Computer Networks III

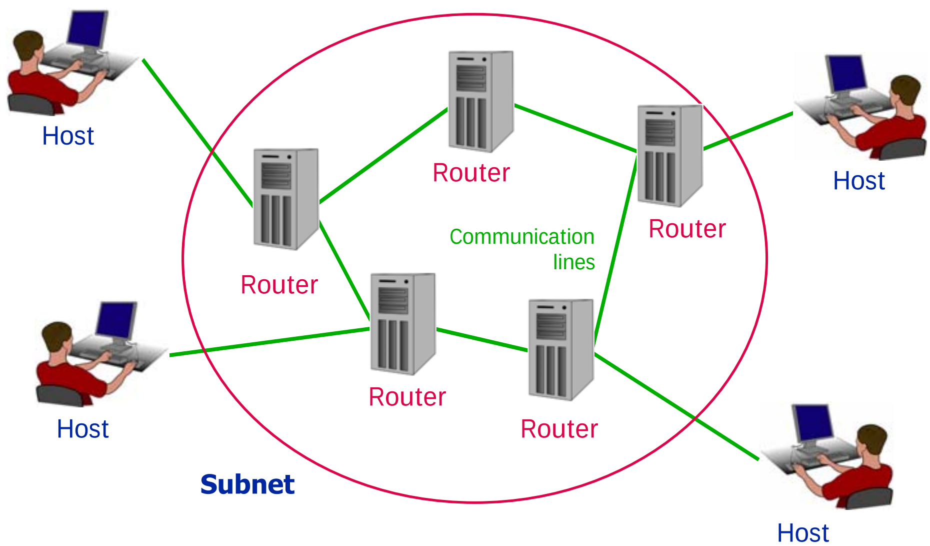
- Wide Area Networks and Packet Switching
- Network Protocols and the OSI Layers
- The Internet
- Internet Infrastructure

1

Wide Area Networks (recap)

2

Basic WAN structure



3

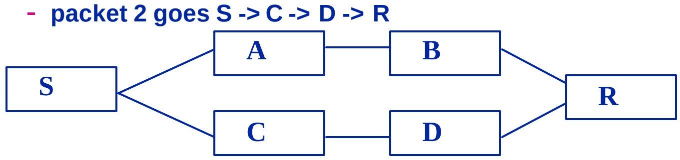
Switching

- **Circuit switching**
  - **Set up dedicated end-to-end channel for duration of connection**
  - **Used for phone network**
- **Message switching**
  - **For sending data messages (e.g., email)**
    - **Each intermediate node stores and forwards the message**
  - **No wasted channels as with circuit switching**
- **Packet switching**
  - **Divide data messages into small packets**
  - **Each packet is "message switched"**
    - **Packets can take different routes**
    - **If one is lost, don't resend whole message**

4

Why break messages into packets?

- If part of message is lost or garbled, resend only the affected packet(s)
- Speed
  - Store-and-forward delay is minimized (pipelining)
    - Each intermediate node has to receive and store a message, then forward it
    - A can send packet 1 to B while receiving packet 2 from S.
    - Not possible if whole message sent at once
  - Packets can take different routes (parallelism)
    - packet 1 goes S -> A -> B -> R
    - packet 2 goes S -> C -> D -> R



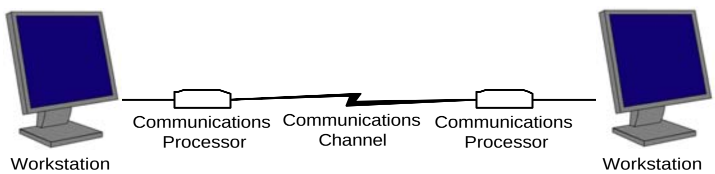
5

Network Protocols and the OSI Layers

6

LAN (point-to-point) network protocols

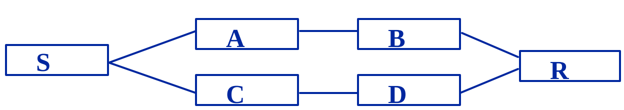
- "Data Link" protocols
  - provide point-to-point error-free transmission
  - break data into frames
  - attach error-detecting info into data
  - wait for acknowledgments and retransmit, if necessary
  - handle collisions (in broadcast networks)



