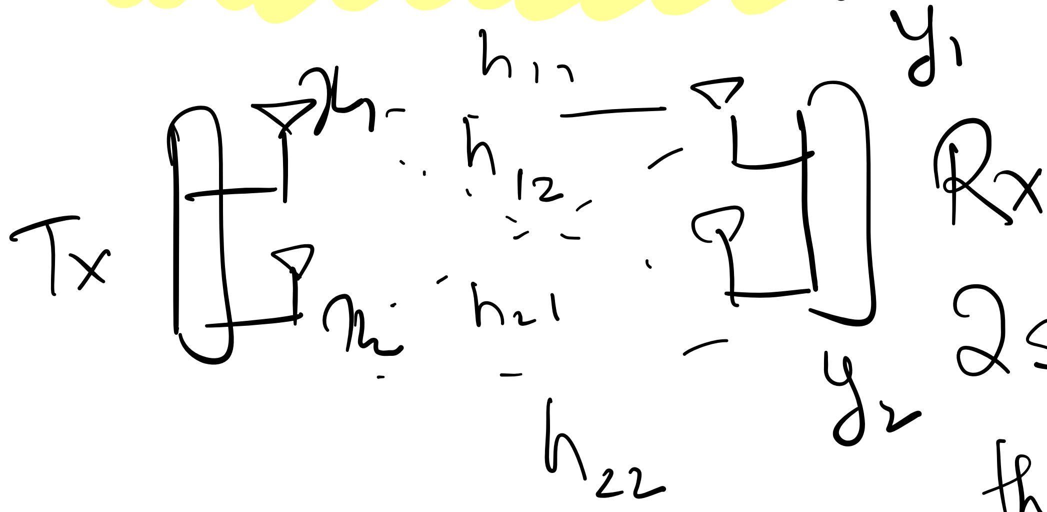
Today

- Interference Nulling
- Interference Alignment
- Localization
  - Signal Strength
  - Fingerprinting
  - Angle of Arrival

