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 poll?

Office Hours to be posted

Friday Tutorial in 66-144 10-11AM

Lab 0 Due next Thursday, Feb 13

Working with IS&T to get Macs

This Week in IoT

Rocket Lab to launch 5 'Internet of Things' satellites Feb. 8 after delay due to orbital traffic

News By Mike Wall last updated 2 days ago

The 'IOT 4 You and Me' launch was delayed to ensure there were no space-collision concerns.

Comments (0)

When you purchase through links on our site, we may earn an affiliate commission. Here's how it works.

Kinéis: Constellation of 25 nanosatellites that “can connect any object from anywhere in the world and transmit useful data from these objects to users in near real time.”

How come 25 satellites alone can provide global connectivity?

If so, how would sending more satellites help?

Areas of use?

- natural risk prevention (detection of forest fires, floods, pollution, etc.)
- monitoring of infrastructures and energy networks (detection of anomalies, predictive maintenance, etc.)
- transport and logistics monitoring
- agriculture
- traceability of wild and farmed animals
- monitoring of commercial and leisure maritime activities.

https://www.rocketlabusa.com/missions/next-mission/

LEO satellites + IoT

<u>How connectivity is achieved?</u>

* On same side of the globe
* On opposite sides

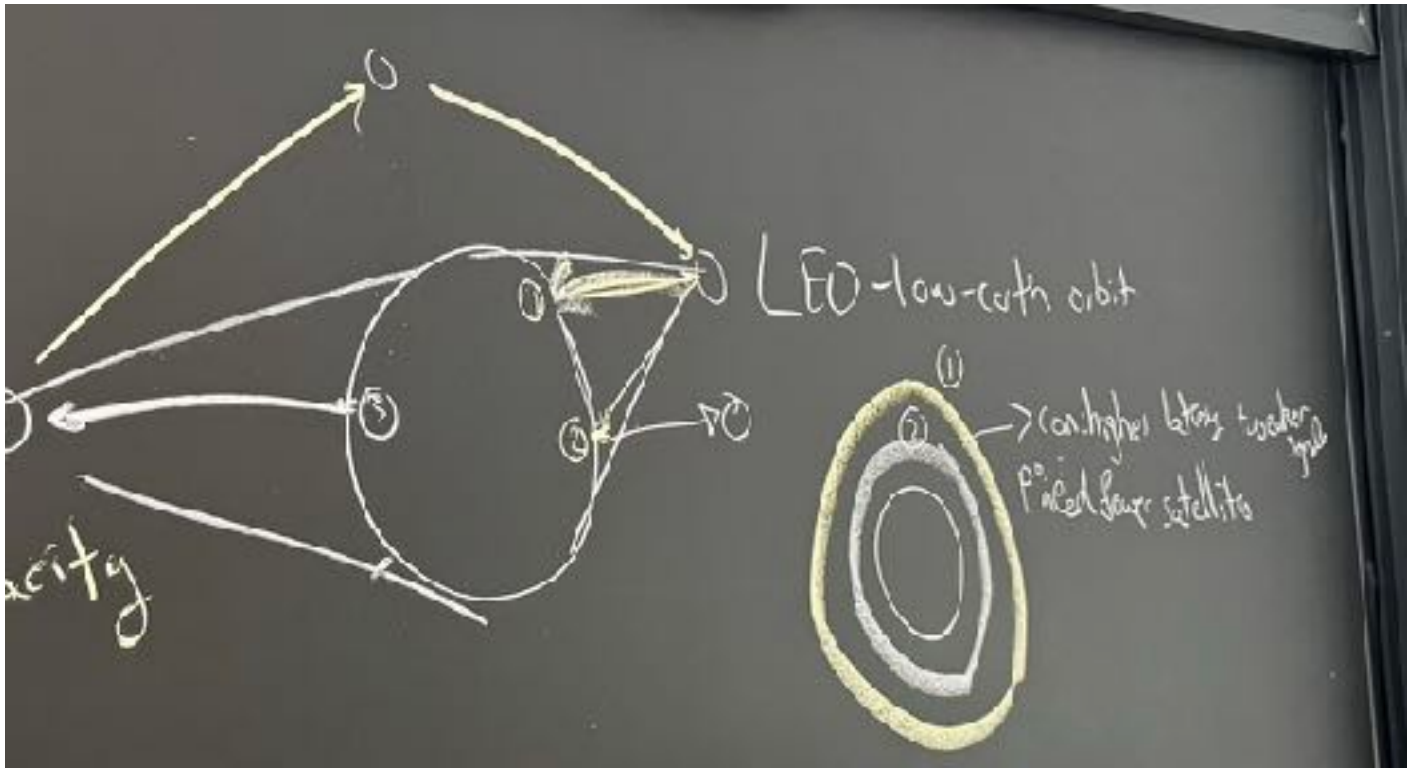
<u>Benefits of more satellites constellations?</u>

- redundancy / fault tolerance
- throughput/capacity
- reduces latency

<u>Closer vs further away constellation</u>

- tradeoffs are latency and number of satellites

(photo from the board)



How to Read a Paper

First Pass:

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

Then: probably use ChatGPT 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?

What is Wireless Positioning (aka Localization)?

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

Applications:

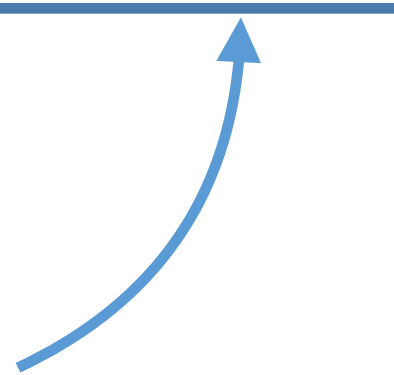
- Navigation: both outdoors (GPS) and indoors (e.g., inside museum)
- Location based services: Tagging, Reminder, Ads
- Virtual Reality and Motion Capture

- 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.

