EE 122: Introduction to Computer Networks – Fall 2002

• Instructors
  - Ion Stoica (i@cs.berkeley.edu, 645 Soda Hall)
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• Lecture time
  - Monday/Wednesday, 4:00 – 5:30pm

• Office hour:
  - Monday, 2-3pm

• Class Web page
  - http://inst.eecs.berkeley.edu/~ee122/

• Textbook

TAs

• Weidong Cui, wdc@eecs.berkeley.edu
• Xuanming Dong, xuanming@eecs.berkeley.edu
• Karthik Lakshmanarayanan, karthik@eecs.berkeley.edu
• Ananth Rajagopala-Rao (AP), ananthar@eecs.berkeley.edu
• Office hours and recitations to be announced by Wednesday!

Overview

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

Administrative Trivia’s

• Course Web page:
  - http://inst.eecs.berkeley.edu/~ee122/
  - Check it periodically to get the latest information

• Deadline means deadline
  - Homeworks: unless otherwise specified, it means 3:50 pm on the date (10 minutes before lecture)

• Exams are closed-book
• Best way to communicate: e-mail
  - But contact your TA first!
• Please let us know any suggestions/complaints about class as early as possible
Goals of this Course

- Learn the main concepts of communication networks in general, and Internet in particular
  - Understand how the Internet works
  - Try to understand why the Internet is the way it is
- Apply what you learned in small scale class projects

What Do You Need To Do?

- Four homeworks
  - Strict deadlines
- Two projects
  - Four slip days. Any additional day – 20%
- One midterm exam
- One final exam

Grading

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homeworks</td>
<td>20%</td>
</tr>
<tr>
<td>Two projects</td>
<td>30%</td>
</tr>
<tr>
<td>Midterm exam</td>
<td>20%</td>
</tr>
<tr>
<td>Final exam</td>
<td>30%</td>
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</tbody>
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Overview

- Administrative trivia
- Overview and history of the Internet
- A Taxonomy of Communication Networks
**What is a Communication Network?**

* (from end-system point of view)

- Network offers a service: move information
  - Bird, fire, messenger, truck, telegraph, telephone, Internet …
  - Another example, transportation service: move objects
  - Horse, train, truck, airplane …
- What distinguish different types of networks?
  - The services they provide
- What distinguish the services?
  - Latency
  - Bandwidth
  - Loss rate
  - Number of end systems
  - Service interface (how to invoke the service?)
  - Other details
    - Reliability, unicast vs. multicast, real-time, message vs. byte …

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**What is a Communication Network?**

* Infrastructure Centric View

- Electrons and photons as communication medium
- Links: fiber, copper, satellite, …
- Switches: electronic/optic, crossbar/Banyan
- Protocols: TCP/IP, ATM, MPLS, SONET, Ethernet, X.25, FrameRelay, AppleTalk, IPX, SNA
- Functionality: routing, error control, flow control, congestion control, Quality of Service (QoS)
- Applications: FTP, WEB, X windows, …

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**Types of Networks**

- Geographical distance
  - Local Area Networks (LAN): Ethernet, Token ring, FDDI
  - Metropolitan Area Networks (MAN): DQDB, SMDS
  - Wide Area Networks (WAN): X.25, ATM, frame relay
  - Caveat: LAN, MAN, WAN may mean different things
    - Service, network technology, networks
- Information type
  - Data networks vs. telecommunication networks
- Application type
  - Special purpose networks: airline reservation network, banking network, credit card network, telephony
  - General purpose network: Internet

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**Types of Networks**

- Right to use
  - Private: enterprise networks
  - Public: telephony network, Internet
- Ownership of protocols
  - Proprietary: SNA
  - Open: IP
- Technologies
  - Terrestrial vs. satellite
  - Wired vs. wireless
- Protocols
  - IP, AppleTalk, SNA
The Internet

- 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 2.4 Gbps, 200 millions computers in 150 countries

