# 6.S062: Mobile and Sensor Computing

aka IoT Systems

## Lecture 2:
## Introduction to Positioning and Indoor Positioning Systems

# What is Wireless Positioning (aka Localization)?

Wireless positioning/localization is the process of obtaining a human or object's location using wireless signals

# Why do we want wireless positioning?

- 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

# What are the different ways of obtaining location?

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

Focus of this lecture

We will discuss the localization techniques in increasing order of sophistication

# Who performs the localization process?

- Device: uses incoming signal from one or more “anchors” to determine its own location
  - Example: GPS
- Network: the anchors (or Access points) use signal coming from device to determine its location
  - Example: Radar

# 1) Identity-based Localization

Idea: Use the identity and known location of anchor nodes

Example:

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

Localize by mapping to one of those locations.

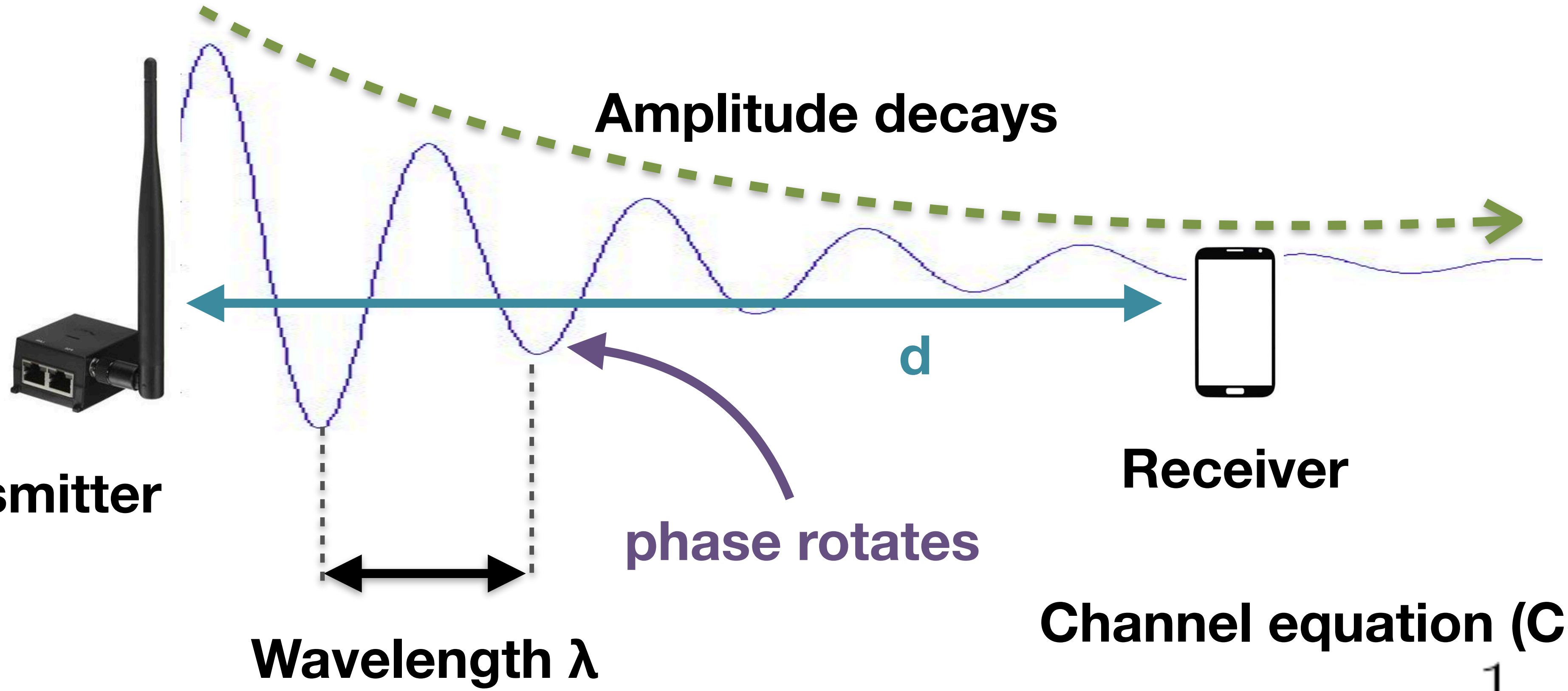
Pros? Cons?

