

# 6.808: Mobile and Sensor Computing

aka IoT Systems

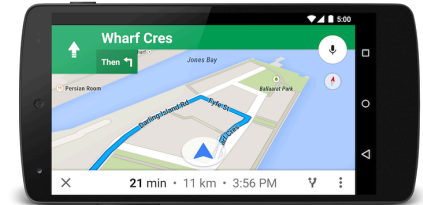
## Lecture 2: Introduction to Positioning and Indoor Positioning Systems

# 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



# 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

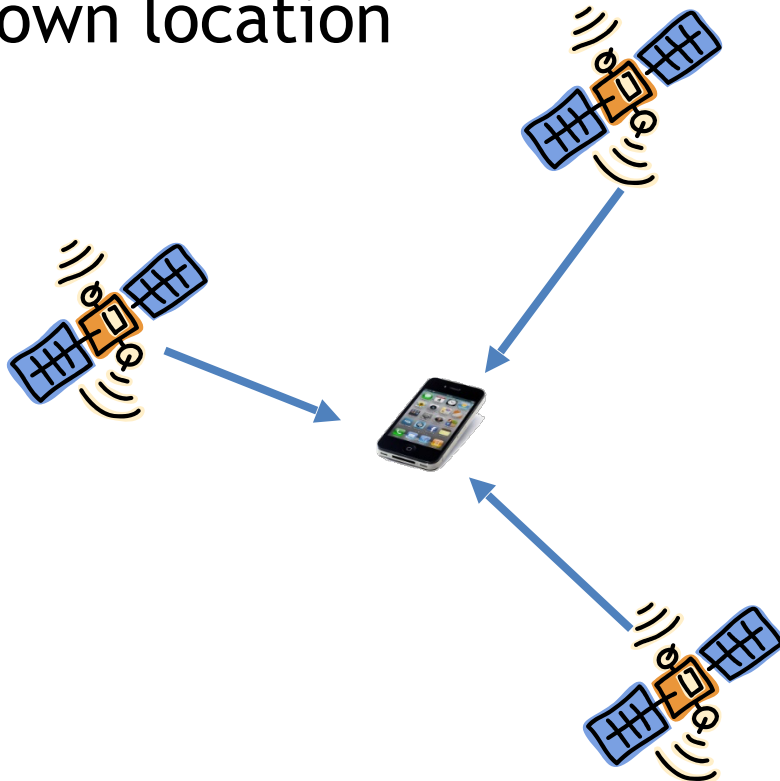
Focus of this lecture



We will discuss the localization techniques in increasing order of sophistication

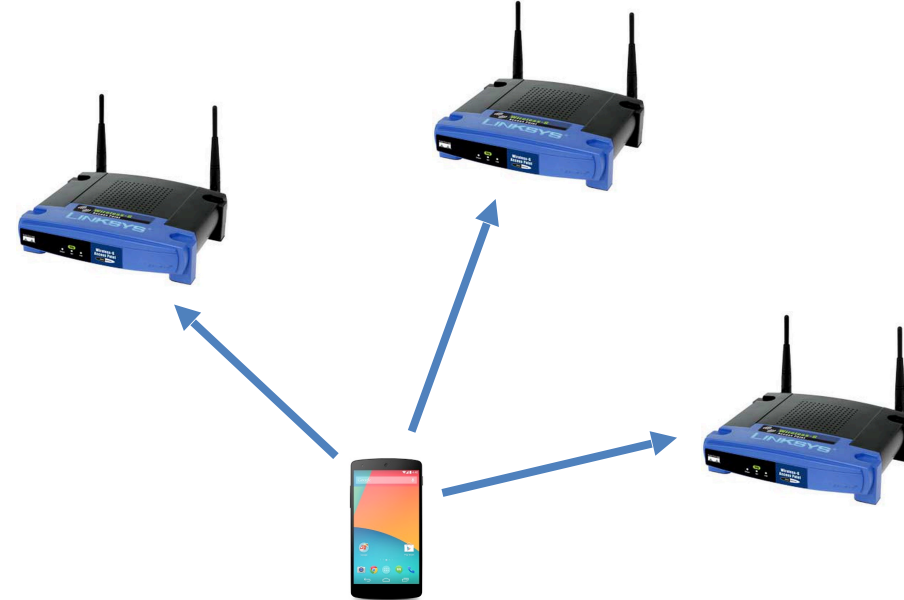
# Who performs the localization process?