Interference Nulling



2 streams at the same time

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

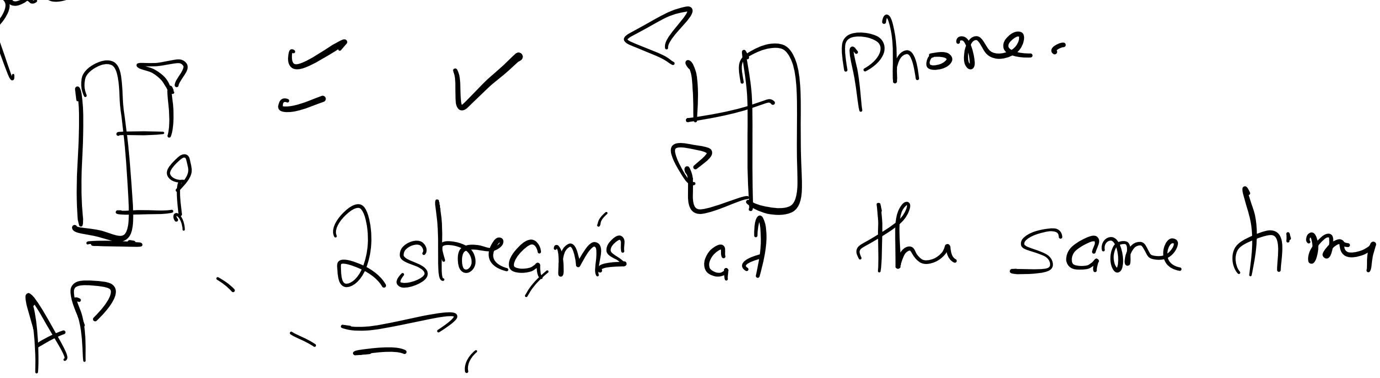
$$y_2 = h_{12} x_1 + h_{22} x_2$$

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

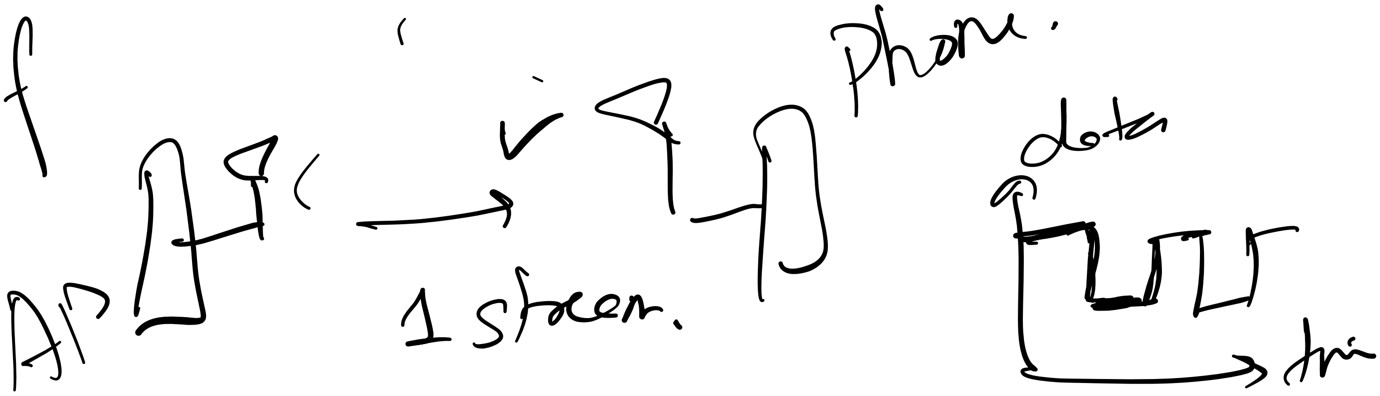
~~3×1~~ ~~3×3~~ 3×1

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

Deep...

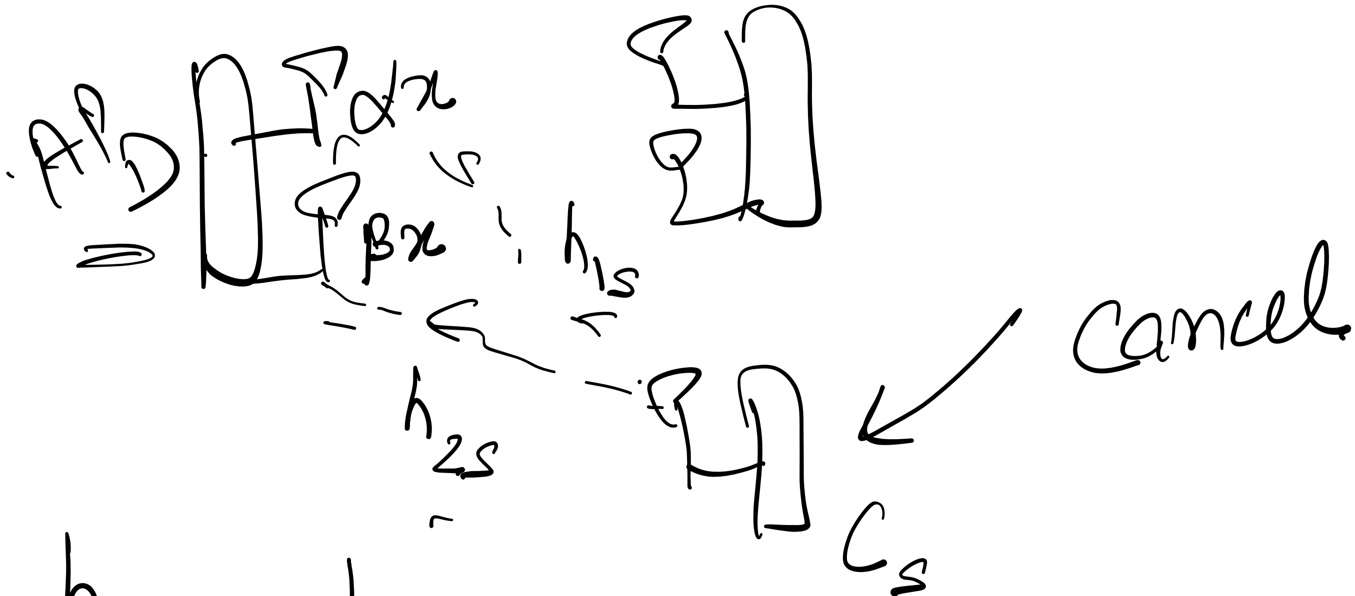


Saif



Deepak's AP can transmit in parallel as long as it cancels interference ~~for~~ to Saif's phone.