# 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)**

$$h = \frac{1}{d} e^{j 2\pi \frac{d}{\lambda}}$$

# Wireless Signals are Waves

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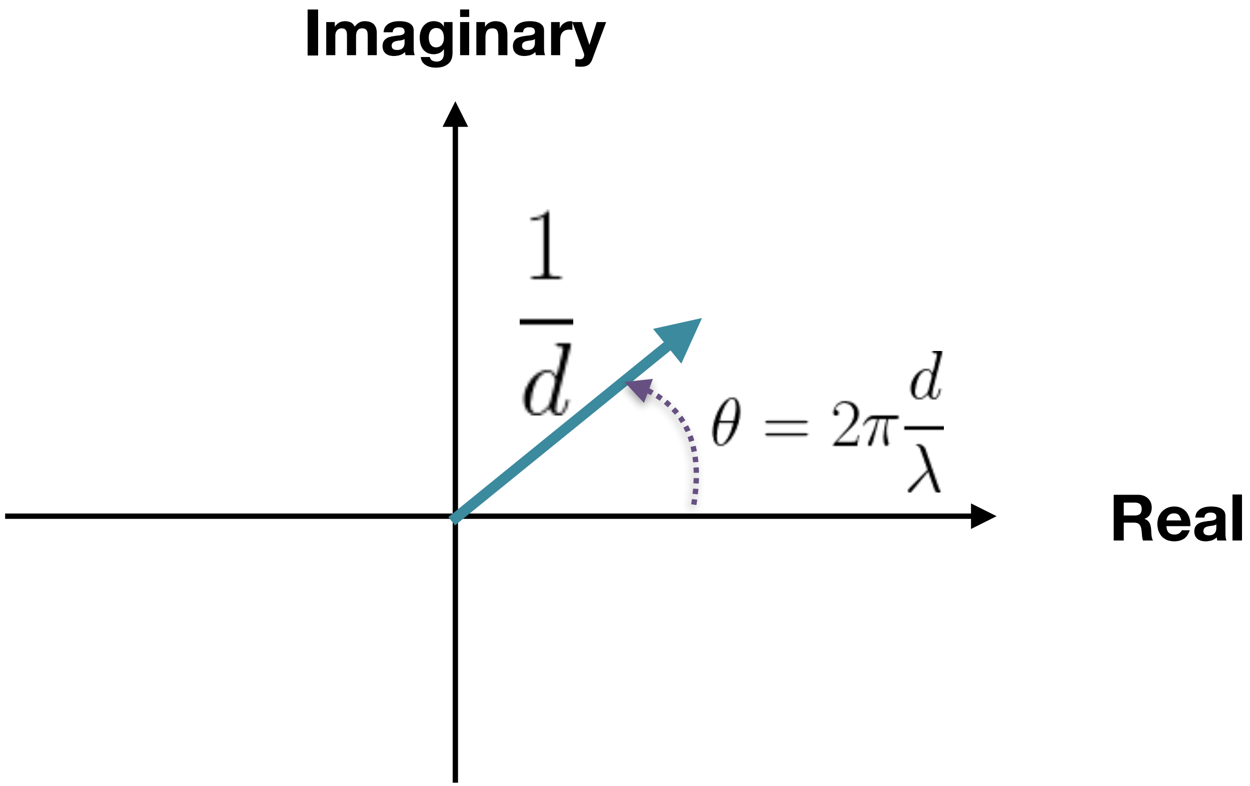
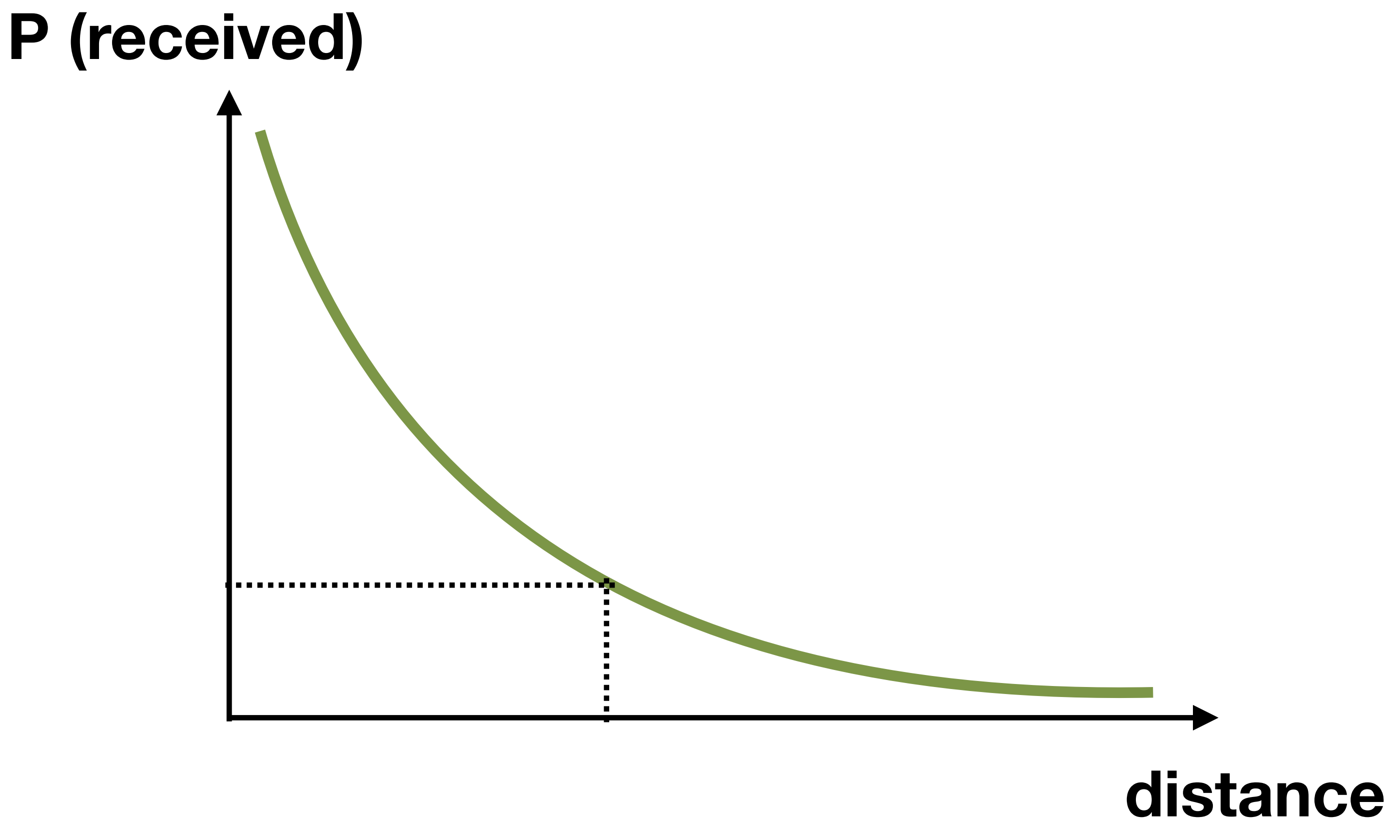