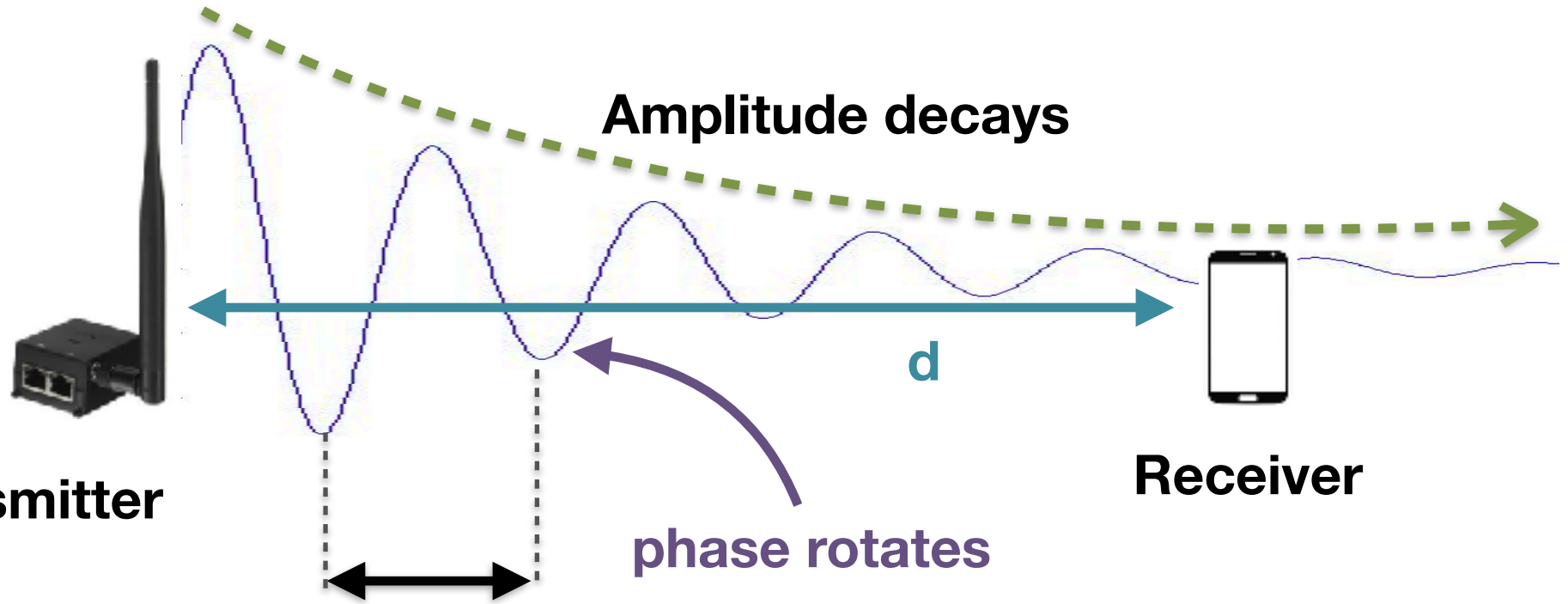
Pros? Cons?

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

Wireless Signals are Waves



Channel equation (Complex number)

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

Wireless Signals are Waves

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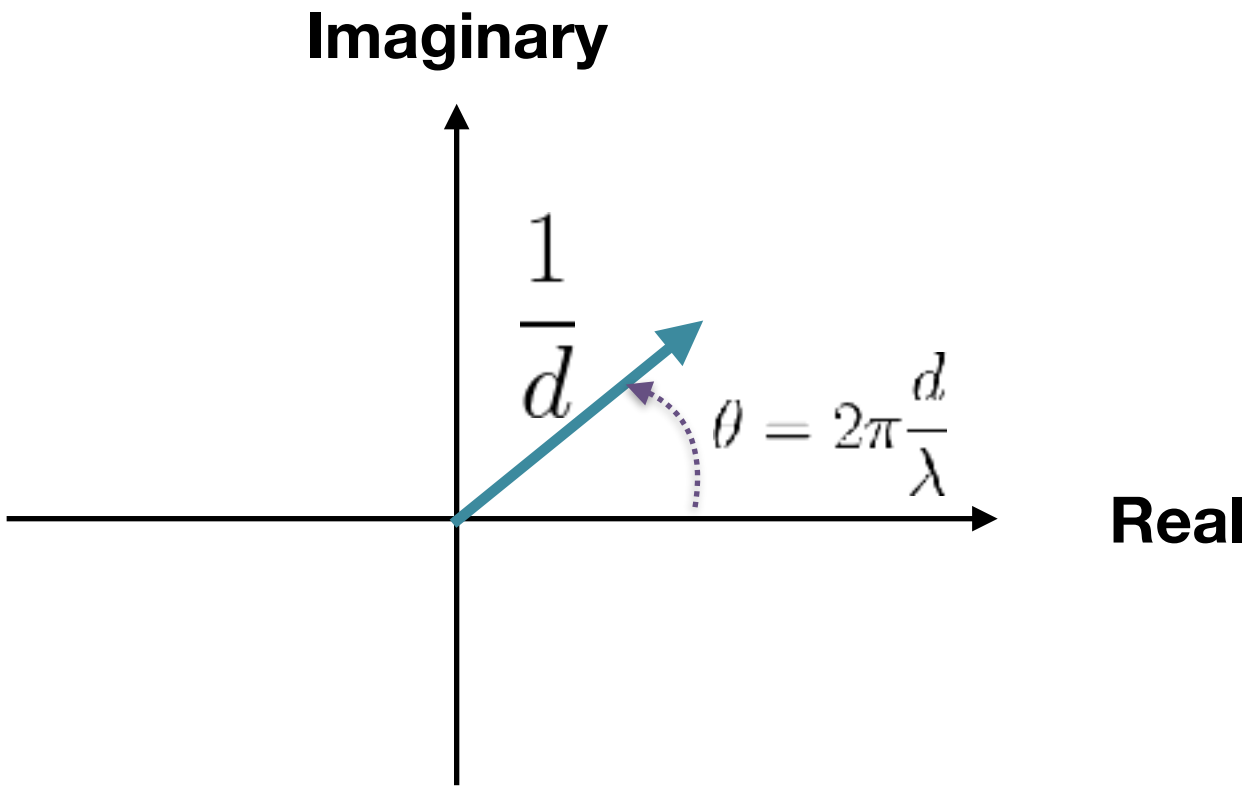
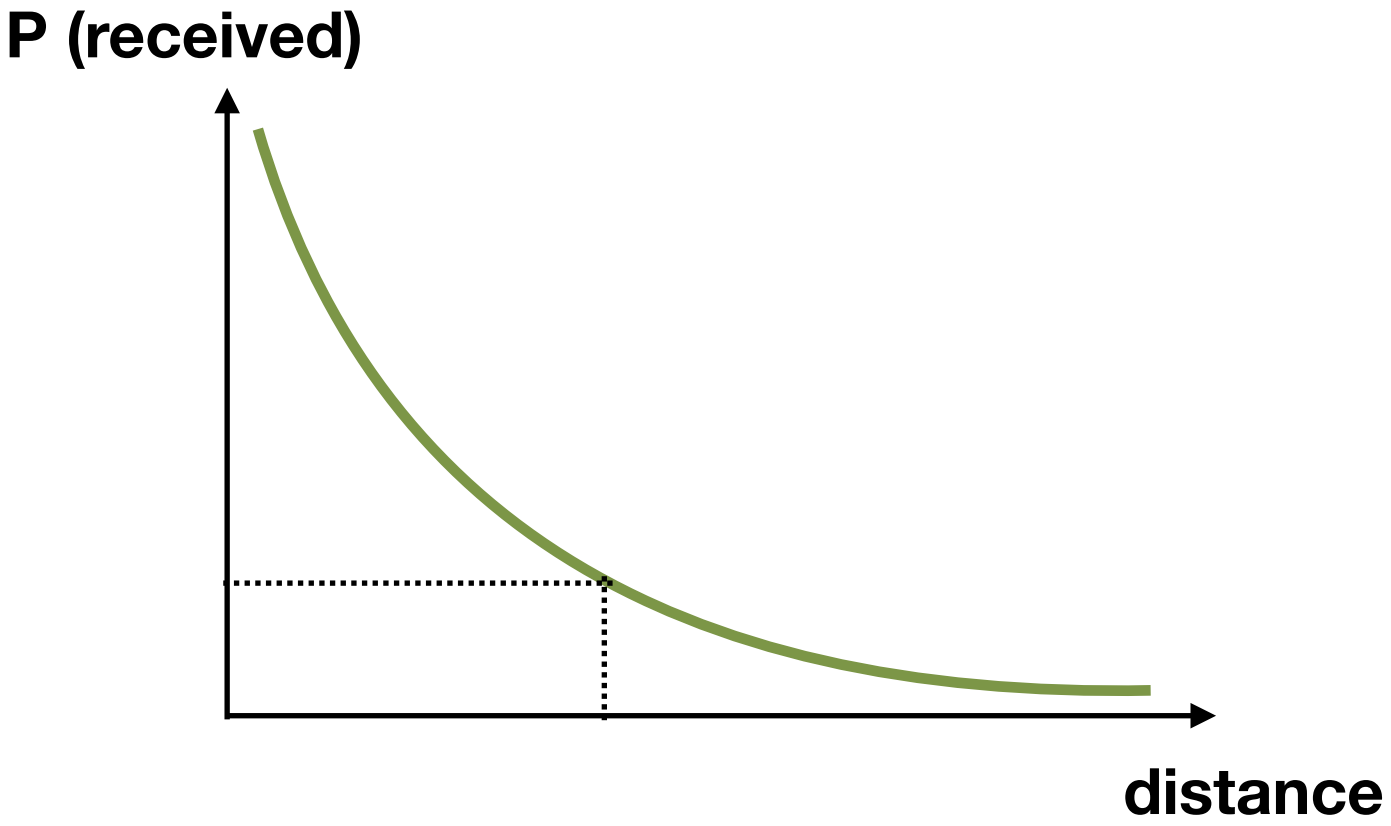


