Welcome!

6.1820/MAS.453: Mobile and Sensor Computing

aka IoT Systems

https://6mobile.github.io/

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Announcements

1- Did you introduce yourself on slack?

2- Did you fill in the survey?

Office Hours to be posted

Friday Tutorial E14-633 4-5PM

Lab 0 Due next Thursday, Feb 12

Working with IS&T to get Macs

How to Read a Paper

First Pass:

- Title, Abstract
- Figures (illustrations? important results?)
- skim intro & conclusions
- References

Then: probably use some LLM to give you a summary

Second Pass

- Intro in details
- Overview, related work, or background sections
- Figures in details

Third pass:

- Read in detail
- Mark references for future read

Objectives of the Upcoming Three Lectures

Learn the fundamentals, applications, and implications of
wireless localization and sensing

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

Where does GPS struggle?

GPS struggles indoors due to

- Attenuation when going through buildings -> decreased SNR
- multipath

GPS also struggles in urban canyons due to similar reasons:

- multipath can also lead to a wrong location, due to overestimating the path that bounces off, say, a building

What is Wireless Positioning (aka Localization)?

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

Applications:

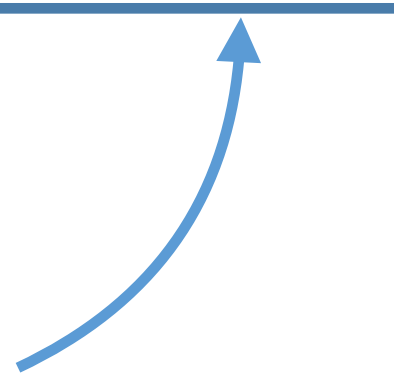
- Navigation: both outdoors (GPS) and indoors (e.g., inside museum)
- Location based services: Tagging, Reminder, Ads
- Virtual Reality and Motion Capture

- Gestures, writing in the air
- Behavioral Analytics (Health, activities, etc.)
- Locating misplaced items (keys)
- Security (e.g., only want to give WiFi access to customers inside a store)
- Delivery drones

- Contact tracing (Bluetooth, etc.)

What are the different modalities of obtaining location?

- Radio signals: GPS, Cellular, Bluetooth, WiFi
- Ultrasound signals: similar to those used in NEST
- Inertial sensors
- Cameras, LIDAR



Focus of this lecture

We will discuss the localization techniques in increasing order of sophistication

Who performs the localization process?

- 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

Let’s say I want to create a localization system that my smartphone can use, say, inside buildings (e.g., the MIT campus)

What’s the simplest one I can build?

1) Identity-based Localization

Idea: Use the identity and known location of anchor nodes

Example:

- Wardriving -- been used to improve the accuracy of GPS
- WiFi indoor localization

Localize by mapping to one of those locations.

Pros? Cons?

2) Received Signal Strength (RSSI)

