Course Goals and Overview

EECS 489 Computer Networks
http://www.eecs.umich.edu/courses/eecs489/w07
Z. Morley Mao
Monday Jan 8, 2007

Acknowledgement: Some slides taken from Kurose&Ross and Katz&Stoica

Instructors

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

    Office hours: Mon, Wed 2-3PM 4629 CSE or by appointment

    Feel free to email me to make an appointment

    Come talk to me after lectures
- GSI:
  - Ying Zhang (wingying@umich.edu)
  - Office hours: Tuesdays 10-11AM, and Thursday 4-5PM.

    Location: TBD

Text books

- (Required) Kurose and Ross, Computer Networking: A Top-Down Approach Featuring the Internet, 3rd. Edition, Addison Wesley, 2004. ISBN: 0321227352
- (Optional) W.R. Stevens, UNIX Network Programming, vol. 1: Networking APIs: Sockets and XTI, 2nd. ed., Prentice-Hall, 1997. Or the latest 3rd. edition.
- (Optional) W. R. Stevens, TCP/IP ILLUSTRATED, VOLUME 1: THE PROTOCOLS, 1st Edition, 1994.

Overview

- Administrivia
- Overview of computer networks

Logistics

- Course web page
  - http://www.eecs.umich.edu/courses/eecs489/w07
  - Check often to get the latest information
- Mailing list will be created this week
- Exams are closed book, with open crib sheet
- Come to office hours, request an appointment, communicate by email
- Please attend the lectures and discussion sections
- Give suggestions/complaints as early as possible

Course goals

- Learn the main architectural concepts and technological components of communication networks with the Internet as the overarching example
  - Understand how Internet works
  - Understand how Internet is the way it is today
- Apply what you learned in course project consisting of several mini-projects

Class workload

- CS489 is a 4 unit course
  - Final Exam: 30%
  - One midterm exam: 20%
  - Course project/Assignments: 45%
  - Class participation: 5%

Grading

- Consultation on assignments is okay, but must hand in own work
- Discussion and working in groups is encouraged for course project
- Exams are to be completed individually
- Cheating is severely punished
- No late homeworks and projects are accepted
  - 5 late days allowed
- Five working days for regrading after the grade is assigned

Main topics covered

- Internet: a network of networks
- Network protocols: evolution and concepts
  - E.g., TCP, UDP, HTTP, etc.
- Network application services
  - E.g., Web, email, DNS, multimedia streaming, VoIP, file sharing, etc.
- Local area networks
  - DSL, cable modem
- Wireless and mobile networks: WIFI, cell networks
- Network security issues
  - Firewalls, worms, viruses, etc.
- Network management

What do you expect to learn?

- Focus on the fundamental concepts, not merely the technology
  - There will always be new protocols, but how do people design them?
  - What are architectural principles?
- Provide high-level overview of computer networks
  - Wired, wireless, sensor, cellular
  - How they are interconnected!
- Highlight industrial trends and research issues
- Possibly predict future network trends

Short break

- Please introduce yourself
  - Name, which year?
  - Say something about what you hope to learn about computer networks.

How do people use networks?

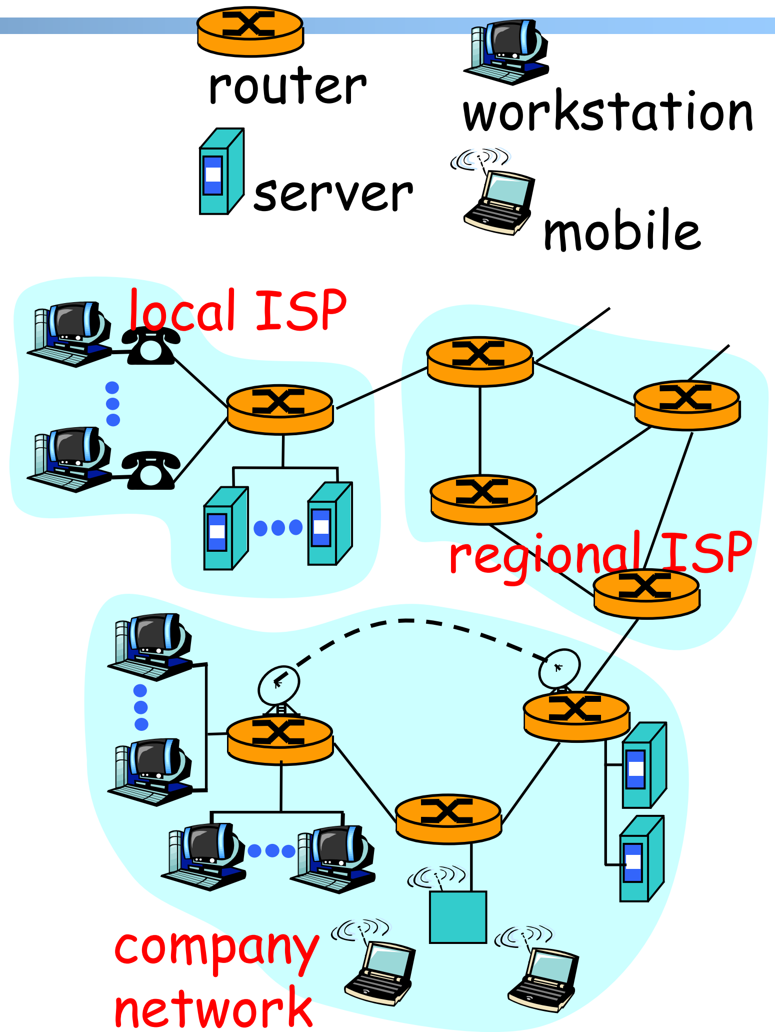
- Phone Network
  - Parses number dialed
  - Sets up a circuit to friend's phone
  - Sends signal to ring friend's phone
- Signaling network for setting up connection
- Circuit-switched network:
  - a circuit is set up between the two ends.