7

Protocols for Packet Switching

- Assume data link protocols provide error-free point-to-point transmission
- Sender must break messages into packets
  - attach sequence number
  - attach destination address, other admin info to packets
- Receiver must reassemble message from packets
  - use sequence numbers in case packets arrive out of order
  - request retransmission of lost, garbled packets
- Intermediary nodes must route packet
  - find best next node in path for each packet
  - route packets to next node



8

Network protocol layers so far

- **Network Layer**
  - routes data from one host to another
  - routes packets to next node
  - attaches destination address, other admin info into data
  - Assumes error-free point-to-point transmission
- **Data Link Layer**
  - provides point-to-point error-free transmission
  - breaks packets into frames
  - attaches error-detecting info into data
  - Assumes existence of physical transmission medium
- **Physical Layer**
  - converts bits to signals and back
  - carries signals over wires

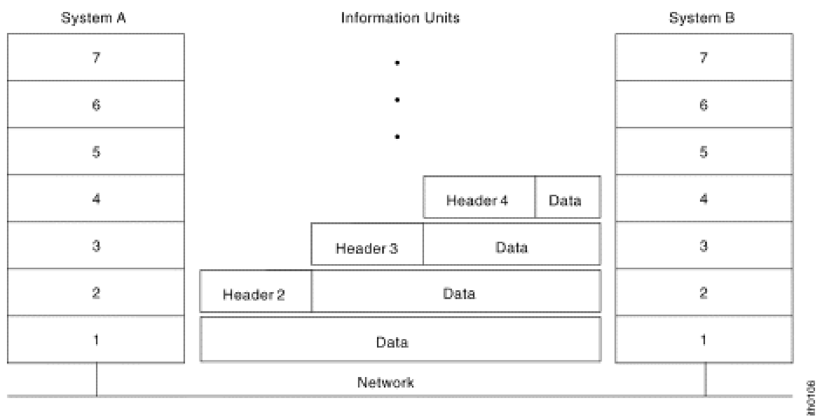
9

OSI Abstraction Layers

- **7: Application layer**
  - E.g., terminal emulation, file transfer
- **6: Presentation layer**
  - Handles encryption, compression, other translation of messages
- **5: Session layer**
  - Establishes and terminates connections between applications
- **4: Transport layer**
  - Divides messages into packets;assembles packets into messages
- **3: Network layer**
  - Finds routes for packets; transmits them to next node
- **2: Link layer**
  - Breaks packets into frames; sends frames between nodes
- **1: Physical layer**
  - Sends bits over wires

10

Information Exchange Process through OSI Layers



11

Example: Voice communication over a packet-switched company network

- Communication between managers in Germany and Wichita, Kansas
- Company network does not have a direct link between Germany and Kansas
  - New York is an intermediate link

12

Some Example Protocols

- Physical layer
  - standards for data lines, radio transmission, etc.
- Data Link layer
  - Ethernet, Token ring, ISDN
- Network layer
  - Novell IPX, Appletalk, IP
- Application layer
  - telnet, ftp, Netscape (HTTP), Eudora (email)

13

Important Idea

- Layered protocols allow protocols on one layer to interoperate with several different protocols on lower layers
  - Ethernet can be used with coaxial cable, infrared, microwave, etc.
  - Novell or Appletalk can be used with Ethernet, Token Rings, ISDN,etc.
  - Eudora, telnet can be used with any network