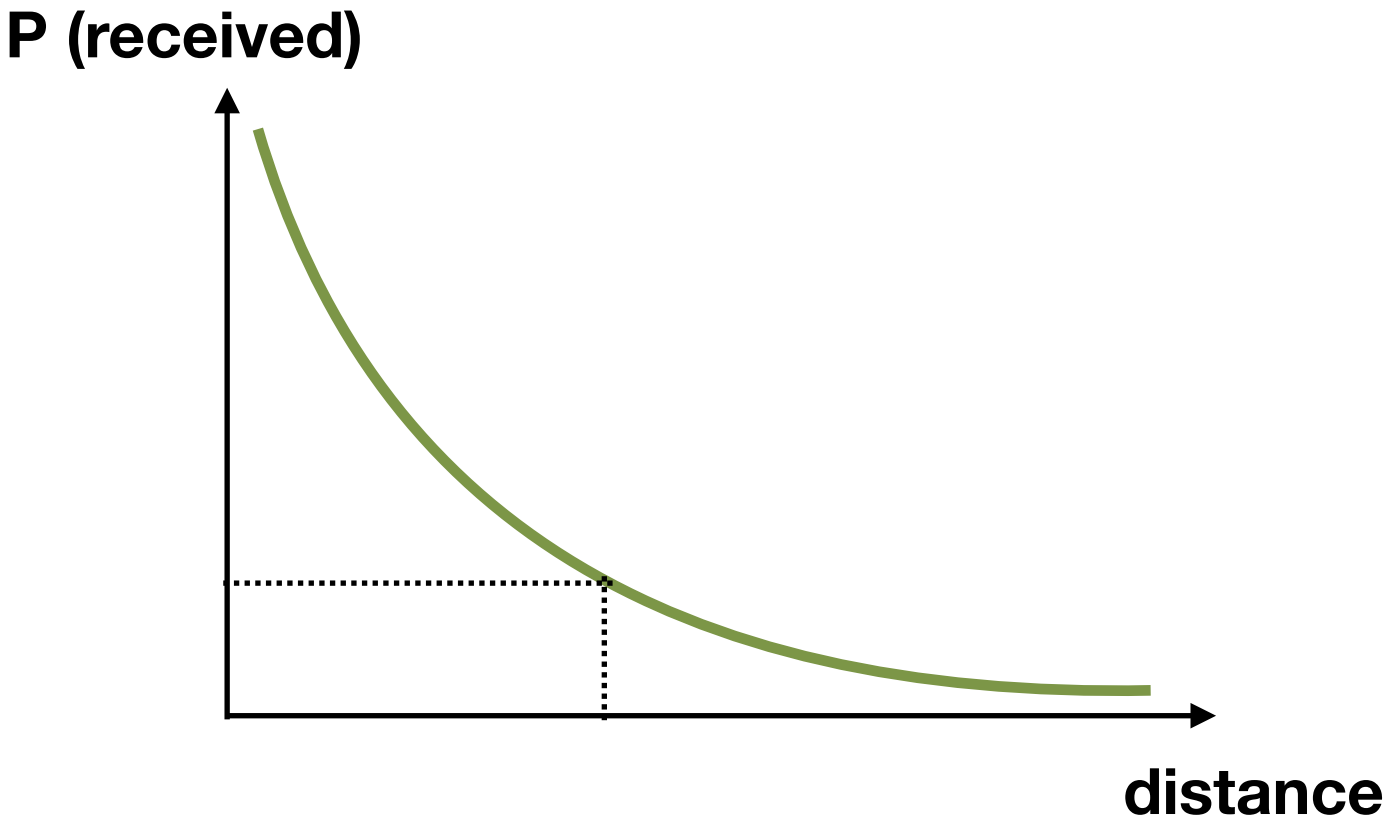
Idea: Higher power -> closer; lower power-> further

In fact, we can extract more information about exact distance from measured power. Need to understand more about wireless signals

2) Received Signal Strength (RSSI)

