CIS 3990

Mobile and IoT Computing

https://penn-waves-lab.github.io/cis3990-24spring

Lecture 2: Fundamentals of Localization

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A Quick Recap & Logistics

Lecture 1: Course Introduction & Overview

- Evolution of computing paradigms: Mainframe, PC, Mobile, and IoT
- Four A's: Acquire, Aggregate, Analyze, and Act
- Main components: Power & Energy, Connectivity, and Sensing & Computing
- Application areas & Example systems
- Lectures + iOS labs + project

Logistics

- Canvas, Ed, and gradescope?
- Grading policy?
- Staff?

Course Organization

Module 1: Localization and Motion Tracking

Module 2: Sensing

Module 3: Connectivity

Module 4: Low-power IoT & Efficient Computing

Module 5: Emerging Topics

Objectives of This Module

Learn the fundamentals, applications, and implications of localization, motion tracking, and sensing

1. What are some motivating applications of localization and location-based services?
2. What are the unifying principles of positioning?
3. How do wireless positioning like GPS, Wi-Fi positioning, and Bluetooth ranging work?
4. What is wireless sensing?
5. How do visual positioning and tracking systems work?

What is Wireless Positioning/Localization?

The process of determining a human or object's location using wireless signals

Applications:

- Navigation: both outdoors (GPS) and indoors (e.g., inside museum)
- Location based services: Tagging, Reminder, Ads
- Virtual reality and motion capture
- Human-computer interactions: gesture, writing in the air
- Behavioral analytics (activities, mobility, etc.)
- Locating misplaced items (e.g., AirTag)
- Delivery drones
- Contact tracing (Bluetooth, etc.)

Sensing Modalities for Localization?

- Radio signals (EM waves): GPS, Cellular, Bluetooth, WiFi
- Ultrasound signals (mechanical waves): smart speakers

