CS589: Advanced Computer Networks

- Instructor
  - Z. Morley Mao (zmao@eecs.umich.edu, 2241 EECS)
- Lecture time: TuTh, 10:30-12:30 PM
- Location: 185 EWRE
- Office hour:
  - TuTh 3-4PM
  - email for appointment

Topics Covered

- Internet routing characterization
- Routing security
- Internet AS relationships
- ISP traffic engineering
- Critical network infrastructure services
- Network security; IDS, worms, and honeypots
- CDNs, Peer to peer and overlay networks
- Wireless networking
- Sensor networking
- Network measurements
- Network security
- Network models

Lecture Overview

- Administrative trivia
- Course overview
- Self introduction, student introduction
- Overview and history of the Internet
- A Taxonomy of Communication Networks

Administrative Trivia

- Course Web page:
  - http://www.eecs.umich.edu/~zmao/eecs589/
  - Check it periodically to get the latest information
- Deadline means deadline
  - Reading summaries are due before each class
  - Attendance is important
- Assignments are done individually, unless otherwise noted
- Research project are encouraged to be done in groups (at most 3 people)

Goals of this Course

- Critical examination of current topics of computer networks
  - What assumptions are no longer valid
  - What are the new research problems to look at
- Understand solutions in context
  - Goals
  - Assumptions
- Learning how to do research in systems
  - Paper review, writing, and presentation
- 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
- Paper reading
- Lead one class discussion
- 2-3 design assignments
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, Sensys)

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) + poster session
- Submit project papers

Paper Reviews

- Goal: synthesize main ideas and concepts in the papers
- Number: up to 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 on lecture day in class
  - See class web page for details

Grading

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<thead>
<tr>
<th>Component</th>
<th>Weight</th>
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<tbody>
<tr>
<td>Final project</td>
<td>40%</td>
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<tr>
<td>Assignments</td>
<td>10%</td>
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<tr>
<td>Paper presentation</td>
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<td>Reading summaries</td>
<td>5%</td>
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<td>Class discussion</td>
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- This is a graduate networking class: more important is what you realize/learn than the grade

Self Introduction

- Faculty in software lab
- Past and ongoing research:
  - Internet routing, BGP
  - Network measurement
  - Content distribution networks
  - Intrusion detection systems
  - Network troubleshooting, debugging

Student Introduction

- Please introduce yourself: name, standing, research area (for grad students)
- Say a few words about what you think you would like to learn about computer networks
- Or what you think are “unsolved” problems in computer networks
Overview

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

What is a Communication Network? (End system 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?)
  - 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, FrameRelay, 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

- 70s: 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), ESN (DOE), DARTNet, TWBNet (DARPA), 100,000 computers
- 90-92: NSFNET moves to 45 Mbps, 16 midlevel 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: 26,174
  - Oct. 1990: 5,065,000
  - Apr. 1995: 5,706,000
  - Jul. 1997: 19,540,000
  - Jul. 1999: 56,218,000
  - Jul. 2001: 125,888,197

Recent Growth (1991-2002)

Who is Who in the Internet?

- Internet Engineering Task Force (IETF): The IETF is the protocol engineering and development arm of the Internet. Subdivided into many working groups, which specify Request For Comments or RFCs.
- IRTF (Internet Research Task Force): The Internet Research Task Force is a composed of a number of focused, long-term and small Research Groups.
- Internet Architecture Board (IAB): The IAB is responsible for defining the overall architecture of the Internet, providing guidance and broad direction to the IETF.
- The Internet Engineering Steering Group (IESG): The IESG is responsible for technical management of IETF activities and the Internet standards process. Standards, Composed of the Area Directors of the IETF working groups.

Internet Standardization Process

- All standards of the Internet are published as RFC (Request for Comments). But not all RFCs are Internet Standards!
  - available: http://www.ietf.org
- A typical (but not only) way of standardization is:
  - Internet Drafts
  - RFC
  - Proposed Standard
  - Draft Standard (requires 2 working implementation)
  - Internet Standard (declared by IAB)
- David Clark, MIT, 1992: "We reject: kings, presidents, and voting. We believe in: rough consensus and running code."
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 telephone network?
- 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)

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:

- Switched Communication Network
- Broadcast 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
  - 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

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

- Host
- Node 1
- Node 2

Circuit Establishment
Data Transmission
Circuit Termination

Circuit Switching

- A node (switch) in a circuit switching network
- Incoming links
- Node
- Outgoing links

A Taxonomy of Communication Networks

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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
- Needs synchronization between sender and receiver
- In case of non-permanent conversations
  - Needs to dynamically bind a slot to a conversation
  - How to do this?

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: Multiplexing/Demultiplexing

- Data from any conversation can be transmitted at any given time
- 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:

A node in a packet switching network
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

Packet 1

Packet 2

Packet 3

Host 1

Host 2

Node 1

Node 2

Node 3

Propagation delay between Host 1 and Node 2

Transmission time of Packet 1 at Host 1

Processing delay at Node 2

Timing of switches

A Taxonomy of Communication Networks

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

  - Circuit-Switched Communication Network
  - Packet-Switched Communication Network
  - Virtual Circuit Network
  - Broadcast Communication 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
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