Q. How do we cancel



$h_{s1} \rightarrow h_{1s}$

$h_{s2} \rightarrow h_{2s}$

$$y_s = h_{1s}(\alpha x) + h_{2s}(\beta x)$$

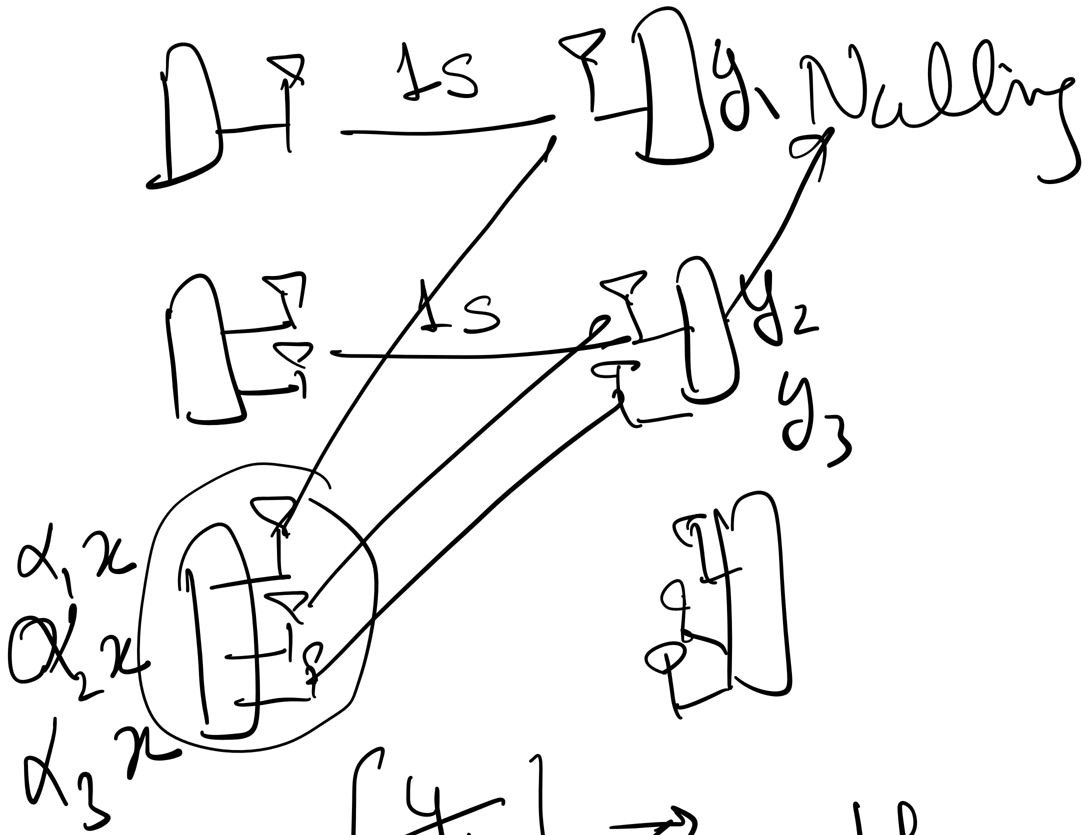
$$\alpha = \frac{-h_{2s}}{h_{1s}} \qquad \beta = 1$$

$$y_s = h_{1s}\left(\frac{-h_{2s}}{h_{1s}}\right)x + h_{2s}x = 0$$

Reciprocity

$$h_{12} = h_{21}$$

Interference Alignment



$$\vec{y} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = H_{3\times3} \begin{bmatrix} \alpha_1 x \\ \alpha_2 x \\ \alpha_3 x \end{bmatrix}$$