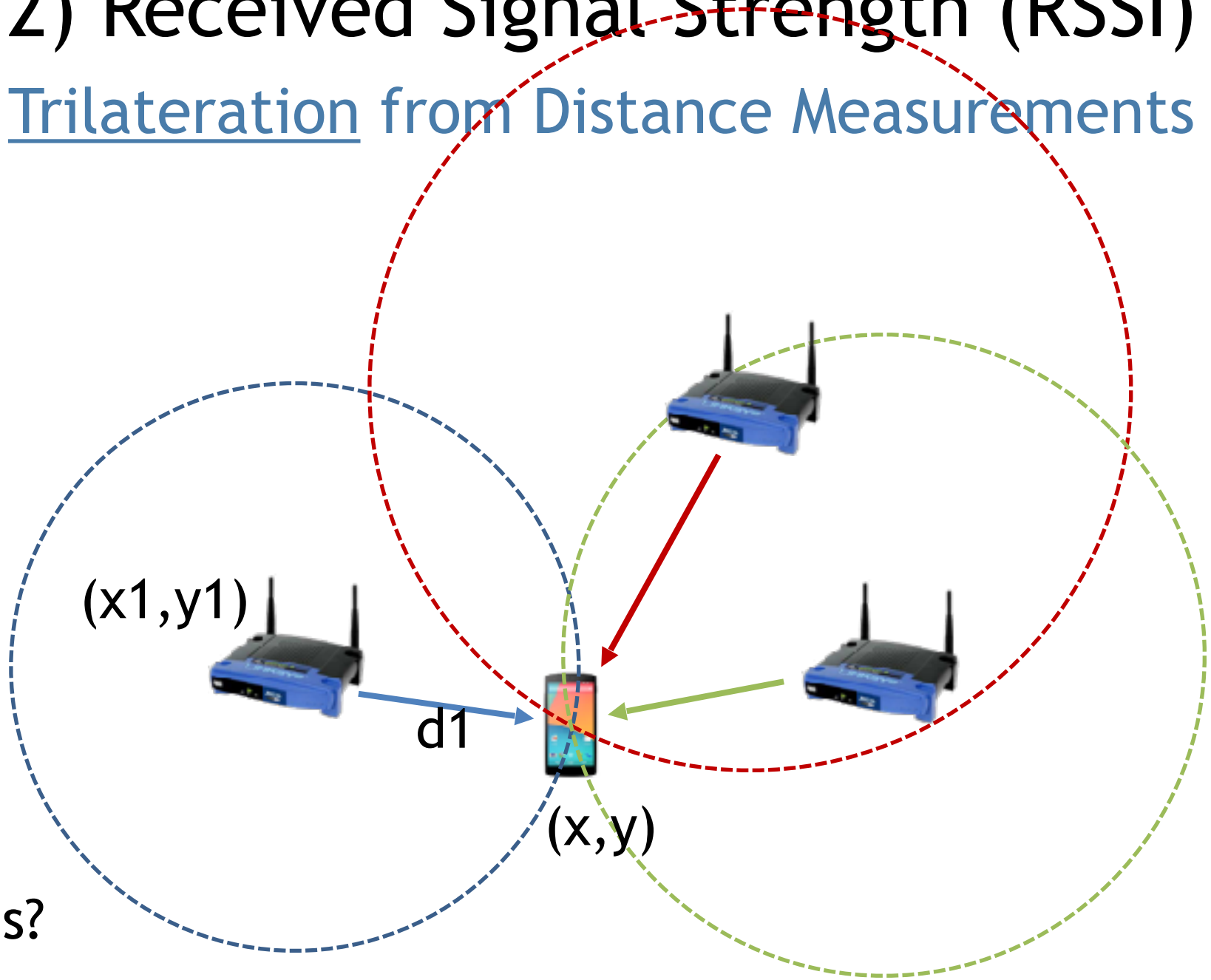
From power to distance

Power is proportional to $1/d^2$



2) Received Signal Strength (RSSI)