# 2) Received Signal Strength (RSSI)

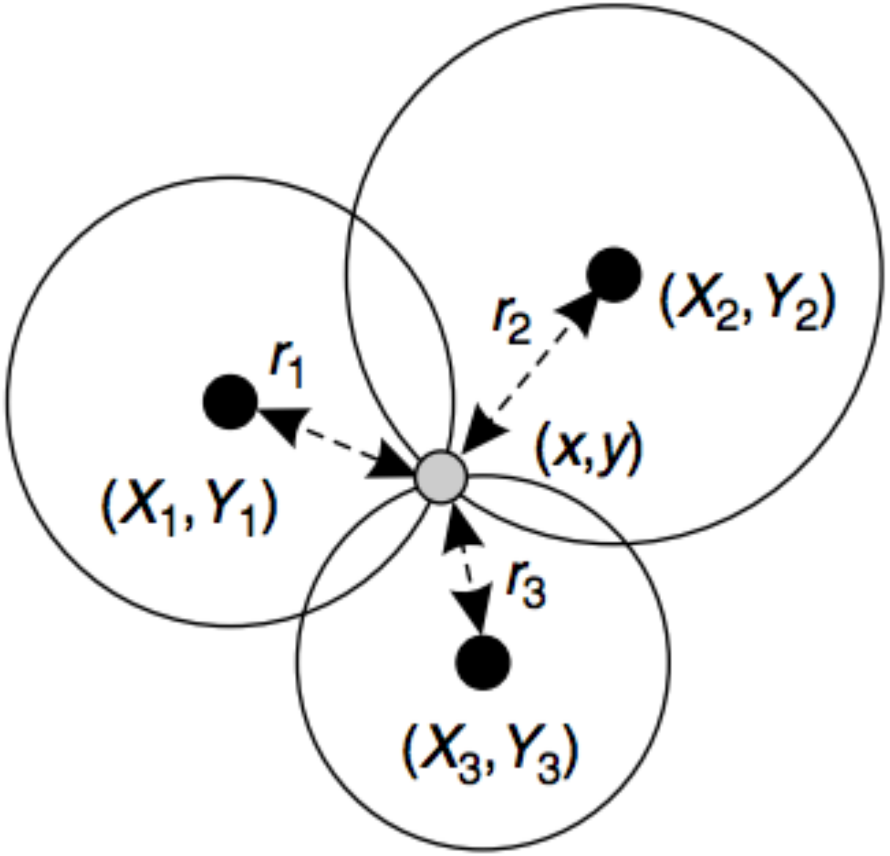
## From power to distance

Power is proportional to $1/d^2$



# 2) Received Signal Strength (RSSI)

## Trilateration from Distance Measurements

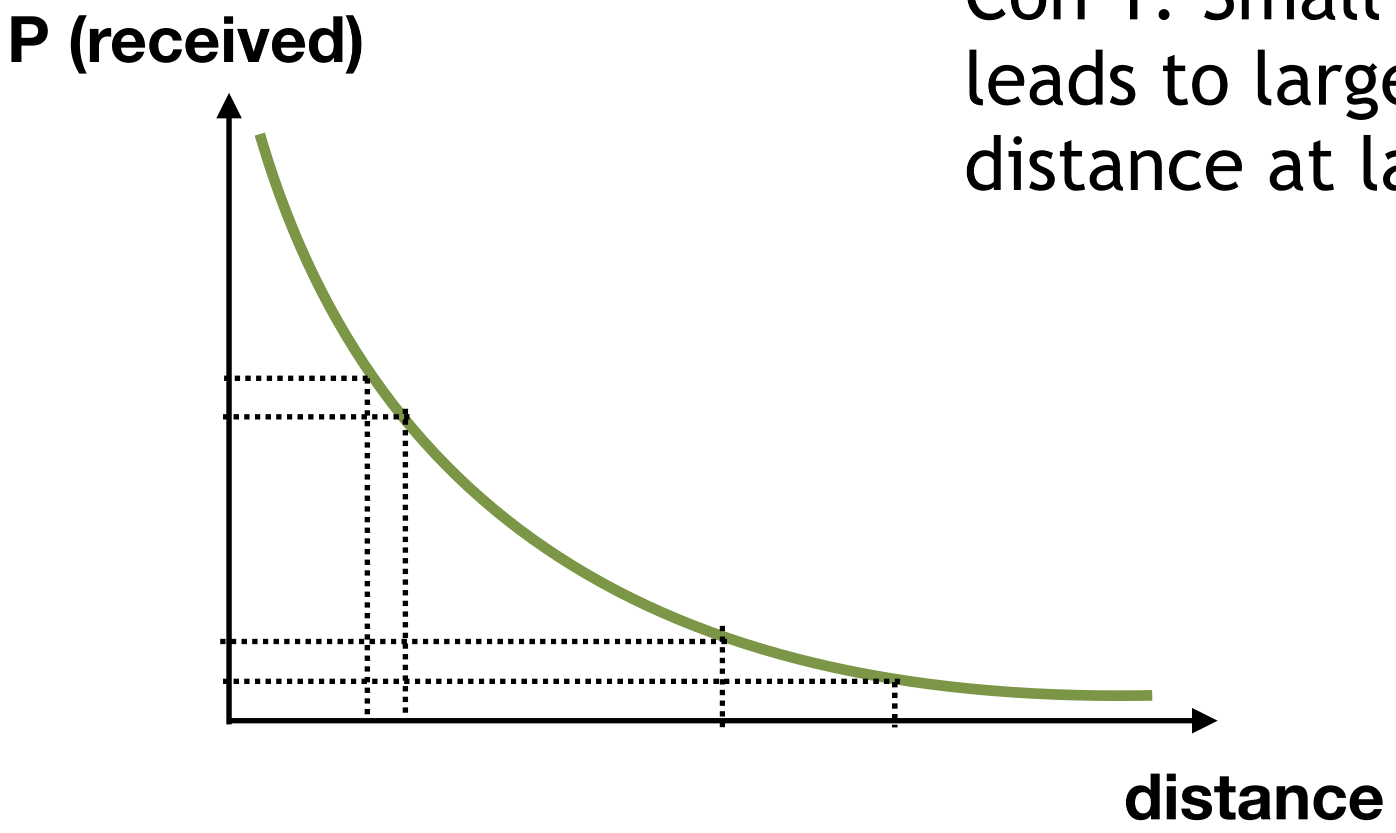



Pros? Cons?

