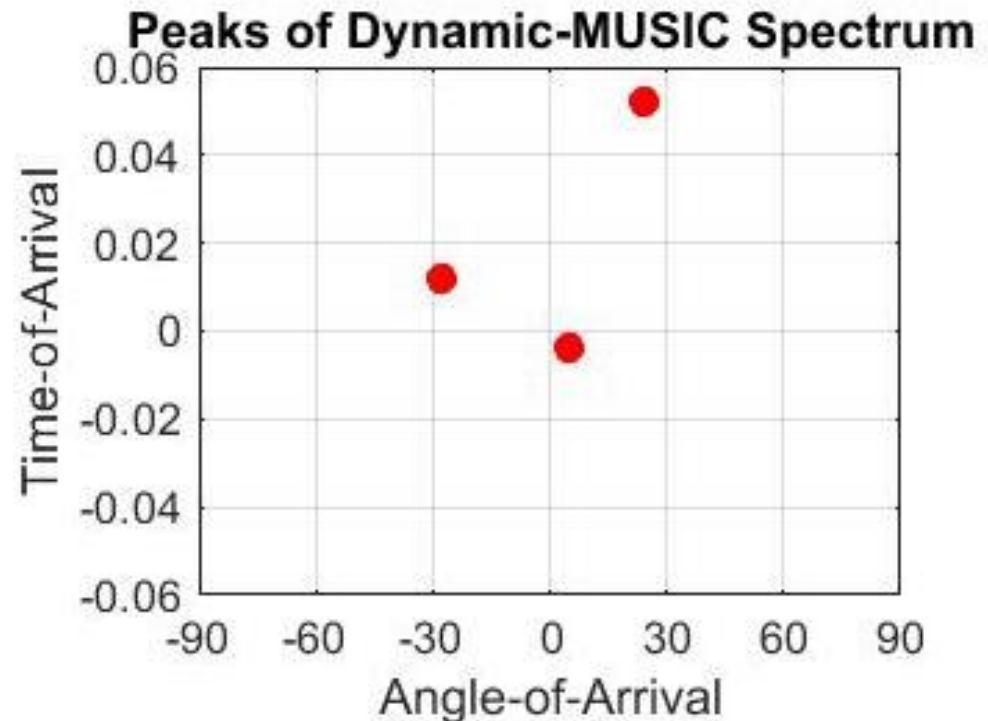
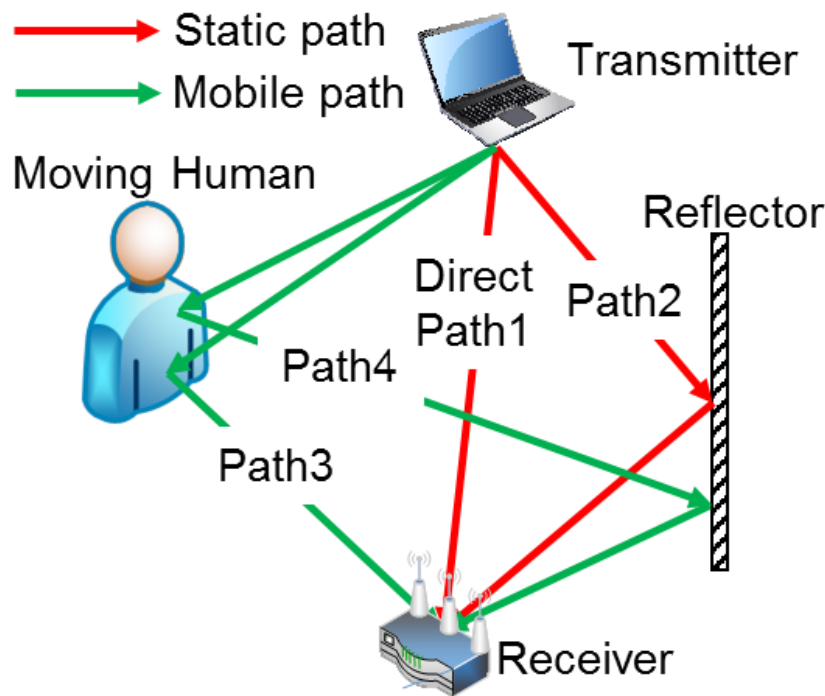


