EE 122: Introduction to Computer Networks – Fall 2002

- Instructors
  - Ion Stoica (istoica@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 Lakshminarayanan, karthik@eecs.berkeley.edu
- Anantha 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>Component</th>
<th>Weight</th>
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<tbody>
<tr>
<td>Homeworks</td>
<td>20%</td>
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<td>Two projects</td>
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<td>Midterm exam</td>
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<td>Final exam</td>
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Overview

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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 …
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
- Functionalities: routing, error control, flow control, congestion control, Quality of Service (QoS)
- Applications: FTP, WEB, X windows, …
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
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, NSI (NASA), ESNet(DOE), DARNet, TWBNNet (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:**
  - Aug. 1981: 213
  - Oct. 1984: 1,024
  - Dec. 1987: 28,174
  - Oct. 1990: 313,000
  - Oct. 1993: 2,056,000
  - Apr. 1995: 5,706,000
  - Jul. 1997: 19,540,000
  - Jul. 1999: 59,249,900
  - Jun. 2002: 200,071,000

Data available at: http://www.netsizer.com/
Recent Growth (1991-2002)
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

- Joe's Company
- Campus Network
- Regional ISP
- Stanford
- Berkeley
- Bartnet
- Xerox Parc
- America On Line
- SprintNet
- UUnet
- IBM
- AT&T
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
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  ➢ 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
    - Broadcast 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
    - 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:
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

processing delay at Node 1

propagation delay between Host and Node 1

propagation delay between Host and Node 1

DATA

Host 1

Node 1

Node 2

Host 2

Circuit Establishment

Data Transmission

Circuit Termination
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!
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  Communication Network
  
    Switched Communication Network

    Circuit-Switched Communication Network

    Packet-Switched Communication Network

    Broadcast Communication Network

    Datagram Network

    Virtual Circuit Network
Packet Switching

- Data are sent as formatted bit-sequences, so-called packets.
- Packets have the following structure:

  ![Packet Structure Diagram]

  - 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 \[\text{Packet 1} \quad \text{Packet 2} \quad \text{Packet 3}\]

Node 1

Node 2

Host 2

transmission time of Packet 1 at Host 1

\{\text{Packet 1} \quad \text{Packet 2} \quad \text{Packet 3}\} \quad \text{propagation delay between Host 1 and Node 2} \quad \text{processing delay of Packet 1 at Node 2}

\{\text{Packet 1} \quad \text{Packet 2} \quad \text{Packet 3}\} \quad \{\text{Packet 1} \quad \text{Packet 2} \quad \text{Packet 3}\}

Ion Stoica, Fall 2002
Datagram Packet Switching
A Taxonomy of Communication Networks

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    - Broadcast Communication Network
      - Datagram 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

- VC establishment
- Data transfer
- VC termination

Propagation delay between Host 1 and Node 1
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 peak 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