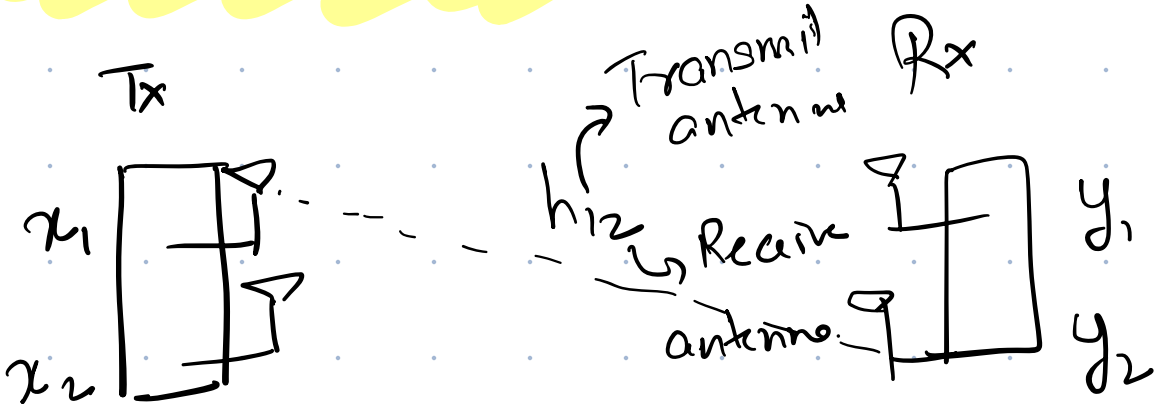
CS 598 WSI: LECTURE 8

- Multi-antenna devices
  - MIMO
  - NULLING
  - RECIPROCITY
  - MU-MIMO
- LOCALIZATION
  - RSSI
  - Angle of Arrival

MIMO: RECAP



$$y_1 = h_{11} x_1 + h_{21} x_2$$

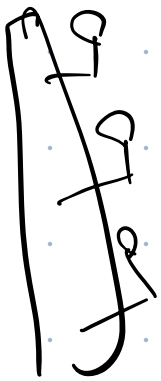
$$y_2 = h_{12} x_1 + h_{22} x_2$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{21} \\ h_{12} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