The Internet

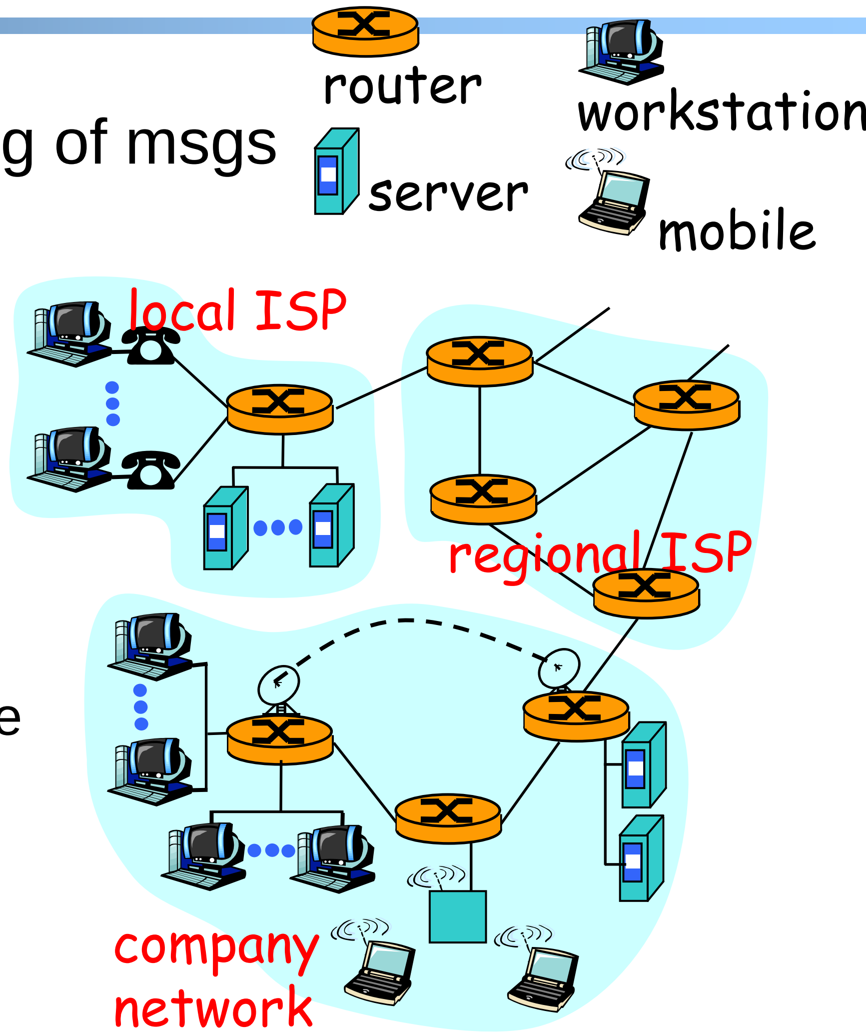
- The Internet is a packet switched network (PSN)
- Data parceled into packets.
- Each packet carries destination address.
- Each packet can ``take the path less traveled'' (be *routed* independently).
- Packets can arrive out of order.
- Packets may not arrive at all.
  - Surprising?!

What's the Internet: “nuts and bolts” view

- millions of connected computing devices: hosts = end systems
- running network apps
- communication links
  - fiber, copper, radio, satellite
  - transmission rate = bandwidth
- routers: forward packets (chunks of data)



What's the Internet: "nuts and bolts" view



- protocols control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, FTP, PPP
- Internet: "network of networks"
  - loosely hierarchical
  - public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force

Network edge: connection-oriented service

- Goal: data transfer between end systems
- handshaking: setup (prepare for) data transfer ahead of time
  - Hello, hello back human protocol
  - set up "state" in two communicating hosts
- TCP - Transmission Control Protocol
  - Internet's connection-oriented service

- TCP service [RFC 793]
- reliable, in-order byte-stream data transfer
  - loss: acknowledgements and retransmissions
- flow control:
  - sender won't overwhelm receiver
- congestion control:
  - senders "slow down sending rate" when network congested

Network edge: connectionless service

- Goal: data transfer between end systems
  - same as before!
- UDP - User Datagram Protocol [RFC 768]:
  - connectionless
  - unreliable data transfer
  - no flow control
  - no congestion control

- App's using TCP:
- HTTP (Web), FTP (file transfer), Telnet (remote login), SMTP (email)

- App's using UDP:
- streaming media, teleconferencing, DNS, Internet telephony

What's a protocol?

<u>human protocols:</u>

- "what's the time?"
- "I have a question"
- introductions

… specific msgs sent

… specific actions taken when msgs received, or other events

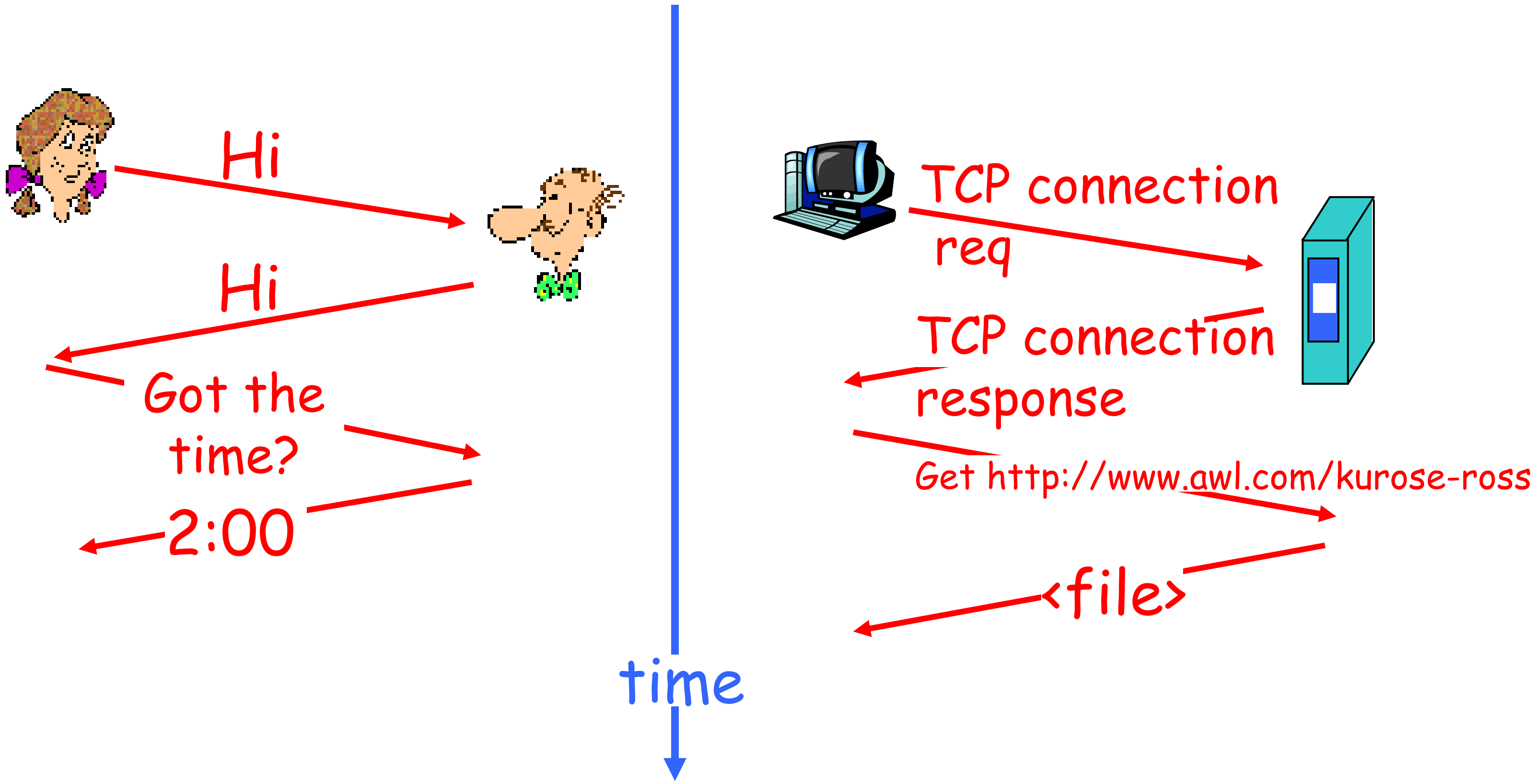
<u>network protocols:</u>

- machines rather than humans
- all communication activity in Internet governed by protocols

protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

What's a protocol?

a human protocol and a computer network protocol:



Q: Other human protocols?

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

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 – attach 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, ...