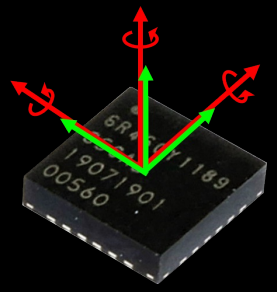
→ **Focus of this lecture**

- Inertial sensors
- Visual sensors: cameras, LIDAR

Radio

Acoustic

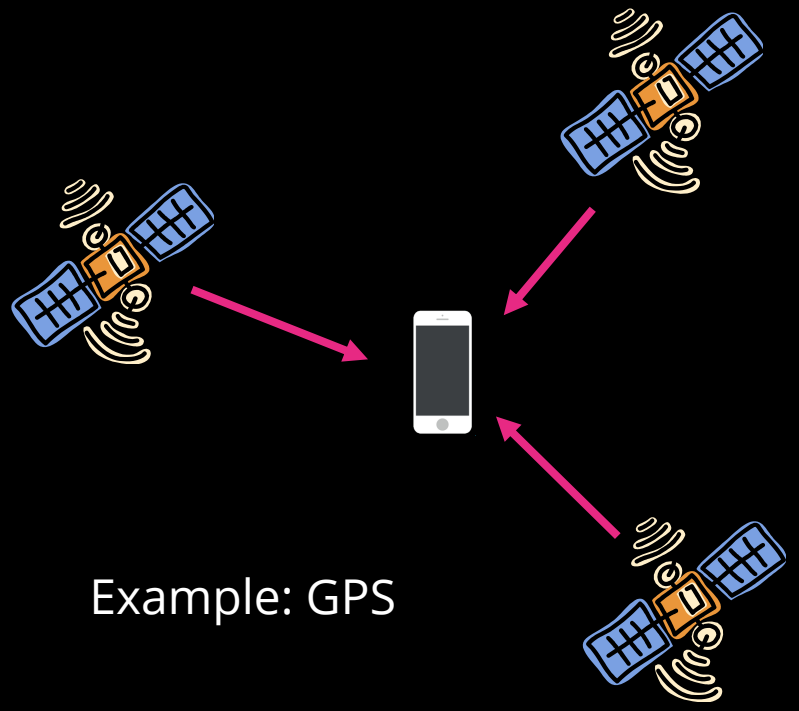
Inertial



Visual

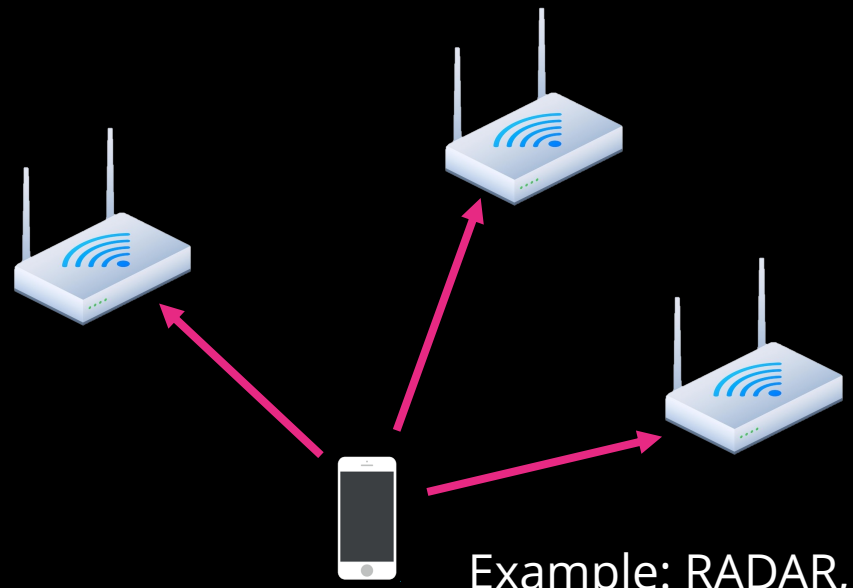
Who performs the localization?

- **Device based:** A device uses incoming signal from one or more “anchors” to determine its own location



Example: GPS

- **Network based:** Anchors (or Access points) use the signal coming from device to determine its location



Example: RADAR, WiFi positioning

Device modification? Computation? Communication?

Positioning Methods

We will discuss the positioning techniques in increasing order of sophistication

1. Identity-based Localization

Idea: use the identity and known location of anchor objects

Examples:

- WiFi indoor localization with SSID or MAC address

Localization by mapping to one of the known locations

Pros? Cons?

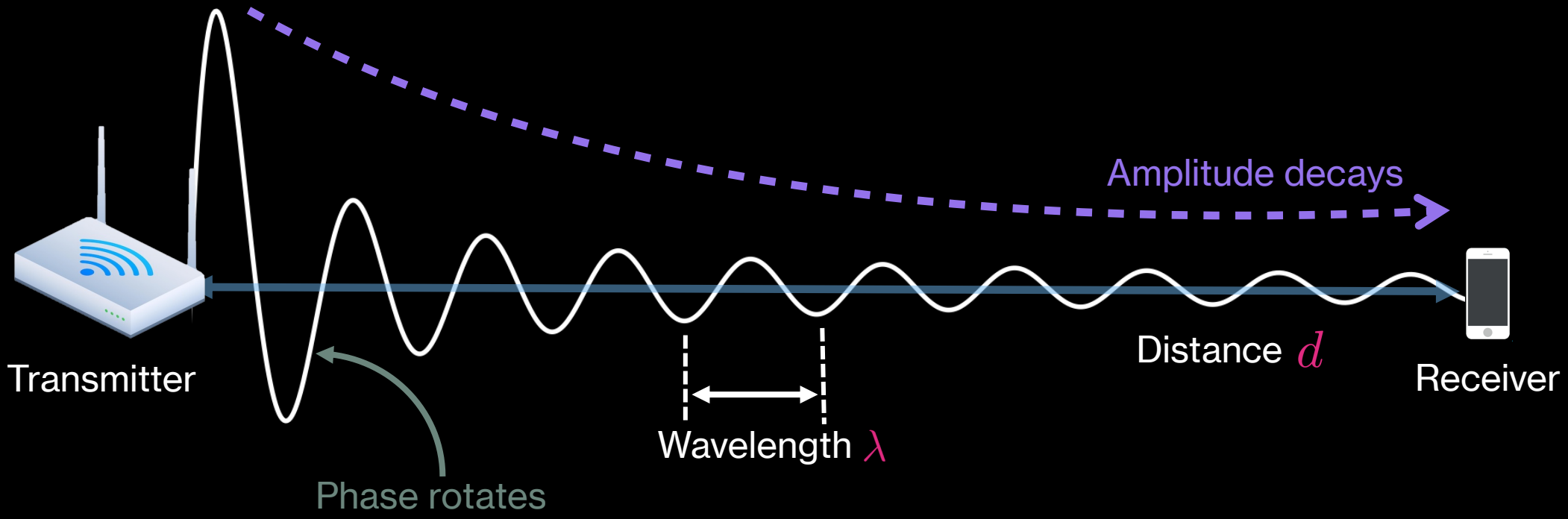
2. Received Signal Strength (RSSI)