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

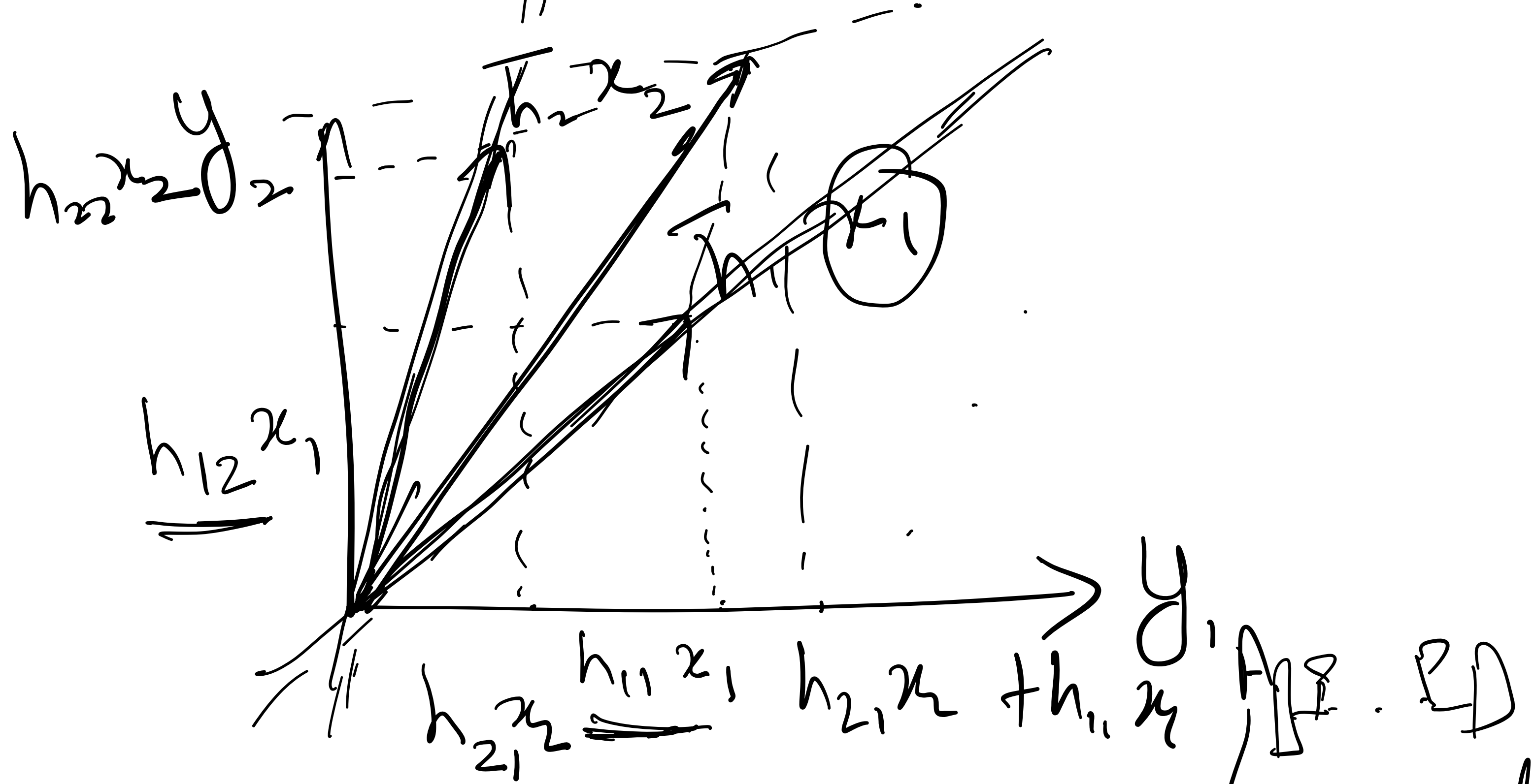
$$y_2 = h_{12} x_1 + h_{22} x_2$$

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

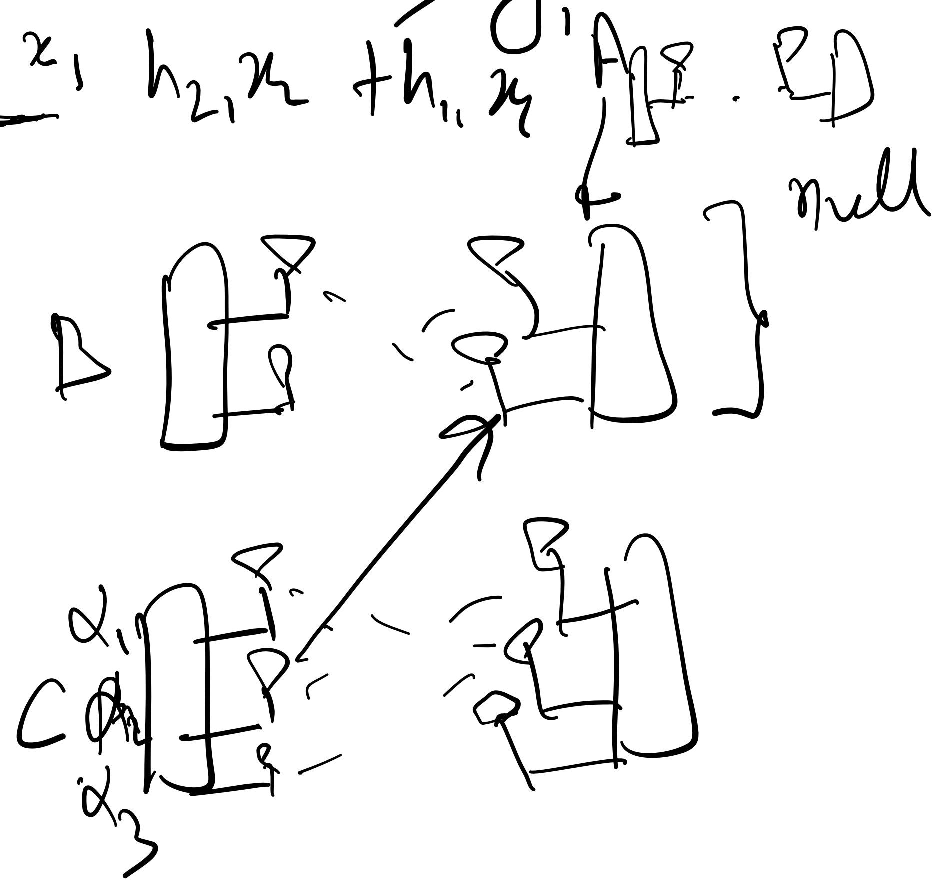
$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \begin{pmatrix} h_{11} \\ h_{12} \end{pmatrix} x_1 + \begin{pmatrix} h_{21} \\ h_{22} \end{pmatrix} x_2$$