Trilateration from Distance Measurements

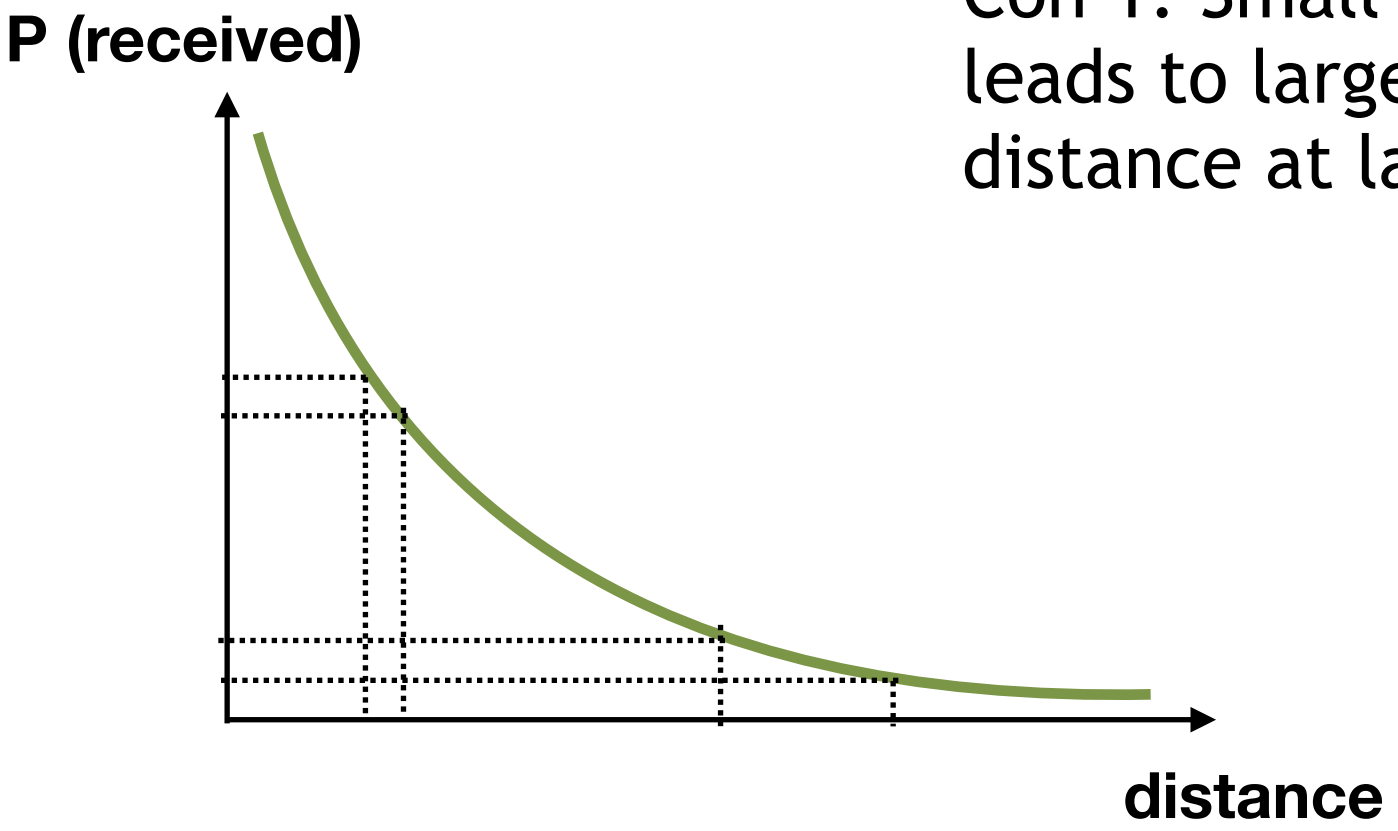


Pros? Cons?

2) Received Signal Strength (RSSI)

From power to distance

Power is proportional to $1/d^2$

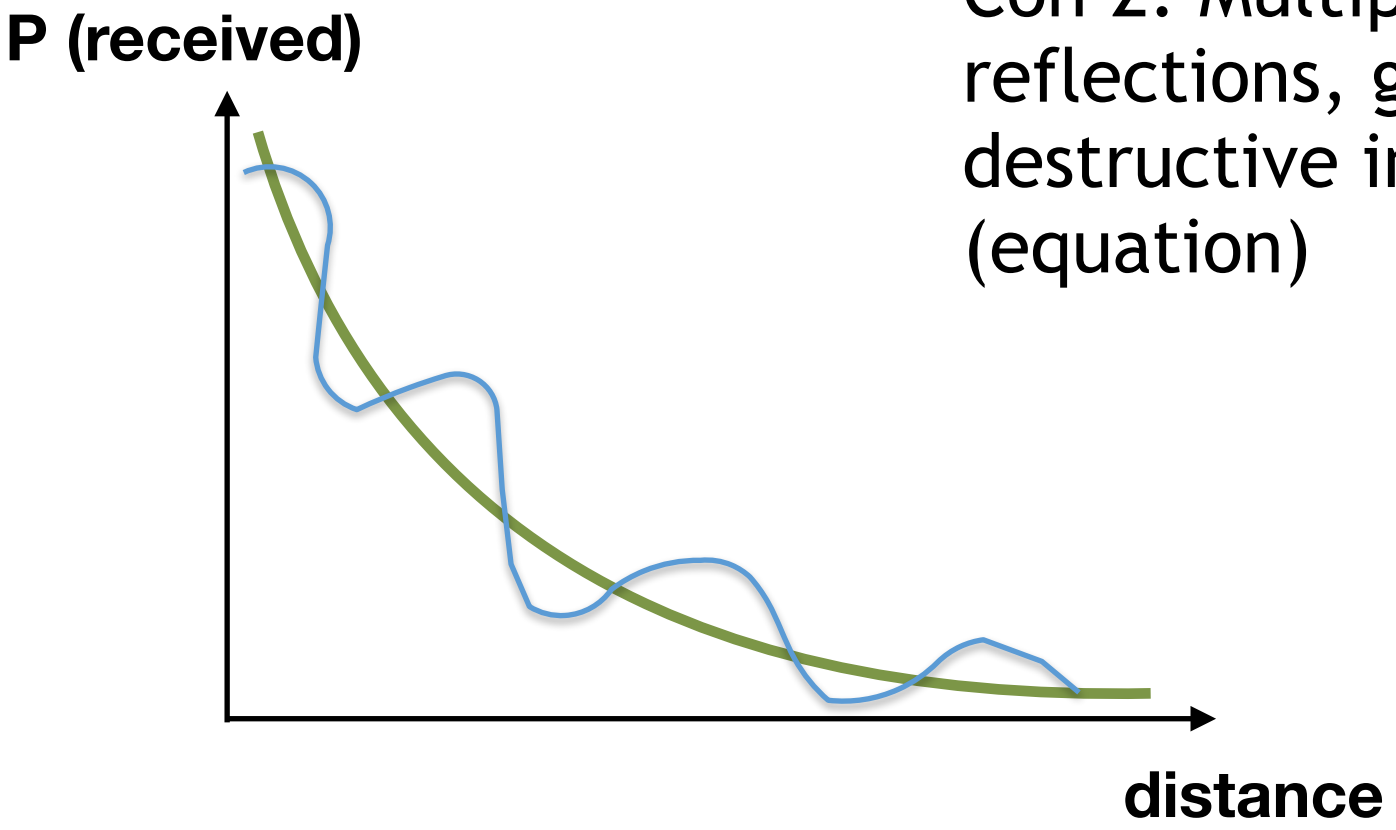


Con 1: Small change in power leads to large deviations in distance at larger distances