# 2) Received Signal Strength (RSSI)

## From power to distance

Power is proportional to $1/d^2$

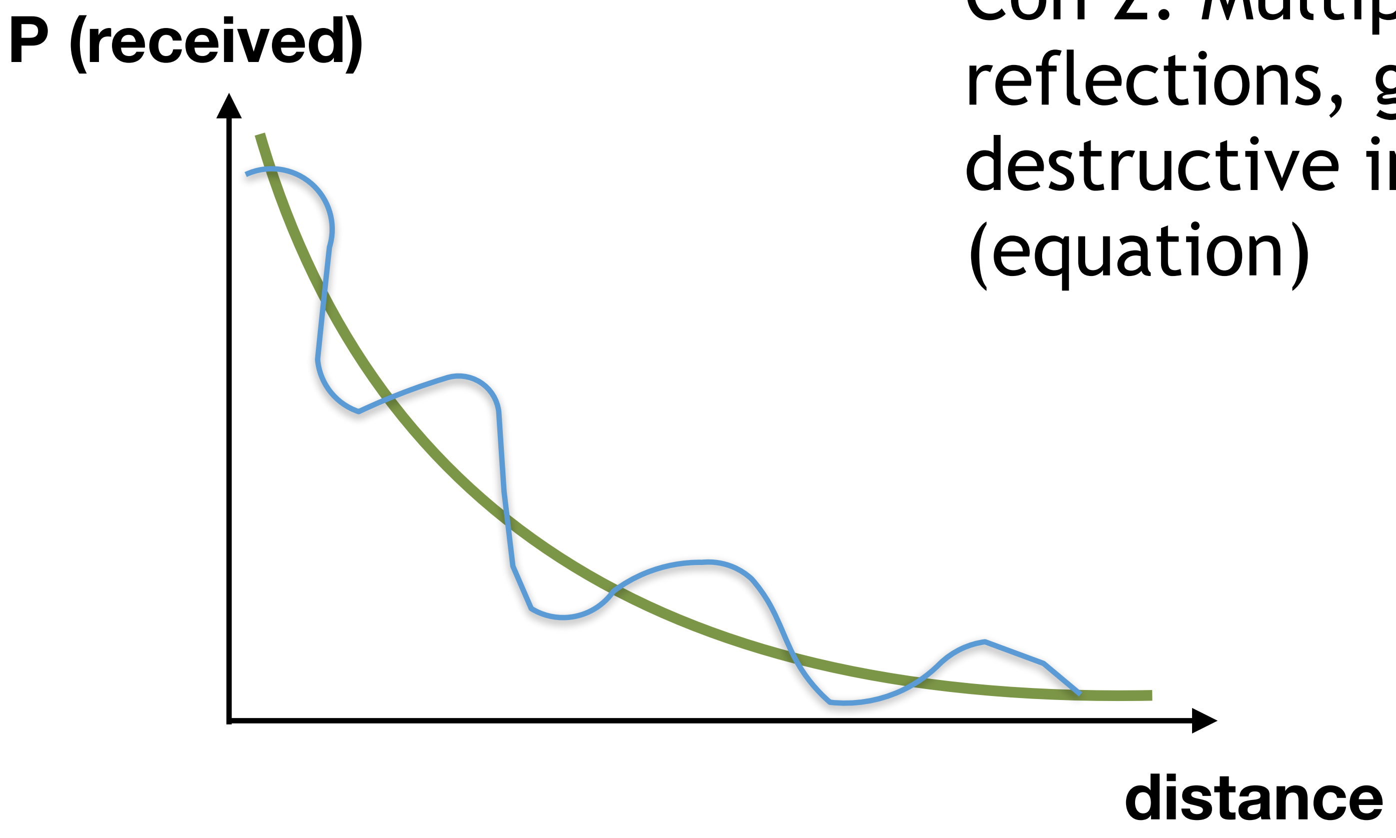



Con 1: Small change in power leads to large deviations in distance at larger distances