$$\vec{y} = \bar{h}_1 x_1 + \bar{h}_2 x_2$$

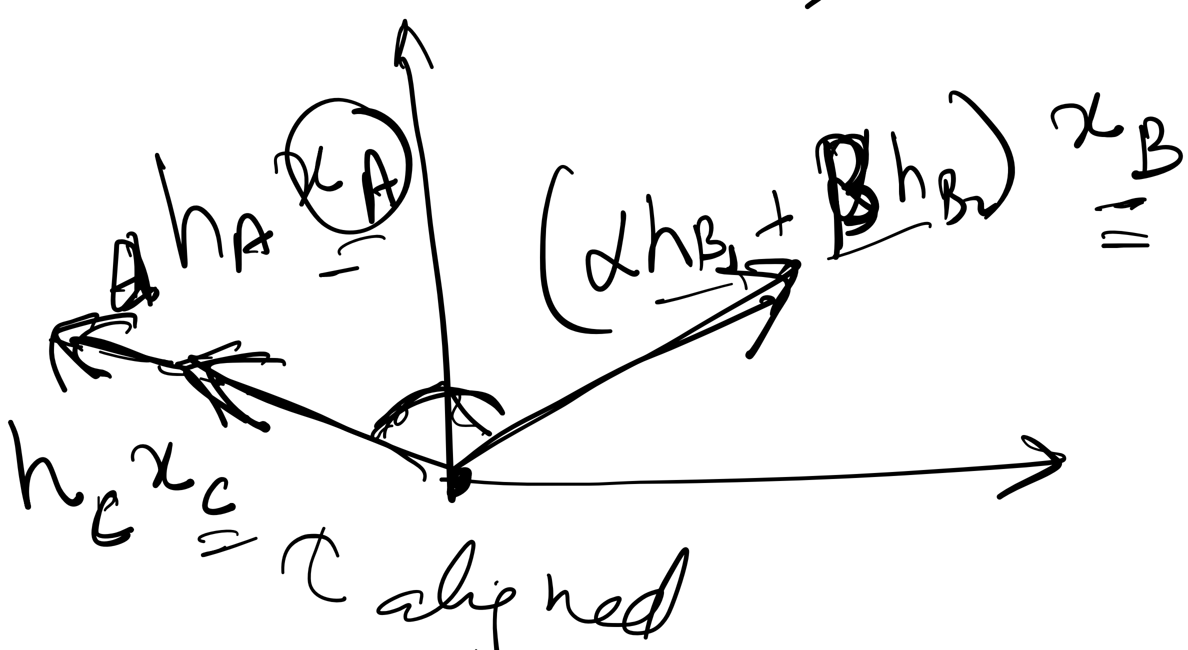
$$x_2 \downarrow 0$$



$h_2 x_2$
$h_{22} x_2$
y_2
$h_1 x_1$
$h_{12} x_1$
y_1
$h_{11} x_1$
$h_{21} x_2$
$h_{21} x_2 + h_{11} x_1$