Idea:

- higher received power ➔ closer
- lower received power ➔ farther

We could extract more information about the **exact distance** from the measured received power. Need to understand how the signals propagate.

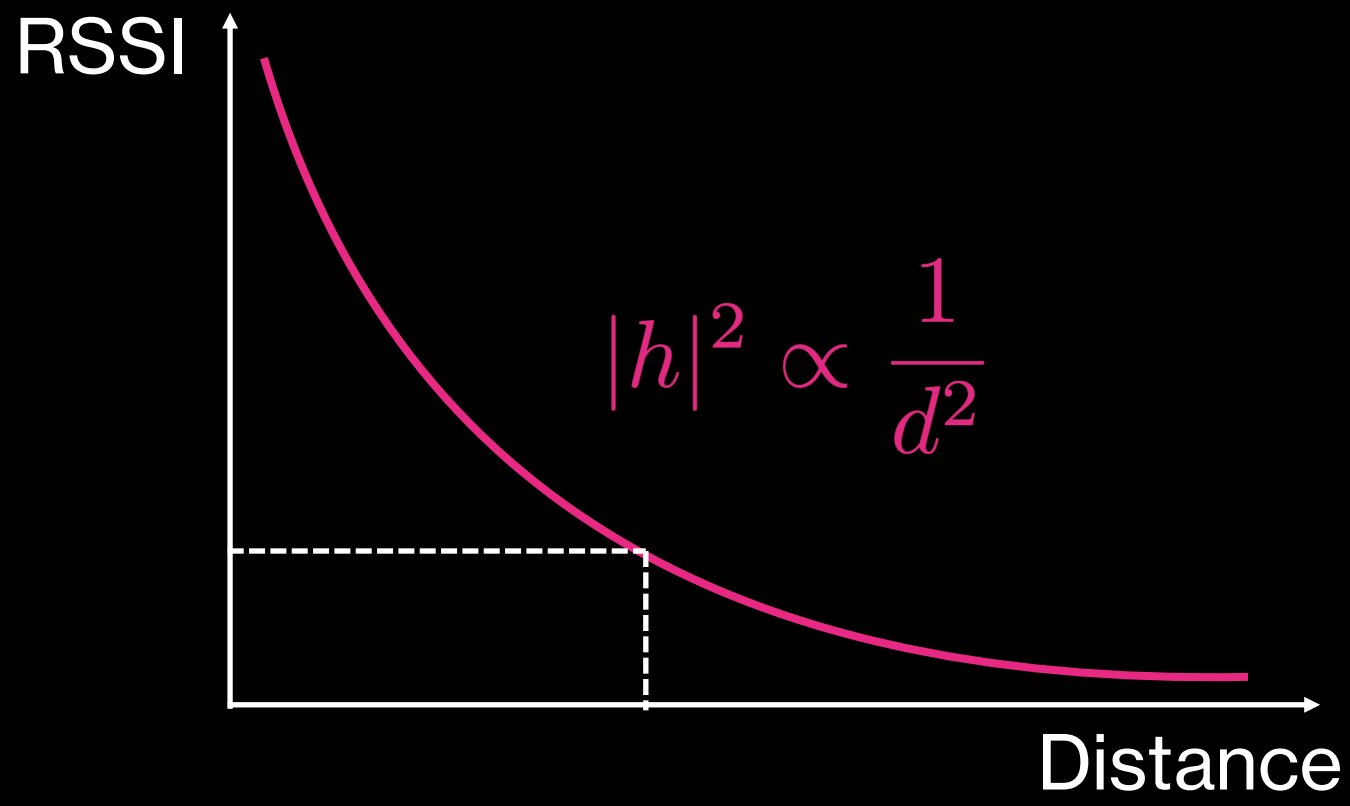
Wireless Signal are Waves



Channel equation: $h = \frac{1}{d} e^{j2\pi \frac{d}{\lambda}}$

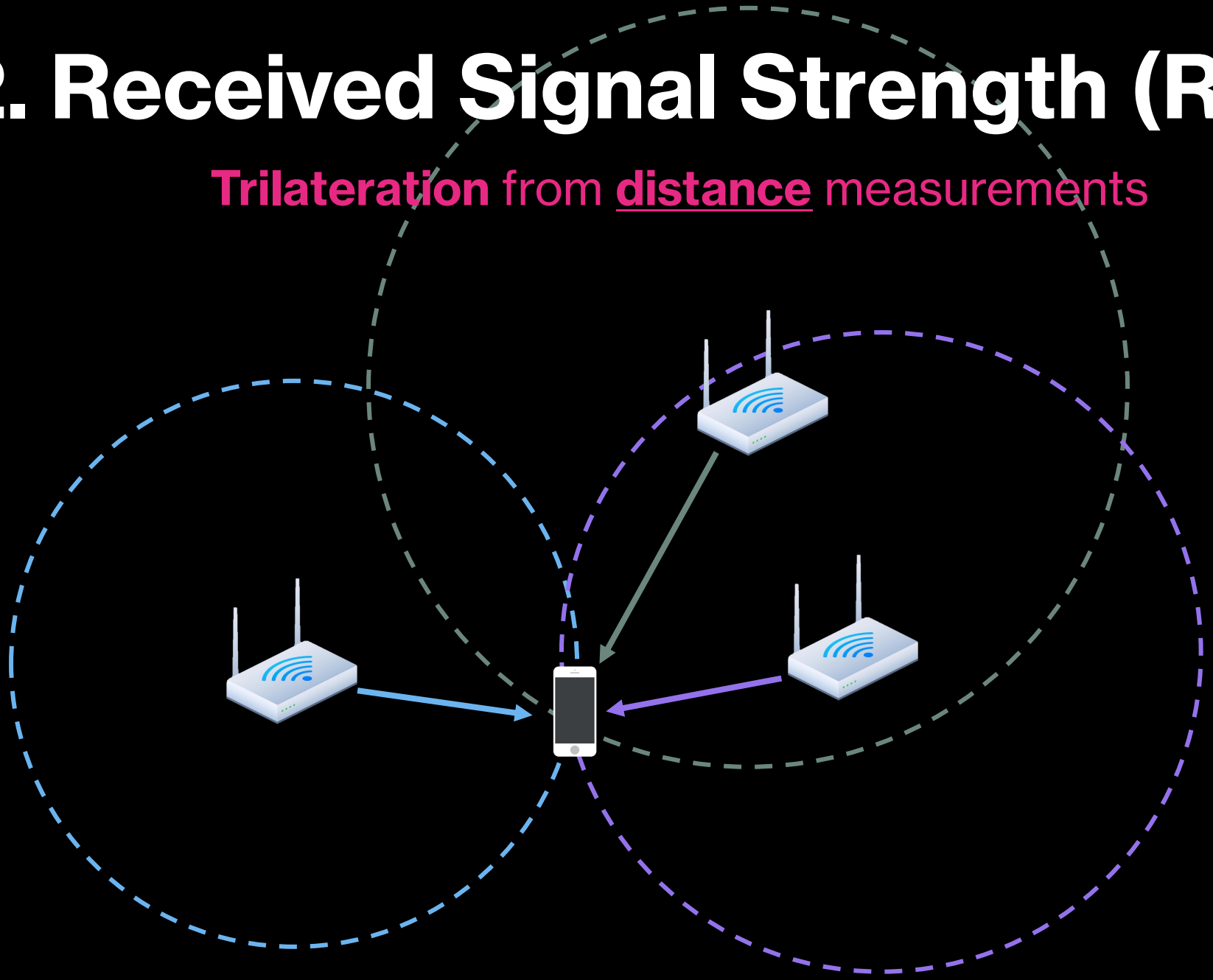
2. Received Signal Strength (RSSI)