2) Received Signal Strength (RSSI)

From power to distance

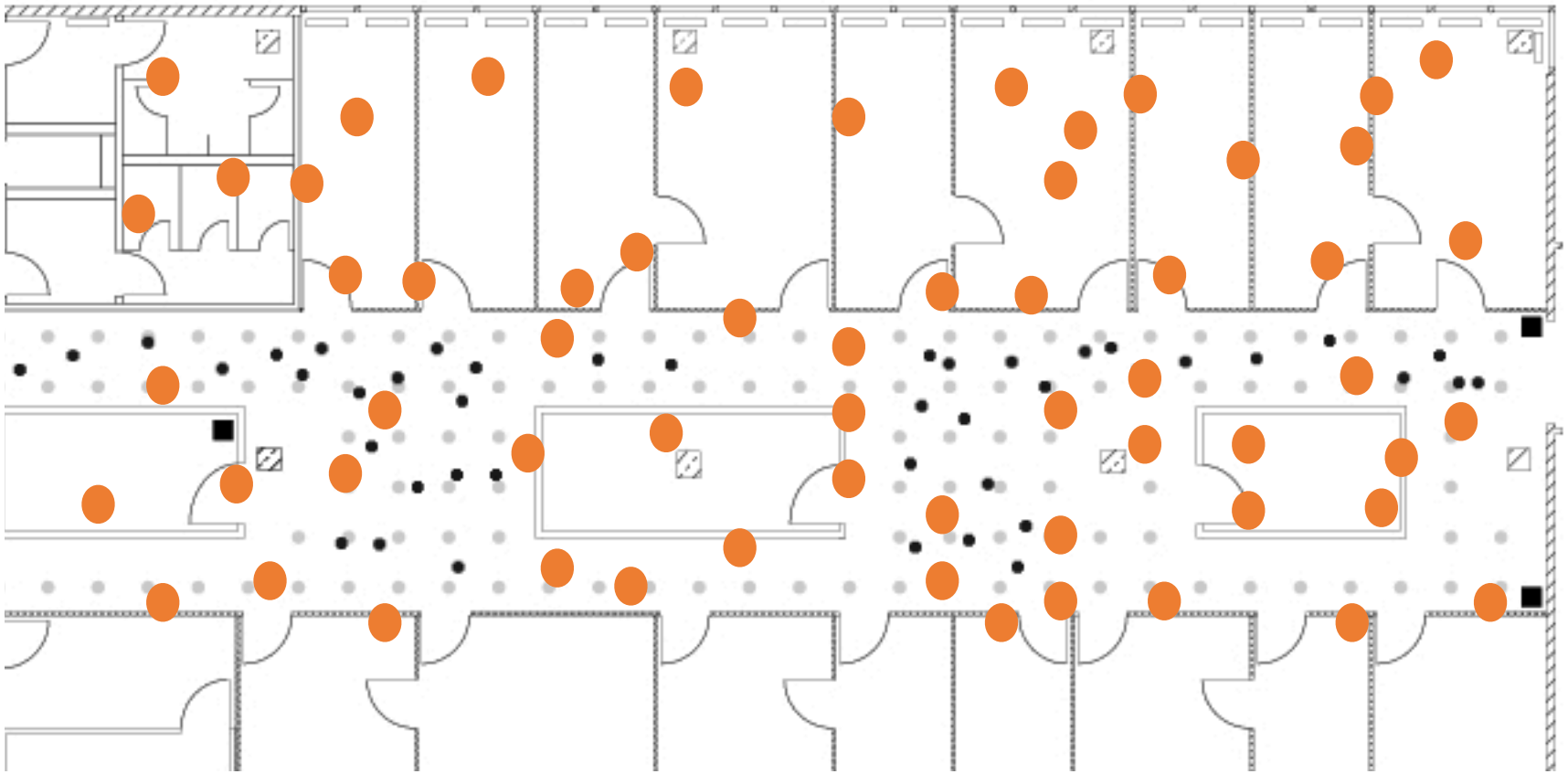
Power is proportional to $1/d^2$



Con 2: Multipath: Due to reflections, get constructive and destructive interference (equation)

2) Received Signal Strength (RSSI)