2) Received Signal Strength (RSSI)

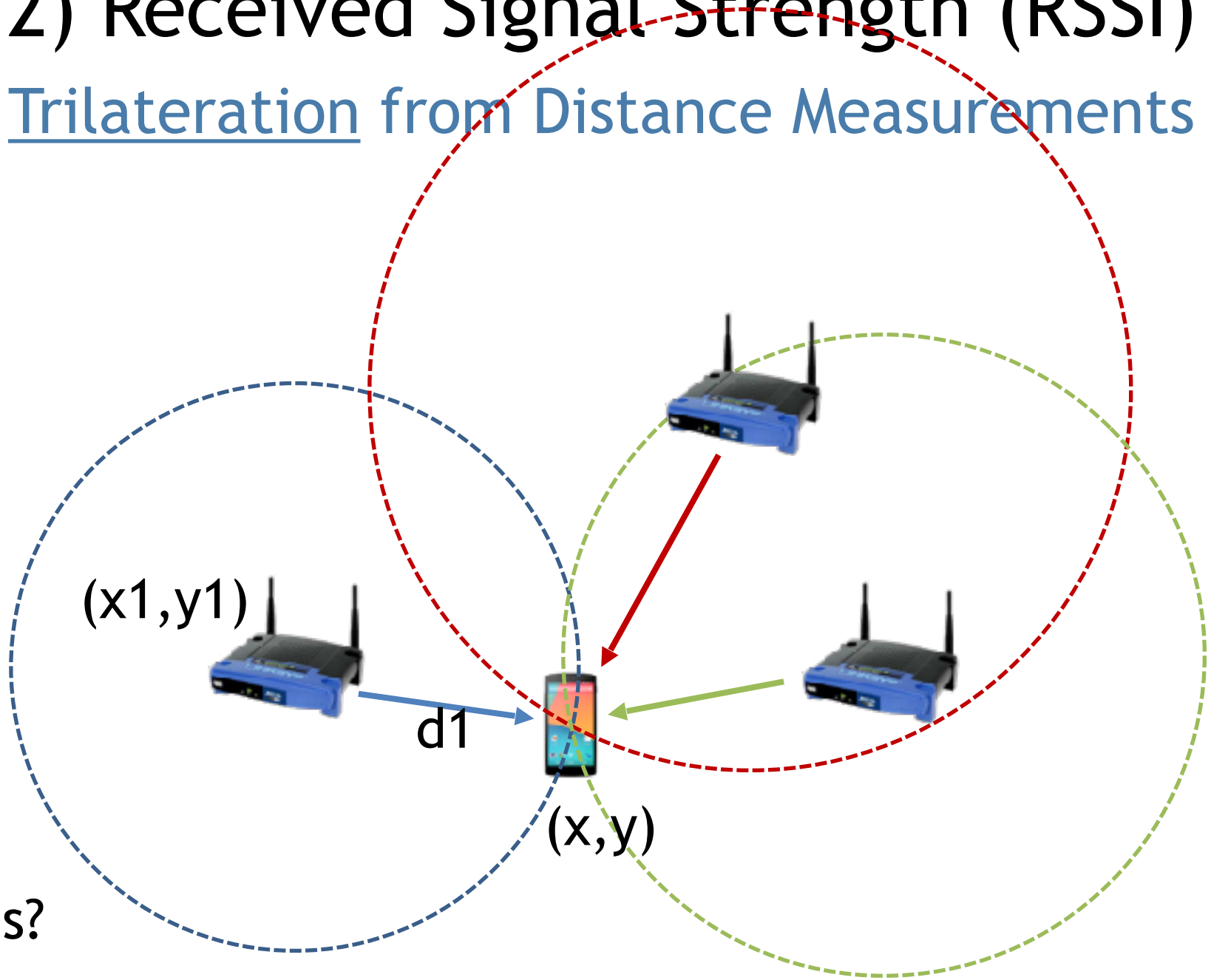
From power to distance

Power is proportional to $1/d^2$



2) Received Signal Strength (RSSI)