Growth of the Internet

- Number of Hosts on the Internet:
<table>
<thead>
<tr>
<th>Month</th>
<th>Number of Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug. 1981</td>
<td>213</td>
</tr>
<tr>
<td>Oct. 1984</td>
<td>1,024</td>
</tr>
<tr>
<td>Dec. 1987</td>
<td>28,174</td>
</tr>
<tr>
<td>Oct. 1990</td>
<td>313,000</td>
</tr>
<tr>
<td>Oct. 1993</td>
<td>2,056,000</td>
</tr>
<tr>
<td>Apr. 1995</td>
<td>5,706,000</td>
</tr>
<tr>
<td>Jul. 1997</td>
<td>19,540,000</td>
</tr>
<tr>
<td>Jul. 1999</td>
<td>59,249,900</td>
</tr>
<tr>
<td>Jun. 2002</td>
<td>200,071,000</td>
</tr>
</tbody>
</table>

Recent Growth (1991-2002)

Internet Domain Survey Host Count

Source: Internet Software Consortium (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, instant messaging (1990’s)
  - audio, video (1990’s)
  - replacing telephone network?
- A medium for information dissemination
  - USENET (1980’s)
  - WWW (1990’s)
  - replacing newspaper, magazine?
  - audio, video (1990’s)
  - replacing radio, CD, TV?

Commercial Internet after 1994

Internet Physical Infrastructure

- Residential Access
  - Modem
  - DSL
  - Cable modem
  - Satellite
- Enterprise/ISP access, Backbone transmission
  - T1/T3, DS-1 DS-3
  - OC-3, OC-12
  - ATM vs. SONET, vs. WDM
- Campus network
- Ethernet, ATM
- Internet Service Providers
- access, regional, backbone
- Point of Presence (POP)
- Network Access Point (NAP)
**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:
Broadcast vs. Switched Communication Networks

- Broadcast communication networks
  - Information transmitted by any node is received by every other node in the network
  - Examples: usually in 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
  - Examples: WANs (Telephony Network, Internet)
  - Problem: how to forward information to intended node(s)
  - This is 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:

  - Broadcast Communication Network
  - Switched Communication Network
  - Circuit Switching
  - Packet Switching
  - ATM

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
Circuit Switching

- A node (switch) in a circuit switching network

Circuit Switching: Multiplexing/Demultiplexing

- Time divided in frames and frames divided in slots
- Relative slot position inside a frame determines which conversation the data belongs to
  - E.g., slot 0 belongs to red conversation
- Needs synchronization between sender and receiver
- In case of non-permanent conversations
  - Needs to dynamic bind a slot to a conversation
  - How to do this?
- If a conversation does not use its circuit the capacity is lost!

A Taxonomy of Communication Networks

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

Packet Switching

- Data are sent as formatted bit-sequences, so-called packets.
- Packets have the following structure:
  - Header and Trailer carry control information (e.g., destination address, check sum)
  - Each packet is passed through the network from node to node along some path (Routing)
  - At each node the entire packet is received, stored briefly, and then forwarded to the next node (Store-and-Forward Networks)
  - Typically no capacity is allocated for packets
Packet Switching

- A node in a packet switching network

Packet Switching: Multiplexing/Demultiplexing

- Data from any conversation can be transmitted at any given time
  - A single conversation can use the entire link capacity if it is alone
  - How to tell them apart?
    - Use meta-data (header) to describe data

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**

- Host 1
- Node 1
- Node 2
- Host 2

- Transmission time of Packet 1 at Host 1
- Propagation delay between Host 1 and Node 2
- Processing delay of Packet 1 at Node 2

**Datagram Packet Switching**

- Host A
- Host B
- Host C
- Host D
- Host E
- Host F
- Node 1
- Node 2
- Node 3
- Node 4
- Node 5
- Node 6
- Node 7

**A Taxonomy of Communication Networks**

- Communication networks can be classified based on the way in which the nodes exchange information:
  - Serial Communication Network
  - Broadcast Communication Network
  - Packet-Switched Communication Network
  - Virtual-Circuit Network

**Virtual-Circuit Packet Switching**

- Hybrid of circuit switching and 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

Timing of Datagram Packet Switching

Datagram Packet Switching

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) exciting