CS598 WSI Lecture 8 Scribe Notes (FA2023)

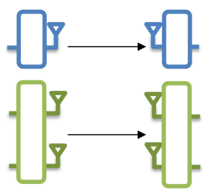
Image Credits: https://courses.engr.illinois.edu/ece598hh/fa2020/

Lecture Part 1 - MIMO Continue

Scenario 1:

Setup:

1. 2 Antenna AP <-> 2 Antenna iPhone
2. 1 Antenna Ap <-> 1 Antenna iPhone



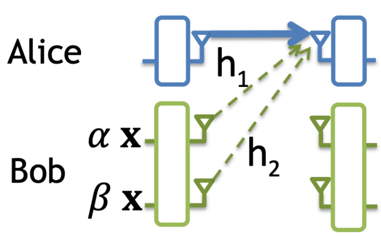
Problem:

Green transmitter's signals will interference at the Blue Receiver. How can Green and Blue transmit the singal in parallel?

Solution:

Interferance Nulling

Solution Details:



$$h1\alpha\boldsymbol{x} + h2\beta\boldsymbol{x} = 0 \Rightarrow h1\alpha = -h2\beta \quad (1)$$

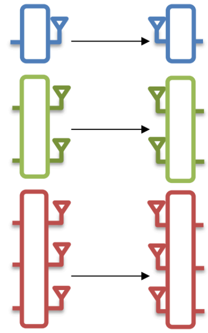
h1 and h2 can be known by

(1) feed back from Alice

(2) reciprocity: e.g., h12 = h21 **(Note: Not true for other medium like water. Reference: https://dl.acm.org/doi/10.1145/3544216.3544258)**

Scenario 2:

Setup:



Problem:

In this setup, the red transmitter (3 antennas) needs to do nulling on blue and green receivers (in total 3 antennas). Mathmatically, we cannot find α, β, γ because the only solution for the following equations is

$$\alpha = \beta = \gamma = 0 \tag{2}$$

, which means we are transmit nothing.

$$(h_{11}\alpha + h_{21}\beta + h_{31}\gamma)z = 0$$

$$(h_{12}\alpha + h_{22}\beta + h_{32}\gamma)z = 0$$

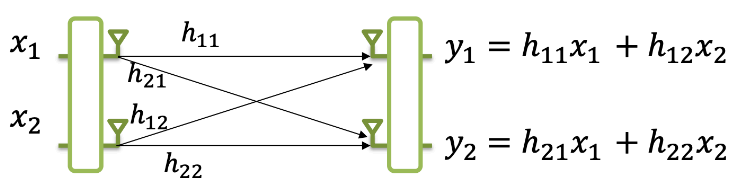
$$(h_{13}\alpha + h_{23}\beta + h_{33}\gamma)z = 0$$

Solution:

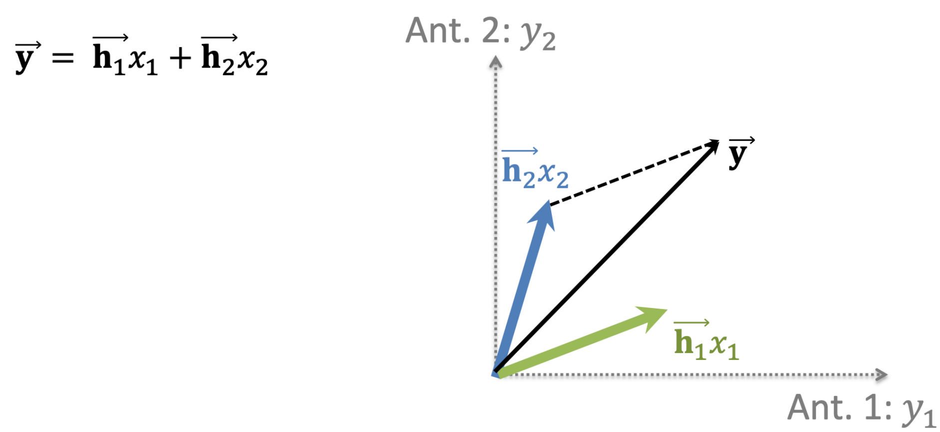
Alignment

Solution Details:

Recap1 Antenna Space:



$$\mathbf{y} = \begin{bmatrix} h_{11} \\ h_{21} \end{bmatrix} x_1 + \begin{bmatrix} h_{12} \\ h_{22} \end{bmatrix} x_2 = \overrightarrow{\mathbf{h}_1} x_1 + \overrightarrow{\mathbf{h}_2} x_2$$

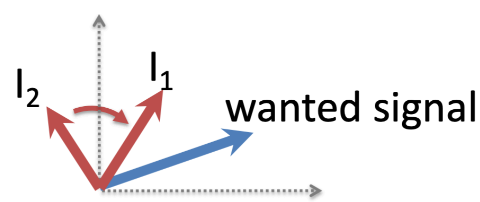


Knowing $\vec{h1}$, you can prohect $\vec{y}$ to $\vec{h1}^{\perp}$ to decode $\boldsymbol{x_2}$.