- Device 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

# 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.

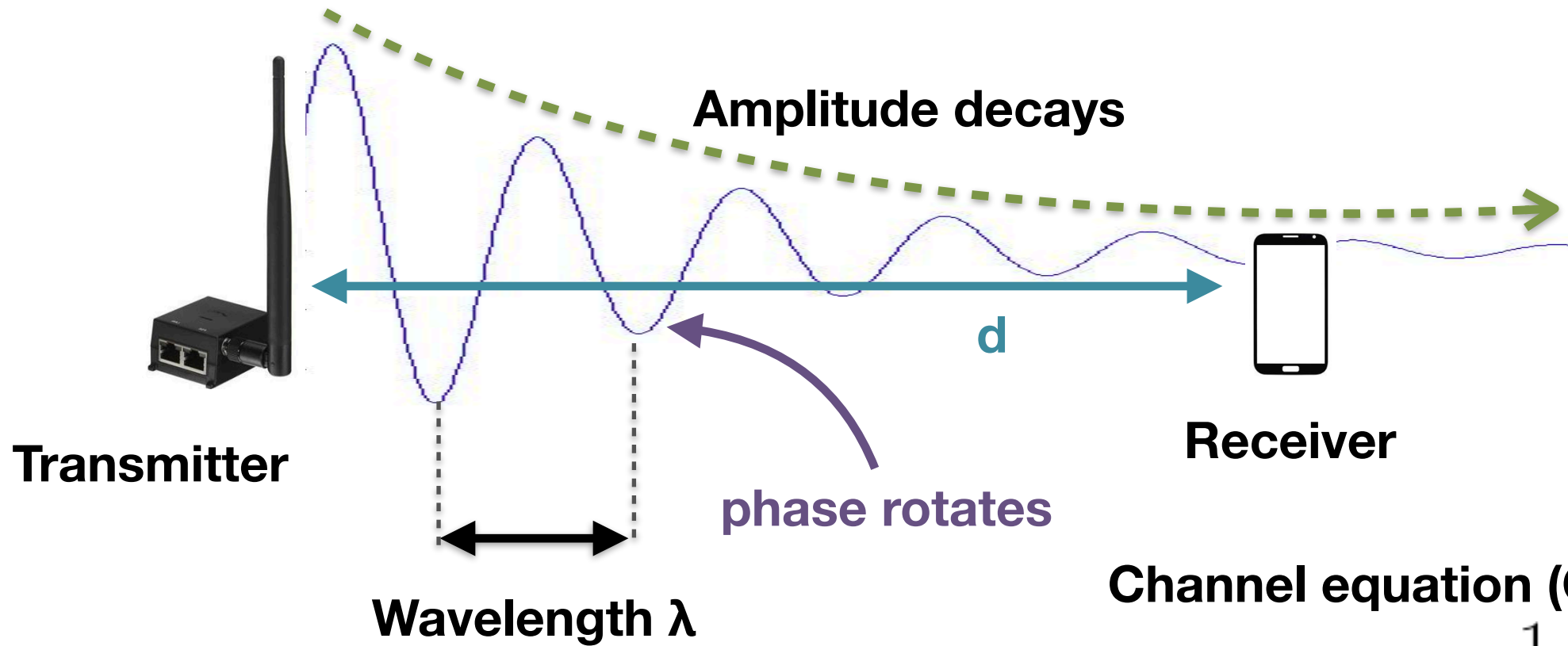
Pros? Cons?