Static



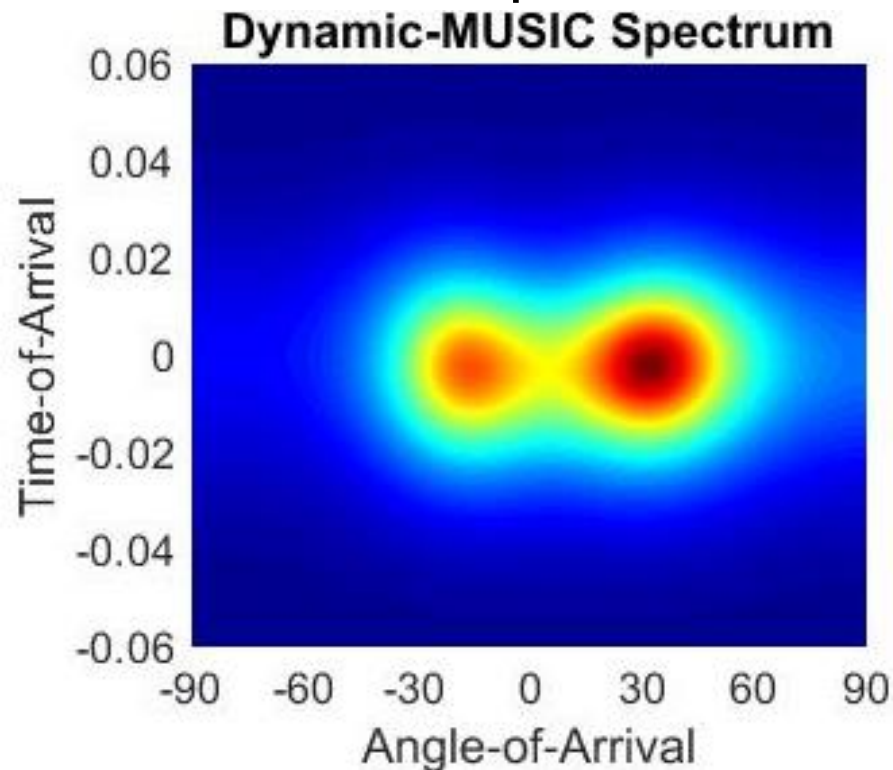
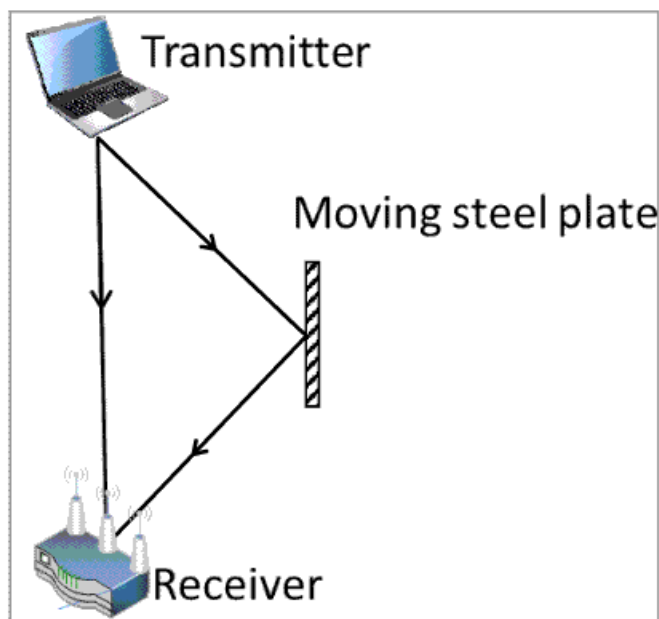
Move