# 2) Received Signal Strength (RSSI)

## From power to distance

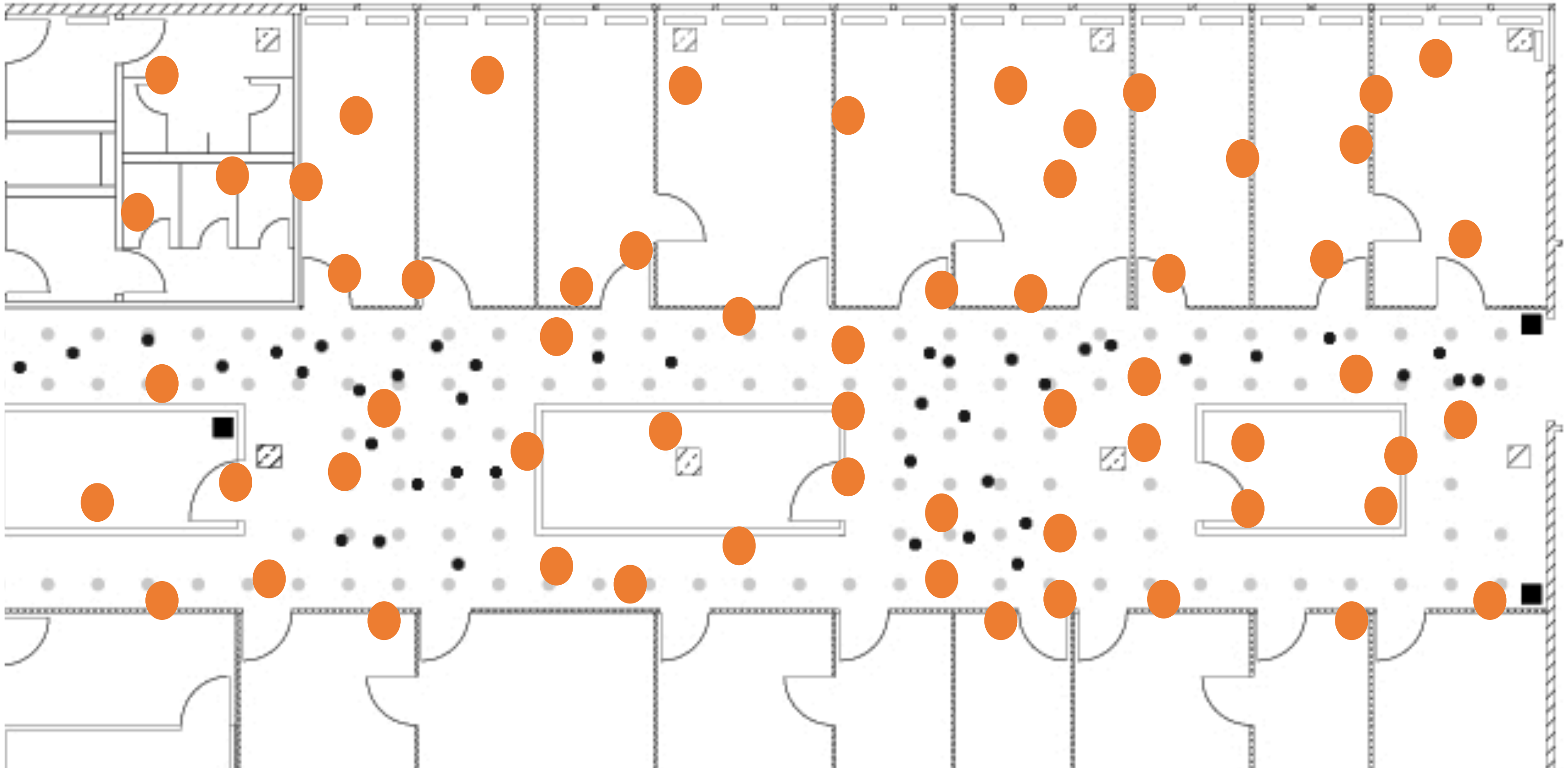
Power is proportional to $1/d^2$




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

# 2) Received Signal Strength (RSSI)

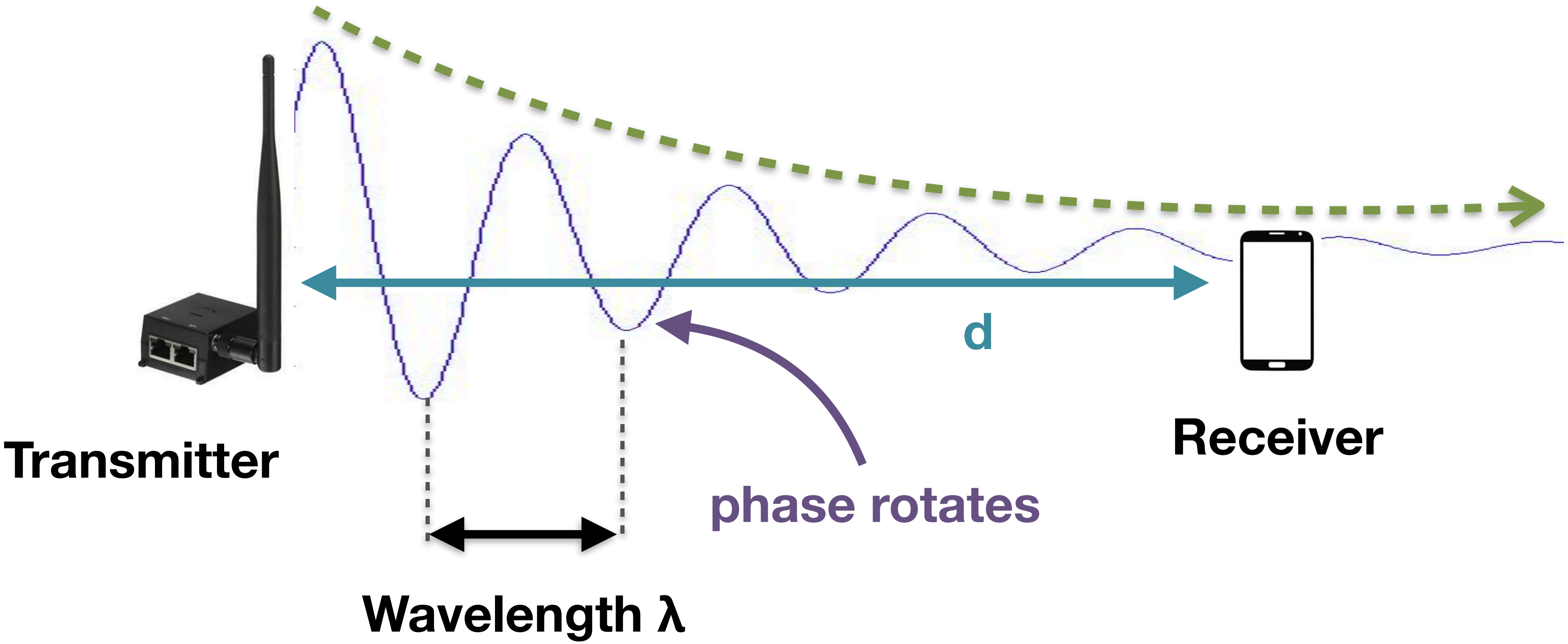
<u>Solution:</u> Fingerprinting
i.e., measuring device records signal strength fingerprints at each location



Pros? Cons?