## 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



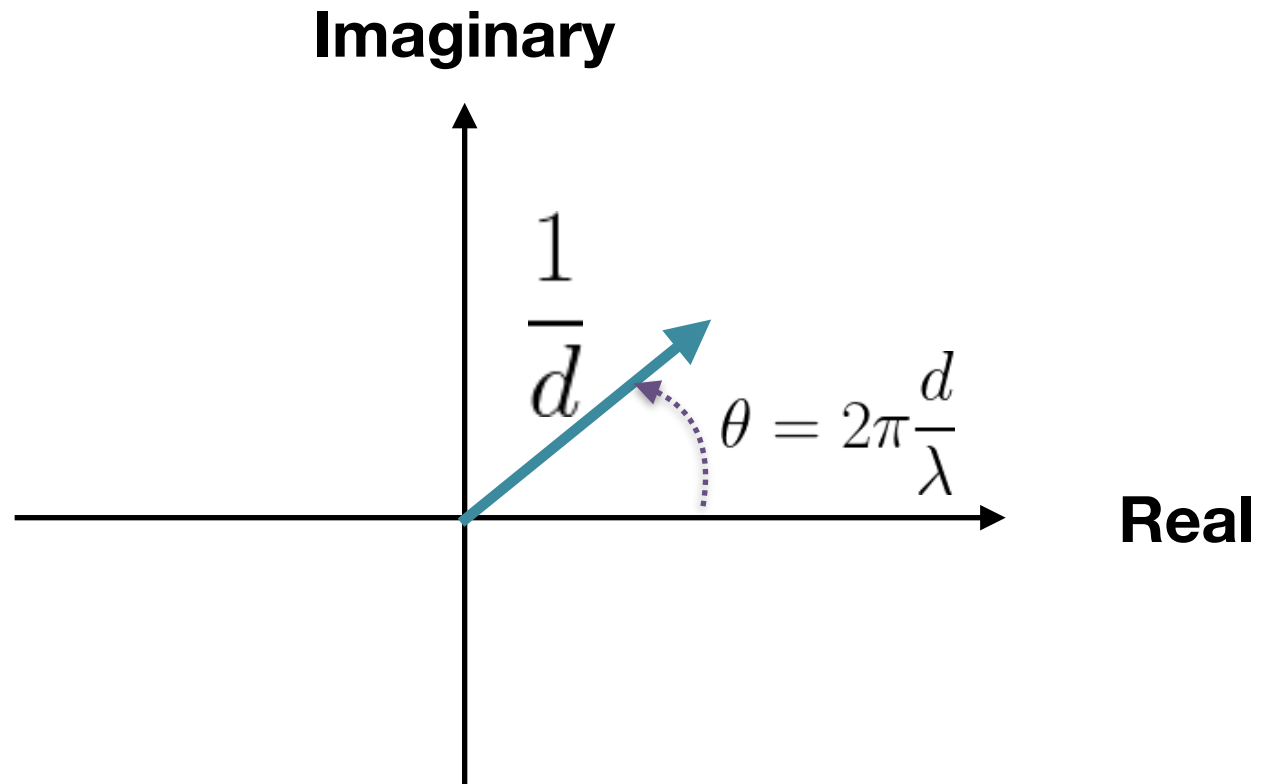
**Channel equation (Complex number)**

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

# Wireless Signals are Waves

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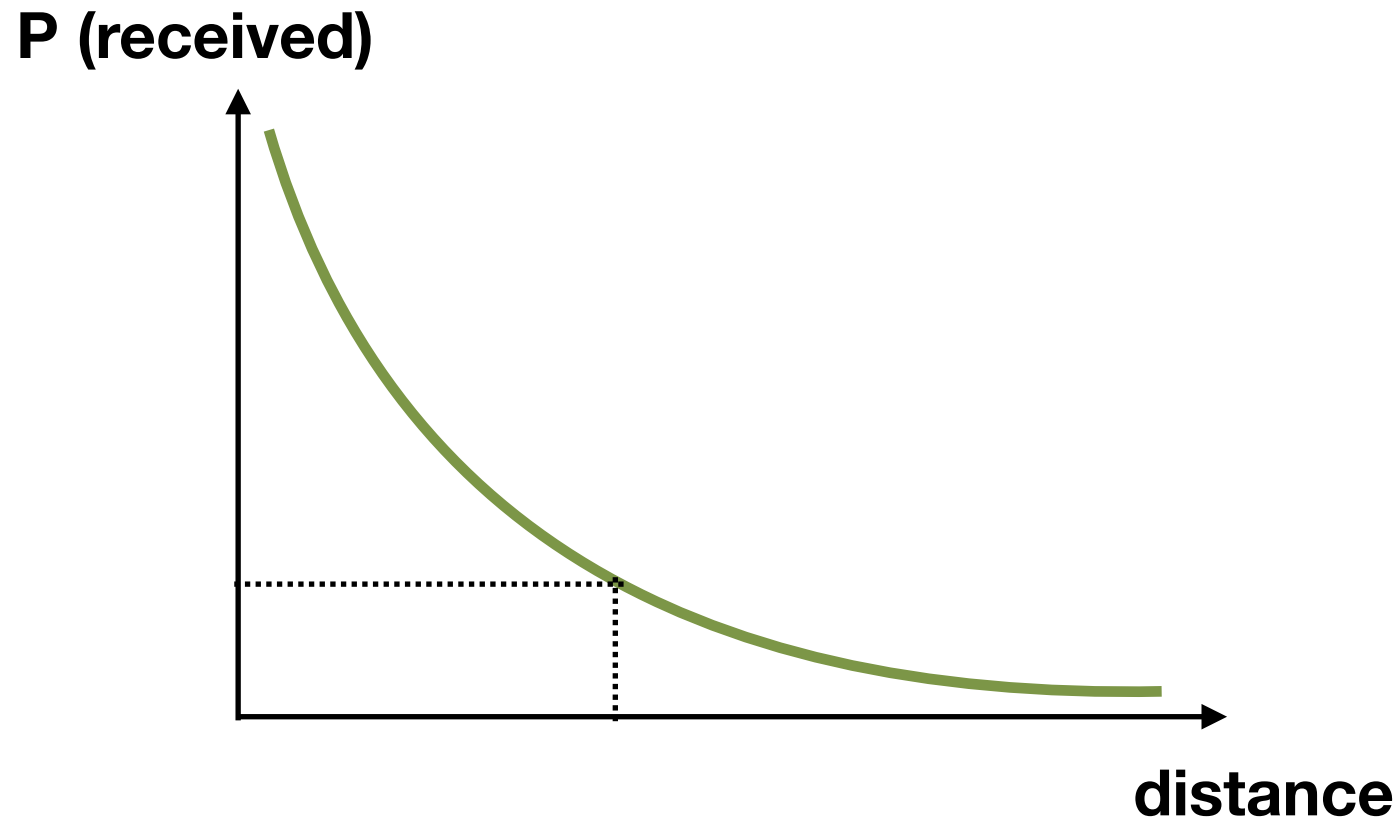