Trilateration from Distance Measurements

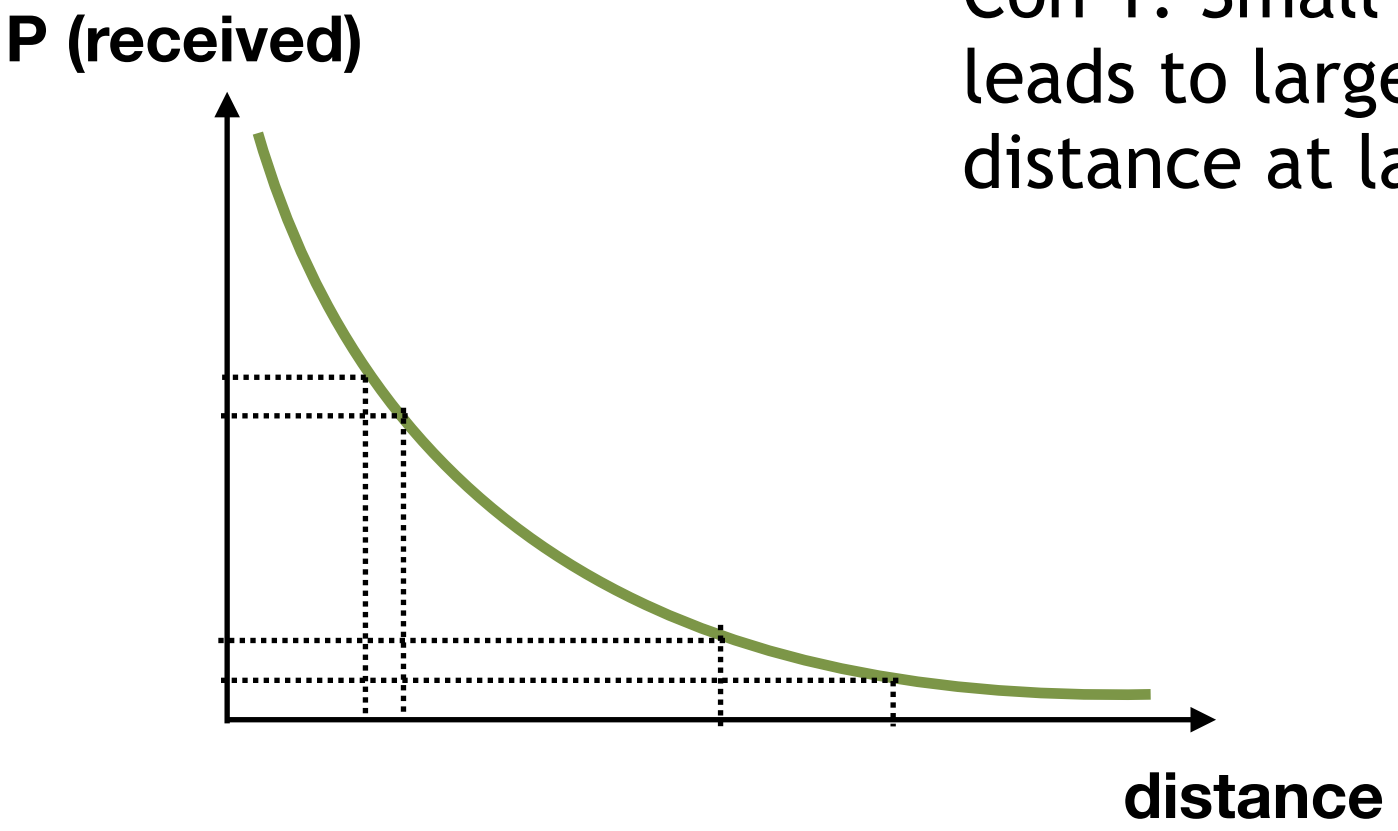


Pros? Cons?

2) Received Signal Strength (RSSI)