$$\bar{y} = H \bar{x}$$

$$\bar{x}' = H^{-1} \bar{y}$$

2 parallel streams of data



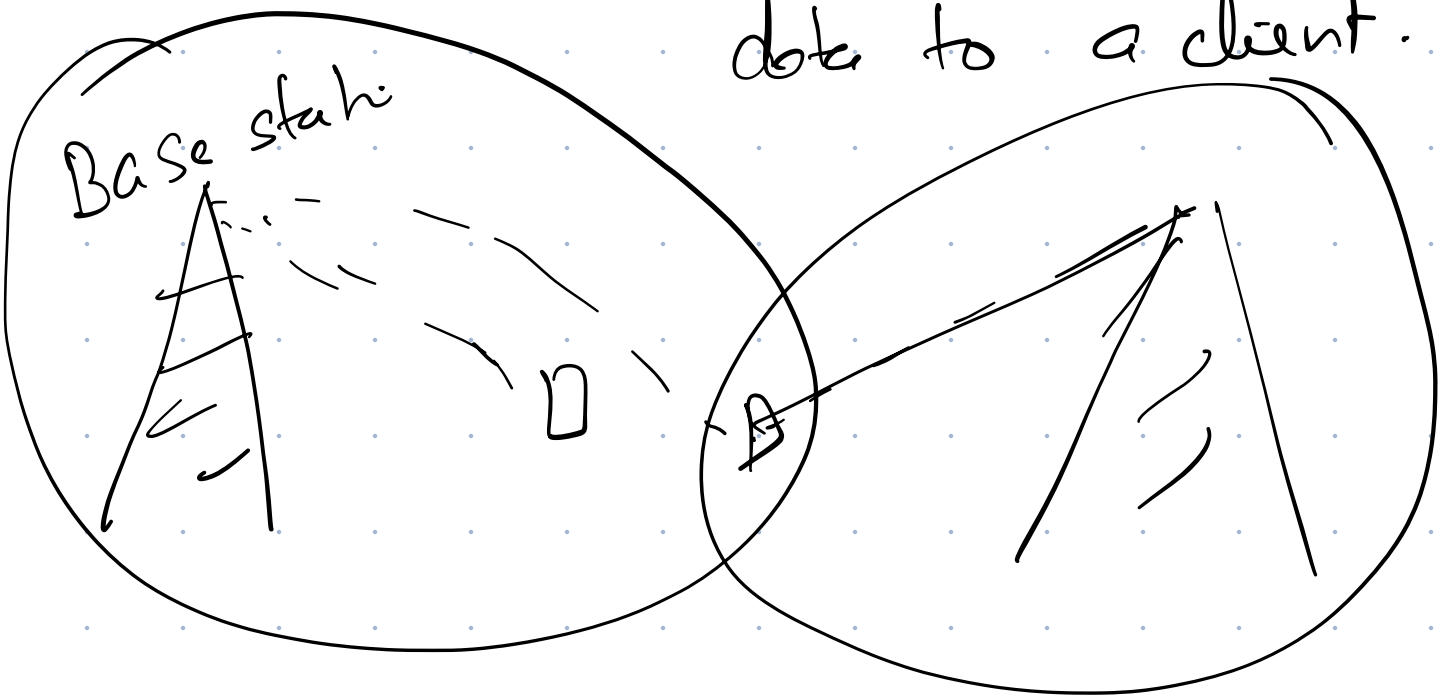
upto 3 parallel streams of data

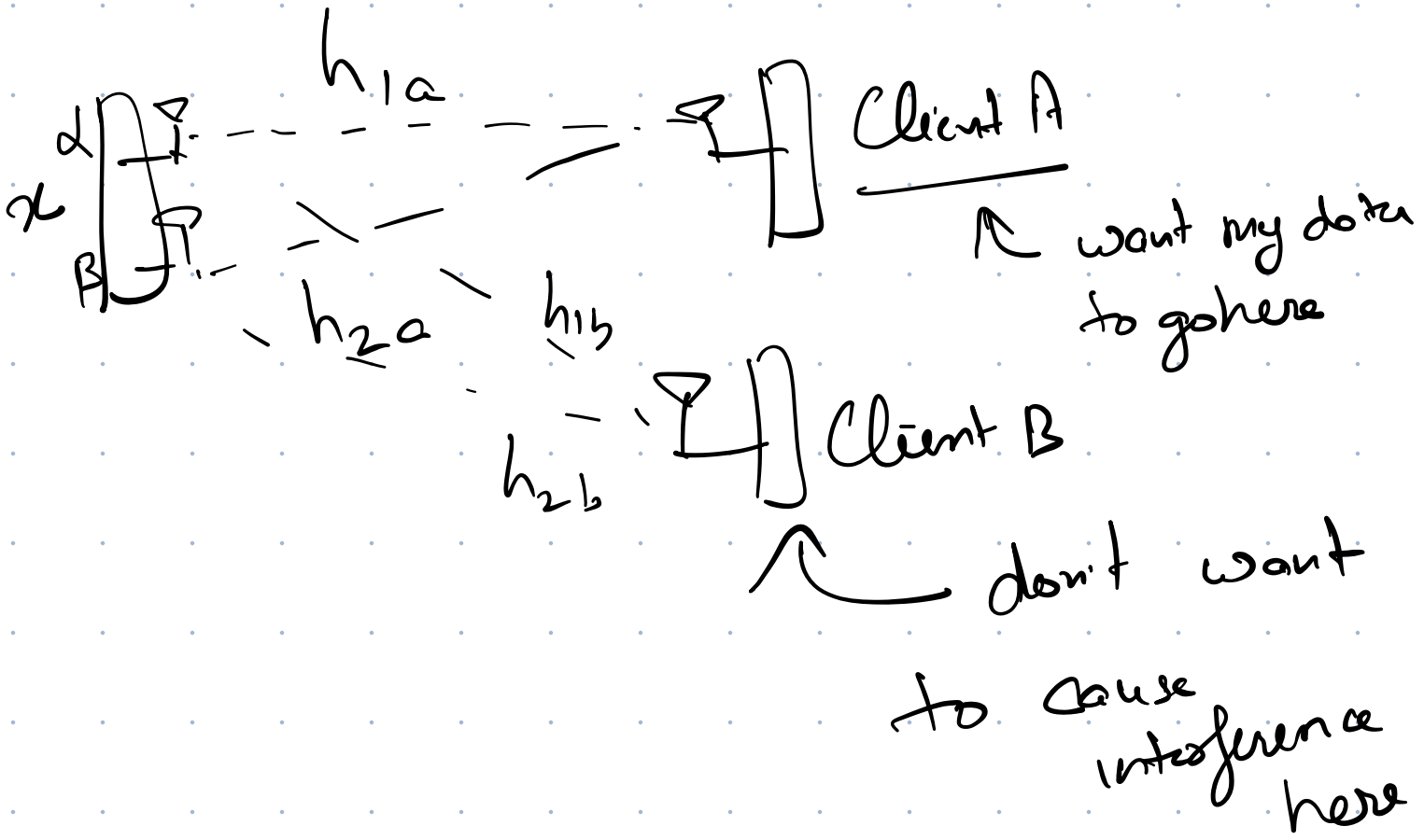
N antennas on each side

$\Longrightarrow$ N parallel streams of data.

NULLING

↳ don't want to send data to a client.





↖ want my data to go here

↖ don't want to cause interference here.

$$y_B = h_{1b}\alpha x + h_{2b}\beta x$$

$$= (h_{1b}\alpha + h_{2b}\beta)\, x$$

$$= 0$$

$\alpha = 1$

$$\beta = -\frac{h_{1b}}{h_{2b}}$$