## 2) Received Signal Strength (RSSI)

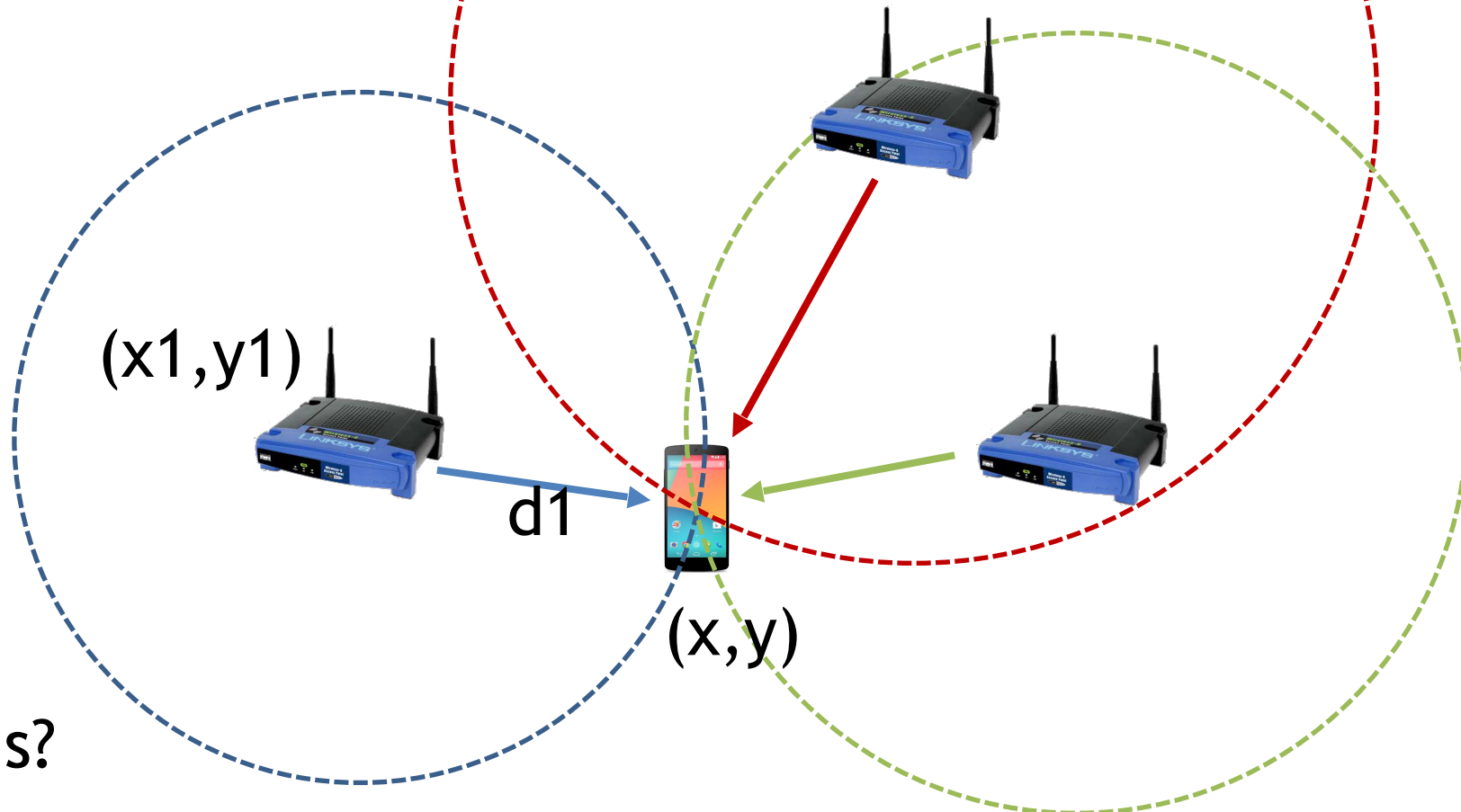
From power to distance

Power is proportional to  $1/d^2$



## 2) Received Signal Strength (RSSI)

### Trilateration from Distance Measurements



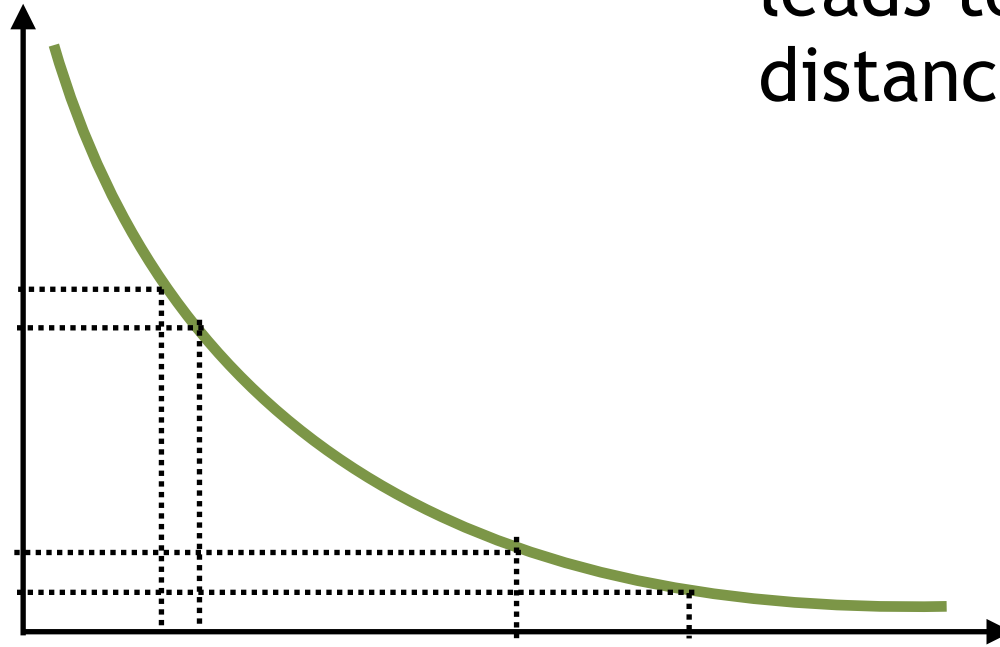
Pros? Cons?