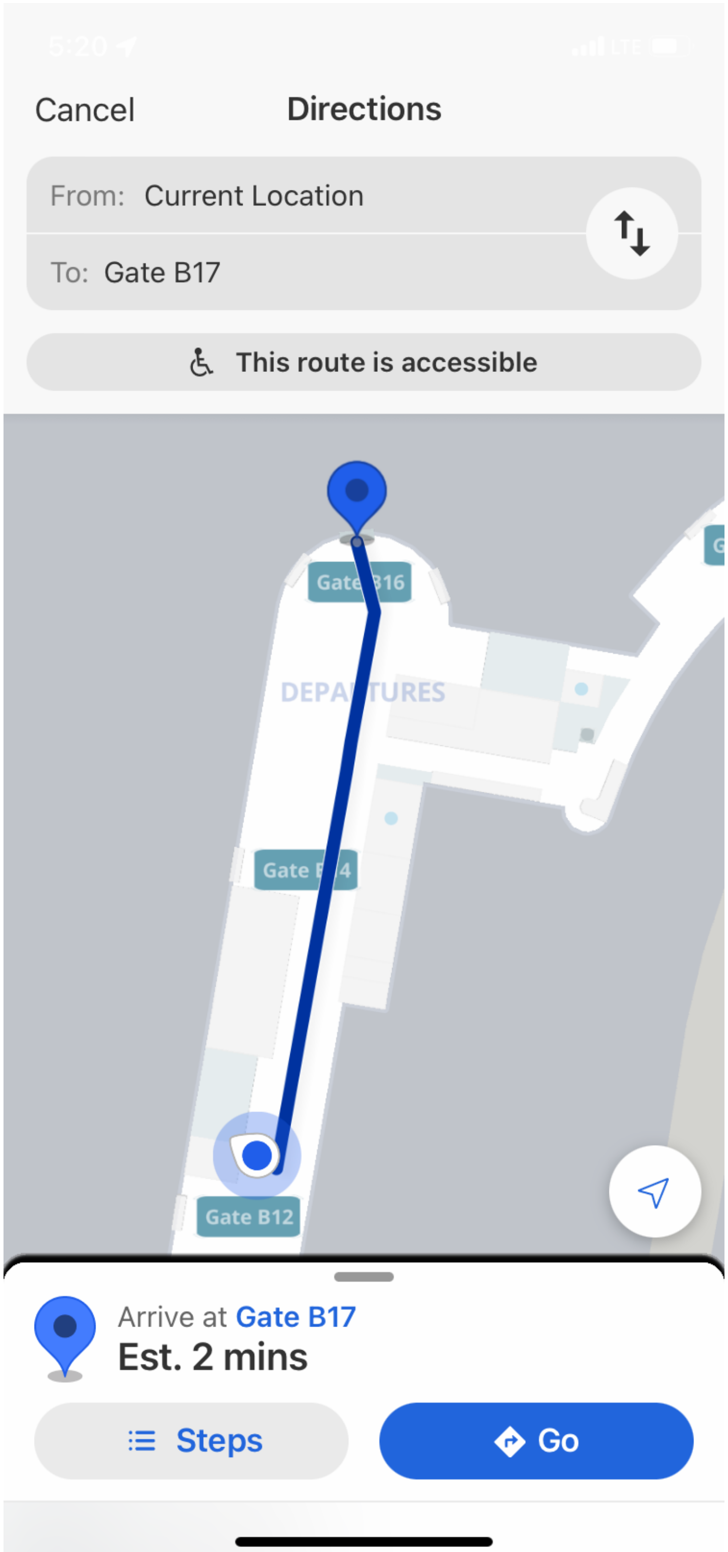


A
D
null
B
α_1
C
α_2
α_3



$h_A x_A$
$(\alpha h_{B_1} + \beta h_{B_2}) x_B$
$h_C x_C$
C aligned

Localization



Ideas

↳ Distance

↑

Signal strength

RSSI

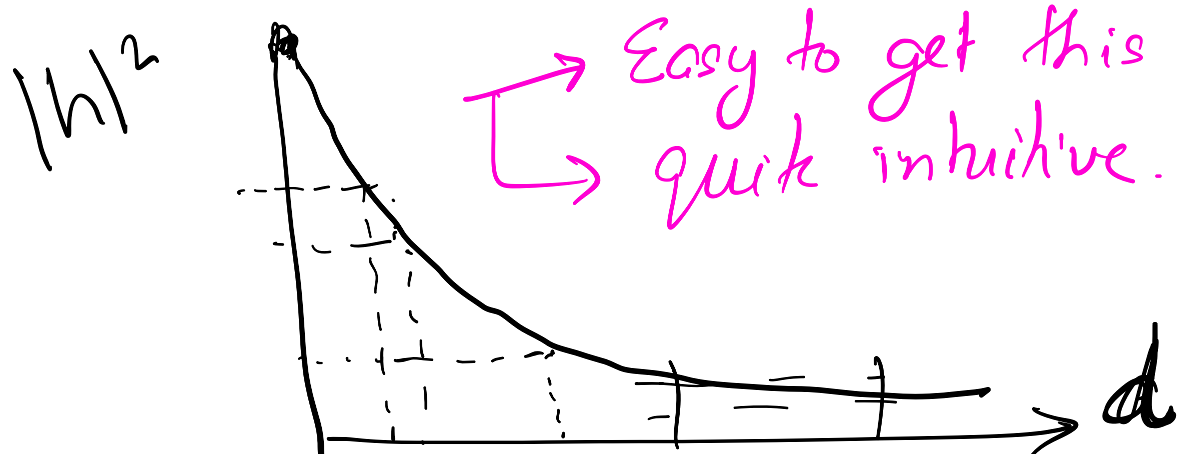
Received Signal Strength Indicator.