14

The Internet

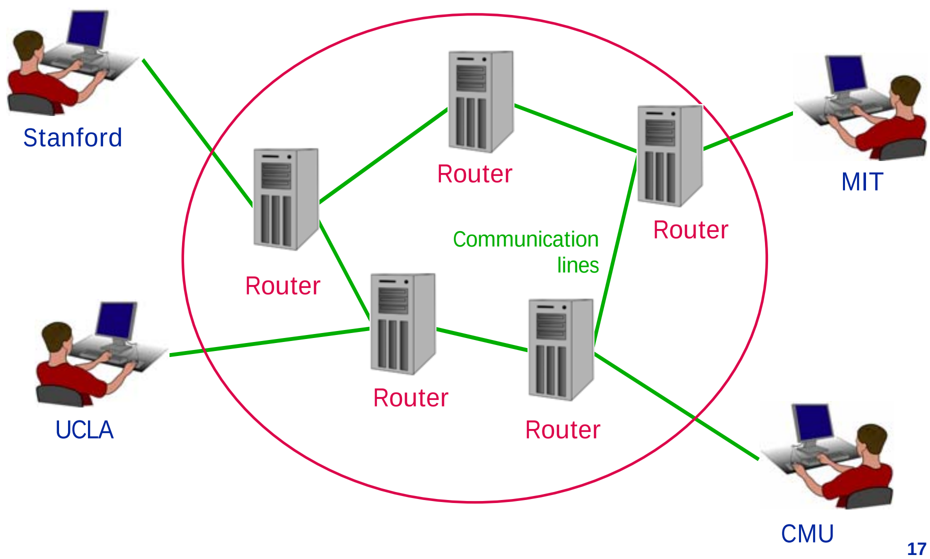
15

The Internet

- Grew out of ARPANET, NSFNET
  - as more and more independent networks adopted the Arpanet protocol suite and connected themselves to it through gateways
- Internet statistics
  - 265 million hosts in 2001
  - 60 million hosts in 1999
  - 36 million in 1998
  - 16,1 million in 1997
  - 9.5 million in 1996
  - 4.9 million in 1995
  - 2.2 million in 1994
  - 1.3 million in 1993

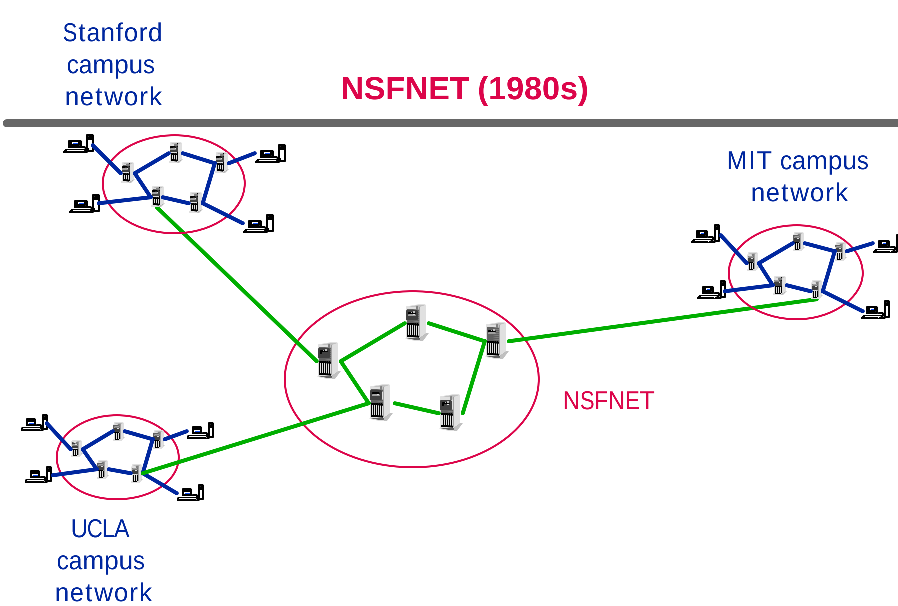
16

ARPANET (1970s)



