CS 268: Graduate Computer Networks – Spring 2004

- Instructor:
  - Ion Stoica (istoica@cs.berkeley.edu, 645 Soda Hall)
- Lecture time: MW, 9:00-11:30 am
- Place: 310 Soda Hall
- Office hour: Tu, 4 - 5 pm

1

Overview

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

2

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3

Administrative Trivia's

- Course Web page:
  - http://www.cs.berkeley.edu/~istoica/cs268/04/ (it will move at http://inst.eecs.berkeley.edu/~cs268/sp04)
  - Check it periodically to get the latest information
- Deadlines
  - Unless otherwise specified, it means 10 minutes before the lecture
  - Special circumstances should be brought to my attention ahead of deadlines

4

Goals of this Course

- Understand
  - How does the Internet work?
  - What are the Internet's design principles?
  - Where is the Internet heading to?
- Get familiar with current Internet research efforts
- Understand solutions in context
  - Goals
  - Assumptions

5

Goals of this Course (cont'd)

- Appreciate what is good research
  - Problem selection
  - Solution & research methodology
  - Presentation
- Apply what you learned in a class project

6

What Do You Need To Do?

- A research-oriented class project
- Two exams
- Paper reading

7

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)

8

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)
- Poster session
- Submit project papers

9

Paper Reviews

- Goal: synthesize main ideas and concepts in the papers
- Number: around 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 e-mail before the class on lecture day
  - See class web page for details

10

Grading

Term project	50%
Final exam	15%
Midterm exam	15%
Class participation	10%
Paper reviews	10%

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

11

Enrollment Policy

- Graduate students get highest priority
- Among other students, priority is given to those who
  - Have backgrounds in networking, operating systems
  - Have relatively light course load
- Procedure of enrollment for undergraduate students
  - Be officially on the waiting list
  - Send me an email with URL that has pointers to
    - Your resume or cv
    - A short statement of relevant courses (textbook, university, grade) and experiences
    - Other courses you are taking this semester

12

Send the Following Information

- Please send me (istoica@cs.berkeley.edu) an e-mail with the subject "cs**268 registration**" and the following information:
  - Last and first name
  - Student ID
  - Your department
  - Preferred email address
  - URL of your home page
- Please indicate explicitly if I can add you to the on-line web page that lists each student enrolled in the class (only your name and URL will be made publicly available here).

13

Overview

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14

What is a Communication Network? (End-system Centric View)

- Network offers one basic 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 services?
  - Latency
  - Bandwidth
  - Loss rate
  - Number of end systems
  - Service interface (how to invoke the service?)
  - Others
    - Reliability, unicast vs. multicast, real-time...

15

What is a Communication Network? (Infrastructure Centric View)

- Communication medium: electron, photon
- Network components:
  - Links – carry bits from one place to another (or maybe multiple places): fiber, copper, satellite, …
  - Interfaces – attache devices to links
  - Switches/routers – interconnect links: electronic/optic, crossbar/Banyan
  - Hosts – communication endpoints: workstations, PDAs, cell phones, toasters
- Protocols – rules governing communication between nodes
  - TCP/IP, ATM, MPLS, SONET, Ethernet, X.25
- Applications: Web browser, X Windows, FTP, ...

16

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

17

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

18

The Internet (cont'd)

- 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

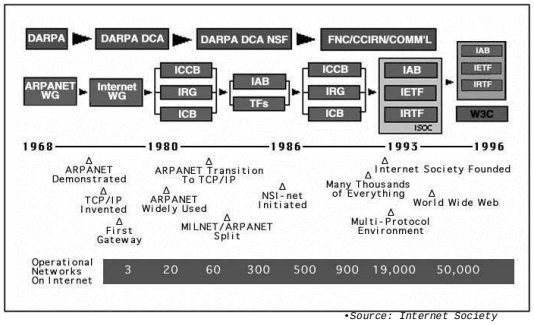
19

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

20

Time Line of the Internet



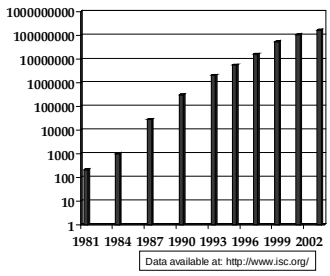
•Source: Internet Society

21

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
Jan. 1997	16,146,000
Jan. 1999	56,218,000
Jan. 2001	109,374,000
Jan 2003	171,638,297



22

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.