## 2) Received Signal Strength (RSSI)

From power to distance

Power is proportional to  $1/d^2$

**P (received)**



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

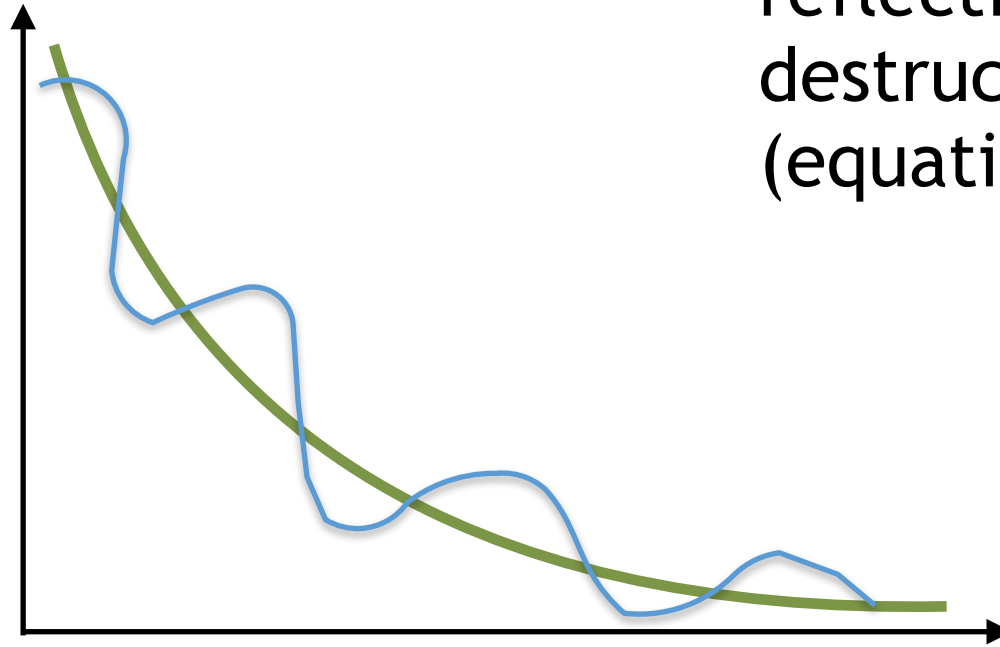
**distance**

## 2) Received Signal Strength (RSSI)

From power to distance

Power is proportional to  $1/d^2$

**P (received)**

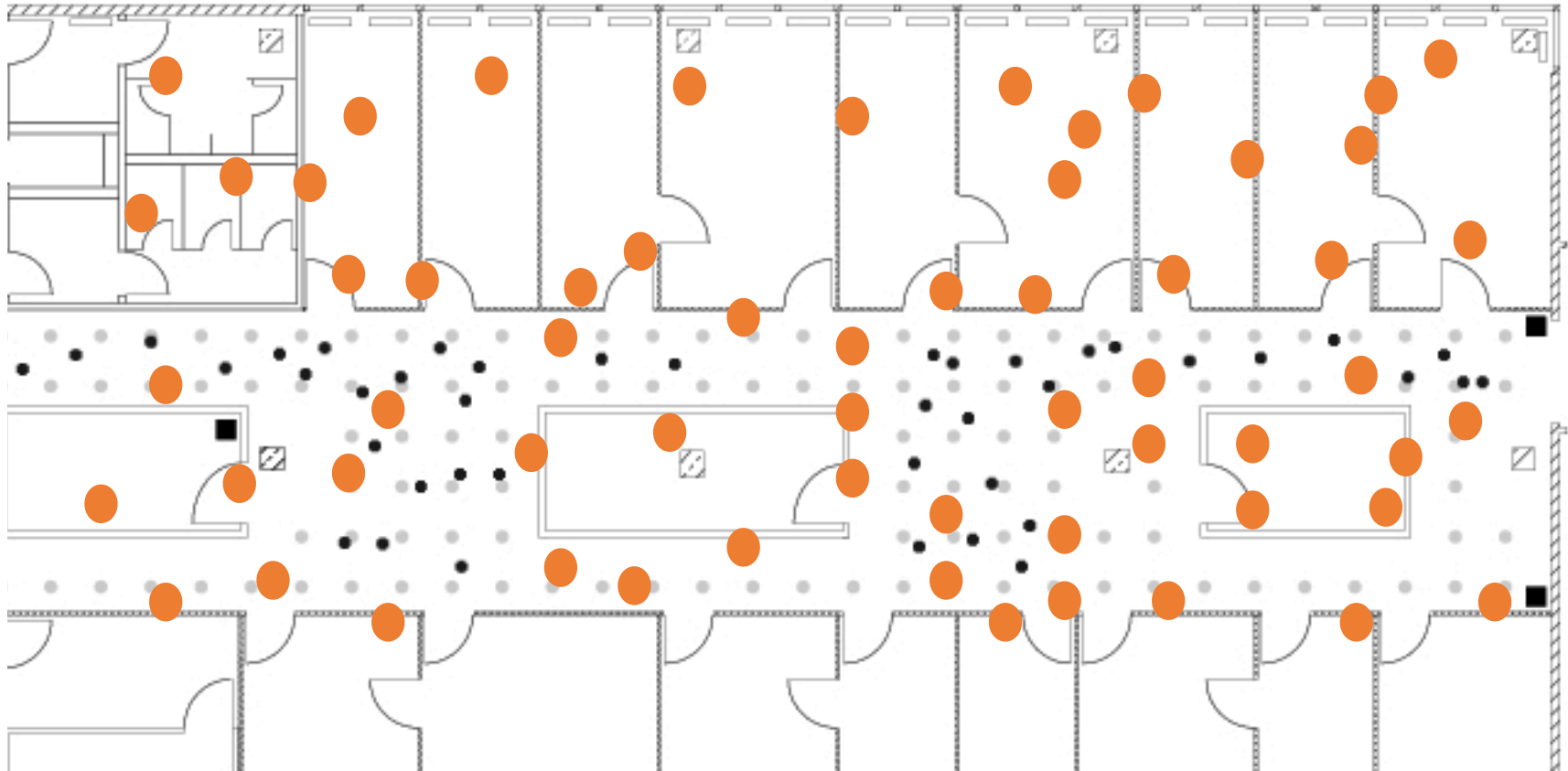


Con 2: Multipath: Due to reflections, get constructive and destructive interference (equation)

## 2) Received Signal Strength (RSSI)

Solution: Fingerprinting

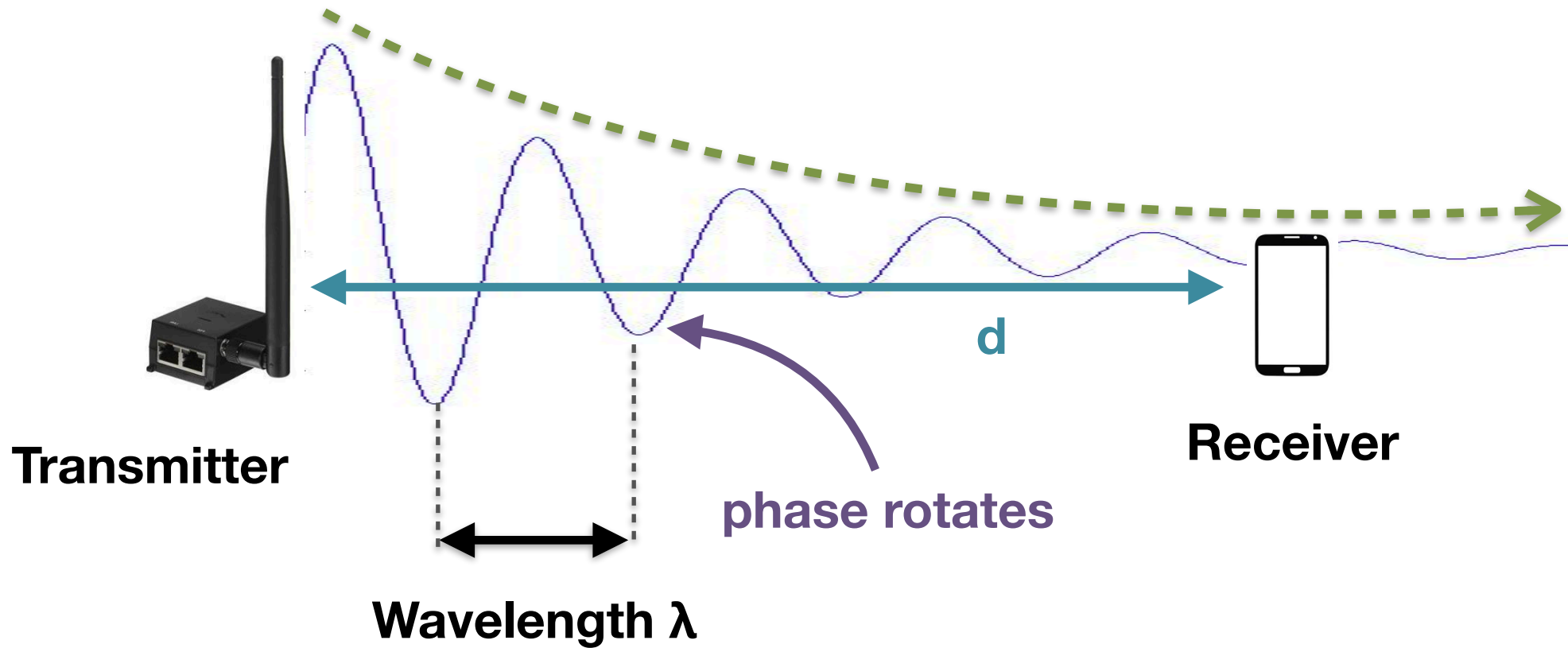
i.e., measuring device records signal strength fingerprints at each location