From power to distance

Power is proportional to $1/d^2$

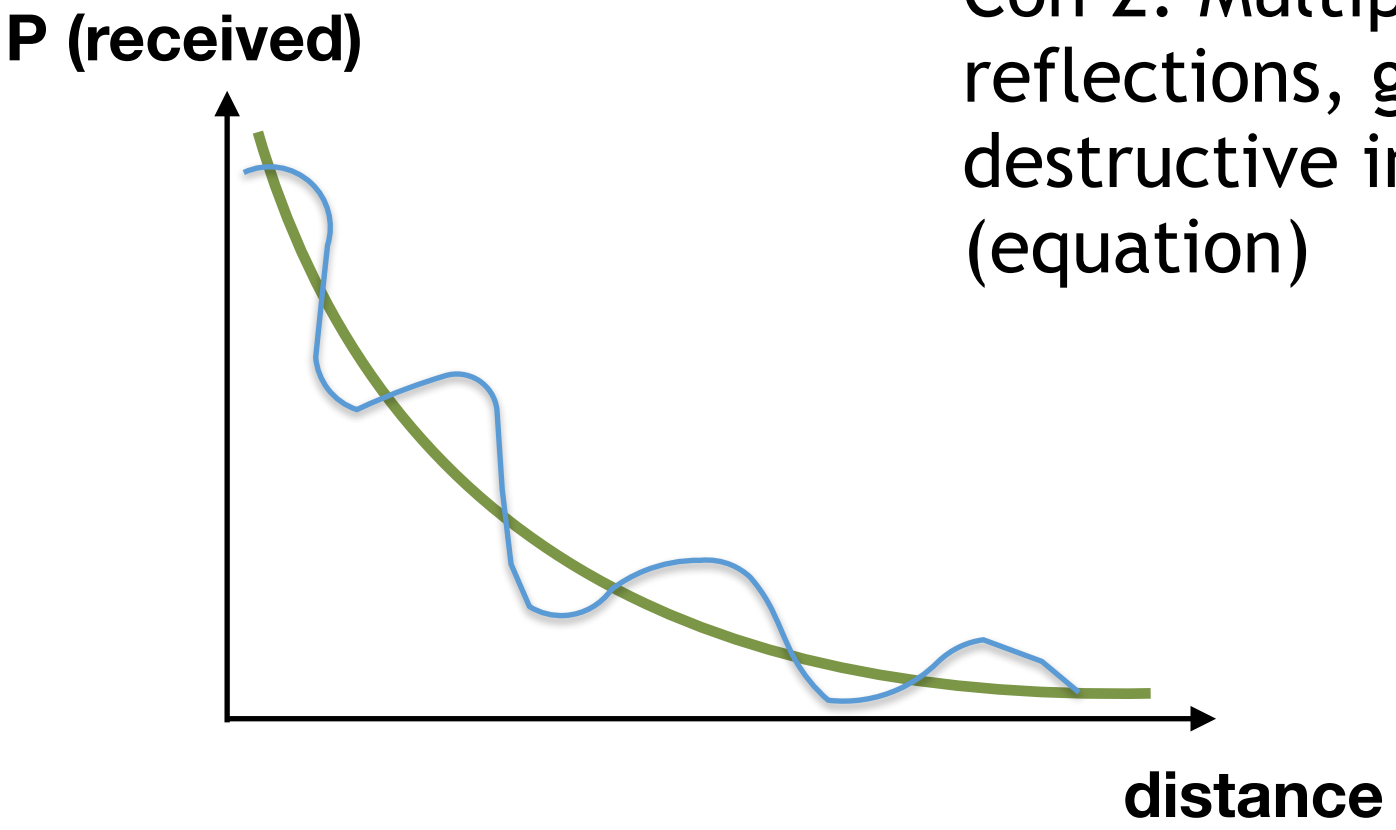


Con 1: Small change in power leads to large deviations in distance at larger distances

2) Received Signal Strength (RSSI)

From power to distance

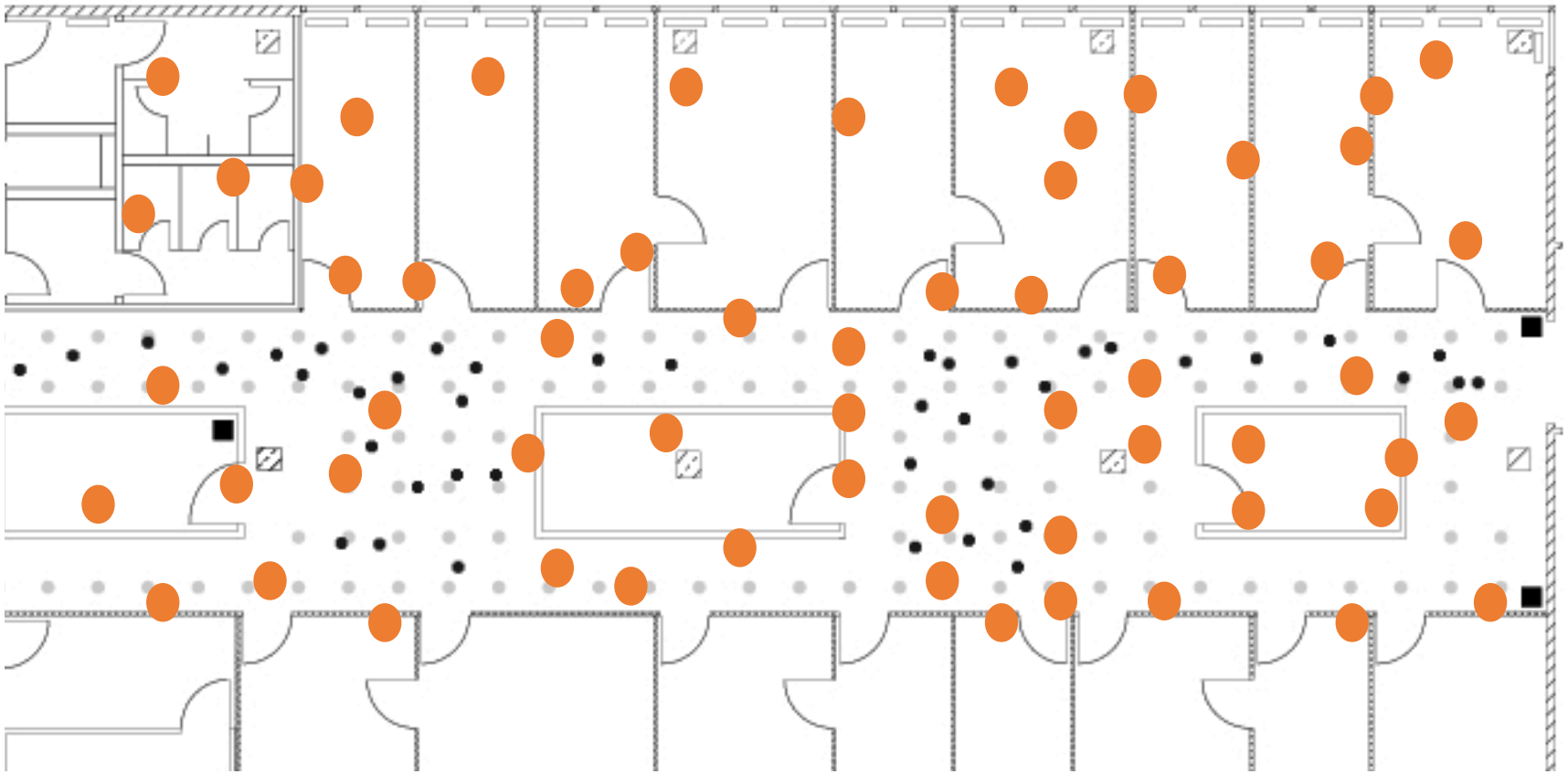
Power is proportional to $1/d^2$



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

2) Received Signal Strength (RSSI)