Network Components (Examples)

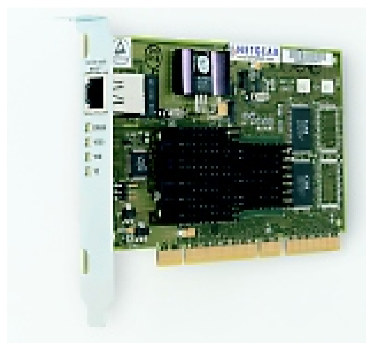
Links

Fibers

Coaxial Cable

Interfaces

Ethernet card



Wireless card

Switches/routers

Large router

Telephone switch

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 (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

Internet vs. Telephone Net

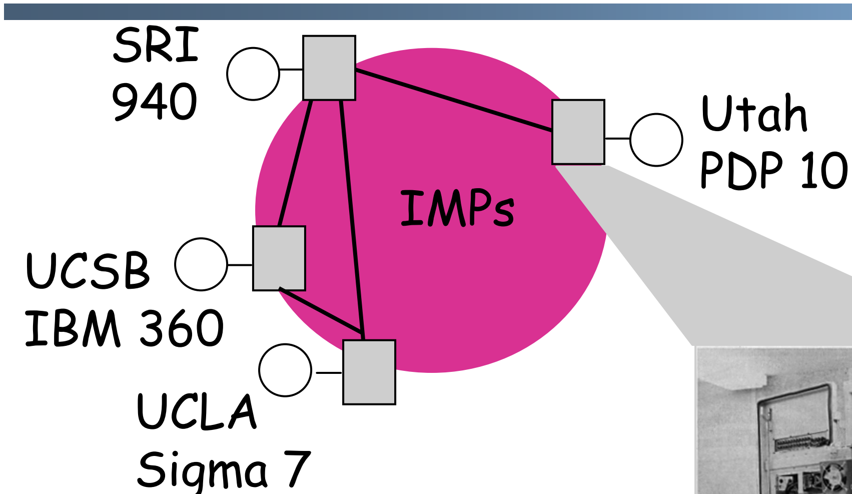
- Strengths
  - Intelligence at ends
  - Decentralized control
  - Operates over heterogeneous access technologies
- Weaknesses
  - No differential service
  - Variable performance delay
  - New functions difficult to add since end nodes must be upgraded
  - No trusted infrastructure

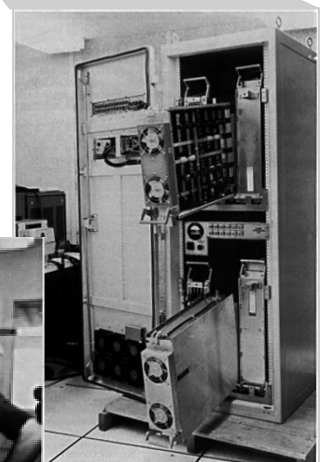
- Strengths
  - No end-point intelligence
  - Heterogeneous devices
  - Excellent voice performance
- Weaknesses
  - Achieves performance by over-allocating resources
  - Difficult to add new services to "Intelligent Network" due to complex call model
  - Expensive approach for reliability

History of the Internet

- 68-70's: started as a research project, 56 kbps, initially 4 nodes (UCLA, UCSB, SRI, Utah) then < 100 computers
- 80-83: TCP/IP, DNS; 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; Introduction of Commercial Internet
- Today: backbones run at 10 Gbps, close to 200 millions computers in 150 countries

The ARPANet

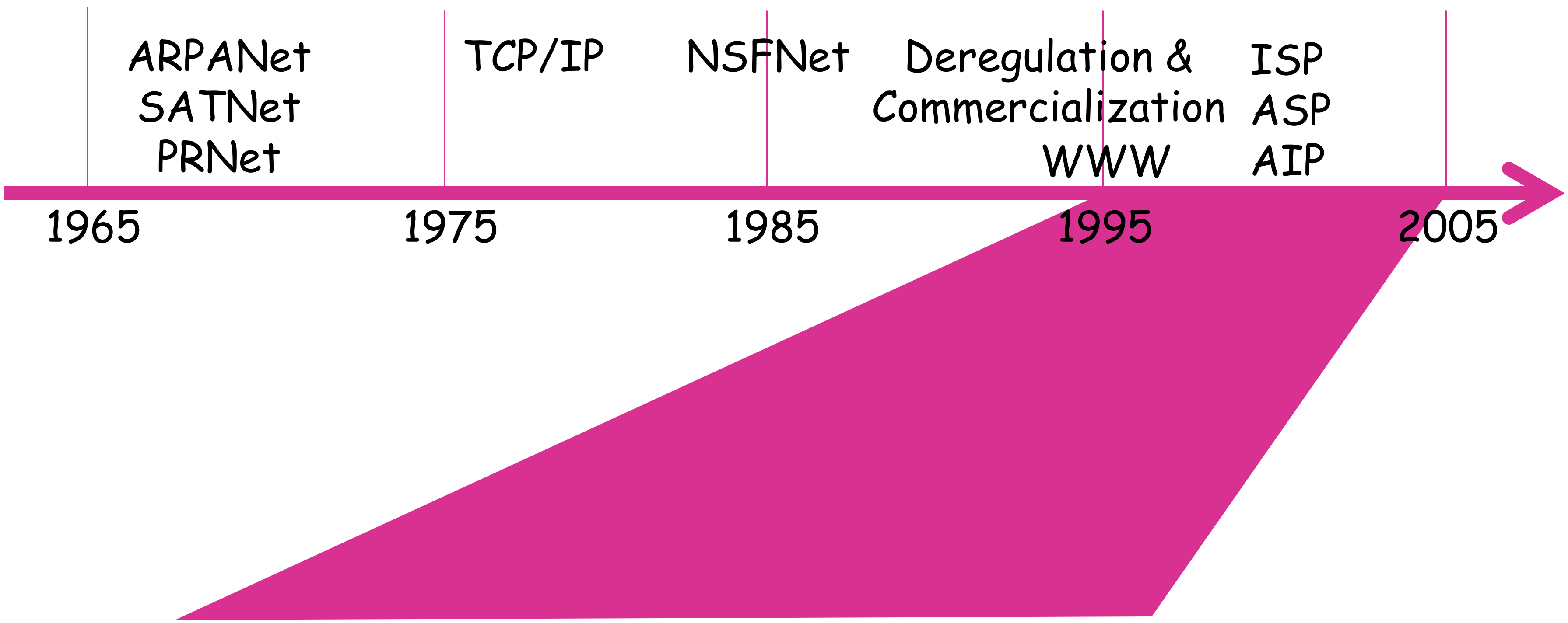




BBN team that implemented the interface message processor

- Paul Baran
  - RAND Corp, early 1960s
  - Communications networks that would survive a major enemy attack
- ARPANet: Research vehicle for “Resource Sharing Computer Networks”
  - 2 September 1969: UCLA first node on the ARPANet
  - December 1969: 4 nodes connected by phone lines