Pros? Cons?

### 3) Use the Signal “Phase”

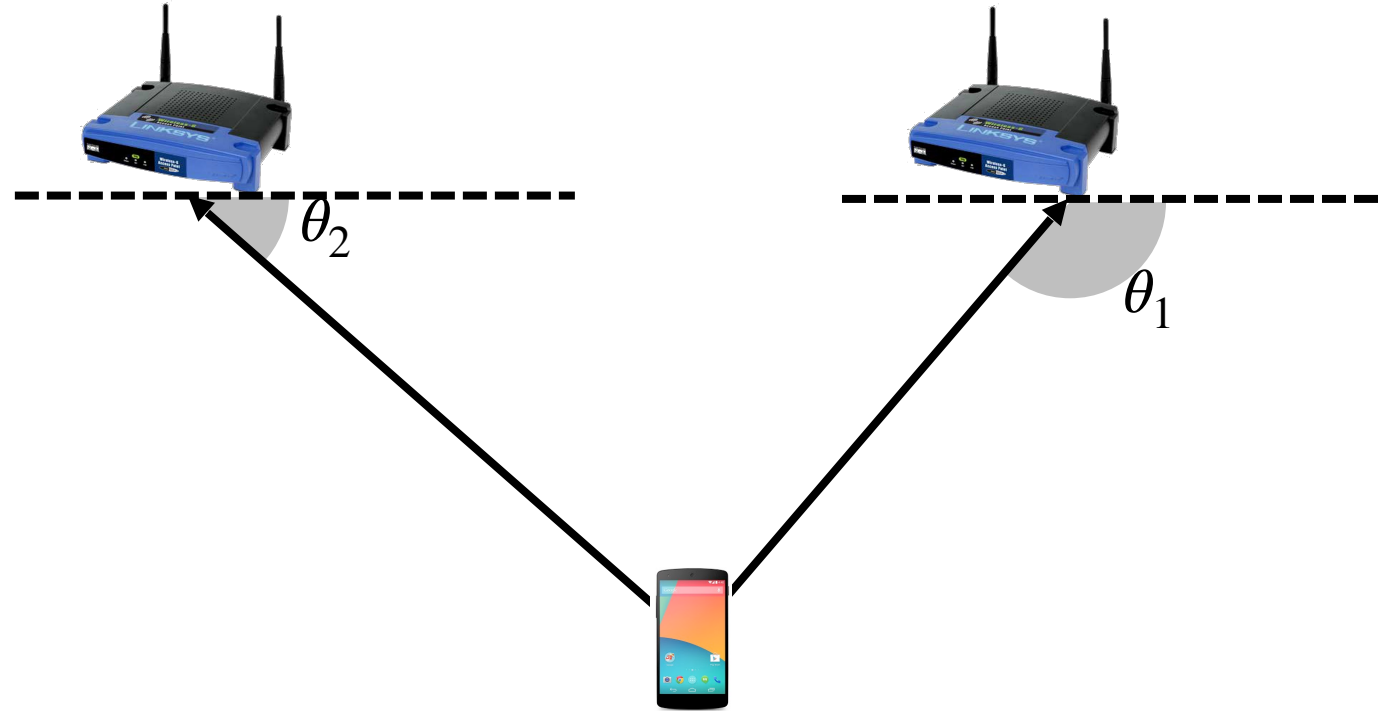
Phase  $\phi = 2\pi \frac{d}{\lambda}$



Pros? Cons?