$$y_A = h_{1a}\alpha x + h_{2a}\beta x$$

$$= (\alpha h_{1a} + \beta h_{2a})\, x$$

$$= \left(h_{1a} - \frac{h_{1b} h_{2a}}{h_{2b}}\right) x$$

→ how does the tx know h values?

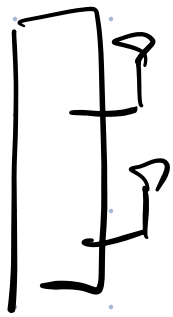
→ When I measure h, when I apply h ← can be different times?

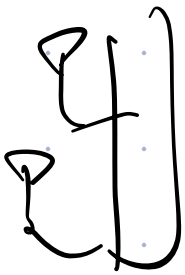
RECIPROCITY

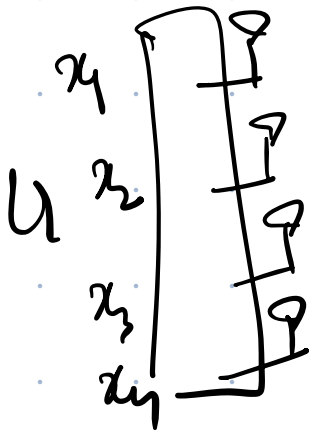
$h_{AB} \simeq h_{BA}$ (α)

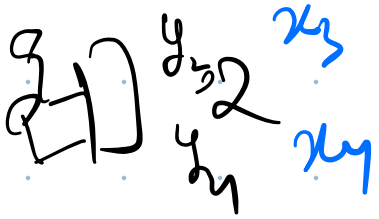
$$\left.\begin{aligned} h_{1B} &\approx h_{B1} \\ h_{2B} &\approx h_{B2} \end{aligned}\right\} \Longrightarrow \alpha, B$$