Solution 1.2: Expanding MUSIC spectrum to 2-dimension by exploring the frequency diversity



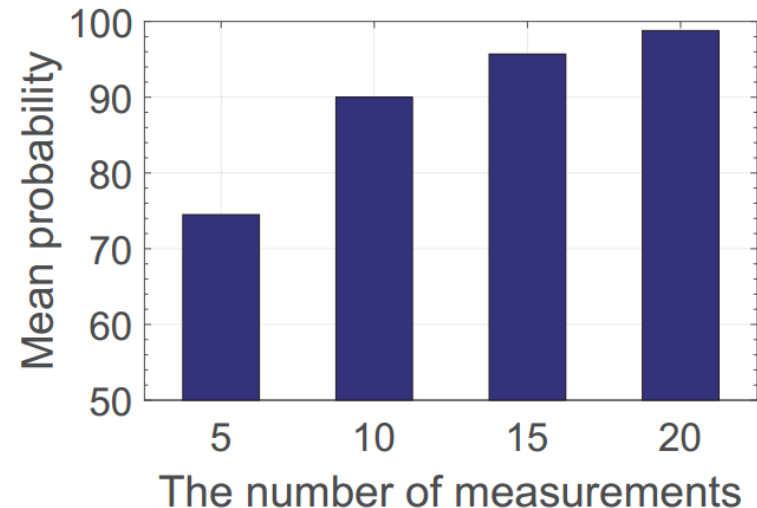
Step 2: Identify target reflection path signals on the spectrum.

- **Challenge:** The target reflection path signals and the merged-static path signal coexist on the spectrum.



Solution 2: Identify mobile path signals according to stability of signals.

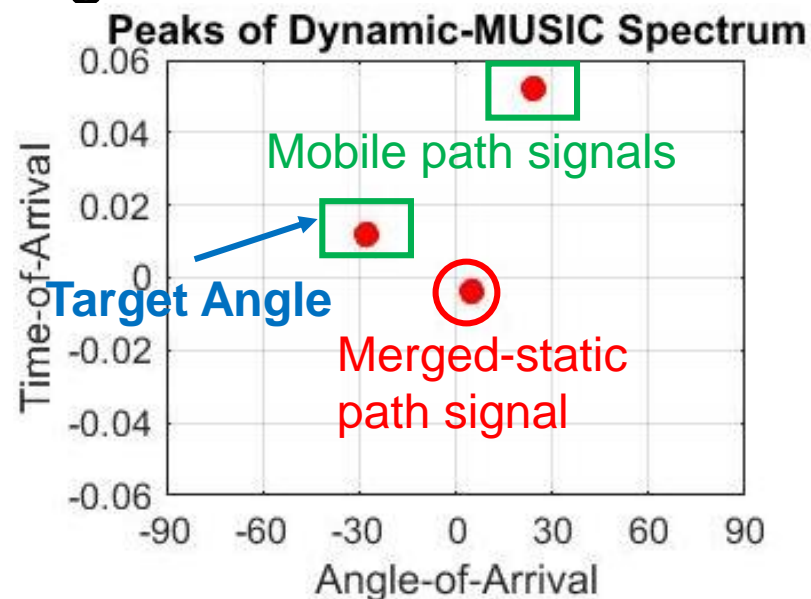
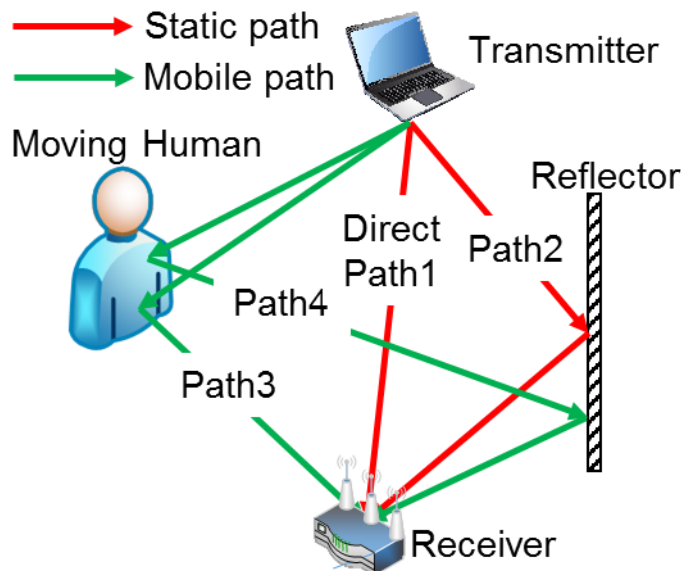
- The mobile paths may not be detected sometimes.
- The merged-static path signal will always be detected.



