Lecture 8: Wireless MAC: Link Adaptation Protocols

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Link Adaptation

- Wireless channel varies with time – coherence time of a channel measures the frequency of change
- Coherence time is a few hundreds of millisec indoors, even smaller outdoors
- What does change mean? SNR and other channel properties at receiver change with time
- Link adaptation changes the properties of the wireless link to cope with changing channel conditions
  - Adapt modulation and coding to get better decoding performance for a given SNR. Also called bit rate adaptation.
  - Adapt transmit power to adjust the SNR at the receiver.

Link Adaptation (2)

- Bit rate adaptation or adaptive modulation and coding (AMC) is widely used in wireless LANs (WiFi) and in 3G/4G cellular networks
- Power control is mostly used in cellular networks
  - Adjust transmit power so that users near and far from base station perceive similar received power
  - Very critical to CDMA based cellular systems
- We will mostly deal with bit rate adaptation in this lecture.

Bit Rate Adaptation

- Refer to “Bit-rate Selection in Wireless Networks” on the class web page for a thorough treatment of bit rate adaptation. In particular, Sections 1 and 2 explain the motivation and background. Section 5 describes the SampleRate algorithm, which is one of the most popular bit rate adaptation algorithms used in WiFi devices today.
- Pages 9, 10, 11 in the paper show SNR vs. BER and SNR vs. packet delivery ratio graphs for various WiFi bit rates.
- The concept of “best rate”: for a given channel state and SNR, there exists a best rate that maximizes some objective
  - For example, we may want the rate that gives the maximum throughput, as defined by packet_delivery_rate * physical_layer_rate
  - Or, we may want the highest rate that has less than 10% packet loss rate
- Goal of bit rate adaptation algorithms – identify the best rate under changing channel conditions

Estimating the wireless channel

- One way to estimate the wireless channel is to simply compute some metric of channel quality like SNR. Cellular systems use the term Channel Quality Index (CQI). There are special frequencies and time slots that transmit known reference signals, which are used for estimating channel quality. Typically, receivers (say, user phones) compute CQI and convey it to the sender (say base station). There exists a pre-defined mapping between CQI and modulation/coding, using which the sender picks a suitable bit rate.
- In wireless LANs (WiFi) also, one can measure SNR and send it as a feedback in link-layer ACK, using which sender picks best bit rate. Such proposals exist, but no such mechanism in current commercial systems.
  - Wide variety of hardware and SNR estimation methods vary, so SNR to best rate mapping is not fixed
  - No standard notion of reference signals to measure SNR, so one particular value of SNR can lead to different loss rates in different environments
  - As a result, bit rate adaptation in wireless LANs is a harder problem

Bit rate adaptation in wireless LANs

- In wireless LANs, rate adaptation is usually done by measuring frame loss rates.
- Instead of measuring SNR and then computing frame loss rates, directly measure loss rates (and hence, throughput) at various bit rates
- Inherently slower than SNR-based rate adaptation
  - Need many frames at each bit rate to get a statistically significant estimate of frame loss rate
  - Need to measure frame loss rate at many bit rates before identifying correct rate
  - Instead, with SNR-based rate adaptation, we only need one SNR measurement (to give us throughput at all rates, and hence the best rate)
- However, frame-based rate adaptation is widely used in WiFi devices due to practical considerations

SampleRate overview

- SampleRate is one of the popular frame-based rate adaptation algorithm. Most other algorithms revolve around a similar idea, so we will study SampleRate in some detail.
- At a high level, SampleRate computes the average loss rate at various bit rates, and picks the rate with the highest throughput
- Actually, it picks the rate with the lowest average transmission time (which is almost the same as picking the rate with the highest throughput)
- Every 10^{th} packet, it “samples” a rate that could potentially give a higher throughput, so that it can move to better rates if channel conditions have changed.
- Please refer to the paper for more details

Bit rate adaptation - challenges

- Bit rate adaptation algorithms must lower bit rate only when frames are lost due to bad channel, not when frame loss is due to collisions (why?). Existing rate adaptation algorithms do not deal with this problem very well.
- With new physical layers features like MIMO, rate adaptation algorithms have to make more choices (not just modulation and coding, but also spatial multiplexing vs. diversity etc.) as the set of possible bit rates is higher. Current algorithms may not perform very well in future wireless LAN hardware.