MU-MIMO



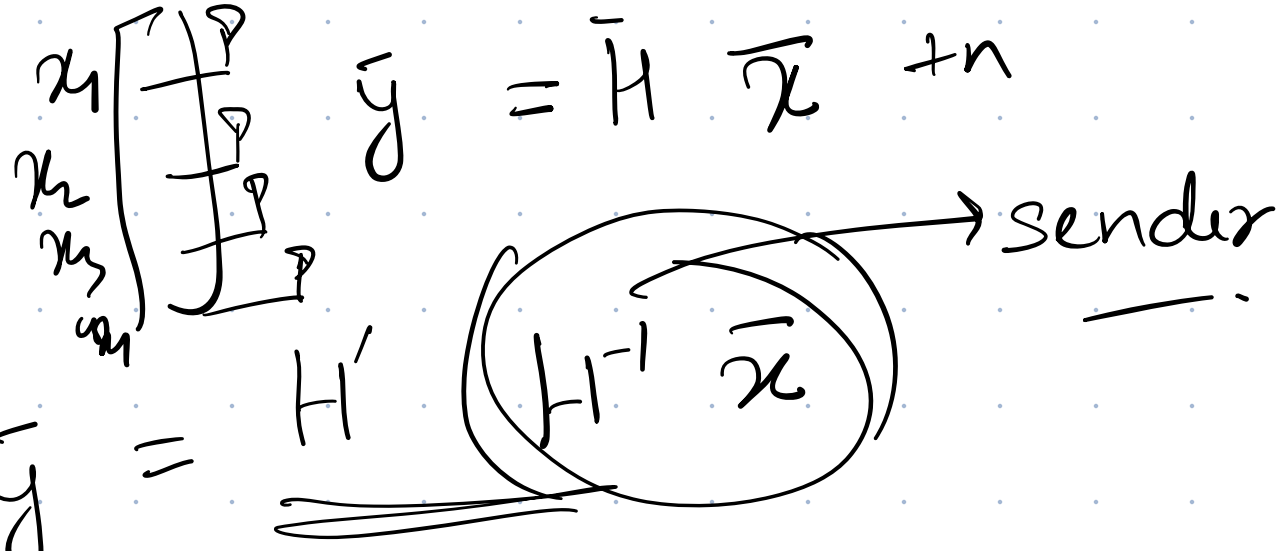






$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{pmatrix} = \begin{bmatrix} & H & \end{bmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{pmatrix} + n$$

(At receiver, you know H, $H^{-1} y = (x)$)



