MIMO and Interference Management

Note: a = alpha

Multi antenna receiver Diversity

Ex: single antenna Tx, two antenna Rx

- Two channels
    - Y1 = h1x + n1
    - Y2 = h2x + n2

What to do with both signals

1. Decode both streams and compare difference
2. Add recv signals together
    - Will get stronger signal but more noise
    - Y1 + y2 = (h1+h2)x + (n1+n2)
        - If signals are aligned -> strong signal
        - If Not aligned -> weak signal
3. a1y1 + a1y2
    - Maximal ratio combining
        - $a1=h1^*$
        - $a2=h2^*$
    - Adding together cancels out phase
        - Means that signals are always aligned

Comparing SNR of approaches

SNR = S/N

Before -> $h1^2 x^2 / n^2$ (1 antenna case)

After -> = $(|h|_1^2 + |h|_2^2) * x^2 / n^2$ (2 antenna case)

- If $|h1|^2$ ~= $|h2|^2$ -> double signal strength when using maximal ratio combining
- If $|h1|^2 << |h2|^2$ -> Not much improvement
- If $|h1|^2 >> |h2|^2$ -> lots of improvement

What we lose

- More power
- More antennas ($)
- More computation / hardware complexity

Multi antenna Transmitter Diversity

Ex: 2 antenna tx, 1 antenna rx

$y = h1x1 + h2x2 = n$

Options

1. Send same signal on both antennas: $x1 = x2 = x$
    - $y = (h1+h2)x + n$
    - Problem
        - h1 and h2 can destructively collapse to 0
        - Power is doubled
2. $Y = a1h1x + a2h2x + n$
    - $a1=h1^*$ and $a2=h2^*$
        - Prevents constructive / destructive
    - ?; Why are channels different even if they are so close?
        - lambda/2 away -> different channels
            - This is why phones only have like 2 antennas
    - SNR improvement = $|h1|^2 + |h2|^2 / |h1|^2$
        - Same improvement aa Rx case

<u>Transmitter needs to know channel when calculating a values</u>

What if we don't know channels

Use Space time codes

- Step1: Send x1 on antenna 1, send x2 on antenna 2
- Step 2: send $x2^*$ on antenna 1 and $-x1^*$ on antenna 2
- 2 linear equations
    - $y1 = h1x1 + h2x2 +n$
    - $y2 = h1x2^* - h2x1^* + n$
    - Solution of 2 equations
        - Recovers x1 and x2

Basic Idea; Try to spread out same info in space and time

Pro

- Don't need to send channel feedback

Con

- More computation

MIMO

2x2 Tx and Rx

hij = channel from Tx_i to RX_j

$y1 = h_{11}x2 + h_{21}x2 + n1$
$y2 = h_{12}x1 + h_{22}x2 + n2$
- H must be invertible to solve
    - In practice this means we need the distance lamba/2 between channels
- Solution: $y = Hx + n$
    - can have as many dimensions
- Bottleneck by which device has smaller number of antennas

Example

1 Tx with 3 antenna
3 Rx with 1 antenna each

Send H^{-1} to all Rx
- Can send all 3 streams at the same time with only overhead of computing+sending channel
    - Multi user MIMO

Diversity vs Multiplexing(MIMO)

Tradeoff
- Improve SNR by using diversity
    - Use all antennas to send to just one device more consistently
- Increase throughput with MIMO

Data Rate vs SNR graph
- When SNR is low, small improvements to SNR give big data rate improvement
- When SNR high, small improvement to SNR does not matter much

Low SNR -> diversity
- SNR and Data rate increase

High SNR -> MIMO
- Since there is not much extra benefit for improving SNR, improve throughput

Rate Adaptation

Can do rate adaption along number of antennas

At a certain point, increasing symbol paradigm (ex: BPSK -> 16QAM) does not have major improvements

- Instead, combine modulation scheme with spatial dimension increase
    - Ex: 16QAM 1 antenna -> BPSK 2 antenna