ARPANet Evolves into Internet

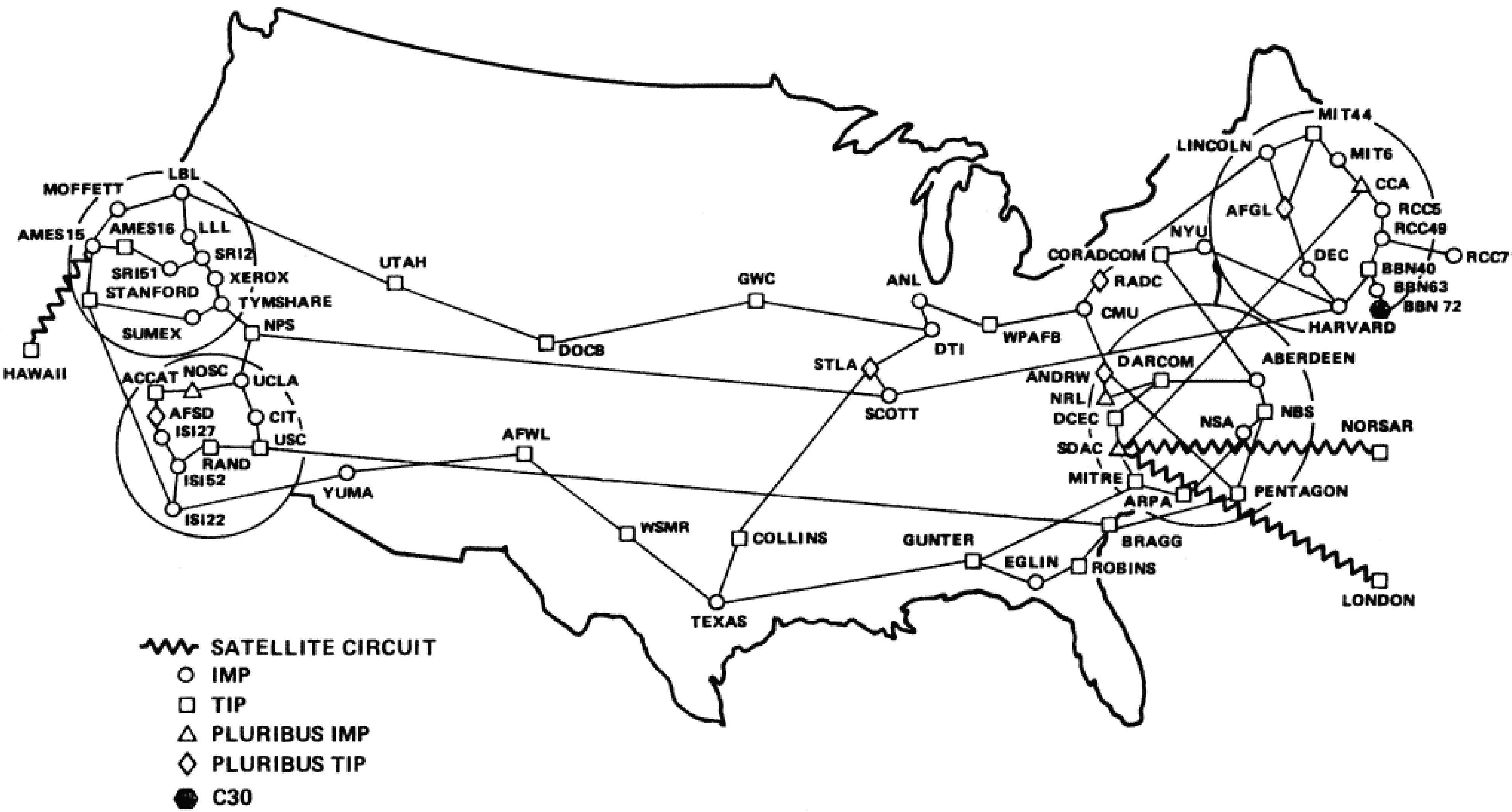


Web Hosting
Multiple ISPs
Internet2 Backbone
Internet Exchanges

→

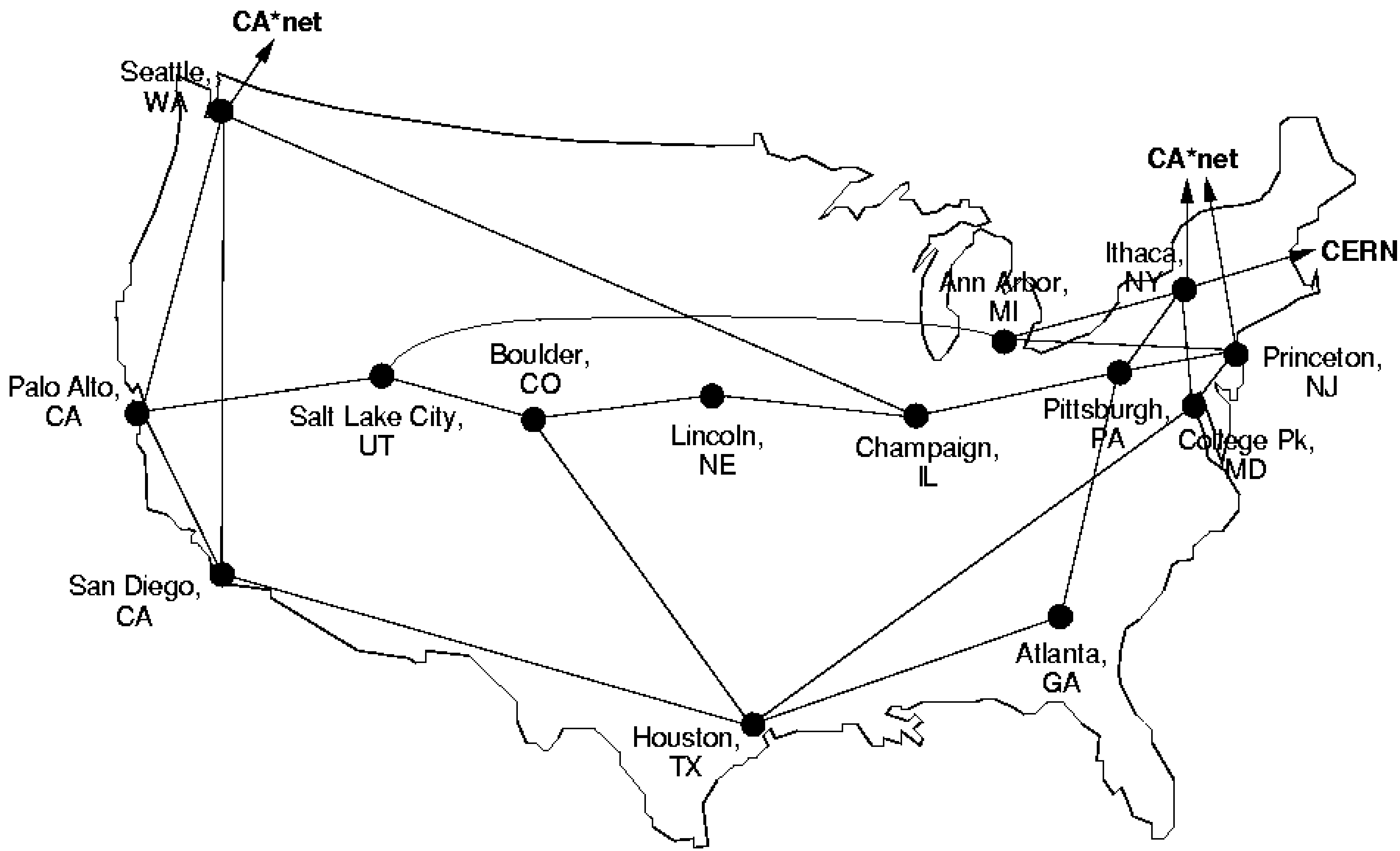
Application Hosting
ASP: Application Service Provider
AIP: Application Infrastructure Provider (e-commerce tookit, etc.)

