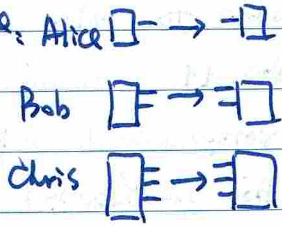
6.888 10/10/2013

▷ Motivation: heterogeneity of # of antennas.

- when single-antenna tx is transmitting, the other will not transmit to avoid interference
  $\rightsquigarrow$ far from the DoF that is allowed

Motivating example:

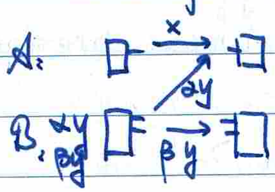


How to avoid interference?

802.11 n^+: - Enable 802.11 nodes to contend both for time and frequency
- Maintains random access

▷ How to transmit w/o interference to others?

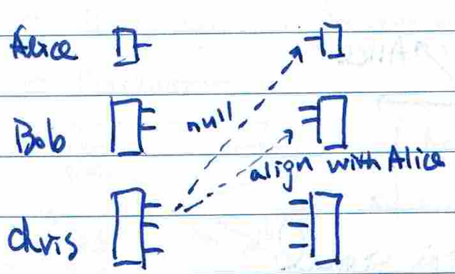
- Interference Nulling



$\rightsquigarrow h_2\alpha y + h_3\beta y \to$ could be nulled if $h_2\alpha + h_3\beta = 0$

How to know the channel:
reciprocity / beforehand comm

- Now more advanced example



Can Chris use interference nulling?
— No!!
— Chris needs to null at 3 antennas
only solution $\alpha = \beta = \gamma = 0$

- How people join this system?
  * The other guy will ask if it can join
  * Guys w/ higher # of antennas are able to join, but the opposite (lower # of antennas) is going to be not able to join
  * standard 802.11

    three time slots:

    Alice → 1 Bob → 2 Chris → 3

    Average:

    Alice: $\frac{1}{3}$ Bob: $\frac{2}{3}$ Chris: 1

    802.11 n^+

    possibility: A = 1, B = 0 C = 2 / B = 1, C = 1; B = 2, C = 1; C = 3

    Average:

    $A = \frac{1}{3}$

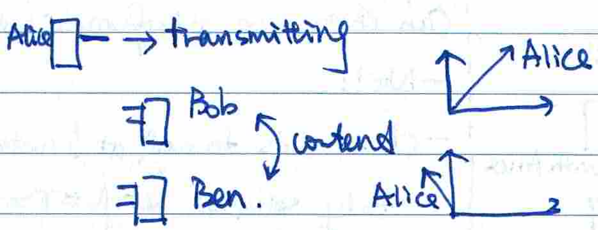
    $B = \frac{2+0.5}{3}$

    $C = \frac{3+1+1.5}{3}$

    Nobody is worse off in the new system
  * a side note: when joining, they will make sure that the size of the packets matches

▷ How to achieve the random access manner?

- 802.11 uses carrier sense
- 802.11 n^+: multi-dimensional carrier sense



project orthogonal to Alice's signal

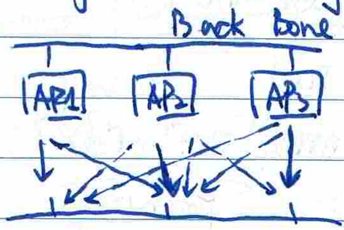
on that orthogonal space, they will contend (generate random number)

If Bob wins, Ben will know he loses since there's now power in the orthogonal direction.

▷ Performance

Doubling the throughput

▷ Megamimo: using a distributed MIMO Tx

- 

~ all other interferences null themselves.

users

(no ethernet)

Basically, they will be a big $\overbrace{\text{MIMO}}^{\text{distributed}}$ system

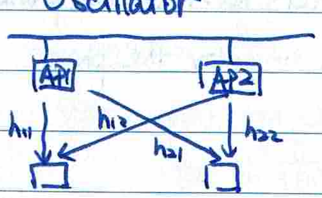
- Beamforming (same oscillator → no freq. offset).

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} d_1 & 0 \\ 0 & d_2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

~~H = U~~ · Do SVD decomposition.

$$\vec{y} = H \cdot \vec{x} \Rightarrow H \cdot (\underbrace{H^{-1}\vec{x}}_{\text{pre-coding}})$$

- Challenge now: time synchronization / freq. sync
- Time sync : SourceSync (later)
- Oscillator



$$\begin{bmatrix} h_{11}e^{j(w_{T1}-w_{R1})t} & h_{12}e^{j(w_{T2}-w_{R1})t} \\ h_{21}e^{j(w_{T1}-w_{R2})t} & h_{22}e^{j(w_{T2}-w_{R2})t} \end{bmatrix}$$

Distributed Phase Synchronization sync

- lead / slave AP, all slave APs ~~have~~ to the lead

Decomposing $H(t)$:

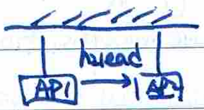
$$\begin{bmatrix} e^{-j\omega_{R1}t} & \\ & e^{-j\omega_{R2}t} \end{bmatrix} \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} e^{j\omega_{T1}t} & \\ & e^{j\omega_{T2}t} \end{bmatrix}$$

reference to ω_{T1}:

$$\underbrace{\begin{bmatrix} e^{j(\omega_{T1}-\omega_{R1})t} & \\ & e^{j(\omega_{T1}-\omega_{R2})t} \end{bmatrix}}_{R(t)} H \underbrace{\begin{bmatrix} 1 & \\ & e^{j(\omega_{T2}-\omega_{T1})t} \end{bmatrix}}_{T(t)}$$

$$\vec{y} = R(t)\cdot H \cdot T(t)\,\vec{x} \Rightarrow R(t)\cdot H\cdot T(t)\Big\{\underbrace{[T(t)^{-1}\cdot H^{-1}]\,\vec{x}}_{\text{precoding}}\Big\}$$

- estimating ω is NOT enough: accumulating error (multiplied by t)
- Need to resynchronize frequently



$$h_{2read}(t) = h_{21}\exp(j(\omega_{T2}-\omega_{T1})t)$$

- Synchronization in time
  - Packet detection delay: sliding window approach
  - Estimate Packet Detection Delay:

    First sample: all OFDM subcarrier has the same phase

    detection after T: $f_1\cdot T$, $f_2\cdot T$, ... for the phase