## 4) Use Angle of Arrival (AoA) Triangulation from Angular Measurements

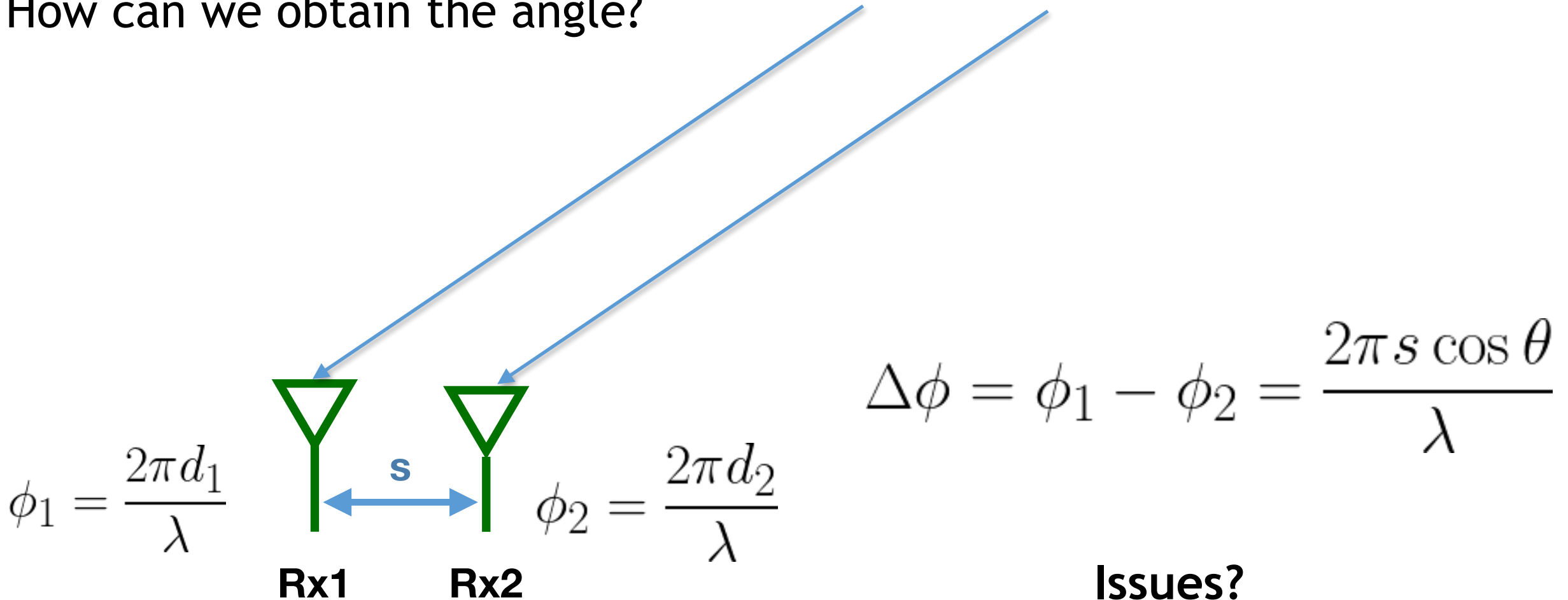
Measure Angle of Arrival (AoA) from device to each AP



## 4) Use Angle of Arrival (AoA)

### Triangulation from Angular Measurements

How can we obtain the angle?