ARPANET GEOGRAPHIC MAP, OCTOBER 1980

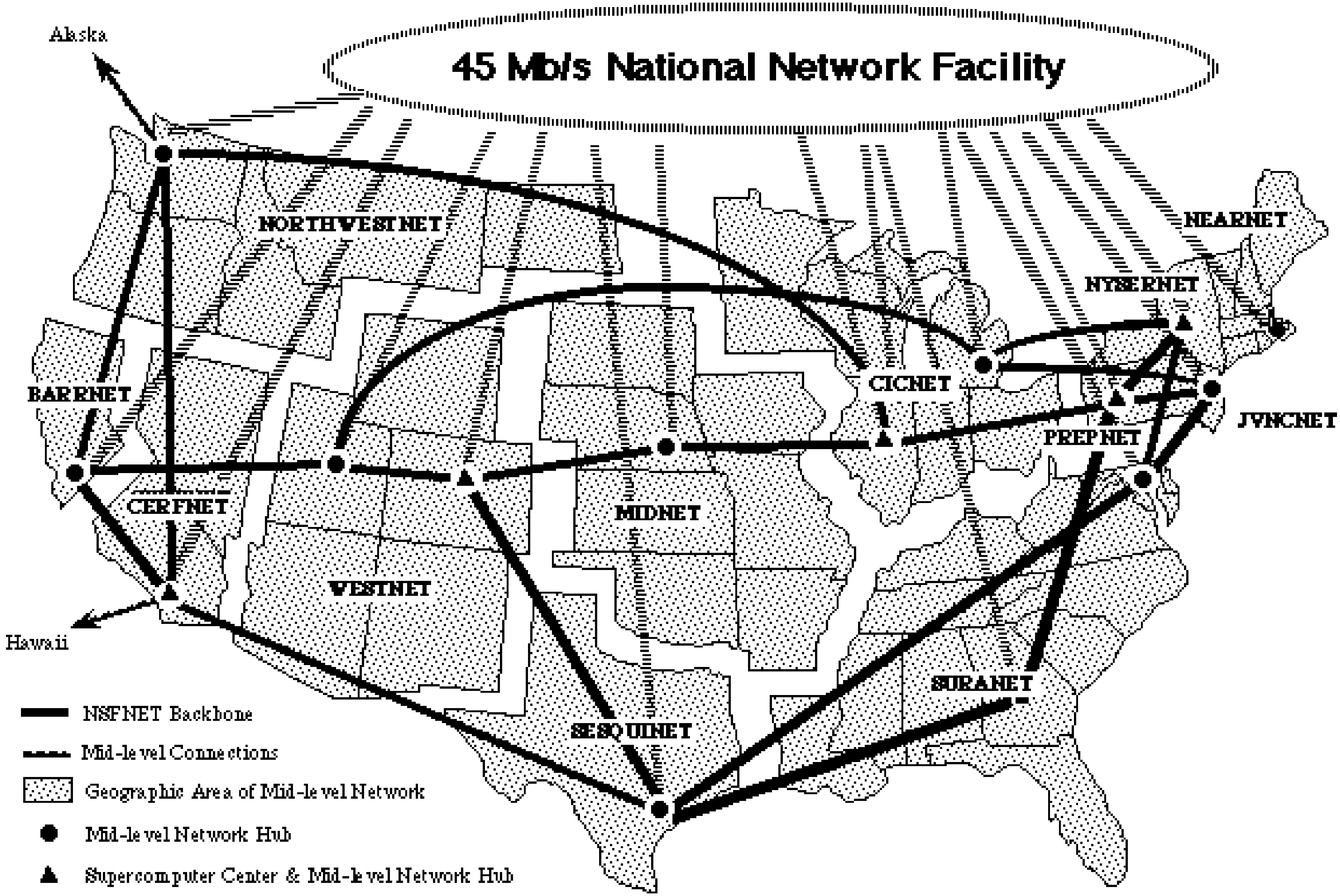


(NOTE: THIS MAP DOES NOT SHOW ARPA'S EXPERIMENTAL SATELLITE CONNECTIONS)
NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES

