# CS 268: Graduate Computer Networks – Spring 2005

<table>
<thead>
<tr>
<th>Instructors:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Scott Shenker (<a href="mailto:shenker@cs.berkeley.edu">shenker@cs.berkeley.edu</a>, 683 Soda Hall)</td>
</tr>
<tr>
<td>- Ion Stoica (<a href="mailto:istoica@cs.berkeley.edu">istoica@cs.berkeley.edu</a>, 645 Soda Hall)</td>
</tr>
</tbody>
</table>

- Lecture time: MW, 2:30-4:00 am
- Place: 405 Soda Hall
- Office hour: tba

## Overview

- Administrative trivia
- Overview and history of the Internet
- A Taxonomy of Communication Networks

## Administrative Trivia’s

- Course Web page:
  - [http://www.cs.berkeley.edu/~istoica/cs268/05/](http://www.cs.berkeley.edu/~istoica/cs268/05/) (check it By tomorrow)
  - Check it periodically to get the latest information
- Deadlines
  - Unless otherwise specified, it means 10 minutes before the lecture
  - Special circumstances should be brought to our attention ahead of deadlines

## Goals of this Course

- Understand
  - How does the Internet work?
  - What are the Internet’s design principles?
  - Where is the Internet heading to?
- Get familiar with current Internet research efforts
- Understand solutions in context
  - Goals
  - Assumptions

## Goals of this Course (cont’d)

- Appreciate what is good research
  - Problem selection
  - Solution & research methodology
  - Presentation
- Apply what you learned in a class project

## What Do You Need To Do?

- A research-oriented class project
- Two exams
- Paper reading
- One 20min paper presentation
Research Project

• Investigate new ideas and solutions in a class research project
  - Define the problem
  - Execute the research
  - Work with your partner
  - Write up and present your research
• Ideally, best projects will become conference papers (e.g., SIGCOMM, INFOCOM, MOBICOM)

Research Project: Steps

• We’ll distribute a list of projects
  - You can either choose one of these projects or come up with your own
• Pick your project, partner, and submit a one page proposal describing:
  - The problem you are solving
  - Your plan of attack with milestones and dates
  - Any special resources you may need
• A midterm presentation of your progress (five minutes)
• Poster session
• Submit project papers

Paper Reviews

• Goal: synthesize main ideas and concepts in the papers
• Number: around two papers per class
• Length: no more than half page per paper
• Content
  - Main points intended by the author
  - Points you particularly liked/disliked
  - Other comments (writing, conclusions…)
• Submission:
  - Submit each review via e-mail before the class on lecture day
  - See class web page for details

Grading

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term project</td>
<td>50%</td>
</tr>
<tr>
<td>Midterm exam</td>
<td>10%</td>
</tr>
<tr>
<td>Midterm exam</td>
<td>15%</td>
</tr>
<tr>
<td>Class participation and presentation</td>
<td>15%</td>
</tr>
<tr>
<td>Paper reviews</td>
<td>10%</td>
</tr>
</tbody>
</table>

• This is a graduate networking class: more important is what you realize/learn than the grade

Enrollment Policy

• Graduate students get highest priority
• Among other students, priority is given to those who
  - Have backgrounds in networking, operating systems
  - Have relatively light course load
• Procedure of enrollment for undergraduate students
  - Be officially on the waiting list
  - Send us an email with URL that has pointers to
    • Your resume or cv
    • A short statement of relevant courses (textbook, university, grade) and experiences
    • Other courses you are taking this semester

Send the Following Information

• Please send me (istopic@cs.berkeley.edu) an e-mail with the subject “cs268 registration” and the following information:
  - Last and first name
  - Student ID
  - Your department
  - Preferred email address
  - URL of your home page
Overview

- Administrative trivia
  - Overview and history of the Internet
  - A Taxonomy of Communication Networks

The Internet (cont’d)

- Global scale, general purpose, heterogeneous-technologies, public, computer network
- Internet Protocol
  - Open standard: Internet Engineering Task Force (IETF) as standard body (http://www.ietf.org)
  - Technical basis for other types of networks
    - Intranet: enterprise IP network
  - Developed by the research community

