MIT 6.829: Computer Networks Fall 2017

Lecture 4: Interference

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1 Overview

This lecture is on mainly three topics:

- Capacity, Rate Region
- Interference Cancellation (IC)
- ZigZag Decoding: combating hidden terminals in wireless networks [1]

2 Capacity (C)

In the scenario of a single T_x and R_x the maximum achievable power of $R_x = P_{R_x}$ and N is the power of the noise.

$$R_{achievable} \leq C = BW * log(1 + \frac{P_{R_x}}{N})$$

The capacity (C) is an upper bound for the power which can be achieved. Rate adaptation tries to get as close as possible to C. See Fig. 1 where the power of Alice and Bob at the Access Point (AP) equals.

$$P_A = P_B = P$$

and

$$R_{max} = BW * log(1 + \frac{P}{N})$$

When both Alice and Bob transmit the AP will see

$$y(t) = y_a(t) + y_b(t) + w(t)$$

where $w(t)$ is noise.

Let's consider the case where AP decodes Alice first and assumes Bob is noise. We get at AP:

$$R'_{achievable} \leq BW * log(1 + \frac{P_A}{P_B + N})$$

The second case we consider is, AP subtracts Alice's signal and decodes Bob. We get at AP:

$$R_{max} = BW * log(1 + \frac{P}{N})$$

Putting all theses equations together yields to Fig. 2. Where $R'_{achievable}$ and R_{max} are only the same because we decided that $P_A = P_B = P$.

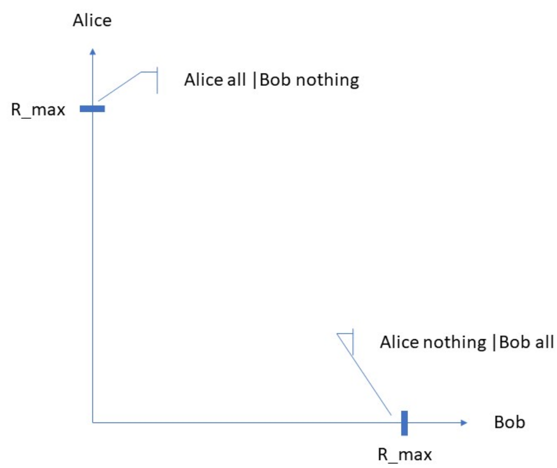

Figure 1: Example with Alice and Bob.

3 Remarks about C and IC

- The line between $(R', R_{max})(R_{max}, R')$ can be a channel via IC
- IC works beyond 2 T_xs, e.g. Alice + Bob + Charlie
  Decode Bob at $BW * log(1 + \frac{P}{2P+N})$
  Decode Charlie at $BW * log(1 + \frac{P}{P+N})$
  Decode Alice at $BW * log(1 + \frac{P}{N})$
- IC can achieve higher rates than TDMA, CDMA, FDMA, CSMA.
- Why don't we use IC in practice more often? See Fig. 3 and Fig. 4. In the high SNR case IC $\approx$ TDMA and that the enviorment Wifi or LTE are operating in, so the performance difference is not high enough.
- Alice needs to know SNR of Bob at AP. The rate in IC depends on other clients channel / power not just the client's channel.