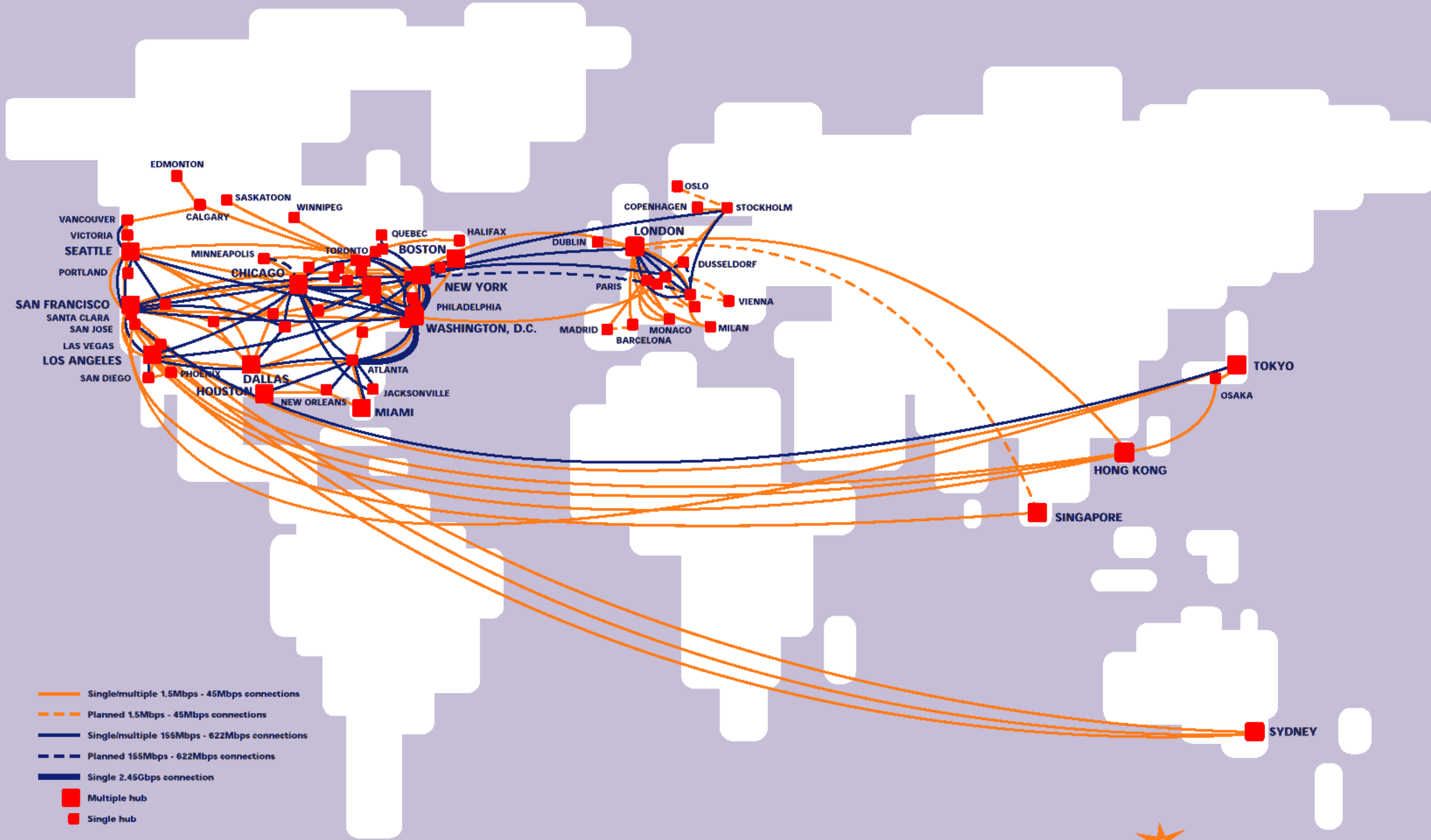
NSFNET T1 Network 1991



The Old NSFNET Backbone



UUNET's Global Internet Backbone



UUNET
An MCI WorldCom Company

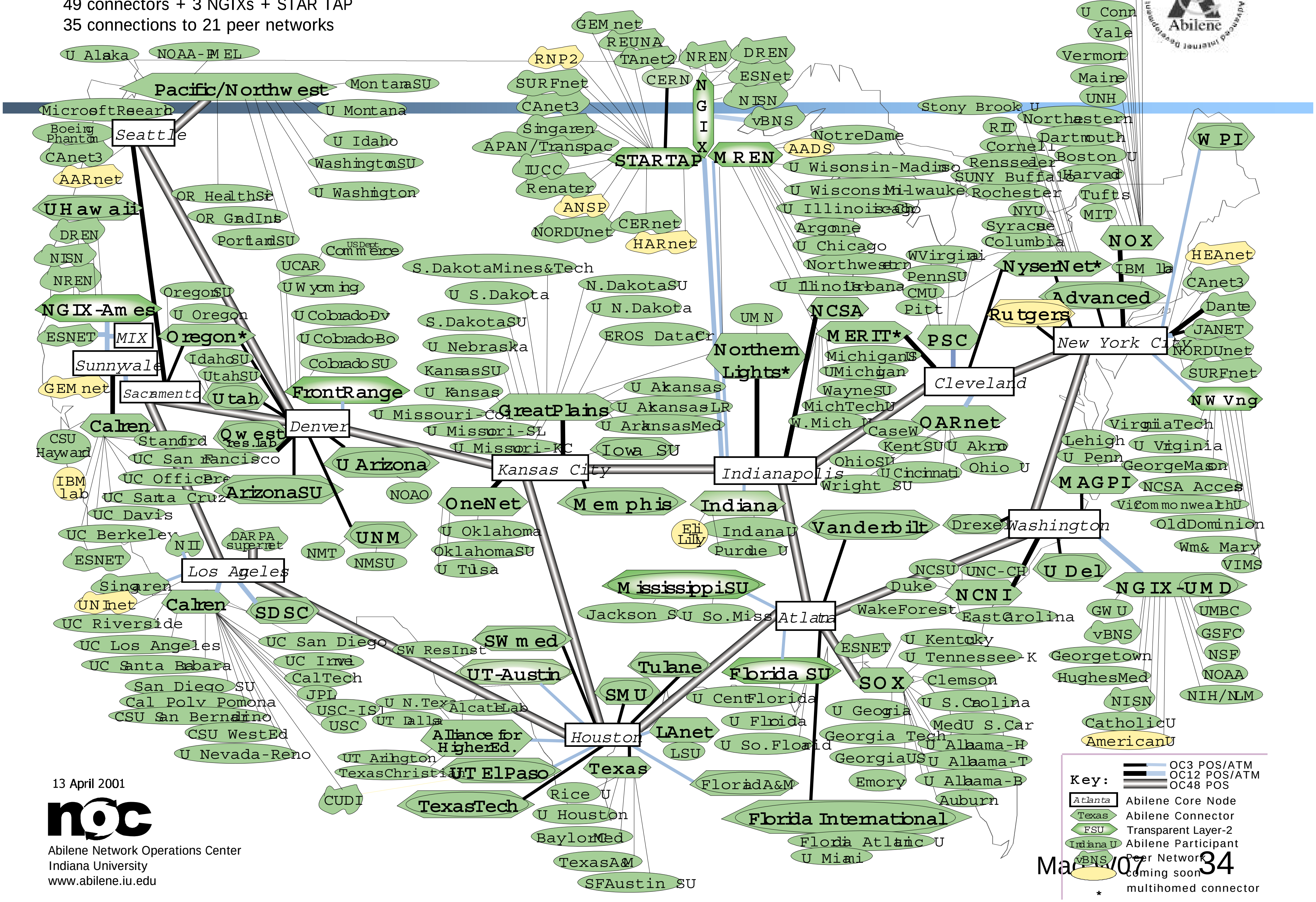
For more information visit www.uu.net

NB: With the exception of North America, Spain & Germany, all major 'in-country' links have been excluded from this map. 'In-state' links within the USA have also been excluded.

May/June 1999 2nd edition

The Abilene Network

completed connections:
194 participants
49 connectors + 3 NGIXs + STAR TAP
35 connections to 21 peer networks



13 April 2001

noc

Abilene Network Operations Center
Indiana University
www.abilene.iu.edu

Network Core: Circuit Switching

network resources (e.g., bandwidth) divided into "pieces"

- pieces allocated to calls
- resource piece *idle* if not used by owning call *(no sharing)*

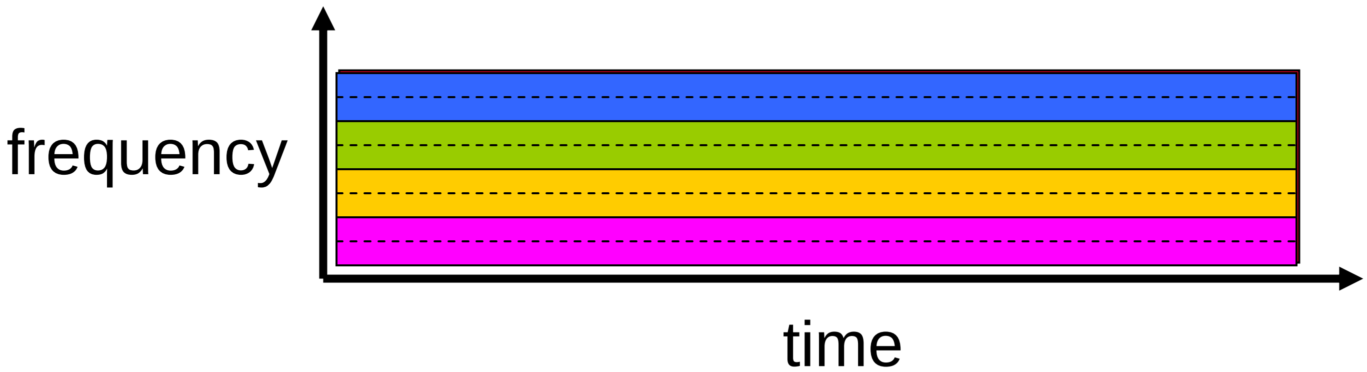
- dividing link bandwidth into "pieces"
  - frequency division
  - time division