From power to distance



2. Received Signal Strength (RSSI)

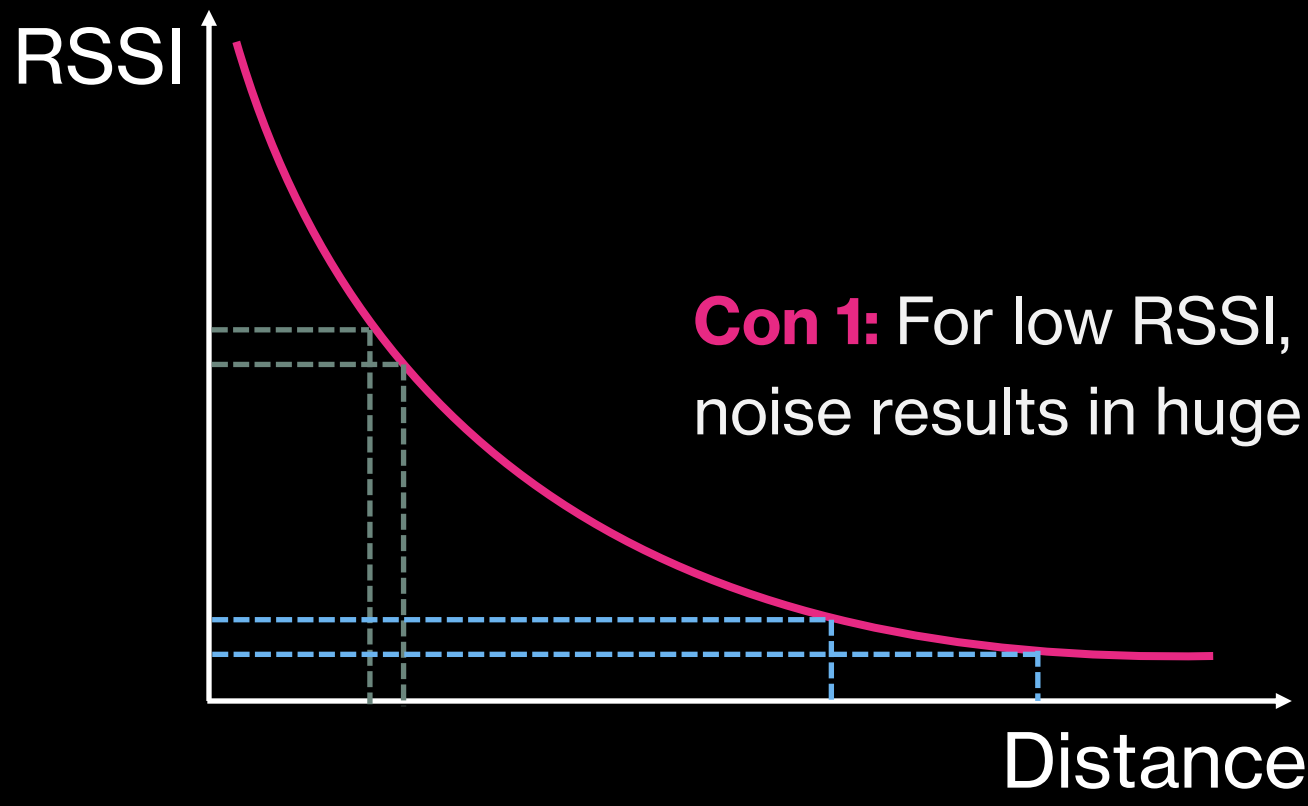
Trilateration from **distance** measurements