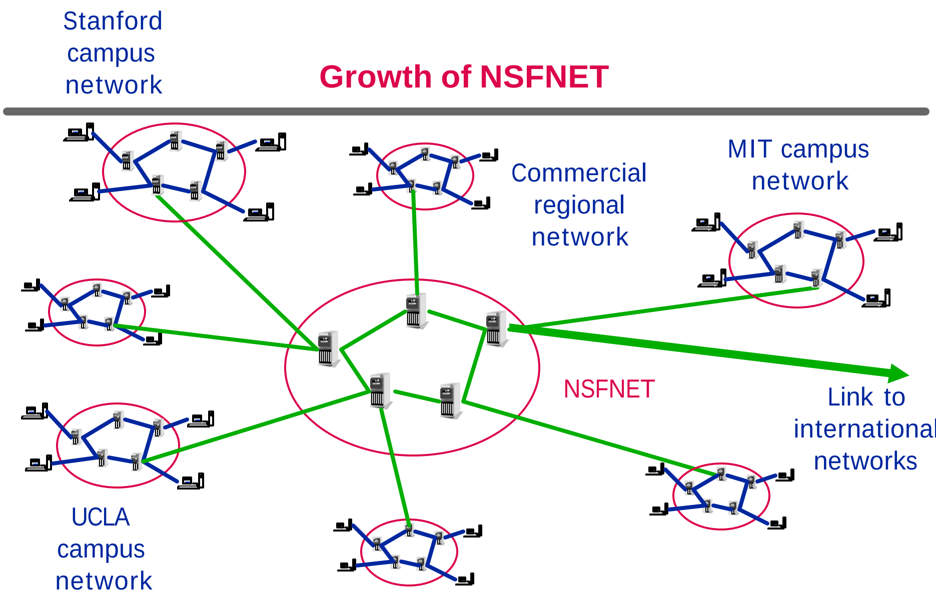
17

NSFNET (1980s)



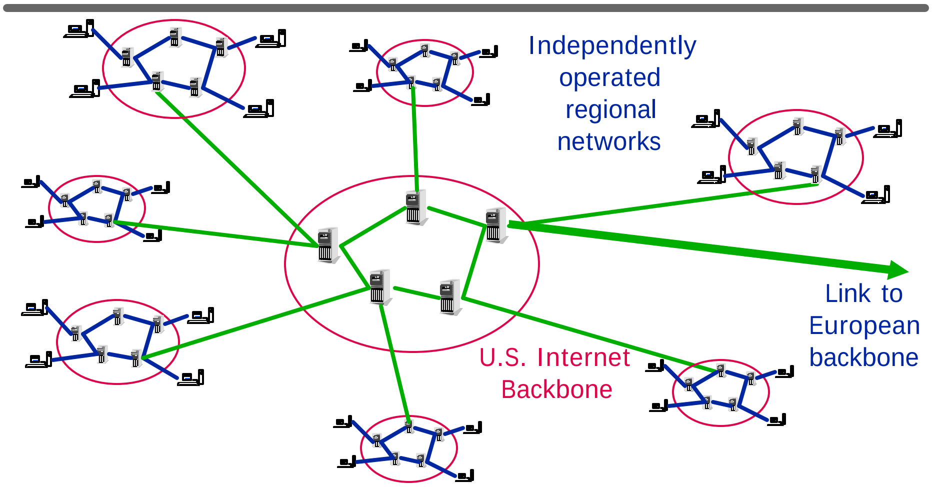
18

Growth of NSFNET



19

The Internet: a Network of Networks



20

Internet Properties

- All hosts on the Internet communicate using common network protocols
  - TCP/IP, first developed for ARPANET
- Different parts of the Internet are operated by different entities
  - governments, telephone companies, universities etc.
- No single organization controls or owns the Internet

21

A bird's eye view of the Internet

22

What does it mean to be on the Internet?

- Run TCP/IP protocol
- Have an IP address
- Have ability to send IP packets to other machines on the Internet

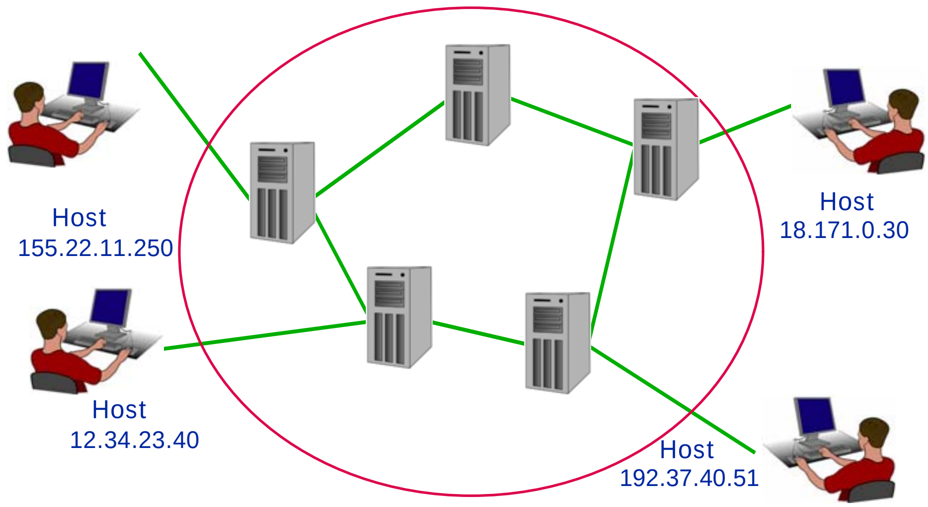
23

TCP/IP Protocol Stack

- Same layering ideas as OSI, (slightly) different layer definitions
  - IP corresponds to network layer
  - TCP corresponds to transport layer
- Protocol only defines network and transport layer.
  - can be used on top of many different physical network organizations