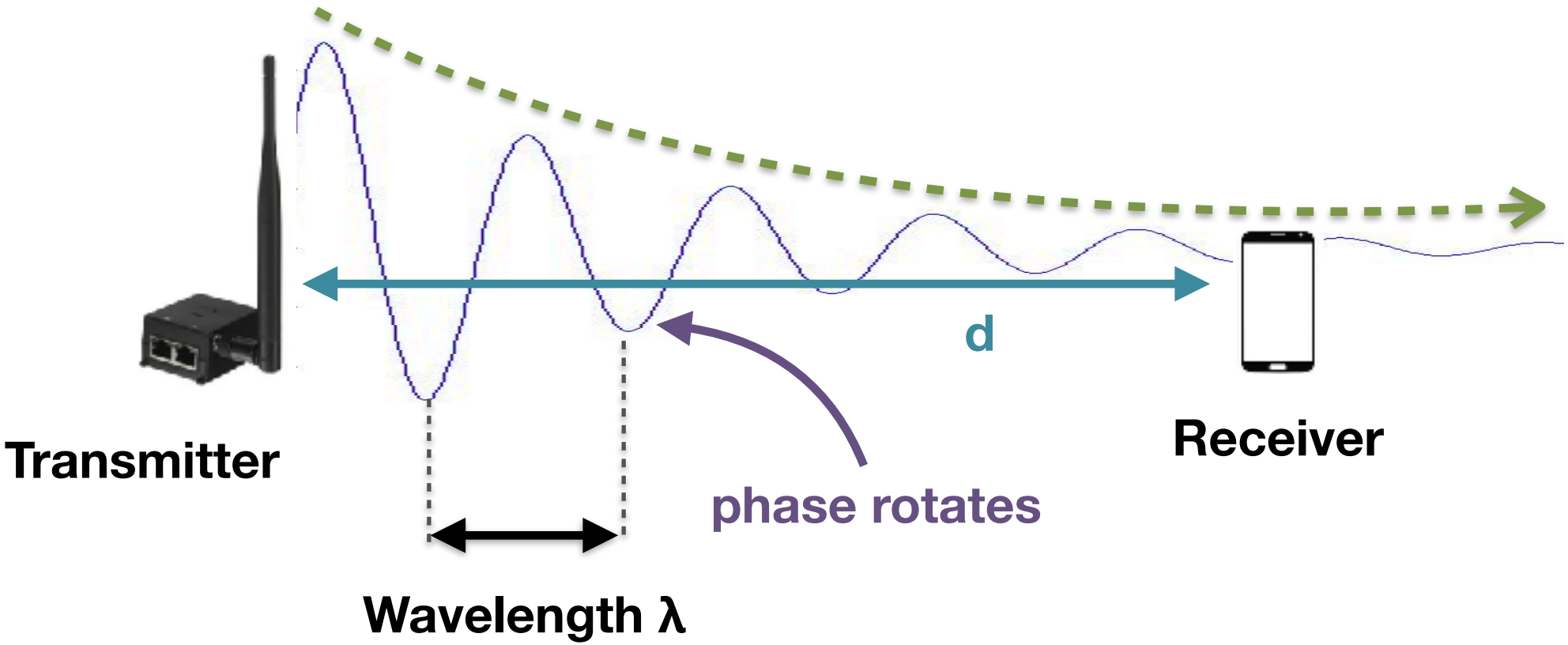
Solution: Fingerprinting
i.e., measuring device records signal strength fingerprints at each location



Pros? Cons?

3) Use the Signal “Phase”

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

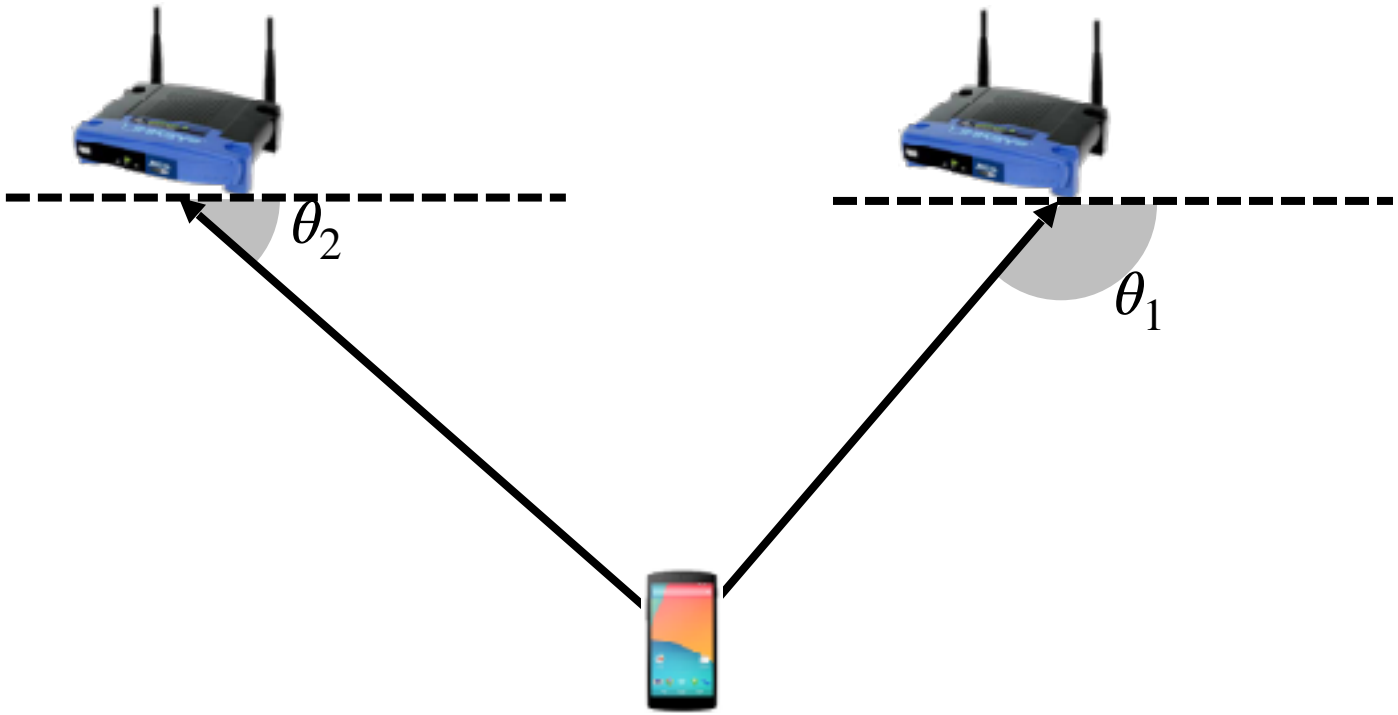


Pros? Cons?