$y_1 = x_1 + n$ $\quad y_3 = x_3 + n$

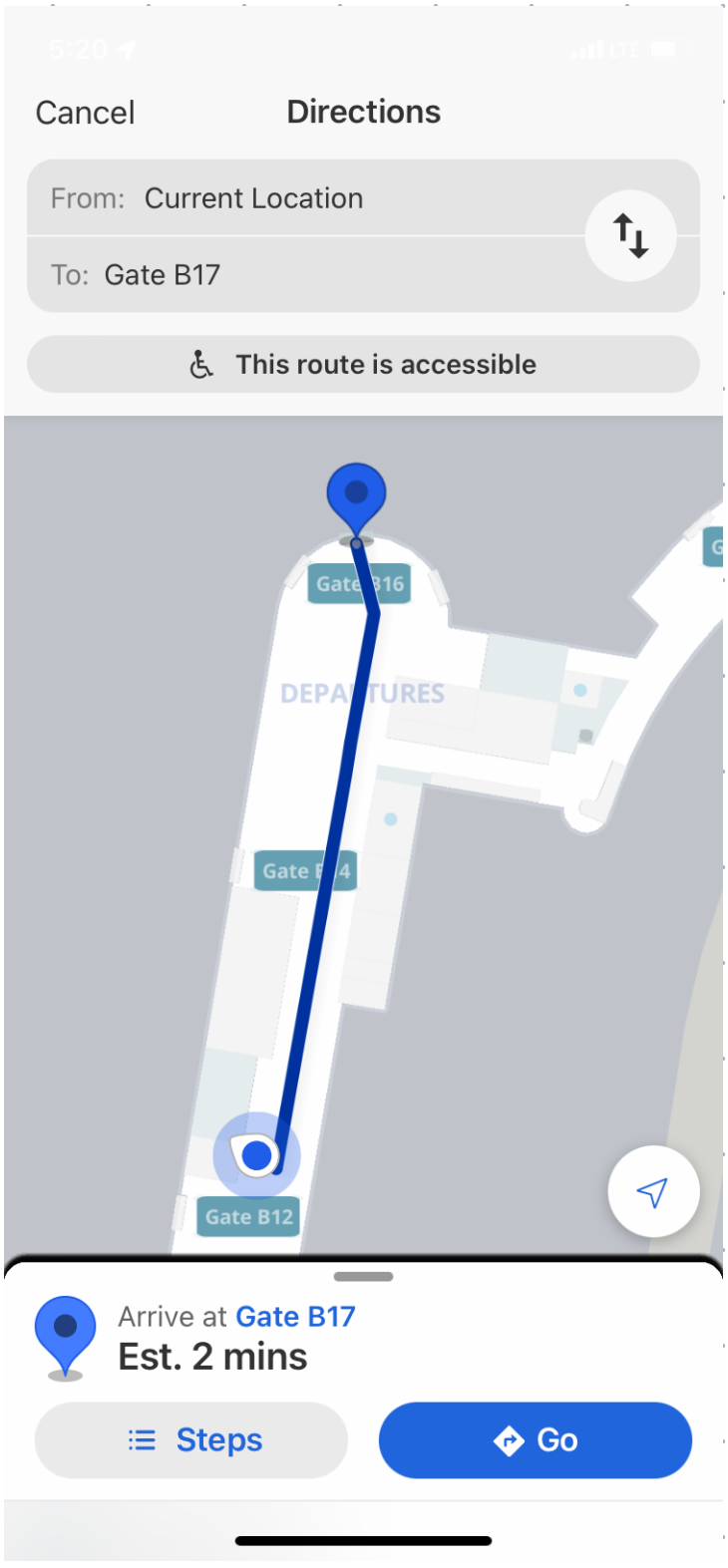
$y_2 = x_2 + n$ $\quad y_4 = x_4 + n$

n antennas → n parallel streams even to different devices