Circuit Switching: FDM and TDM

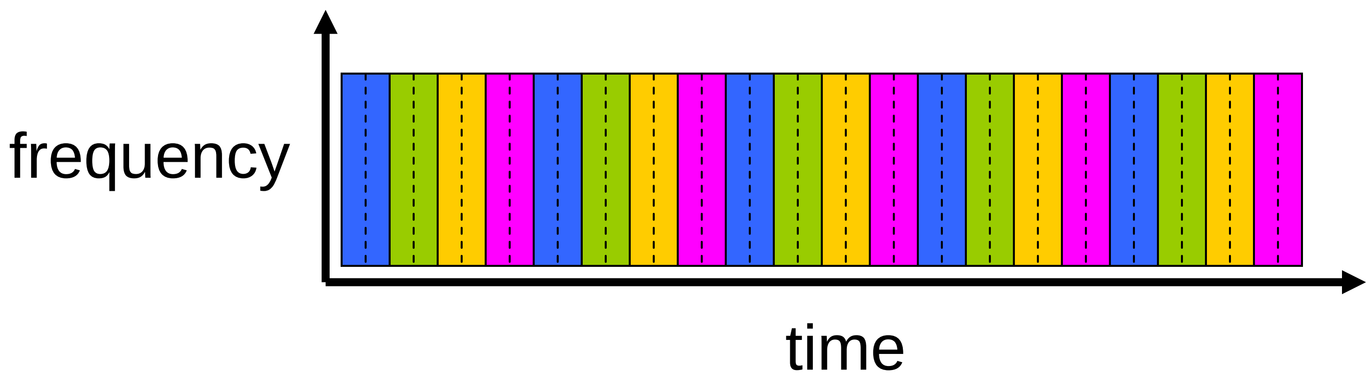
Example:

4 users

FDM



TDM



Network Core: Packet Switching

each end-end data stream divided into *packets*

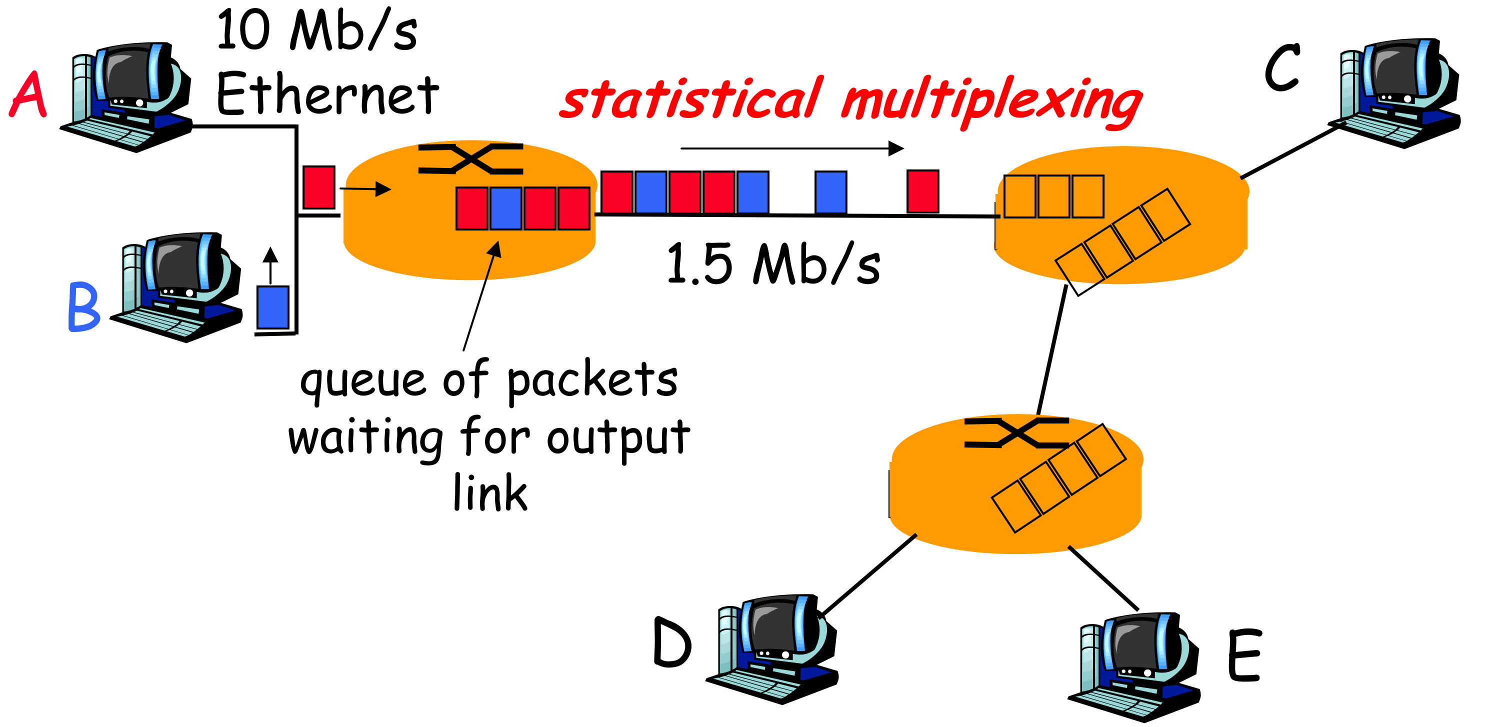
- user A, B packets *share* network resources
- each packet uses full link bandwidth
- resources used *as needed*

Bandwidth division into "pieces"
Dedicated allocation
Resource reservation

resource contention:

- aggregate resource demand can exceed amount available
- congestion: packets queue, wait for link use
- store and forward: packets move one hop at a time
  - Node receives complete packet before forwarding

Packet Switching: Statistical Multiplexing



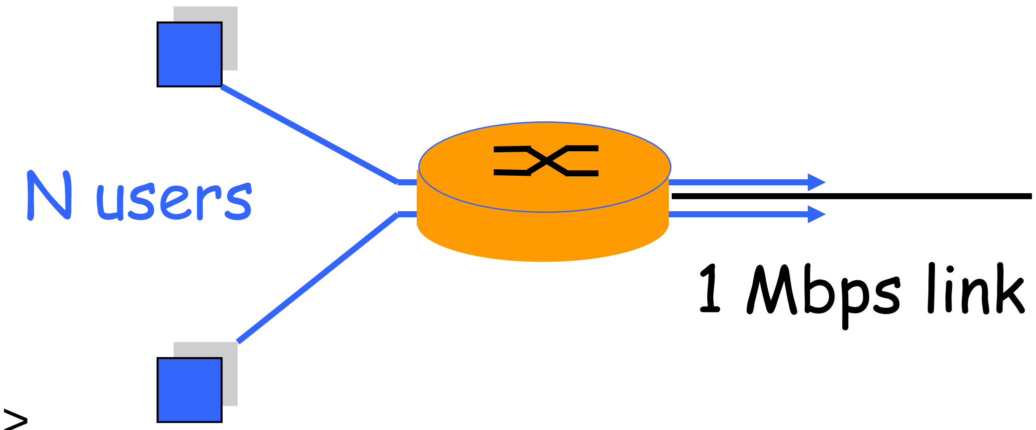
Sequence of A & B packets does not have fixed pattern ➔ ***statistical multiplexing***.

In TDM each host gets same slot in revolving TDM frame.

Packet switching versus circuit switching

Packet switching allows more users to use network!

- 1 Mb/s link
- each user:
  - 100 kb/s when “active”
  - active 10% of time
- circuit-switching:
  - 10 users
- packet switching:
  - with 35 users, probability > 10 active less than .0004

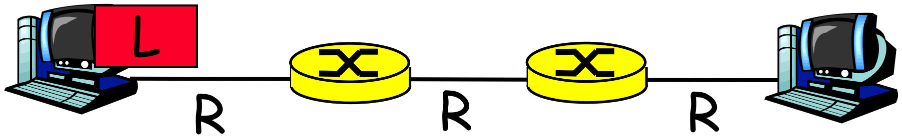


Packet switching versus circuit switching

Is packet switching a "slam dunk winner?"