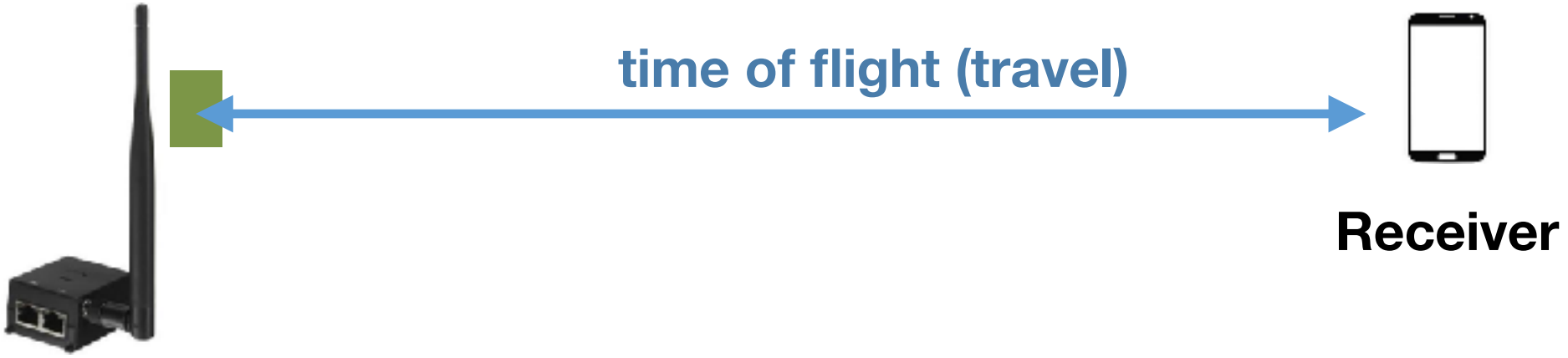
4) Use Angle of Arrival (AoA)

Triangulation from Angular Measurements

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



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

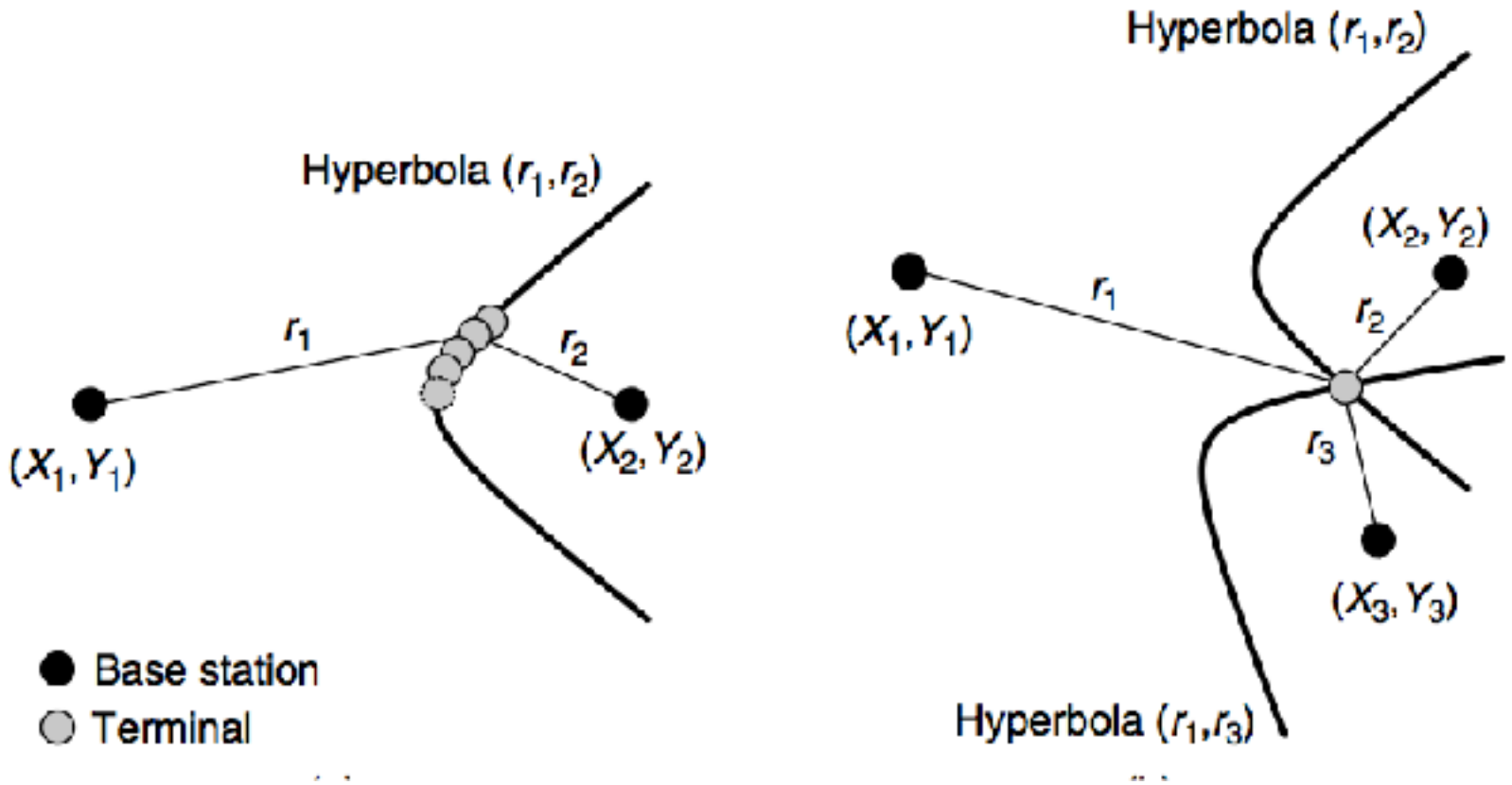


Distance = Time of flight x speed of travel

Can use trilateration (intersection circles/spheres)

How do we know when the signal was transmitted?

