CS589: Advanced Computer Networks

- Instructor
  - Z. Morley Mao (zmao@umich.edu, 4629 CSE)

- Lecture time: TuTh, 10:30-12:30 PM

- Location: 1018 DOW

- Office hour:
  - TuTh 1-2PM
  - email for appointment
Topics Covered

- Internet design philosophies and principles
- Internet routing characterization, Internet AS relationships
- Routing security
- ISP traffic engineering
- Critical network infrastructure services
- Network security: IDS, worms, and honeypots
- CDNs, Peer to peer and overlay networks, DHTs
- Wireless networking, meshed networks, mobile systems
- Sensor networking
- Network measurements
- Network security
- Network models
- Network algorithmics: building fast networks
- Networking in challenging environments
- Data center networking
Interesting new/hot topics

- A research agenda for Web 2.0
- Architectural support for security or availability
- Computing in the cloud: what role for networking research?
- Ensuring correctness for distributed protocols
- Evolution of storage area networks
- Lessons drawn from failed research, and controversial or disruptive topics
- Measurement and management of metro-area WiFi networks
- Network coding: hype or reality?
- Power as a first-class design property; "green" protocols/implementations
- Protocol design for optical switching
- The future role of network processors
- Third-world networking challenges
- Understanding the economics of operational costs
- Unique challenges of massive multi-player game systems
- Validation of measurement-based research: what are our standards?
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/courses/eecs589](http://www.eecs.umich.edu/courses/eecs589)
  - Linked from my home page: [http://www.eecs.umich.edu/~zmao](http://www.eecs.umich.edu/~zmao)
  - Check it periodically to get the latest information

- Please come prepared for each class
  - 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  - What assumptions are no longer valid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 readings, selective book chapters
- Lead at least one class discussion
- 2-3 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, Mobisys, IMC)
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 (>10 minutes)
- Final project presentation (>30 minutes)
- Submit project papers
Paper Reviews

- Goal: synthesize main ideas and concepts in the papers
- Number: about 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

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

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Self Introduction

- Faculty in the software lab
- Past and ongoing research:
  - Internet routing, BGP
    - How to protect the Internet routing systems better?
  - Network measurement
    - How do we know how well networks are doing?
  - Content distribution networks
  - Intrusion detection systems
  - Network troubleshooting, debugging
  - Network configuration management, provisioning
  - Denial of service attacks
  - General interest: Internet networks, routing systems, network security.
Example research project 1: dark DNS

Improperly Delegated
Dark DNS

Properly Delegated

Diagram:

1. PTR Query: 11.22.33.44
2. Recursive Resolver
3. Authoritative Dark DNS Monitor
4. Query Response: host-11-22-33-44.merit.edu
5. ATTACK!
Example research project 2: Testing the reachability of (new) address space

“The Internet”
Testing reachability

- We can identify regions in the Internet that do not have reachability
- It is possible to achieve a reasonable coverage of the Internet
- We don’t only check reachability: we also detect places where there is "non-optimal" connectivity
Example research project 3: On the Impact of Route Monitor Selection

- Use of route monitoring
  - Dynamic properties:
    - Routing instability monitoring
    - IP prefix hijacking detection
  - Static properties:
    - AS topologies
    - Prefix to origin AS mappings
  - Inference of important network properties
    - AS relationships
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
- And what you think are “unsolved” problems in computer networks
Some unsolved problems…

- **QoS**
  - Networks are not fast enough
  - Networks do not satisfy application requirements
  - Networks are not robust, highly available

- **Security**
  - There are attacks everywhere on the Internet
  - Hosts are easily compromised

- We still don’t have ubiquitous access

- New technologies: can networks take advantage of them?
  - Dual core, new algorithms (machine learning, statistical techniques, optimization)
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 services are missing from today’s Internet?
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, …
- New “infrastructures”:
  - Wireless access points, NATs, firewalls, caches, traffic shapers, or middleboxes
  - Anything you can think of?
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
  - Private networks or virtual private networks (VPNs)
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
- Internet organically evolved!
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
Recent Growth (1991-2002)

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)

Where do you think the bottleneck is on today’s Internet?
• Is it easy to create network partitions?
• Where are the shared bottlenecks?
• How do we guarantee fault isolations?
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
  - New technologies: optical packet switching!
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

Circuit Establishment

Data Transmission

Circuit Termination

Host 1

Node 1

Node 2

Host 2

processing delay at Node 1

propagation delay between Host 1 and Node 1

propagation delay between Host 2 and Node 1
Circuit Switching

- A node (switch) in a circuit switching network

Switches and routers are very complicated!
- new requirements for today’s routers: ability to filter traffic at line speed graceful degradation under attacks, anything else?
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
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)
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

Research issues: defense against DDoS attacks, malicious traffic behavior.
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
Transmission time of Packet 1 at Host 1

Propagation delay between Host 1 and Node 2

Processing delay of Packet 1 at Node 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

Transmission time of Packet 1 at Host 1

Propagation delay between Host 1 and Node 2

Processing delay of Packet 1 at Node 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
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
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

Packet 1
Packet 2
Packet 3

Data transfer

Packet 1
Packet 2
Packet 3

VC termination

Packet 1
Packet 2
Packet 3

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
What’s in the news that’s relevant?

Bots slim down to get tough

By Dawn Kawamoto
http://news.com.com/Bots+slim+down+to+get+tough/210...
Crocodile hunter's death clogs Web sites

By Reuters

Story last modified Tue Sep 05 05:13:31 PDT 2006

In death as in life, iconic TV naturalist Steve Irwin captivated millions worldwide and clogged the Internet as fans from Guam to Glasgow reacted with disbelief to news that "The Crocodile Hunter" was dead.

Some Web sites groaned to a halt within hours of the first reports on Monday that Irwin had been killed by a stingray's barb through his chest in a freak diving accident off Australia's northeast coast.

Web measurement company Hitwise said Irwin's death was the biggest news event read by Australians on the Internet since two Australian miners were trapped by a mine collapse in southern Tasmania state in late April.

"We noticed that the Web site www.crocodilehunter.com increased in popularity quite substantially. It became the No. 1 entertainment personality Web site in Australia on Monday and in the United States it also became the third-most popular," Hitwise Asia-Pacific marketing director James Borg told Reuters.

Australian news Web sites struggled to keep up with demand.

The Australian Broadcasting's site (www.abc.com.au) had to temporarily shut down, posting a notice on Monday that it was experiencing higher than normal traffic.

It resumed soon after in a low-bandwidth format to cope with hundreds of thousands of hits.

Newspaper Web sites also wobbled but kept up with demand.

A spokesman for The Sydney Morning Herald's site, www.smh.com.au, said it had experienced a "huge" 40 percent spike in page impressions compared with the previous week's average weekday number of about 500,000.
Russia accused of unleashing cyberwar to disable Estonia

- Parliament, ministries, banks, media targeted
- Nato expected to strengthen

Ian Traynor in Thursday March 25
The Guardian

A three-week wave of massive cyber attacks have hit the small Baltic state of Estonia, the first major incident of its kind, causing alarm and a Western alliance urgent examination of the offensive and its implications.

While Russia and Estonia are embroiled in a dispute since the collapse of the Soviet Union, a row that erupted at the end of

Typical Attacks
- Phishing
- Email SPAM
- Web Site Defacing
- Syn / ICMP floods
- BotNets
Summary

- Course administrative trivia
- Internet history and trivia
- Rest of the course a lot more technical and (hopefully) exciting