- Great for bursty data
  - resource sharing
  - simpler, no call setup
- Excessive congestion: packet delay and loss
  - protocols needed for reliable data transfer, congestion control
- Q: How to provide circuit-like behavior?
  - bandwidth guarantees needed for audio/video apps
  - still an unsolved problem

Packet-switching: store-and-forward



- Takes L/R seconds to transmit (push out) packet of L bits on to link or R bps
- Entire packet must arrive at router before it can be transmitted on next link: *store and forward*
- delay = 3L/R

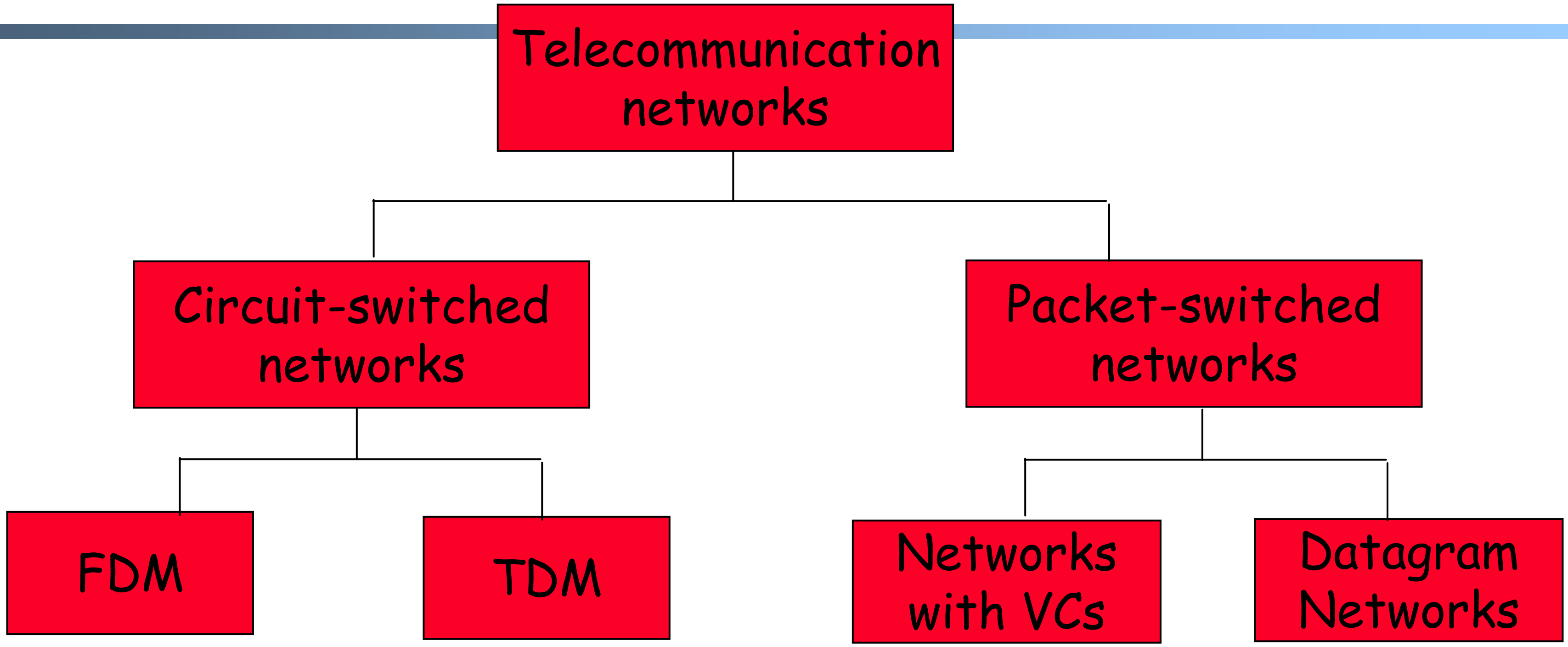
Example:

- L = 7.5 Mbits
- R = 1.5 Mbps
- delay = 15 sec

Packet-switched networks: forwarding

- *Goal:* move packets through routers from source to destination
  - we'll study several path selection (i.e. routing) algorithms
- datagram network:
  - *destination address* in packet determines next hop
  - routes may change during session
  - analogy: driving, asking directions
- virtual circuit network:
  - each packet carries tag (virtual circuit ID), tag determines next hop
  - fixed path determined at *call setup time*, remains fixed through call
  - *routers maintain per-call state*

Network Taxonomy



- Datagram network is *not* either connection-oriented or connectionless.
- Internet provides both connection-oriented (TCP) and connectionless services (UDP) to apps.

Summary

- Course administrative trivia
- Internet history and background

Recent news

- Taiwan earthquake on Dec. 26, 2006
- Damaged several undersea cables, disrupting telecommunication services in various parts of Asia.
- Is Internet not redundant enough?

Traceroute from Taiwan to China goes through U.S.!

```
[michigan_1@planetlab1 michigan_1]$ traceroute scut1.6planetlab.edu.cn
traceroute to scut1.6planetlab.edu.cn (219.243.200.25), 30 hops max, 38 byte packets
 1  140.112.107.254 (140.112.107.254)  0.459 ms  0.435 ms  0.371 ms
 2  140.112.0.21 (140.112.0.21)  0.506 ms  0.630 ms  0.468 ms
 3  140.112.0.1 (140.112.0.1)  0.621 ms  0.534 ms  0.478 ms
 4  203.160.226.233 (203.160.226.233)  0.953 ms  0.839 ms  0.806 ms
 5  tp_j160_1.twgate.net (203.160.227.176)  1.607 ms  1.431 ms  1.357 ms
    MPLS Label=580977 CoS=3 TTL=1 S=0
 6  la_c124_1.twgate.net (203.160.228.246)  139.122 ms  143.088 ms  138.635 ms
    MPLS Label=187 CoS=3 TTL=1 S=0
 7  ge41.ny_c76_2.twgate.net (203.160.228.190)  203.585 ms  203.288 ms  203.461 ms
 8  12.118.94.65 (12.118.94.65)  203.806 ms  203.779 ms  204.823 ms
 9  12.122.82.158 (12.122.82.158)  209.953 ms  210.320 ms  204.227 ms
    MPLS Label=31209 CoS=3 TTL=1 S=0
10  ggr2-p3120.n54ny.ip.att.net (12.123.3.109)  203.499 ms  203.746 ms  205.360 ms
11  att-gw.nyc.dtag.de (192.205.32.58)  205.137 ms  206.690 ms  205.350 ms
12  * 217.239.41.10 (217.239.41.10)  450.638 ms *
13  * * *
14  * 202.112.61.17 (202.112.61.17)  532.956 ms *
15  202.112.61.193 (202.112.61.193)  509.868 ms  528.050 ms *
16  202.112.53.181 (202.112.53.181)  529.697 ms  531.163 ms  526.445 ms
17  202.127.216.22 (202.127.216.22)  559.867 ms *  562.172 ms
18  * 202.112.53.150 (202.112.53.150)  552.522 ms  552.684 ms
19  * * *
20  * * *
21  * *
```