$y = h x$

$|h| \propto \frac{1}{d}$ ← distance

$d \uparrow$, $|h| \downarrow$, signal strength

$RSSI = |h|^2 \propto \frac{1}{d^2}$

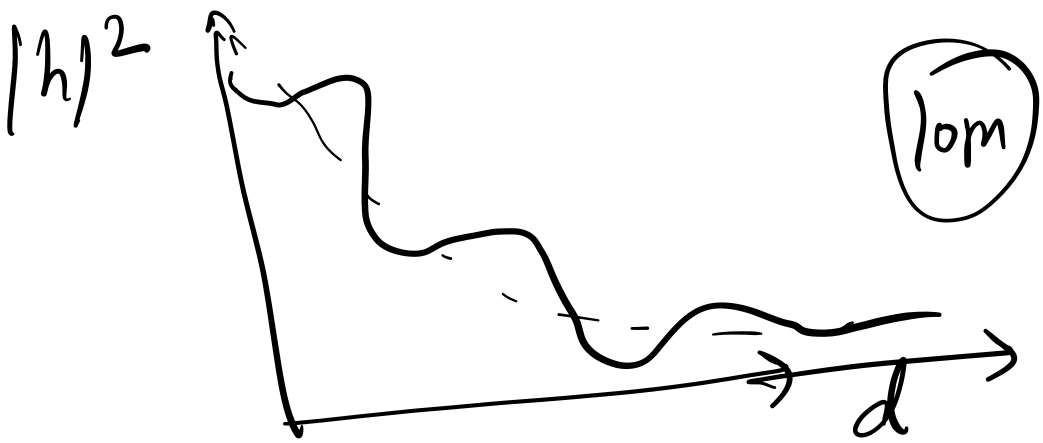


→ Easy to get this info

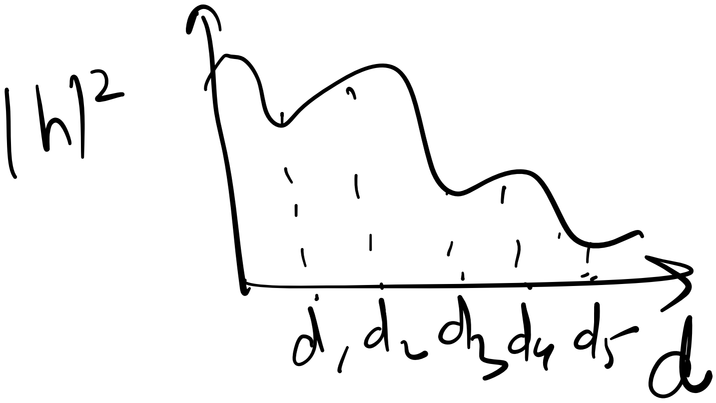
→ quik intuitive.

single path.

$$h = \frac{c_1}{d_1} e^{j\Phi_1} + \frac{c_2}{d_2} e^{j\Phi_2}$$



Fingerprinting



→ Training phase → fingerprint

→ Deployment phase

↳ Compare my channel to the database

"All APs that you can listen to"

$(h_1, h_2 \ldots h_5)$ $(h_1, \ldots$

Good

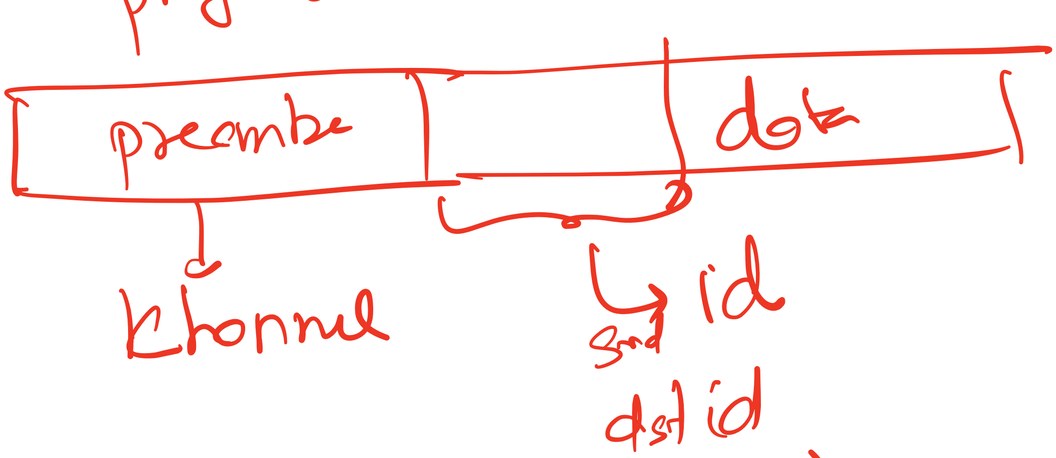
→ Deals with multipath.