Step 3: Use the AoA of a mobile path signal to represent the target angle

- **Challenge:** Not all mobile path signals can represent the target angle.

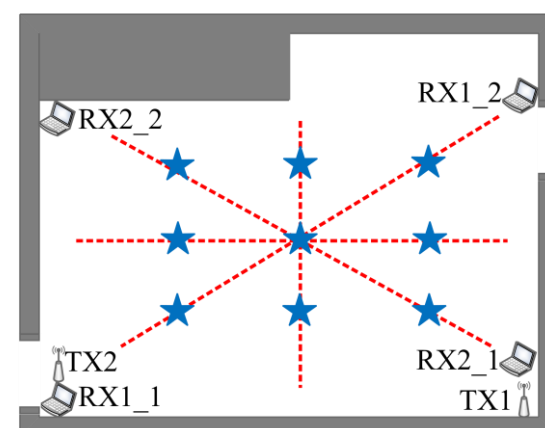
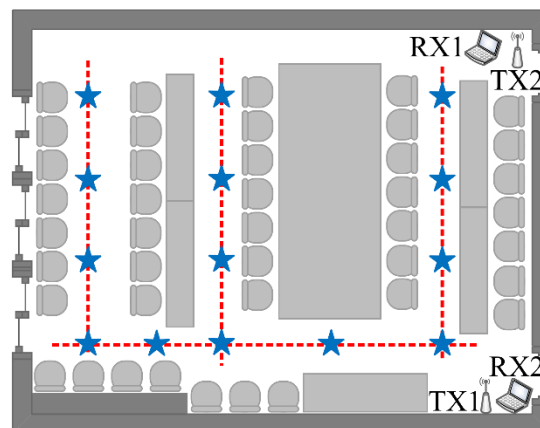
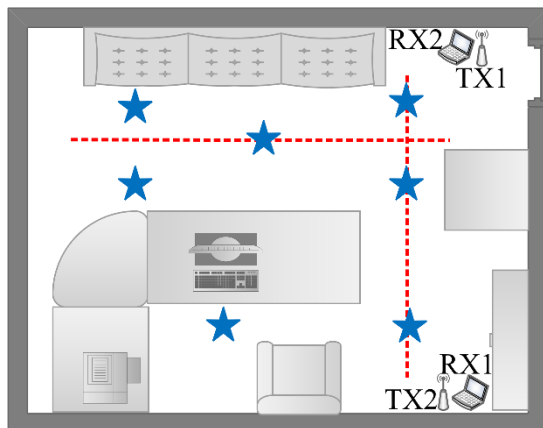
Solution 3: The **shortest** mobile path signal is suitable –pick it out according to the **ToA estimation**.