23

Internet Standardization Process

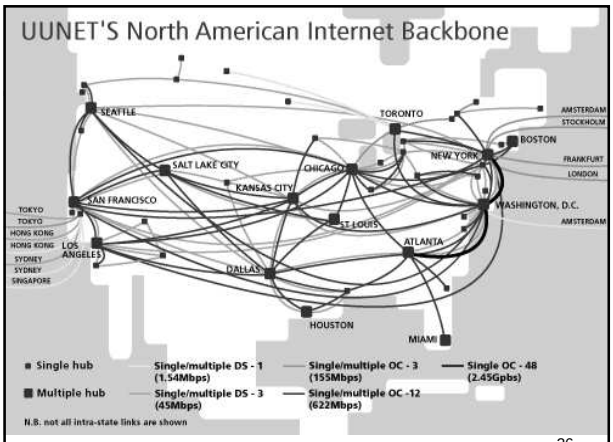
- All standards of the Internet are published as RFC (Request for Comments). But not all RFCs are Internet Standards
  - available: http://www.ietf.org
- A typical (but not only) way of standardization is:
  - Internet Drafts
  - RFC
  - Proposed Standard
  - Draft Standard (requires 2 working implementation)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

24

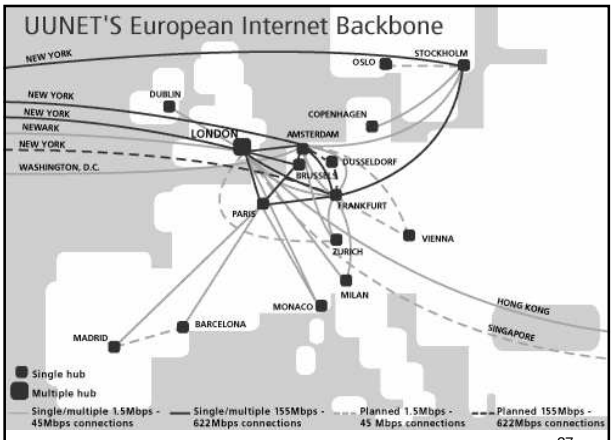
Services Provided by the Internet

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

25



26



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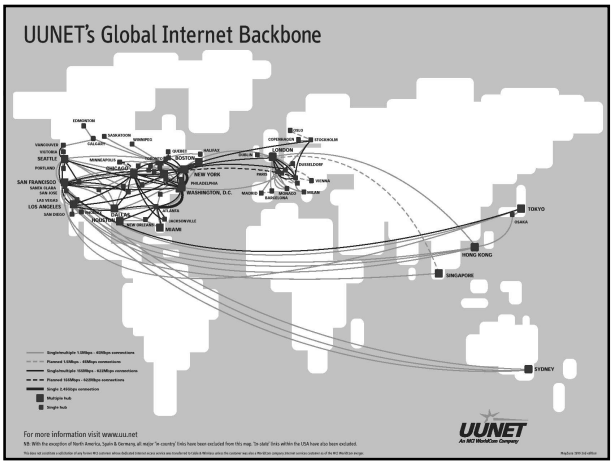

