CS589: Advanced Computer Networks

- Instructor
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- 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/](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  - What assumptions are no longer valid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
This is a graduate networking class: more important is what you realize/learn than the grade

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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
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
  - 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), 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

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: 5,706,000
  - Jul. 1997: 19,540,000
  - Jul. 1999: 56,218,000
  - Jul. 2001: 125,888,197

![Bar graph showing growth of Internet hosts from 1981 to 2002](image-url)
Recent Growth (1991-2002)

Internet Domain Survey Host Count

Source: Internet Software Consortium (www.isc.org)
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)
    - Replacing telephone network?
- 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)
Overview

- Administrative trivia
- Overview and history of the Internet
  - 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
- Datagram Network
- Virtual Circuit Network
- Broadcast Communication Network

A Taxonomy of Communication Networks
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
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
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 1  
Node 1  
Node 2  
Host 2

- Circuit Establishment
- Data Transmission
- Circuit Termination

- Propagation delay between Host 1 and Node 1
- Propagation delay between Host 2 and Node 1
- Processing delay at Node 1
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
- Needs synchronization between sender and receiver
- In case of non-permanent conversations
  - Needs to dynamic bind a slot to a conservation
  - How to do this?
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
- 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
Datagram Packet Switching
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
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 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