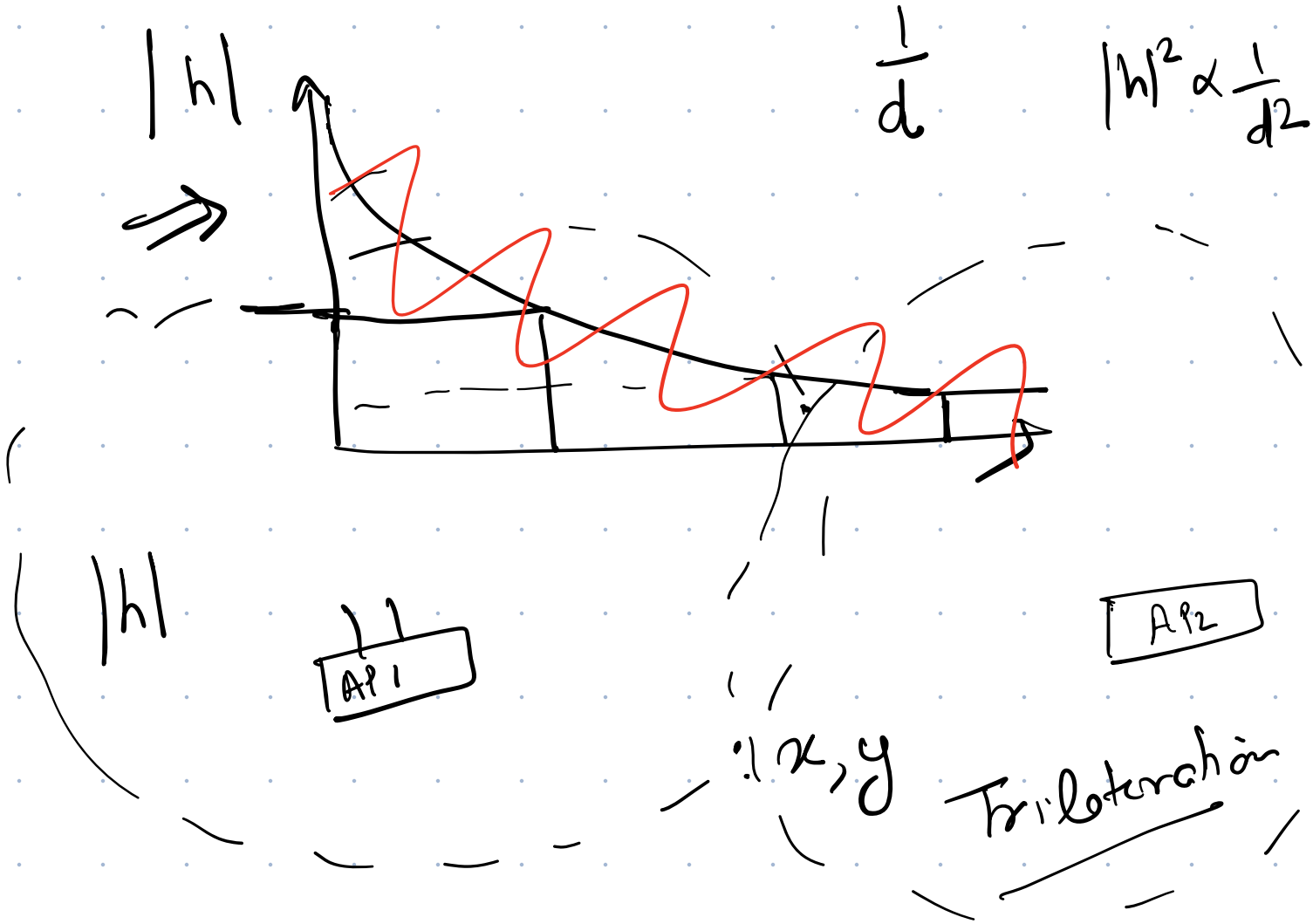
↓

requires some work

LOCALIZATION



RSSI strength of the signal.

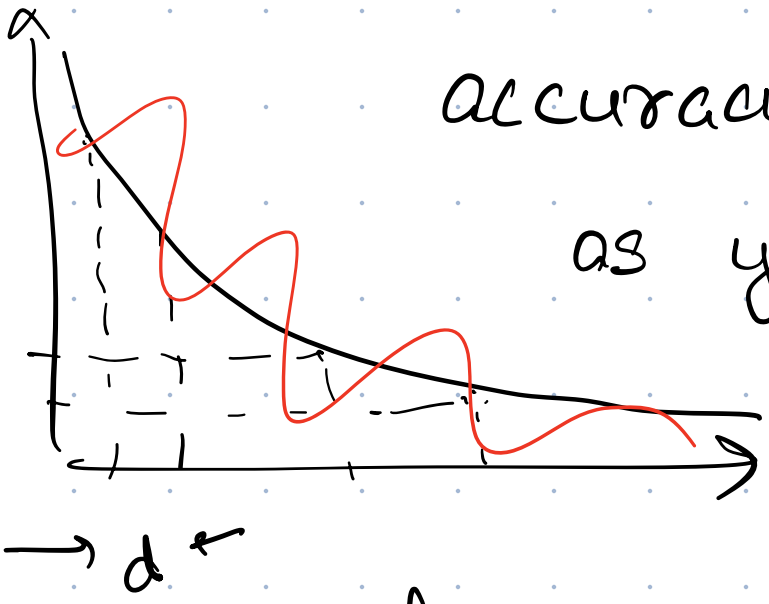


→ obstacles cause attenuation.

→ device-specific variation.