Challenge

↳ If you change the environment

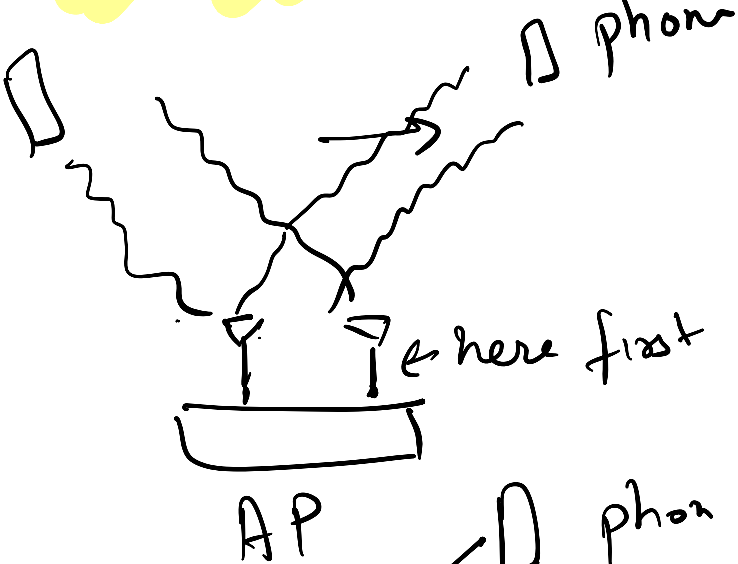
↳ labor intensive.

phy layer head



MAC randomization.

Angle of Arrival

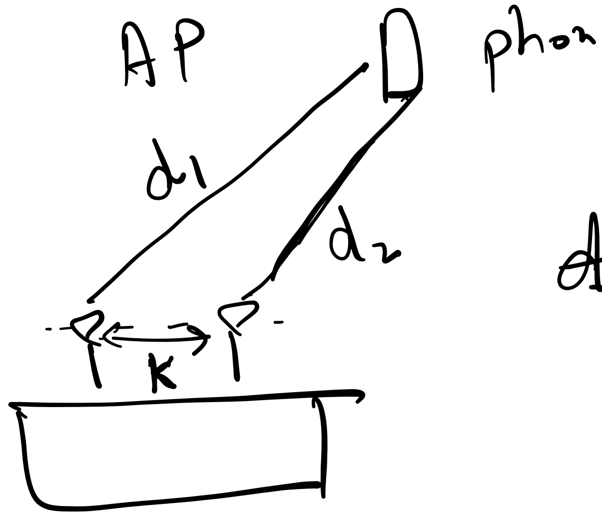


$$h \propto \frac{1}{d} e^{j\Phi}$$

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

↙ distance

↖ wavelength

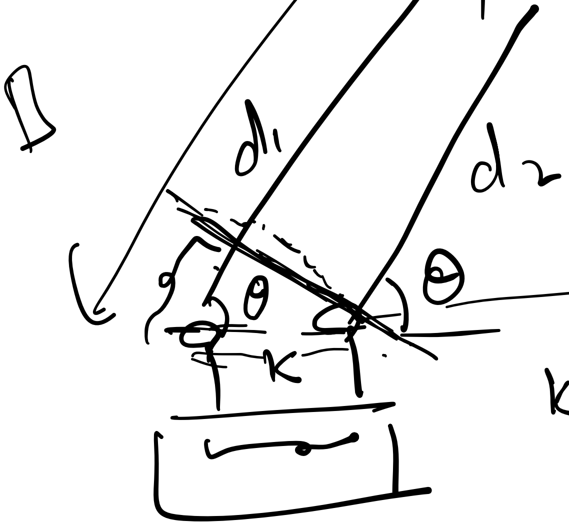


~~$d_1 = 2\pi$~~

$$\Phi_1 = -\frac{2\pi}{\lambda} d_1 \mod 2\pi$$

$$\Phi_2 = -\frac{2\pi}{\lambda} d_2 \mod 2\pi$$

$$\underbrace{\Phi_1 - \Phi_2}_{\uparrow \checkmark} = \frac{2\pi}{\lambda} \underbrace{(d_2 - d_1)}_{d_2 - d_1} \mod 2\pi$$



$$k \cos\theta = d_1 - d_2$$

$$\Phi_1 - \Phi_2 = \frac{2\pi}{\lambda}(d_2 - d_1) \mod 2\pi$$

$$\Phi_1 - \Phi_2 = -\frac{2\pi}{\lambda} k \cos\theta \mod 2\pi$$

measure