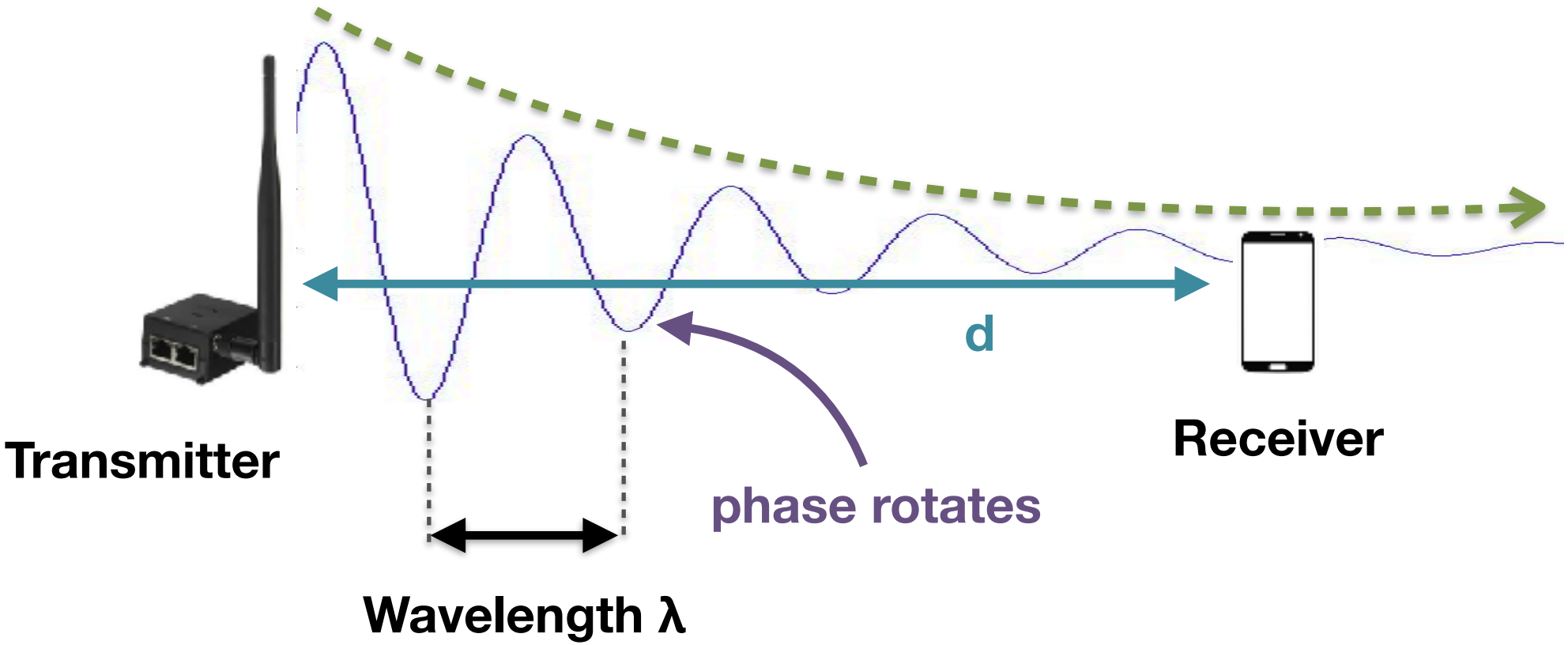
Solution: Fingerprinting
i.e., measuring device records signal strength fingerprints at each location



Pros? Cons?

3) Use the Signal “Phase”