→ Multipath.

|h|



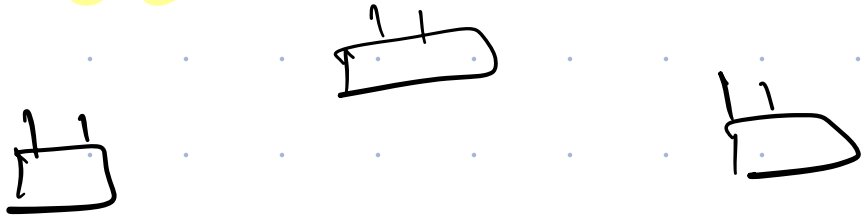
accuracy degrades as you go further.

→ d ←

Room-level accuracy.

RSSI → Received Signal Strength Indicator.

FINGERPRINTING



D (RSSI$_1$, RSSI$_2$, RSSI$_3$)
fingerprint for location

→ Finger printing phase.

database → (x, y) ⇒ (RSSI$_1$, RSSI$_2$, RSSI$_3$)

→ Run time

(RSSI$_1$, RSSI$_2$, RSSI$_3$)

CONS

- environment can change.

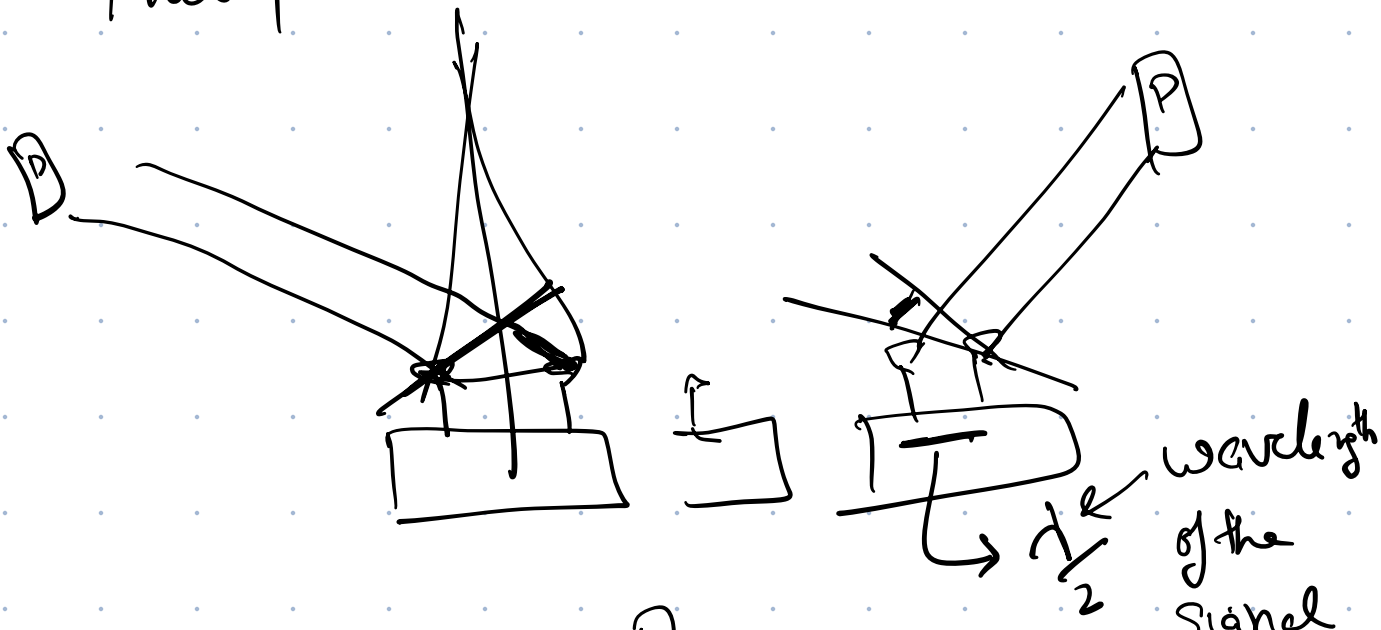
↳ Repeat

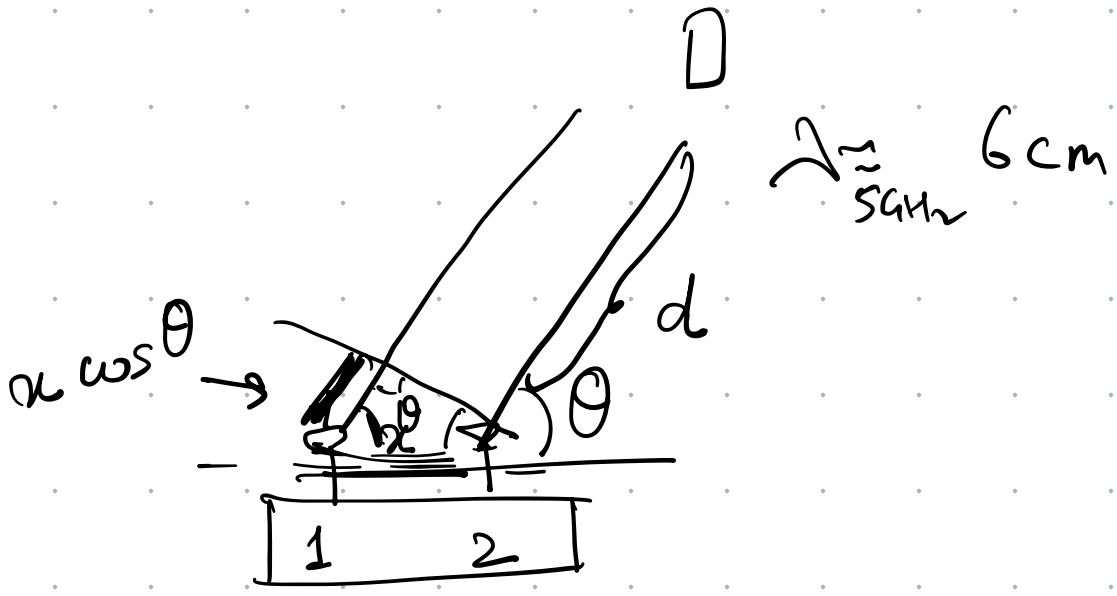
fingerprinting

↳ RSSI can vary often per device

Angle of Arrival

Multiple antennas → phase.





$$\angle h_2 = -\frac{2\pi}{\lambda} d \mod 2\pi$$

$$\angle h_1 = -\frac{2\pi}{\lambda}(d + x\cos\theta) \mod 2\pi$$