# 2) Use the Signal "Phase"

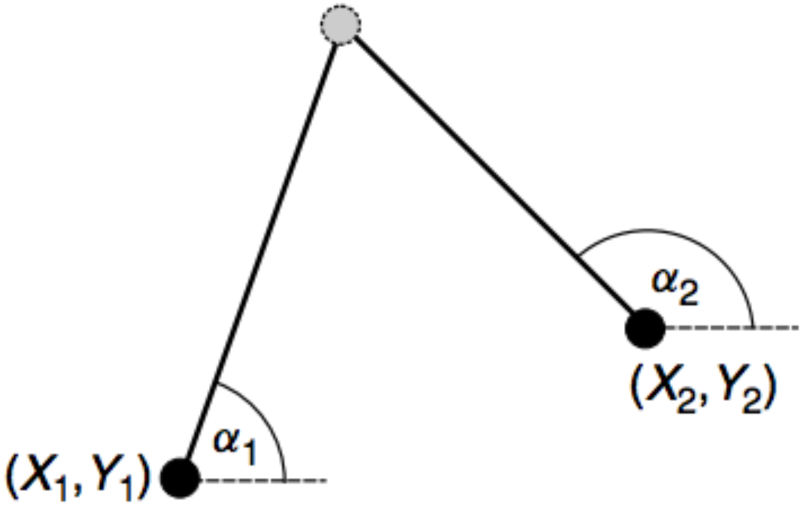
**Phase** $\phi = 2\pi \frac{d}{\lambda}$




Pros? Cons?

# 3) Use Angle of Arrival (AoA)

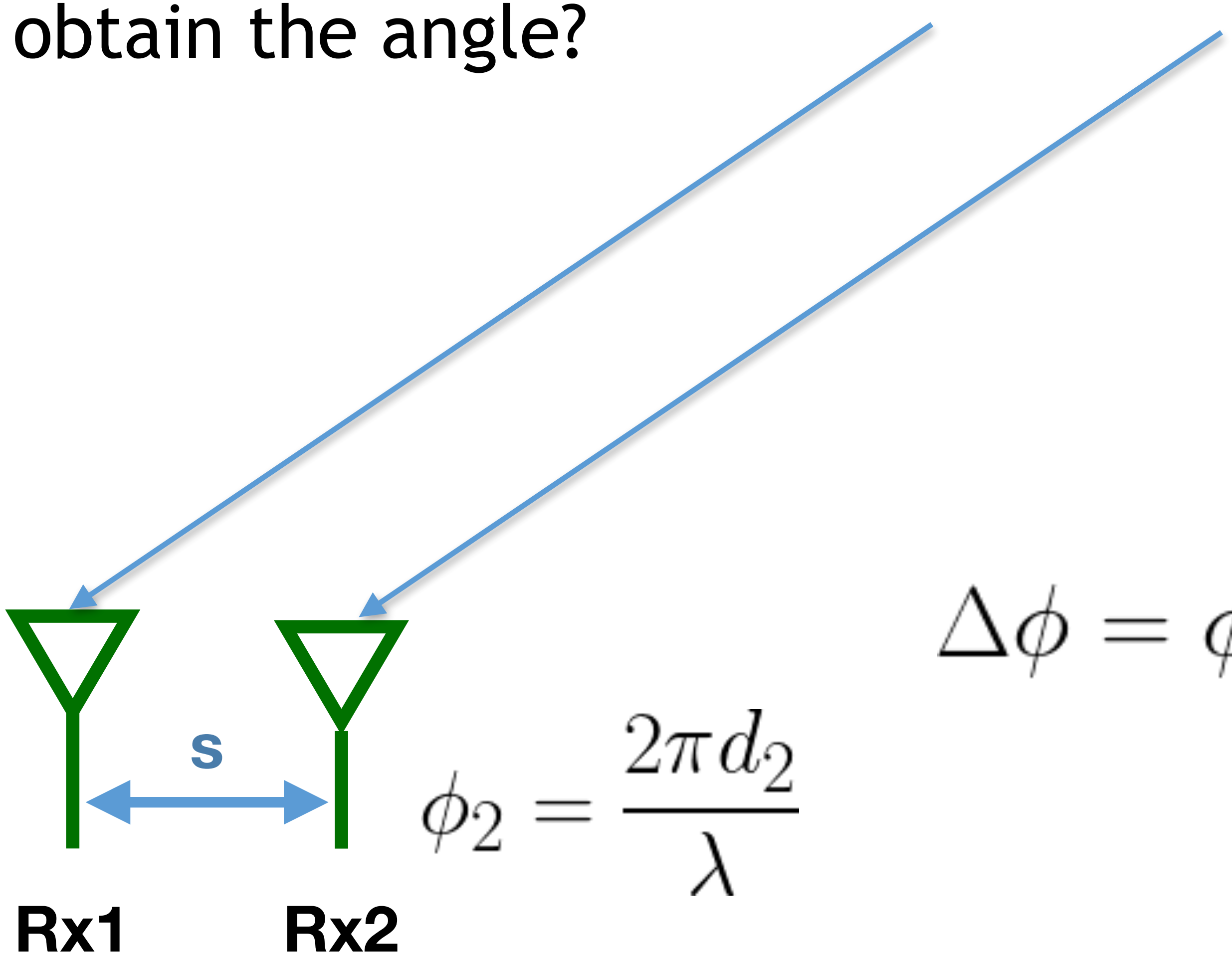
Triangulation from Angular Measurements



# 3) Use Angle of Arrival (AoA)

## Triangulation from Angular Measurements

How can we obtain the angle?