Pros? Cons?

2. Received Signal Strength (RSSI)

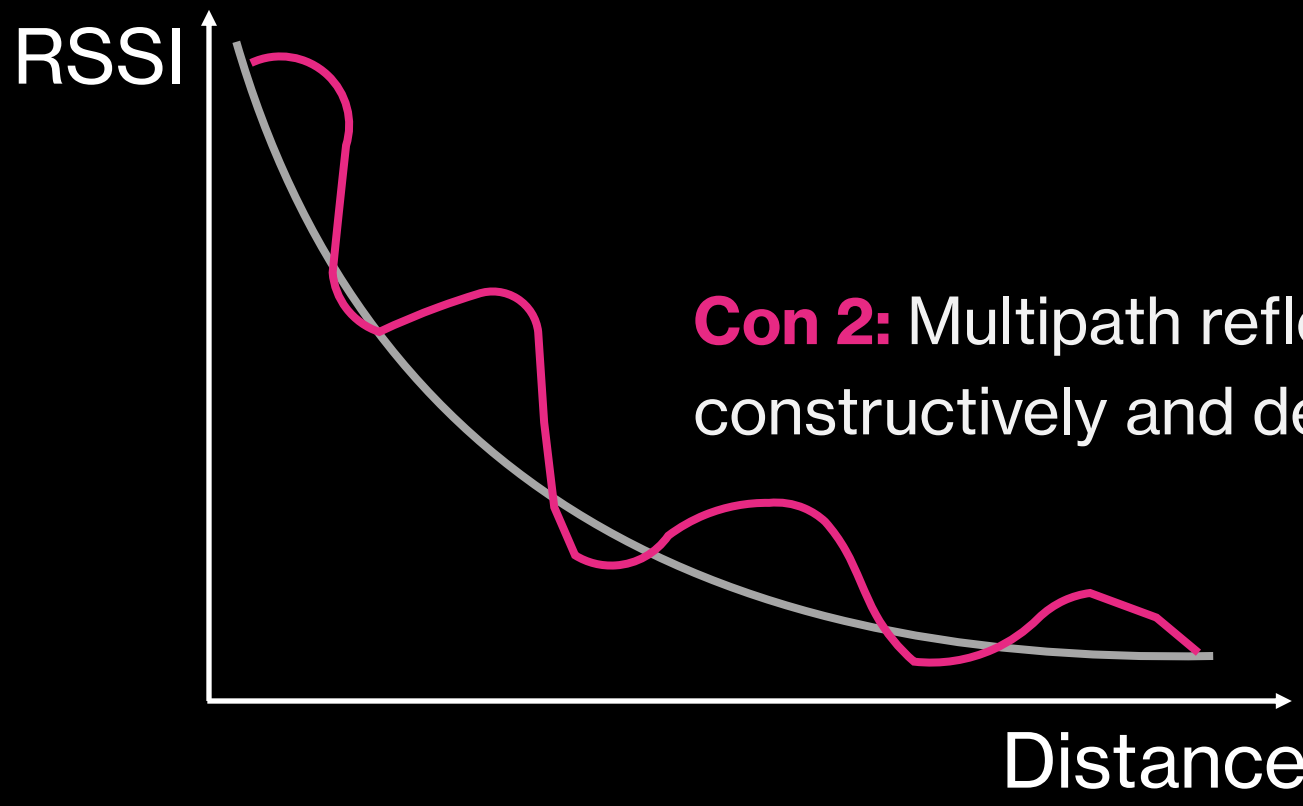
Pros: Very simple, no hardware modifications needed



Con 1: For low RSSI, small error due to noise results in huge distance error!