Receiver with N antennas can decode N signals.

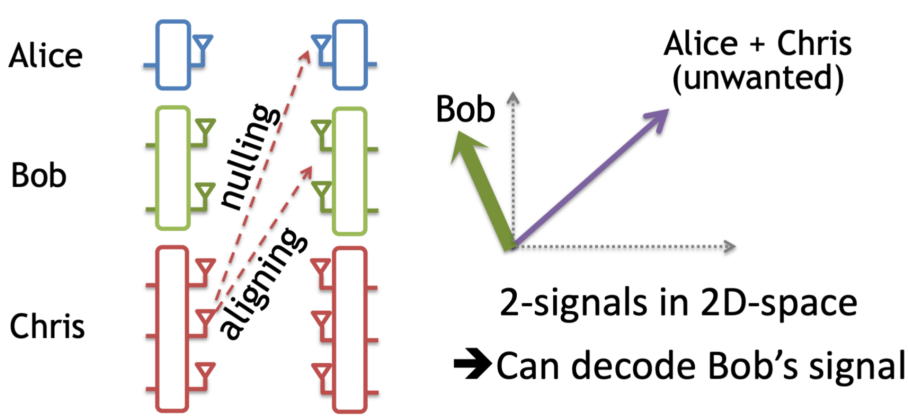
Recap2:

Transmitter can roate $\vec{y}$



Solution:

Red transmitter rotates its signal to align with Blue's signal to reduce the number of unwanted signals at the green reciever from 2 to 1. Now at the green side (two receiver antennas), it can decode two signals (one wanted from green transmitter + aligned unwanted signal from red and blue transmitters). Recap: **Receiver with N antennas can decode N signals.**



Lecture Part 2 - Localization

Application:

1. Airport negivation
2. Shopping mall
3. Automatic Checkout: Amazon Go

Tons of cameras in Amazon Go Seattle (I took them in Summer 2023):

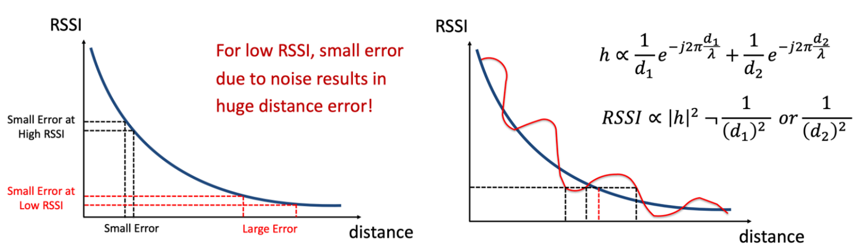
RSSI (Received signal strength Indicator)

Principle:

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

Problems:

1. Hign error at long distance.
2. Multipath problem.
3. Other interference. Microwave oven...



Fingerprinitnig

Principle:

1. Training phase -> get finger print
2. Deployment phase
    1. compare my channel to the data base
3. Use RSSI from all APs that you can listen to to find the best matching in the database.

Can deal with multipath problem.

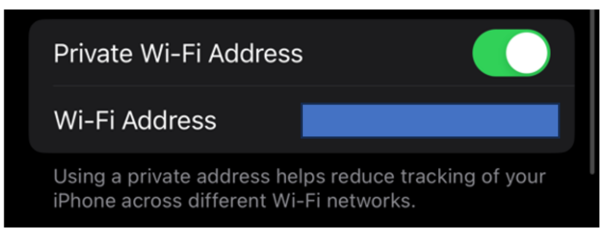
Problems:

1. Does not work with environment change (people, room layout change, ...)
2. Labor intensive

Lecture Part 3 - MAC Randomnization

Change your MAC (can be changed by software) periodically for security and privacy considerations (reduce tracking across Wi-Fi networks).

In your iPhone, click the information symbol ℹ️ next to the Wi-Fi you are connected to then you can find an option called Private Wi-Fi Address which is for enable/disenable MAC randomization.



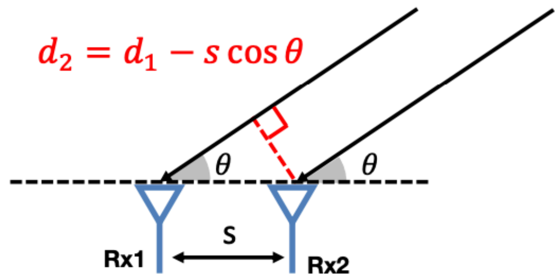
(screenshot from my iPhone)

Lecture Part 4 - Angle of Arrival (AoA) Start

We briefly discussed AoA and I think the content can be covered by the following image.

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

$d_2 = d_1 - s\cos\theta$



$$h_1 \propto e^{-j2\pi\frac{d_1}{\lambda}} \qquad h_2 \propto e^{-j2\pi\frac{d_2}{\lambda}} = e^{-j2\pi\frac{d_1 - s\cos\theta}{\lambda}}$$

$$\Delta\Phi = \angle h_2 - \angle h_1 = 2\pi\, s\cos\theta\,/\lambda \ \bmod 2\pi$$