Lecture 7: Centralized MAC protocols

Mythili Vutukuru

CS 653 Spring 2014

Jan 27, Monday

Centralized MAC protocols

- Previous lecture – contention based MAC protocols, users decide who transmits when in a decentralized manner
- Today's lecture – a central entity allocates resources to users sharing a medium
  - TDMA – Time Division Multiple Access
  - CDMA – Code Division Multiple Access
  - Other concepts – SDMA, FDMA / OFDMA
- Mainly used in cellular networks, as voice requires high QoS.

TDMA

- Assign different time slots to different users
- Fixed TDMA – Each user gets a fixed time slot irrespective of whether he has data to send or not
  - Wastes slots when users have bursty data
- Dynamic TDMA – the decision of which user sends when is decided on a per-slot basis
  - Users signal their intention to send data
  - Slots allocated to users who have data to send
  - Scheduling algorithm decides which user is scheduled to transmit in which slot

Scheduling algorithms

- Dynamic TDMA relies on scheduling algorithms. Tradeoff between efficiency and fairness.
- Common scheduling algorithms used in cellular networks
  - Round robin – schedule all users in a certain order. Guarantees fairness.
  - Max rate – schedule the user that has best channel conditions, i.e., can send at highest rate. This guarantees that the network gets high throughput. But may starve some users at cell edge.
  - Proportionally fair – schedule users according to a priority computed as p = current_rate / average_rate. The current rate is computed based on current channel conditions. So biased towards users with good channel and high rate. Also avoids starving of some users, because if average_rate becomes low enough, the user priority will increase and he will get scheduled.
- Proportionally fair scheduler (or its variants)is the most common design used in today’s networks.

CDMA

- Basic idea: transmit each user’s data using a unique code.
- Take each bit, exor with a longer bit sequence called code, and transmit the resulting new bit stream.
  - For example, suppose a user’s code is 010011. Then, for bit 1 the user sends the code “010011”. For bit 0, the user sends the complement “101100”.
- At the receiver, correlate with the code to recover data.
  - If correlation with 010011 is high, then it is 1. If correlation with complement is high, then it is 0.
- Different users are assigned different “orthogonal” codes, that is, codes which have low correlation with each other.
- Even if the signals of multiple users are combined, the receiver can extract its own transmission by correlating with its own code
- Can be synchronous (code boundaries are aligned) or asynchronous. Codes are generated in different ways for both schemes.

CDMA (2)

- Example, user A uses code 010011 and user B uses code 110101 (example from Schiller's textbook)
- Suppose A wants to send bit 1 and B wants to send bit 0. Let's assume we send -1 for code bit 0.
- A sends (-1,1,-1,-1,1,1) and B sends (-1,-1,1,-1,1,-1)
- In a simplistic model where both signals combine, we get (-2,0,0,-2,2,0)
- Correlate received signal with A's code gives +6 → bit 1
- Correlate with B's code word gives -6 →bit 0
- If B's transmit power is much higher than A's, that is, B's bit sequence is scaled up, then harder to decode A's bit.
- Power control is very important in CDMA, as other transmissions appear as noise and reduce SNR

Frequency Domain View of CDMA

- Multiplying a bit with a code is equivalent to spreading the spectrum in the frequency domain (recall: faster pulses -> wider bandwidth)
- That is, each user uses a larger bandwidth than the original signal
- However, CDMA is not inefficient because many users are multiplexed over the same wider band
- This idea can be used for a single user too – spread spectrum modulation scheme
  - Achieves low rates, but useful with frequency selective fading and resilience to jamming by enemies
  - Direct Sequence Spread Spectrum (DSSS) is used for the 1 and 2 Mbps rates in 802.11b. A special 11 bit code is used to spread each bit.

Other ways of multiplexing

- Space Division Multiple Access (SDMA) – the idea behind having “cells” in cellular networks. Frequencies used in one cell can be reused in another cell that is some distance away.
- Frequency Division Multiple Access (FDMA) – assign multiple narrow channels to different users.
- Orthogonal Frequency Division Multiple Access (OFDMA) – Similar to OFDM, but different sub carriers can be allocated to different transmitters.

Challenges in centralized MACs

- TDMA requires tight time synchronization
- CDMA requires fine-grained power control (and possibly time sync)
- FDMA requires very precise channel filters to restrict users to specific frequencies

Multiple Access in Cellular Networks

- All cellular networks use SDMA to partition frequencies to cells
- 2G networks mainly used plain TDMA (in GSM networks) or CDMA within a cell
- 3G networks use a combination of TDMA and CDMA in a cell
  - Voice mainly uses CDMA
  - Special high speed data channels exist in some 3G technologies. These use a combination of TDMA and CDMA. In every slot, a single user or multiple users can be scheduled. If multiple users, they are multiplexed using different codes.
- 4G / LTE uses TDMA + OFDMA on the downlink. That is, in each slot, a single user can be scheduled, or multiple users can be scheduled over multiple subcarriers in OFDM.