Basic Info

- Instructor: Andreas Terzis (terzis@cs.jhu.edu, 417 Wyman Park)
- Lecture time: MW, 2:00-3:15 pm
- Place: Shaffer 101
- Office hour: Tue, 2 - 3 pm

Overview

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

Administrative Trivia

- Course Web page: http://www.cs.jhu.edu/~terzis/cs644/
- Course List: cs644@cs.jhu.edu
  Send email to majordomo@cs.jhu.edu “subscribe cs644”
- Deadline means deadline
  Unless otherwise specified, it means 1:50 pm on the date (10 minutes before lecture)
  Special circumstances should be brought to my attention way ahead of deadlines
- Exam is closed-book
**Goals of this Course**
- Get familiar with current Internet research efforts
- Understand solutions in context
  - Goals
  - Assumptions
- 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
- One exam (midterm)
- Paper reading

**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**
- I’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)
- Final project presentation (ten minutes)
- Submit project papers
Paper Reviews

- Goal: synthesize main ideas and concepts in the papers
- I will assign one paper for you to review per lecture
- Content
  - Main points intended by the author
  - Points you particularly liked/disliked
  - Other comments (writing, conclusions...)
- Submission:
  - Submit each review via e-mail before 1:50 pm on lecture day
  - See class web page for details

Grading

- Term project: 50%
- Midterm exam: 30%
- Class participation: 10%
- Paper reviews: 10%

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

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What is a Communication Network?
(End system view)

- Network offers a service: move information
- 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?)
  - 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/optical, crossbar/Banyan
- Protocols: TCP/IP, ATM, MPLS, SONET, Ethernet, PPP, X.25, Frame Relay, AppleTalk, IPX, SNA
- Functionalities: routing, error 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

The Internet
- Global scale, general purpose, heterogeneous-technologies, public, computer network
- Internet Protocol
  - Open standard: Internet Engineering Task Force (IETF) as standard body
  - 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, 15 Mbps, 10,000 computers
- 87-90: link regional networks, NSI (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, 10s millions computers in 150 countries

Time Line of the Internet

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: 56,218,000
  - Jul. 2001: 126,888,197
  - Jan 2003: 171,638,297

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)
- A medium for information dissemination
  - USENET (1980's)
  - WWW (1990's)
    - Replacing newspaper, magazine?
  - Audio, video (2000's)
    - Replacing radio, CD, TV

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)
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A Taxonomy of Communication Networks

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

- Switched Communication Networks
  - Information is transmitted to a subset of designated nodes
  - Examples: WANs (Telephony Network, Internet)
  - Problem: how to forward information to intended nodes(s)
    - This is done by special nodes (e.g., routers, switches) running routing protocols

- 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)

Broadcast vs. Switched Communication Networks
Communication networks can be classified based on the way in which the nodes exchange information:

**A Taxonomy of Communication Networks**
- Switched Communication Network
- Broadcast 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)

**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

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**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**

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

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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
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