$$\phi_1 = \frac{2\pi d_1}{\lambda}$$

$$\phi_2 = \frac{2\pi d_2}{\lambda}$$

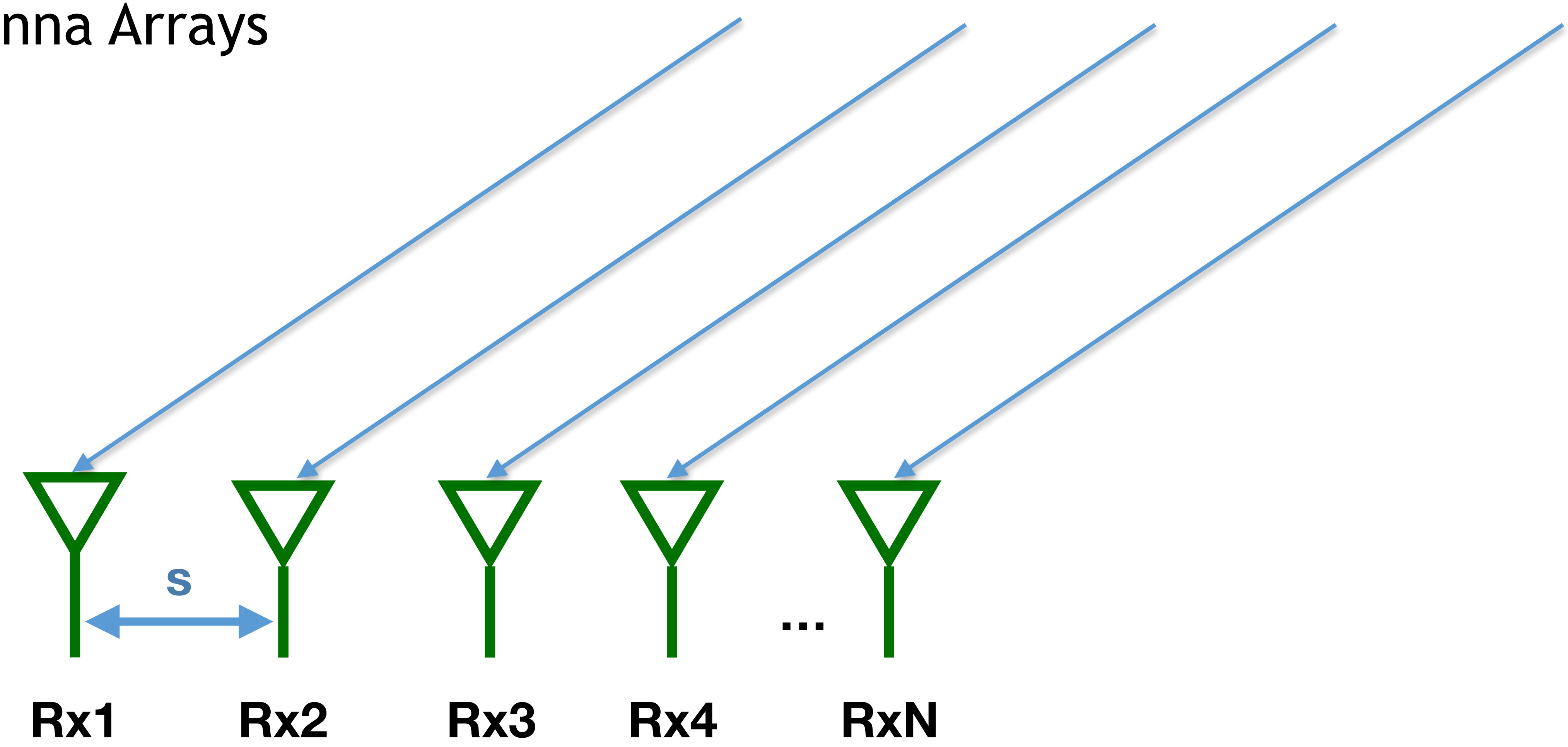
$$\Delta\phi = \phi_1 - \phi_2 = \frac{2\pi s \cos\theta}{\lambda}$$

