EECS 454: Modeling and Analysis of Communication Networks

Spring Quarter 2008

Meeting time: 12:30-1:50 MW

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Course Overview

- Primary goal is to develop *analytical tools* and *conceptual models* that are useful in networking research (and in other fields).
- Focus of the course is on issues identified with data link, network and transport layer - physical layer and application layer issues will not be addressed in detail.
- This graduate level course - you should question what you are learning and think about how what you are learning may be applied in other situations. What are the limitations, key assumptions, etc.

Course Information

Prerequisites:

- **Good understanding of basic probability.** (If you are not comfortable with probability, it may be helpful to take ECE 422 before taking this course.)
- Familiarity with data networks (e.g. ECE 333 or CS 340) is helpful (this provides motivation/context for the material studied here).

Text: *Data Networks*, 2nd Ed. by D. Betsekas and R. Gallager.

For the first half of the course we will follow parts the text closely; for the second half the text will be supplemented with other notes and journal papers. Other references are listed on the course information sheet.

Grading

- Problem Sets - can work in groups - write-up your own solutions.
- 1st mid-term - in-class about 1/2 way through term.
- 2nd mid-term - take home exam - last week of classes
- Final Project - presentation and write-up during last week of classes or final exam week.

ECE 454 vs. EECS 333

- Fewer topics than in 333, but cover each topic in more depth.
- Less emphasis than 333 on describing actual protocols and implementation issues, more emphasis on analytical techniques and performance issues.

Research in Networking

- Multidisciplinary/multifaceted.
- The material in this course focus on the analytical side.
- But this far from the whole story, also a lot of work on measurements, simulation, implementation, protocol design, etc.

Analytical Modeling

Most of this course consists of describing different analytical techniques that can be used for understanding various aspects of networking.

Uses:

- Performance analysis
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- Parameter setting, network provisioning, comparison of different approaches.
- Improve understanding/intuition
  - qualitative behavior, performance trade-offs, system bottlenecks.
- Establish fundamental limitations
  - What is best performance possible?

What makes a good model?

Analytical Modeling

Two uses:

1. Gain deeper insight into perfromance
   - Often simplified “toy” models - need to abstract away much detail to get something you can really understand. Much “art” involved in developing good models.
   - Iterative process.
2. Systems design
   - More detailed - want to acurately capture actual system performance- often too complicated to analyze by hand.

Communication Networks

- Physically communication networks consist of "communication links" connecting together different "nodes" for the purpose of exchanging information (*bits*).
- Here focus on "wire-line" network models (point-to-point links).
- Each link can be thought of as a (possibly lossy) "bit-pipe" with a certain transmission rate.
- Nodes - sources, sinks, routers/switches.
- Mathematically - represent topology as a *graph*.

Networking motivations

- Networks are used to provide different *information services* to end-users (e.g. e-mail, ftp, voice telephony, streaming video,..).
- Key reason for using networks is *resource sharing* (economies of scale/economies of scope).
- Different applications require different *qualities of service* (QoS).
- A key issue is how to share resources and satisfy QoS.

Packets, Sessions, etc.

- users initiate “sessions” and exchange “messages”.
  - connection-orriented/connectionless
- Messages may be broken into smaller “packets” to be sent over network.

Multiplexing

- Multiplexing refers to techniques for sharing a link amoung different bit-streams.
- Two main techniques
  - circuit-based: e.g. TDM/FDM.
    - performance - blocking probability.
  - packet-based: statistical multiplexing/scheduling.
    - performance delay/packet dropping.
- Various hybrids also possible.

Switching/routing

A related issue to mulitplexing is how packets are switched and routed within the network.

Routing - how to determine the next link for a packet.

Switching - how nodes physically send packets from one link to the next.

Network Layers and Protocols

- Conceptually, we think of networks as a sequence of vertical *layers*; each layer providing some type of *service* to lower layers.
- Higher layers provide a higher level abstraction of the network.
- Each layer provides its service by implementing *communication protocols*.
- A protocol specifies how different *processes* in a network interact; this includes specifying the format of *messages* that are exchanged and the *algorithm* used to generate these messages.
  - A fundamental characteristic of most of the algorithms used in networks is that they are *distributed*.

Perfomance Analysis

The two most common performance metrics used in networking are

- **Delay** - i.e., how long does it take to send information from its source to its destination.
- **Throughput** - i.e. how much date per second can be sent across the network.

Much of the behaviour in networks is best modeled as random (e.g. user behaviour, failures); thus performance analysis is typically done in a probabalistic framework.

Modleing scales

- Traffic in a network can be modeled at different scales.
- At the finest scale we have the arrivals and departures of individual packets in a session.
  - Such models are refered to as ”packet-level models.”
- At a larger scale, one can look at ”flow level models.”
  - Focus on the arrival and departure of flows as the random quantity of interest.
  - Model the transmission of packets within a flow as a ”fluid” process.
  - Can think of as looking at system on a longer time-scale.
- In some cases, it is even reasonable to focus on a fixed set of active flows.
  - This leads to deterministic models, e.g. diferential equation models and optimization-based models of TCP.

Course Outline

- Delay models - queueing theory, Markov chains, networks of queues, long-range dependence.
- Switching - input/output switches/ stability/matching.
- Routing - Bellman-ford, adaptive routing, optimal routing, topological design.
- Flow control - TCP, fairness, token buckets, network calculus, pricing models.