Phase $\phi = 2\pi \frac{d}{\lambda}$

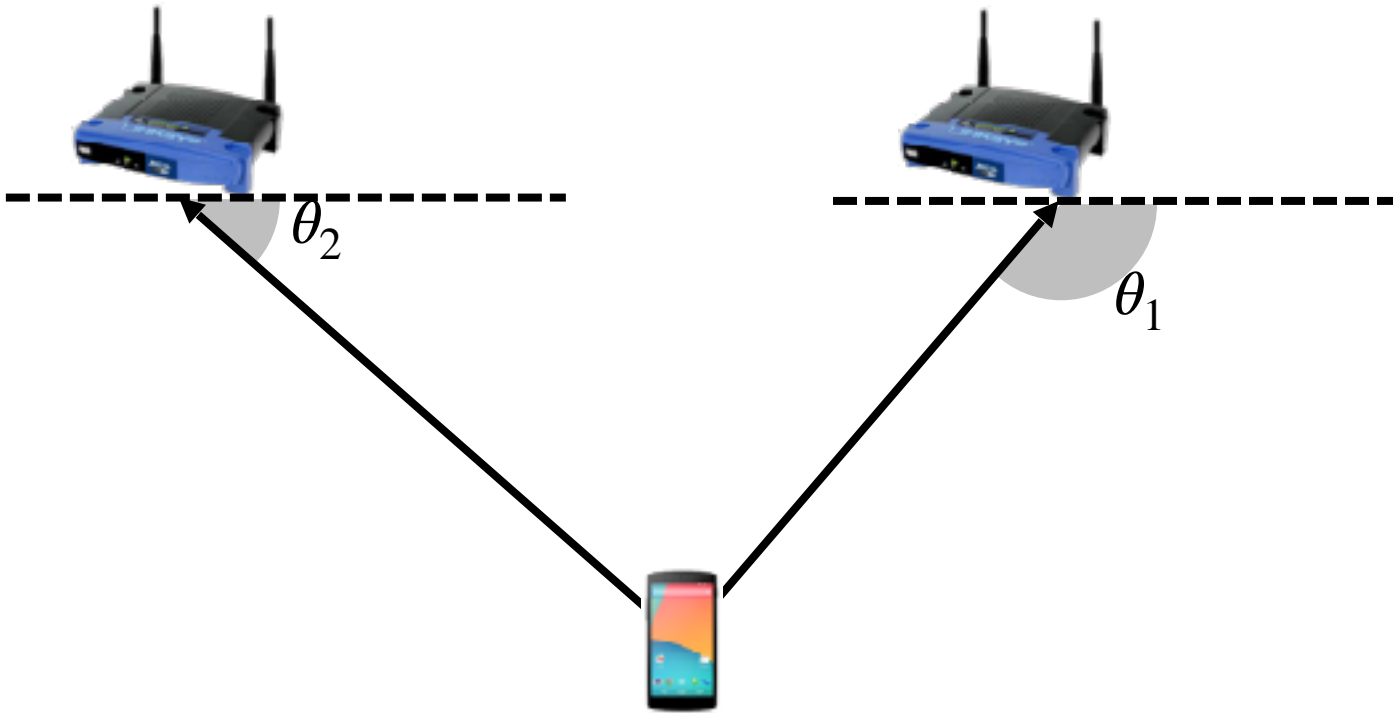


Pros? Cons?

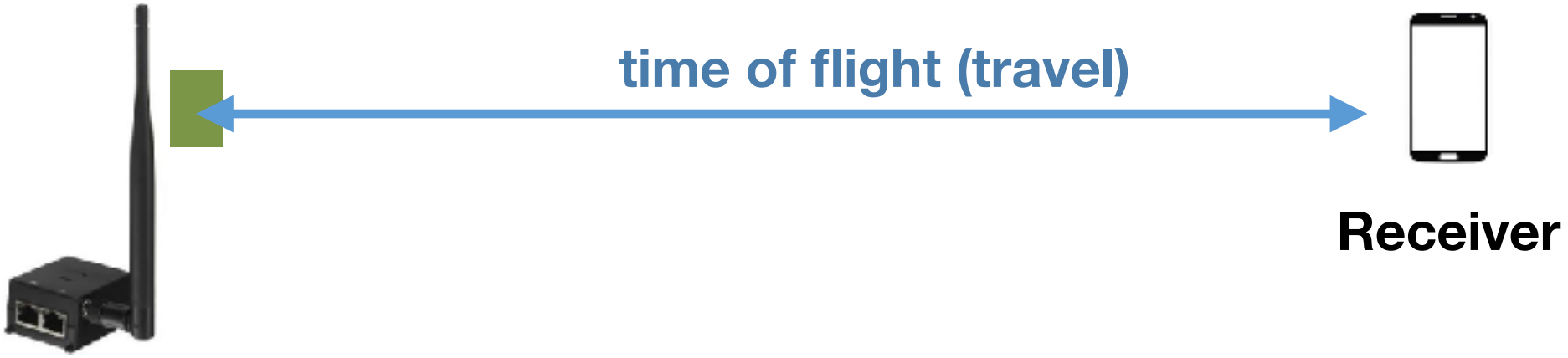
4) Use Angle of Arrival (AoA)

Triangulation from Angular Measurements

Measure Angle of Arrival (AoA) from device to each AP



5) Measure the Time-of-Flight (ToF)