**Issues?**

# 3) Use Angle of Arrival (AoA)

## Triangulation from Angular Measurements

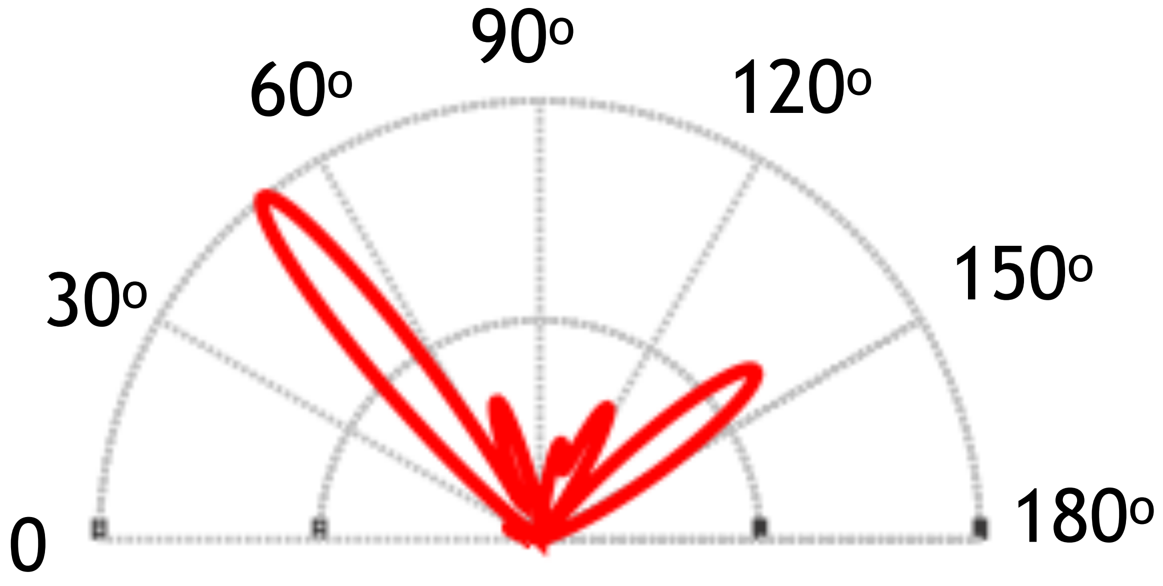
Use Antenna Arrays



# 3) Use Angle of Arrival (AoA)

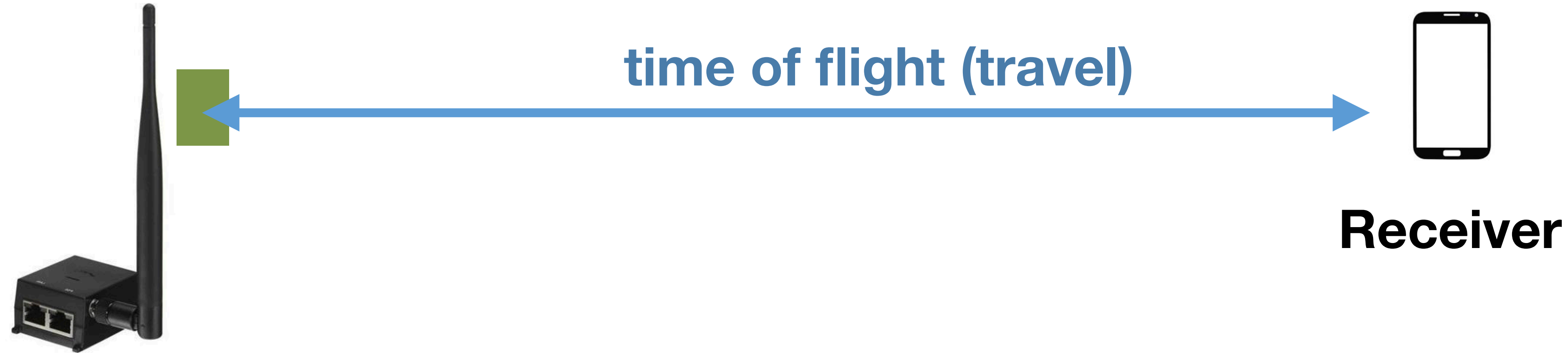
## Triangulation from Angular Measurements

Use Antenna Arrays




How do we know which direction corresponds to the direct path?

# 4) Measure the Time-of-Flight (ToF)



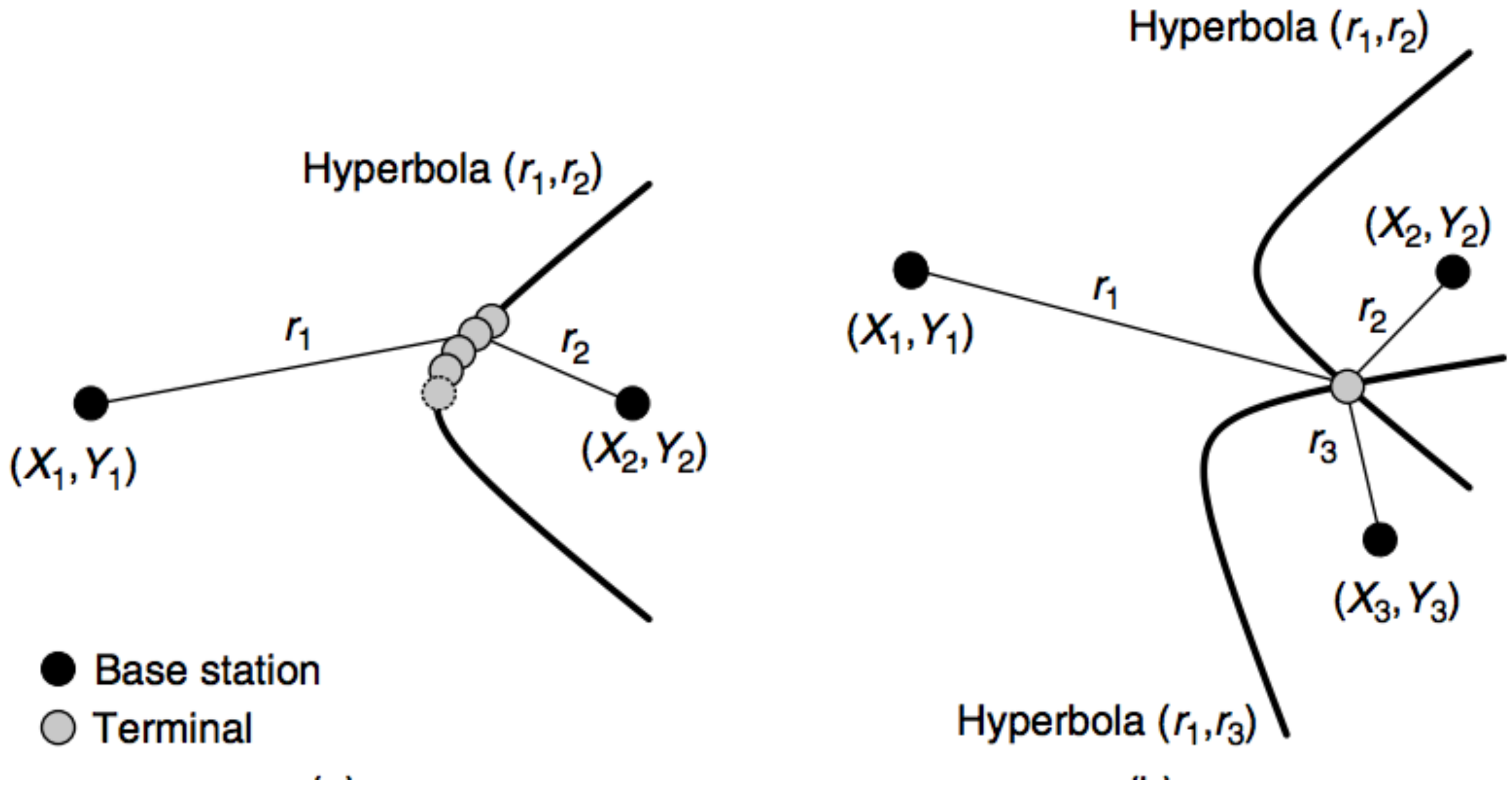

**Transmitter**

Distance = Time of flight x speed of travel

Can use trilateration (intersection circles/spheres)

How do we know when the signal was transmitted?

# 5) 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
- …