$$\angle h_2 - \angle h_1 = \frac{2\pi}{\lambda} x \cos\theta \mod 2\pi$$

$$= \frac{2\pi}{\lambda}\frac{\lambda}{2} \cos\theta \mod 2\pi$$

$$\Delta\phi + \varepsilon = \pi \cos\theta \mod 2\pi$$

$$(-\pi, \pi] \mod 2\pi$$

$$\cos\theta = \frac{\Delta\phi}{\pi} + \frac{\varepsilon}{\pi}$$

$$x = 2\lambda$$

$$\Delta\phi = \underbrace{4\pi \cos\theta}_{(-4\pi,\ 4\pi)} \mod 2\pi \qquad (-1, 1)$$

8π

$$\cos\theta = \frac{\Delta\phi + \varepsilon}{4\pi}$$

$$[-4\pi, -2\pi], (-2\pi, 0], [0, 2\pi), [2\pi, 4\pi]$$

$$-4\pi + \frac{\pi}{2} \qquad -2\pi + \frac{\pi}{2} \qquad \frac{\pi}{2} \qquad 2\pi + \frac{\pi}{2}$$

$\lambda = 3\text{cm}$

$$\frac{3\times10^{-2}\ \text{m}}{3\times10^{8}\ \text{m}}\ /s$$

$10^{-10}\ s$

0.1ns

Cons

- Multiple antennas
- Multipath
- Requires phase.