- Setup

- Transmitter/Receiver: Commodity Wi-Fi cards without any hardware modification
 - GIGABYTE miniPCs with Intel 5300 NIC
- Experiment environments
 - Office room: small and rich multipath
 - Meeting room: big and rich multipath
 - Lobby: big and less multipath

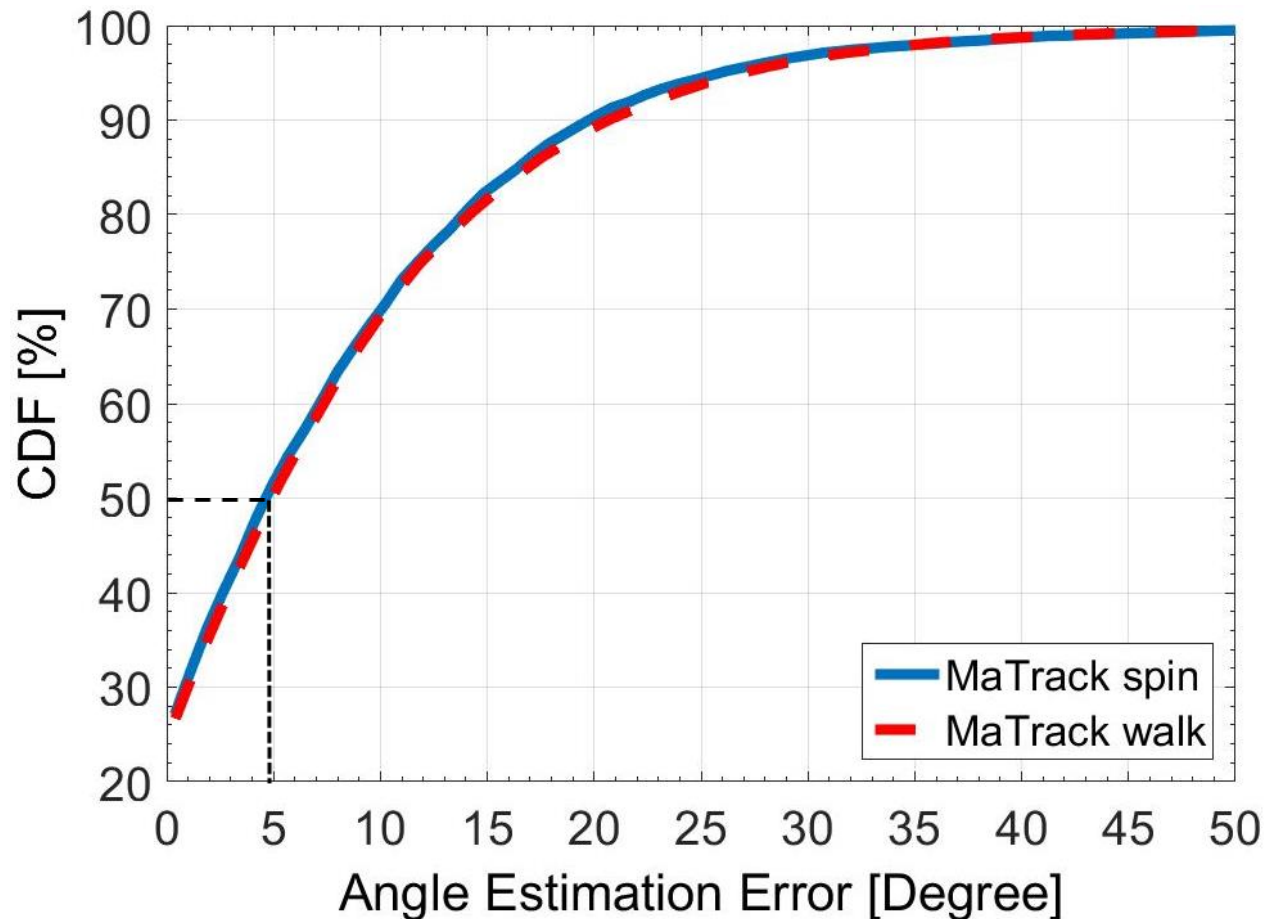
★ Spinning position
..... Walking route



Evaluation: Accuracy of Target Angle Estimation



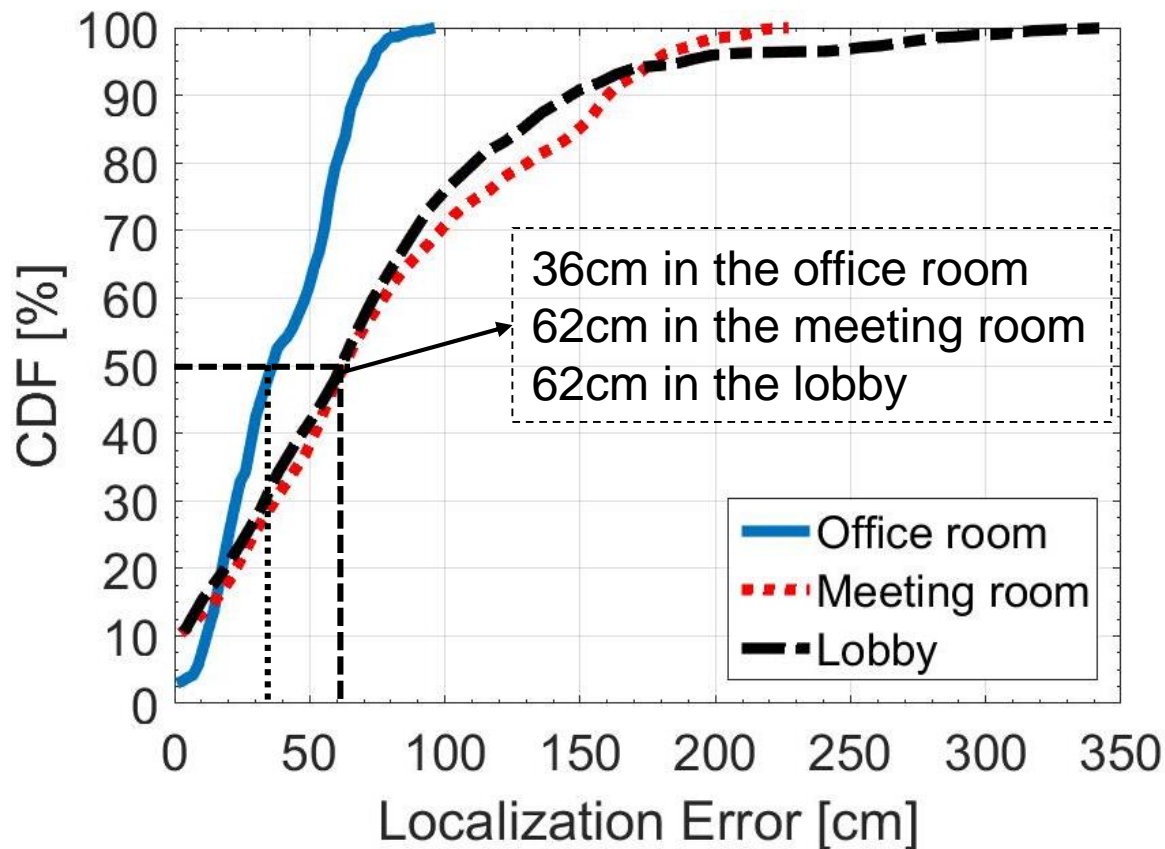
- The median error of angle estimation is 4.6° for spinning and 4.9° for walking.



Evaluation: Accuracy of Localization Estimation



- Only using 2 receivers, localization error is about 60cm for walking in a big room.



1. We are the first to propose an AoA-based device-free localization method on commodity WiFi devices to locate a moving target
 - Get accurate AoA estimation by exploring the coherence among signals and the frequency diversity.
 - Identify target reflection path signals on spectrum according to the stability of signals.
 - Choose suitable signal to get target angle based on ToA information.
2. The median localization error is about only 40 cm with two receivers without any offline training.

Q & A



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Thank you!
Question?