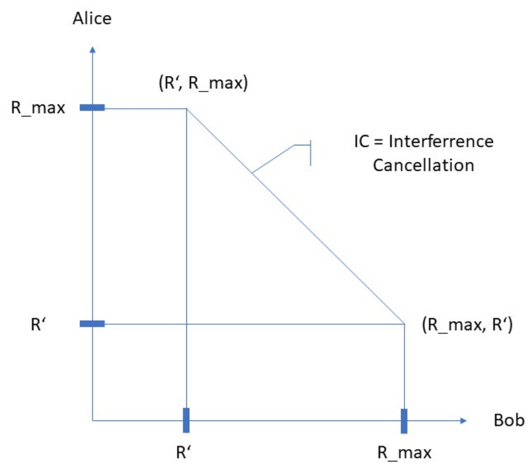

Figure 2: Example with Alice and Bob. Region below the IC line = Rate Region

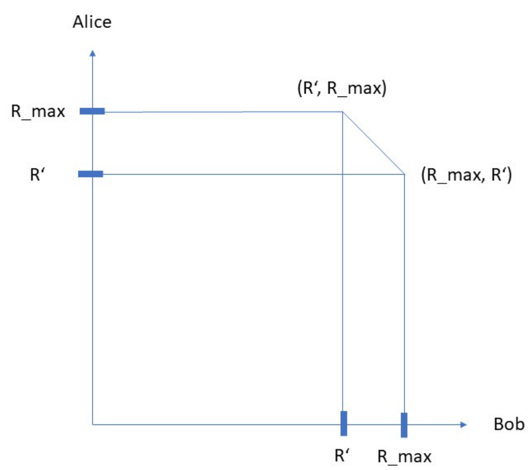

Figure 3: Low SNR: $P \ll N$ yields to $R' = BW * log(1 + \frac{P}{P+N}) \approx R_{max}$

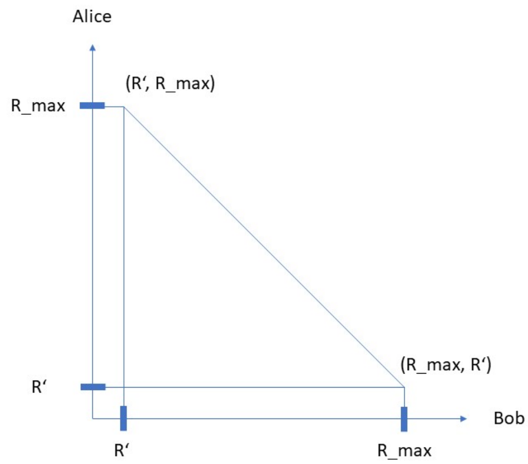

Figure 4: High SNR: $P \gg N$ yields to IC $\approx$ TDMA

4 ZigZag

Fig. 5 gives a short overview of the hidden terminal problem. Alice and Bob don't hear each other. They are assuming idle. Starting to send. This leads to collision. Neither receives an acknowledgment. Note during the lecture: Rate adaptation will lower the bit rate which will make things worse. Why? Packages will take longer which increases probability of collision.

- Wifi re-transmits after collision
- Random offset at the beginning
- The random offset tends to shift from one collision to the next. ZigZag attempts to compute the random offsets and find chunks of time that are interference free in one collision but not the other.
- ZigZag is modulation independent, backwards compatible and can be used in scenarios where there are more than 2 packets.
- ZigZag reduces lost packets in the hidden terminal problem from 72.6% to 0.7%, making it a successful protocol. It is now widely used in many wifi chips/technologies.

References

[1] Gollakota, S., and Katabi, D. (2008). Zigzag decoding: combating hidden terminals in wireless networks (Vol. 38, No. 4, pp. 159-170). ACM.

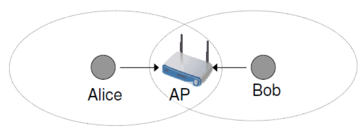

Figure 1: A Hidden Terminals Scenario.

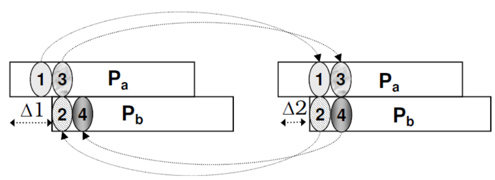

Figure 2: ZigZag Decoding. ZigZag decodes first chunk 1 in the first collision, which is interference free. It subtracts chunk 1 from the second collision to decode chunk 2, which it then subtract from the first collision to decode chunk 3, etc.

Figure 5: Taken from [1]