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

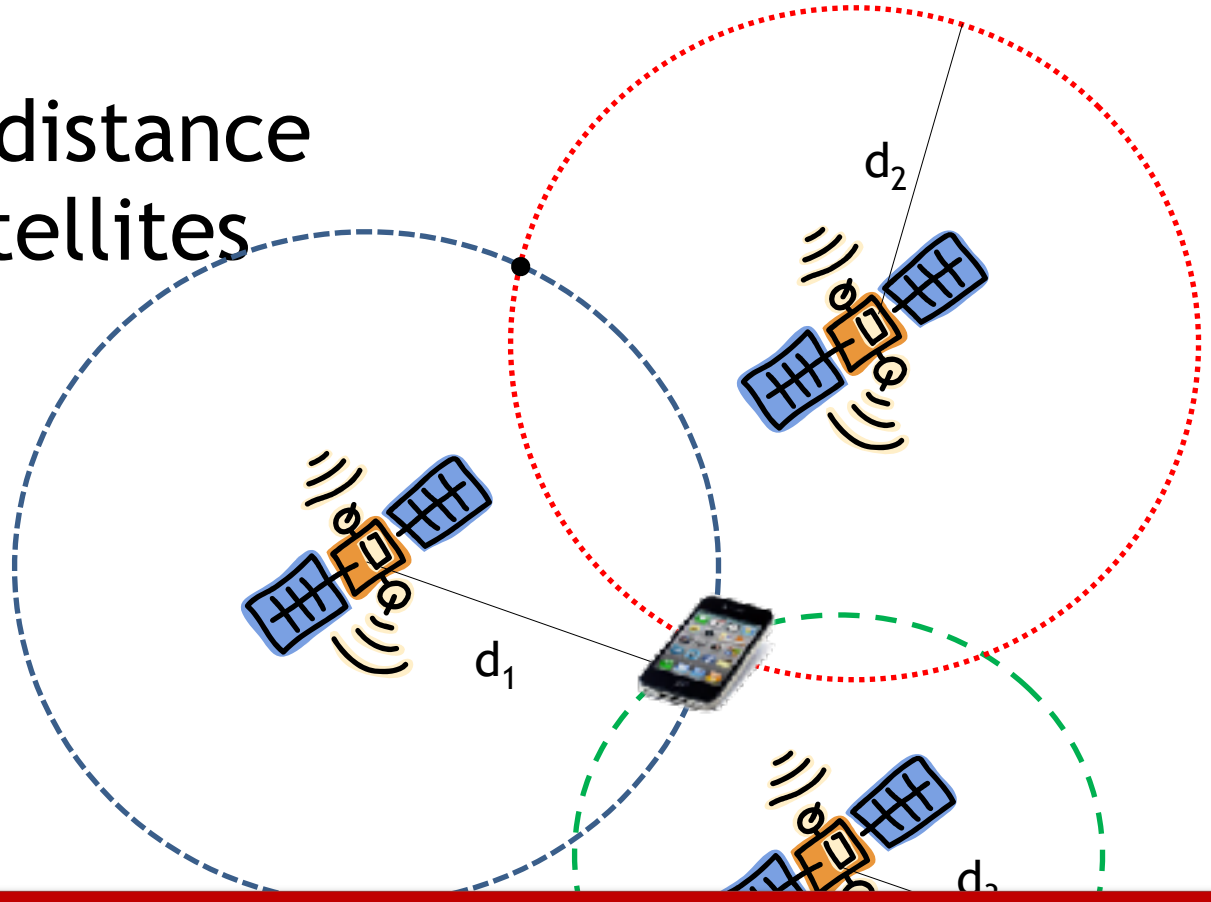


State-of-the-Art Techniques?

- 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
- …

GPS

Compute the distance to the GPS satellites



distance = propagation delay x speed of light

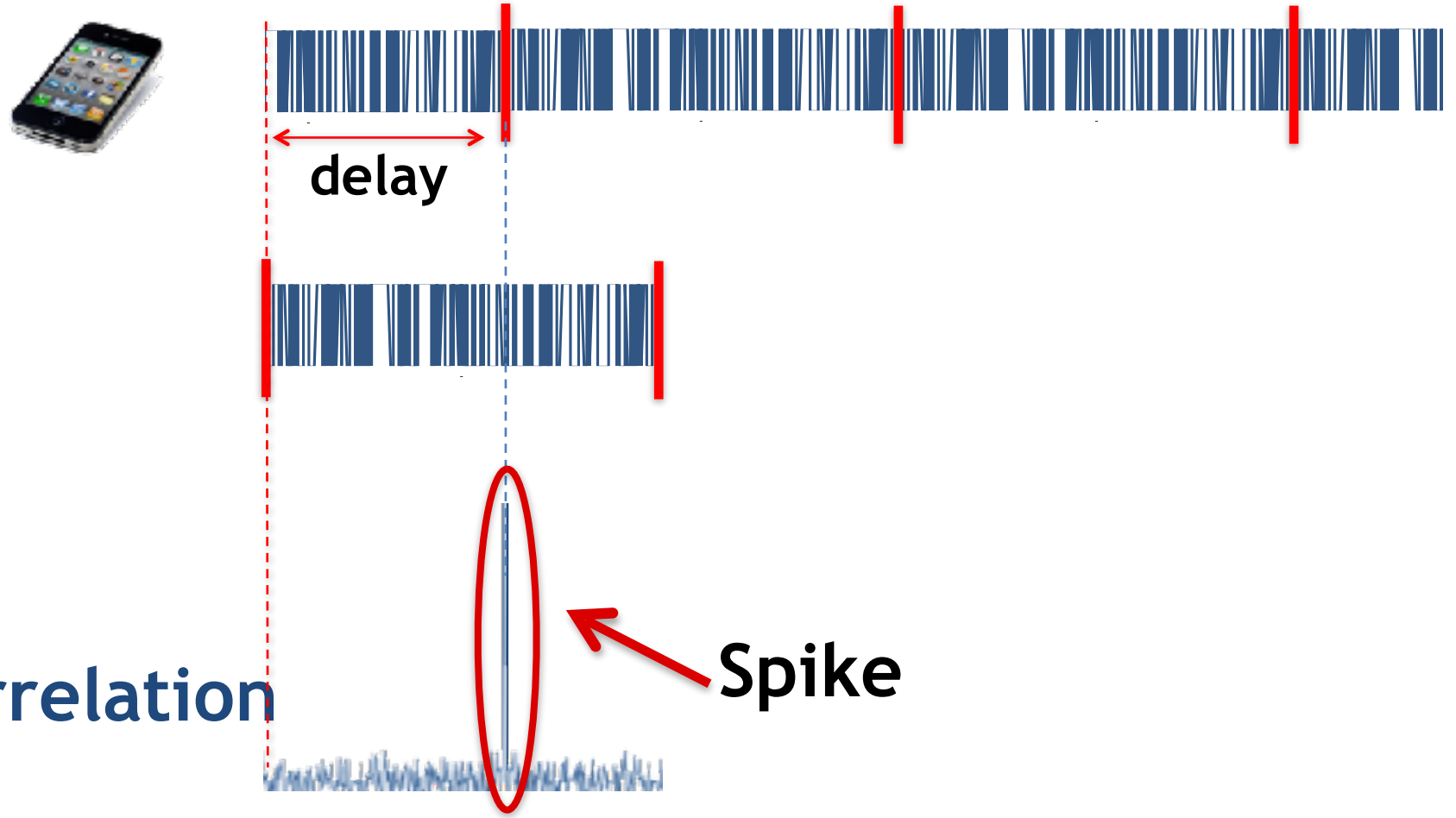
How to Compute the Propagation Delay?

Each satellite has its own code

How to Compute the Propagation Delay?

Code arrives shifted by propagation delay

How to Compute the Propagation Delay?



Spike determines the delay

use it to compute distance and localize

GPS Data Packet

- Almanac & ephemeris data
  - Satellite location, clock, orbital parameters, etc.
  - Bitrate?
    - 50 bits/second
  - Takes about 12.5 minutes to download

- How do today's systems use it?
  - A-GPS (Assisted GPS)
  - WiFi APs are mapped — war-driving

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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