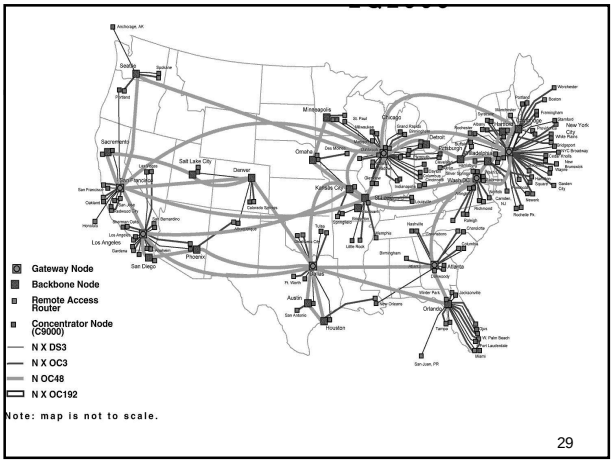

29

Overview

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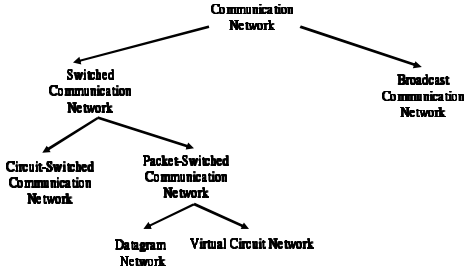
30

A Taxonomy of Communication Networks

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



31

Broadcast vs. Switched Communication Networks

- Broadcast communication networks
  - Information transmitted by any node is received by every other node in the network
    - E.g., 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
    - E.g., WANs (Telephony Network, Internet)
  - Problem: how to forward information to intended node(s)
    - Done by special nodes (e.g., routers, switches) running routing protocols

32

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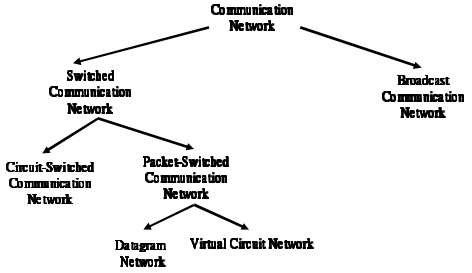


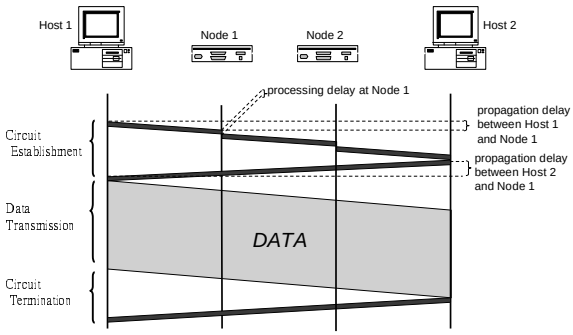
33

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)

34

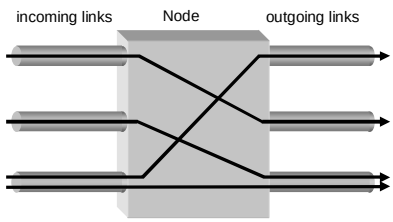
Timing in Circuit Switching



35

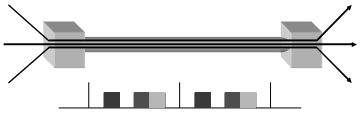
Circuit Switching

- A node (switch) in a circuit switching network



36

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?

37

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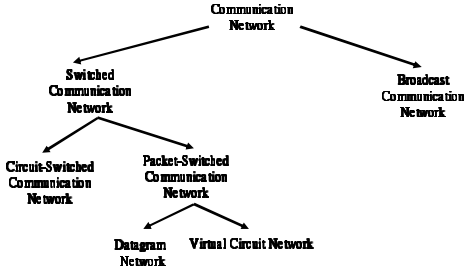


38

Packet Switching

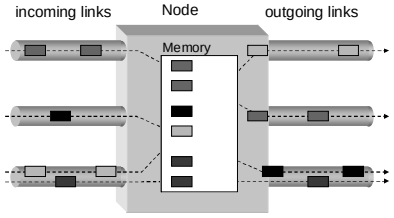
- Data are sent as formatted bit-sequences, so-called packets
- Packets have the following structure:

  - 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

39

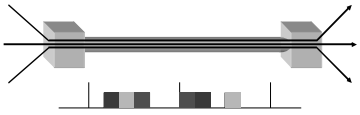
Packet Switching

- A node in a packet switching network



40

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

41

A Taxonomy of Communication Networks

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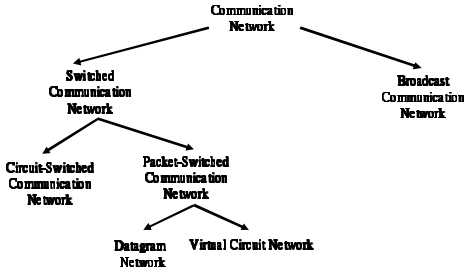


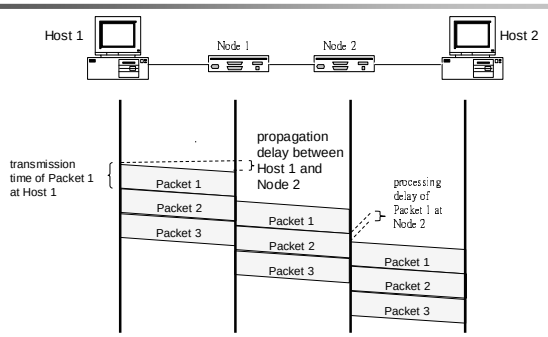
42

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

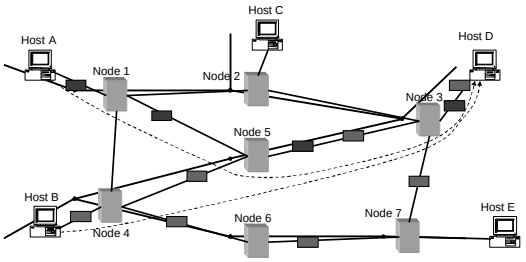
43

Timing of Datagram Packet Switching



44

Datagram Packet Switching



45

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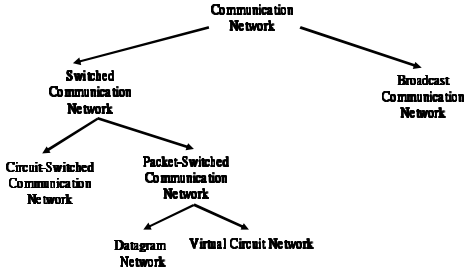


46

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

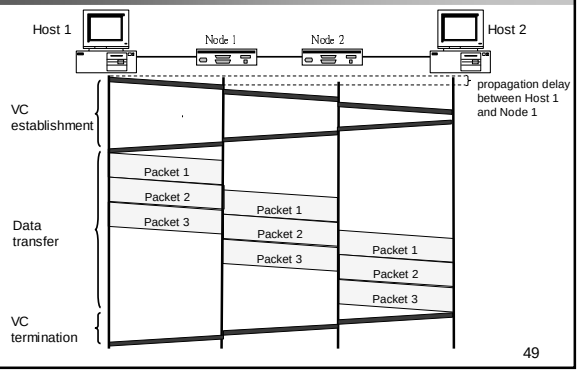
47

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

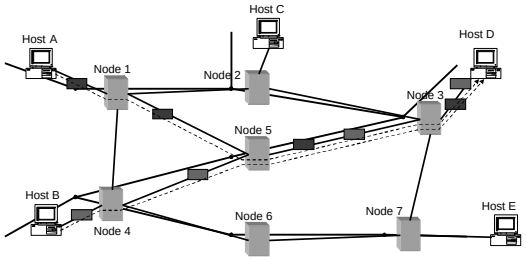
48

Timing of Datagram Packet Switching



49

Datagram Packet Switching



50

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

51

Summary

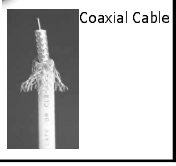
- Course administrative trivia
- Internet history and trivia
- Rest of the course a lot more technical and (hopefully) more exciting

52

Network Components (Examples)

Links


Fibers


Coaxial Cable

Interfaces

Ethernet card

Wireless card

Switches/routers

Large router


Telephone switch

53