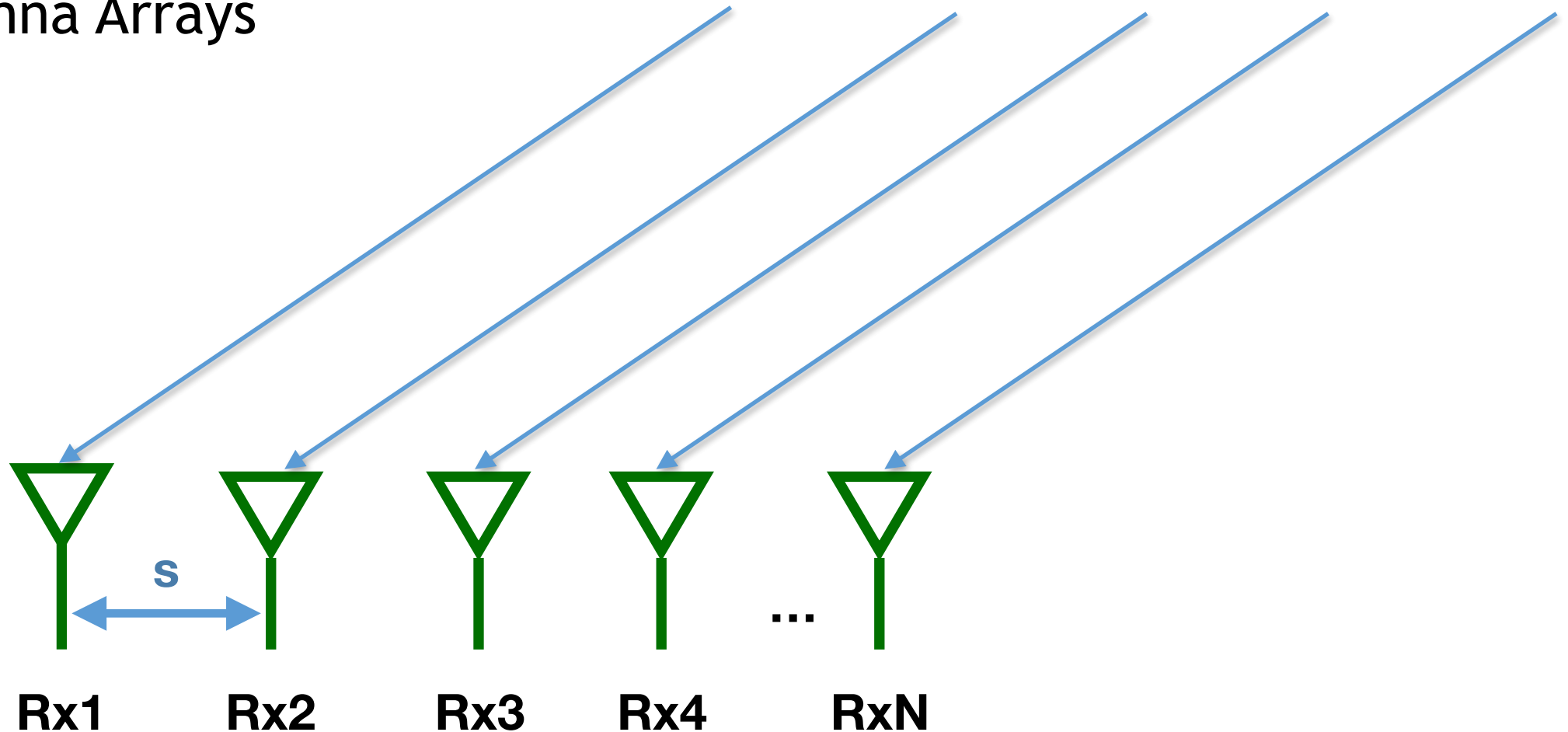




## 4) Use Angle of Arrival (AoA)

### Triangulation from Angular Measurements

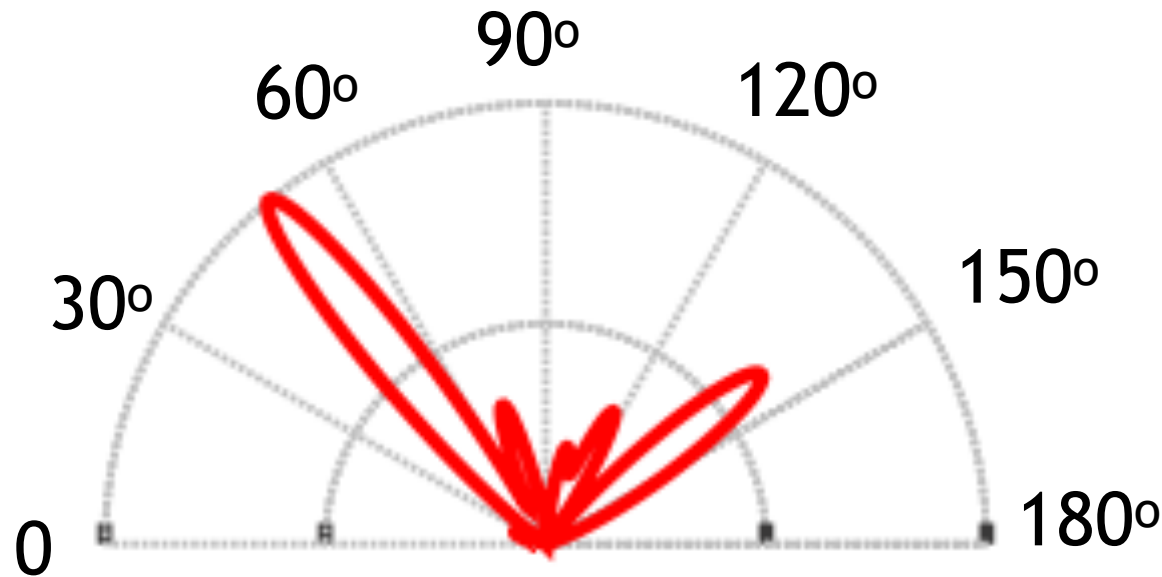
Use Antenna Arrays



## 4) Use Angle of Arrival (AoA)

### Triangulation from Angular Measurements

Use Antenna Arrays



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

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



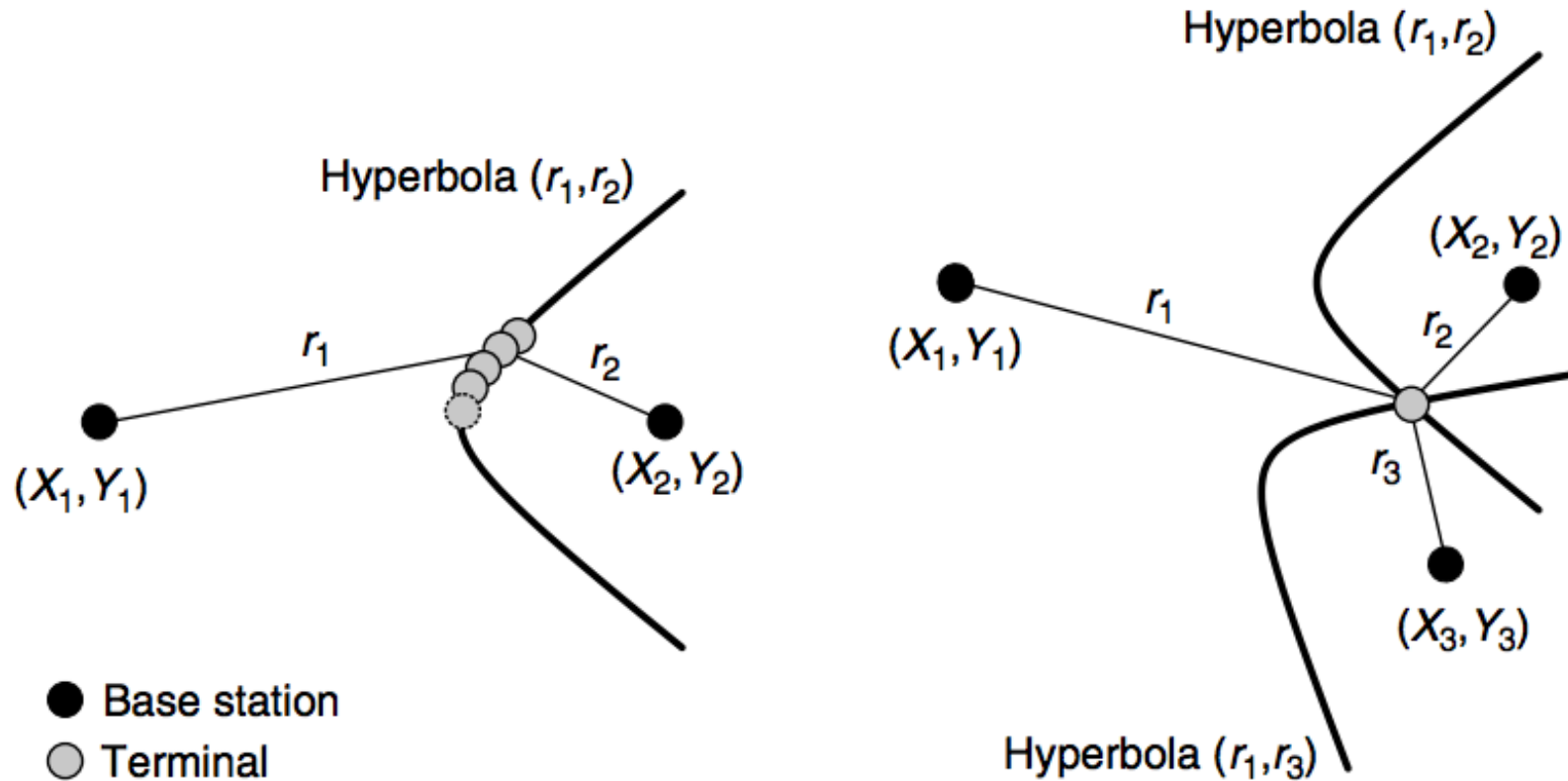
**Transmitter**

Distance = Time of flight x speed of travel

Can use trilateration (intersection circles/spheres)

How do we know when the signal was transmitted?

## 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
- ...