24

Internet Addresses (IP addresses)



25

TCP/IP Explained

- IP is lowest layer (equiv. to OSI network layer)
  - Moves a packet from one host to another
  - Connectionless protocol (no guarantee of reliable delivery)
  - Each packet contains a 32-bit address of the destination host
    - Each host has its own unique address
      - 18.171.0.30 is my machine's
    - Internet is running out of addresses
      - Partly because addresses allocated inefficiently
      - MIT has all of 18 (4M addresses) but not that many computers
    - Eventually move to more than 32-bit addresses
- TCP (equiv. to OSI transport layer)
  - Establishes a reliable connection between processes on two hosts
  - TCP makes up for unreliability of IP by resending lost blocks

26

Understanding Internet Addresses

- 18.154.0.27
  - uniquely assigned to a specific Internet connection point (NOT machine!) by NIC
  - 32-bit address
  - each number between dots is the decimal rep of 8 bits in the address
  - In this case:
    - 18 specifies MIT (MIT owns all addresses 18.xxx.yyy.zzz)
    - 54 specifies the subnet corresponding to building E56
    - 0.27 is host number within the subnet
  - Every internet address can optionally have a descriptive host name (e.g.LASAGNA.MIT.EDU)
  - Other variations are possible

27

Internet Infrastructure

28

Internet Overview

For diagram, see: http://navigators.com/sessphys.html

29

The Internet

Backbone Providers

11 Network Access Points (NAPs)

- San Francisco: Pacific Bell & MAE-West
- Chicago: Ameritech & MAE-Chicago
- New York: SprintLink
- Washington DC: MAE-East & MAE-East+
- FIX-East: Univ Maryland
- FIX-West: NASA Ames
- Los Angeles: MAE-LA
- Dallas: MAE-Dallas

Peering: interconnection between backbone providers

Private peering between operators to avoid NAP bottlenecks

30

Internet ‘Tiering’ Levels

- Tier 1 (nearly 50)
  - MCI Worldcom (UUNET, MCI (divested))
  - Sprint
  - GTE
  - Cable & Wireless
- Tier 2: National Backbone Level
- Tier 3: Regional Networks
- Tier 4: ISPs
- Tier 5: Consumer and Business Markets

31

Cable & Wireless Internet backbone

For diagram, see:
http://www.cwusa.com/internet_backbone.htm

32

Sprint's Internet Backbone

For diagram, see: http://www.sprintbiz.com/ip/backbone.html

33

GTE's Backbone

For diagram, see: http://www.bbn.com/infrastructure/us_back99.htm

34

MCI Worldcom (UUNet) Backbone

For diagram, see: http://www.uu.net/lang.en/network

35

AT&T's Backbone

For diagram, see: http://www.cerf.net/about/Bbone-map.html

36

IPv6: Next Generation IP (IPng)

- designed to solve shortage of addresses in IPv4;
- adds additional features to IPv4, such as security, autoconfiguration, and multicasting;
- provides QoS features making the Internet more suitable for real-time applications;
- need for a smooth transition from IPv4 to IPv6.

37

Additional features of IPv6

- Security
  - packet-level encryption (especially for Internet-based VPNs)
- Autoconfiguration
  - enable an IPv6 host to configure its IPv6 address without (or with very limited) human intervention
- Multicasting
  - can send packets simultaneously to several IP addresses; useful for videoconferencing, Web-casts

38

QoS features in IPv6

- IPv4 provides only best-effort service
- Goal: make IPv6 more suitable for real-time applications (e.g., audio and video)
- How: packets will be assigned different priorities (prioritization-based QoS) and will be treated differently based on these priorities

39

Need for a Smooth Transition from IPv4 to IPv6

- new IPv6 routers should not affect existing IPv4 routers
- IPv4 routers can be upgraded to IPv6 routers easily and at any time
- IPv6 packets should travel over IPv4 pieces of the Internet; mechanism: tunneling.

40