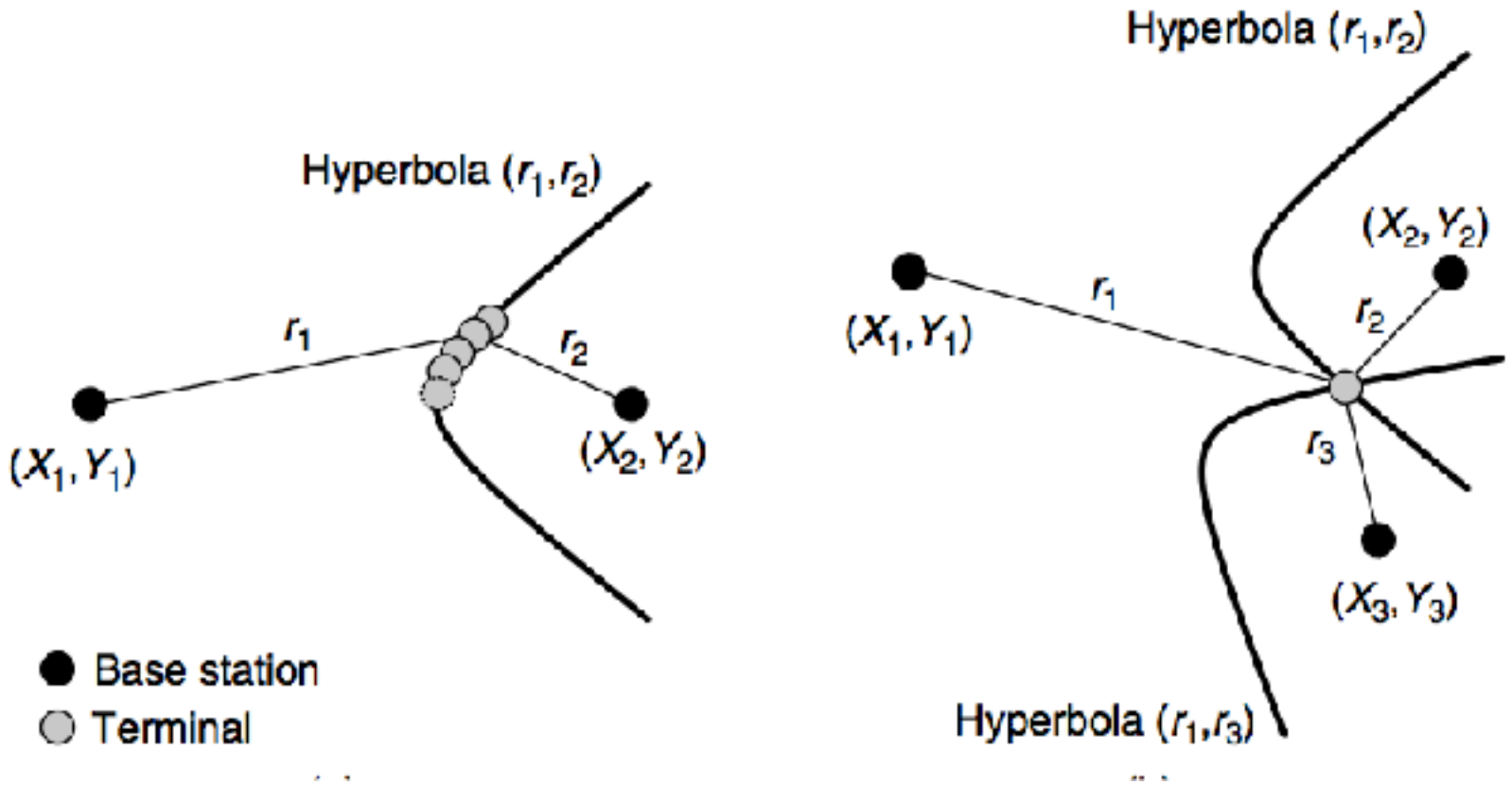


Distance = Time of flight x speed of travel

Can use trilateration (intersection circles/spheres)

How do we know when the signal was transmitted?

6) Time-difference-of-arrival (TDoA)



State-of-the-Art Techniques?

- Sophisticated Combinations of these techniques, e.g.,:
- Combine AoA with time-of-flight
- Use circular antennas and combine with inertial sensing
- Perform synthetic aperture radar and DTW
- Synthesize measurements from multiple frequencies
- …

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1. What are the unifying principles of wireless positioning?
2. How do systems like GPS, Wi-Fi positioning, Bluetooth ranging, and acoustic ranging work?
3. What is wireless (aka WiFi) sensing?
4. What are the industry opportunities and societal implications of wireless sensing (today and in the near+far future)?

next lecture (case studies)

TODO:

1) Lab 0 Due next Thursday at midnight
2) Question for Lecture 3 due on Tuesday at noon
3) Office hours to be posted; iOS tutorial Friday