History of the Internet

- 70’s: started as a research project, 56 kbps, < 100 computers
- 80-83: ARPANET and MILNET split,
- 85-86: NSF builds NSFNET as backbone, links 6 Supercomputer centers, 1.5 Mbps, 10,000 computers
- 87-90: link regional networks, NSF (NASA, ESNet(DOE), DARTnet, TWBNet (DARPA); 100,000 computers
- 90-92: NSFNET moves to 45 Mbps, 16 mid-level networks
- 94: NSF backbone dismantled, multiple private backbones
- Today: backbones run at >10 Gbps, >200 millions computers in 150 countries

Time Line of the Internet

- Source: Internet Society

Growth of the Internet

- Number of Hosts on the Internet:
  - Aug. 1981 213
  - Oct. 1984 1,024
  - Dec. 1987 28,174
  - Oct. 1990 313,000
  - Oct. 1993 2,056,000
  - Apr. 1995 5,796,000
  - Jan. 1997 16,146,000
  - Jan. 1999 56,218,000
  - Jan. 2001 109,374,000
  - Jan. 2003 171,638,297
  - July 2004 285,139,107

Data available at: http://www.isc.org
Services Provided by the Internet

- Shared access to computing resources
  - Telnet (1970’s)
- Shared access to data/files
  - FTP, NFS, AFS (1980’s)
- Communication medium over which people interact
  - Email (1980’s), on-line chat rooms (1990’s)
  - Instant messaging, IP Telephony (2000’s)
- A medium for information dissemination
  - USENET (1980’s)
  - WWW (1990’s)
    - Replacing newspaper, magazine
    - Audio, video (2000’s); peer-to-peer systems
    - Replacing radio, telephony, TV

Overview

- Administrative trivia
- Overview and history of the Internet
  > A Taxonomy of Communication Networks

A Taxonomy of Communication Networks

- Communication networks can be classified based on the way in which the nodes exchange information:

  Communication Network
  - Switched Communication Network
  - Circuit-Switched Communication Network
  - Packet-Switched Communication Network
  - Datagram Network
  - Virtual Circuit Network

Broadcast vs. Switched Communication Networks

- Broadcast communication networks
  - Information transmitted by any node is received by every other node in the network
    - E.g., LANs (Ethernet, Wavelan)
  - Problem: coordinate the access of all nodes to the shared communication medium (Multiple Access Problem)
- Switched communication networks
  - Information is transmitted to a sub-set of designated nodes
    - E.g., WANs (Telephony Network, Internet)
  - Problem: how to forward information to intended node(s)
    - Done by special nodes (e.g., routers, switches) running routing protocols

A Taxonomy of Communication Networks

- Communication networks can be classified based on the way in which the nodes exchange information:

  Communication Network
  - Switched Communication Network
  - Circuit-Switched Communication Network
  - Packet-Switched Communication Network
  - Datagram Network
  - Virtual Circuit Network

Circuit Switching

- Three phases
  1. circuit establishment
  2. data transfer
  3. circuit termination
- If circuit not available: “Busy signal”
- Examples
  - Telephone networks
  - ISDN (Integrated Services Digital Networks)
Timing in Circuit Switching

A node (switch) in a circuit switching network

Circuit Switching

Circuit Switching: Multiplexing/Demultiplexing

A Taxonomy of Communication Networks

Packet Switching

Packet Switching: Multiplexing/Demultiplexing
A Taxonomy of Communication Networks

- Communication networks can be classified based on the way in which the nodes exchange information:

Datagram Packet Switching

- Each packet is independently switched
  - Each packet header contains destination address
- No resources are pre-allocated (reserved) in advance
- Example: IP networks

Timing of Datagram Packet Switching

- Data is transmitted as packets
- All packets from one packet stream are sent along a pre-established path (=virtual circuit)
- Guarantees in-sequence delivery of packets
- However: Packets from different virtual circuits may be interleaved
- Example: ATM networks
Virtual-Circuit Packet Switching

- Communication with virtual circuits takes place in three phases
  1. VC establishment
  2. data transfer
  3. VC disconnect
- Note: packet headers don’t need to contain the full destination address of the packet

Packet-Switching vs. Circuit-Switching

- Most important advantage of packet-switching over circuit switching: ability to exploit statistical multiplexing:
  - Efficient bandwidth usage; ratio between peek and average rate is 3:1 for audio, and 15:1 for data traffic
- However, packet-switching needs to deal with congestion:
  - More complex routers
  - Harder to provide good network services (e.g., delay and bandwidth guarantees)
- In practice they are combined:
  - IP over SONET, IP over Frame Relay

Summary

- Course administrative trivia
- Internet history and trivia
- Rest of the course a lot more technical and (hopefully) more exciting