2. Received Signal Strength (RSSI)

Pros: Very simple, no hardware modifications needed

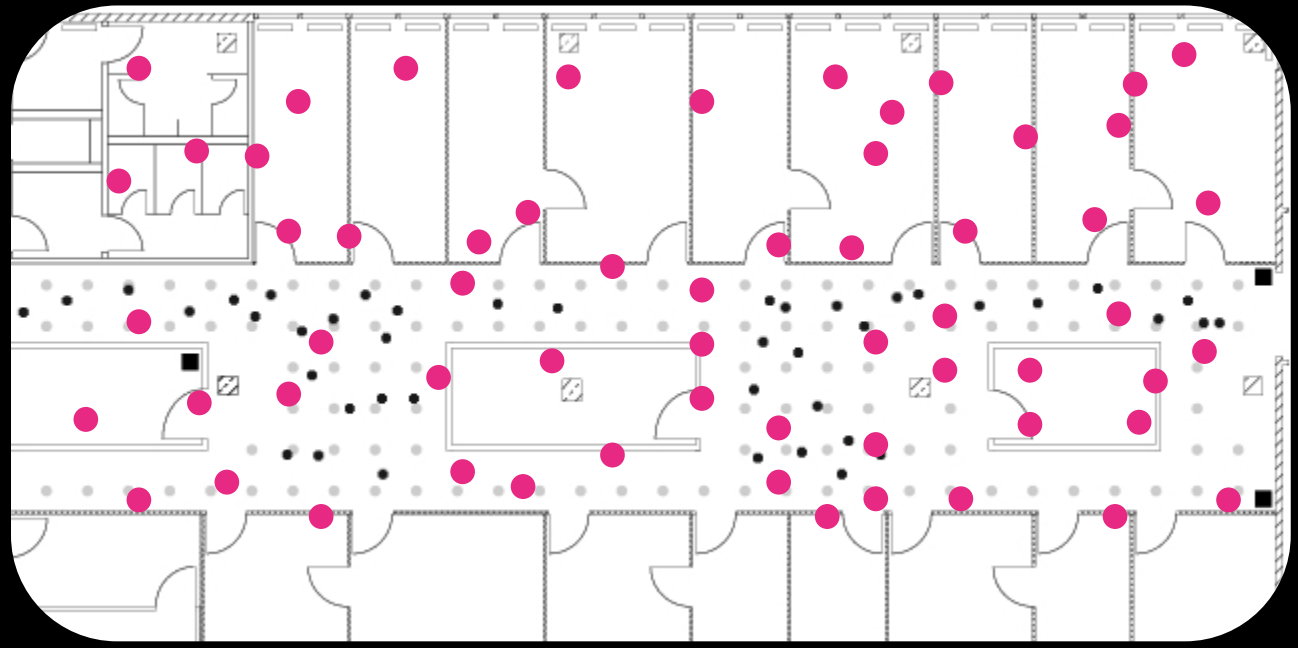


Con 2: Multipath reflections add constructively and deconstructivity.

2. Received Signal Strength (RSSI)

Solution: Fingerprinting

Measure and records RSSI fingerprints at each location



Pros: Works with multipath; No need to know AP locations!

Cons: Changes in environment/movement ➔ change RSSI!

Continuous training is needed. Lots of effort!

Next Lecture

- Time: Mon Jan 27th
- Topic: Continue with the Fundamentals of Localization
- Readings: Fourier Transform