Part 1: Introduction

CSE 3461/5461

Reading: Chapter 1, Kurose and Ross

Part I: Introduction

Our goal:

- Get context, overview, “feel” of networking
- More depth, detail *later* in course
- Approach:
  - Descriptive
  - Use Internet as example

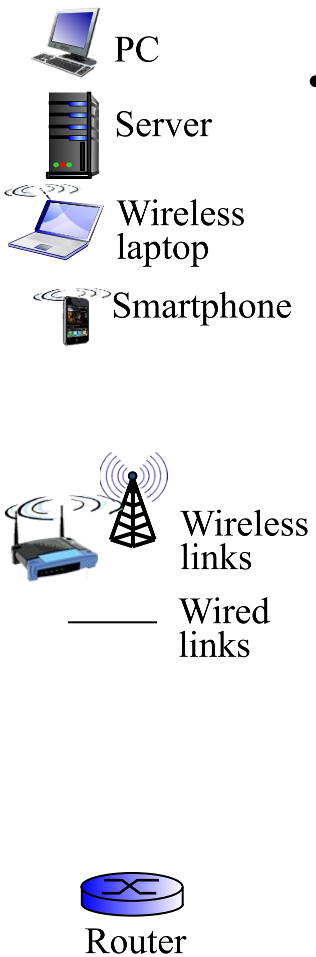
Overview:

- What’s the Internet
- What’s a protocol?
- Network edge
- Network core
- Access net, physical media
- Performance: loss, delay
- Protocol layers, service models
- Backbones, NAPs, ISPs
- History

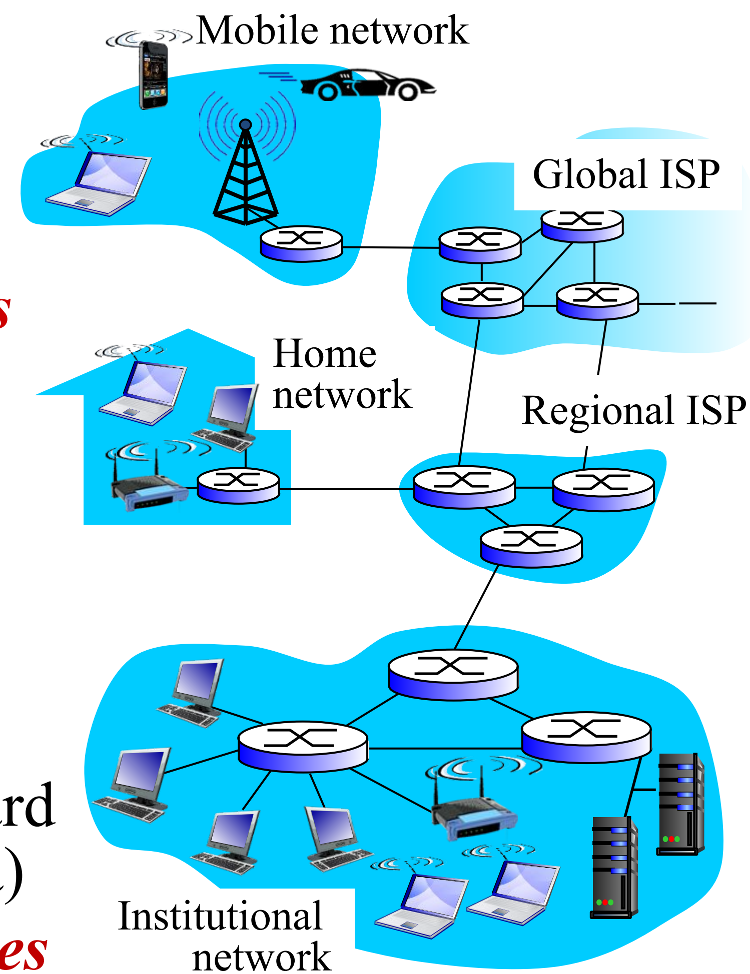
Outline

- **What is the Internet?**
- Network Edge
- Network Core
- Delay, Loss, Throughput in Networks
- Protocol Layers, Service Models
- History

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***
- ***Packet switches***: forward packets (chunks of data)
  - ***Routers*** and ***switches***



“Cool” Internet Appliances

IP picture frame
http://www.ceiva.com/

Web-enabled toaster +
weather forecaster

Tweet-a-watt:
monitor energy use

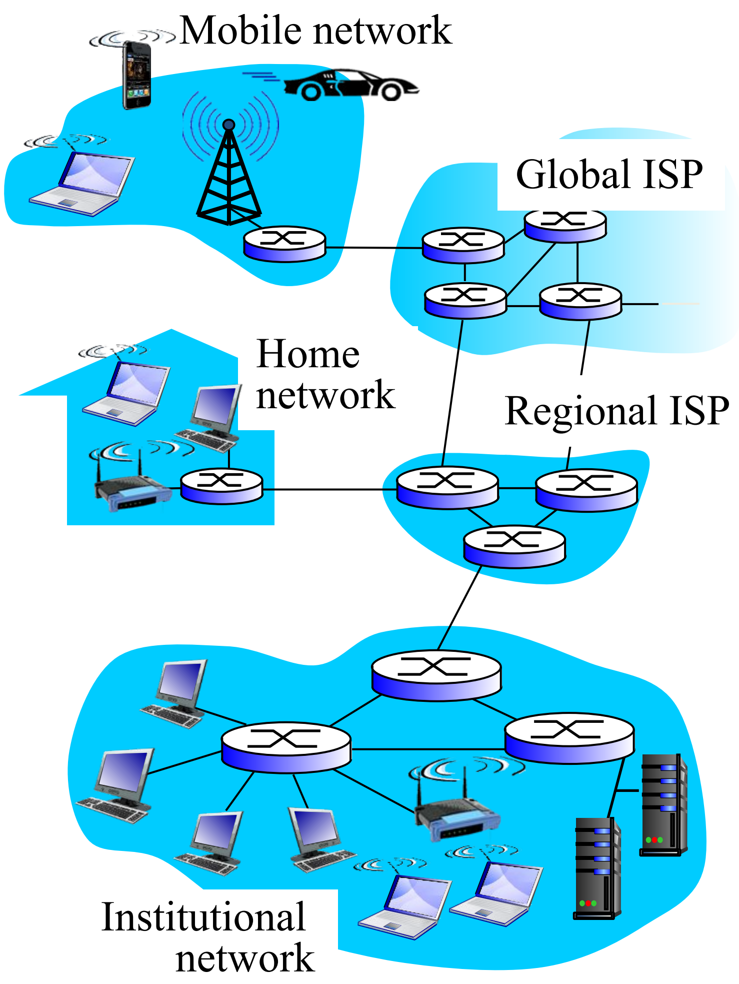
Internet
refrigerator

Slingbox: watch,
control cable TV remotely

Internet phones

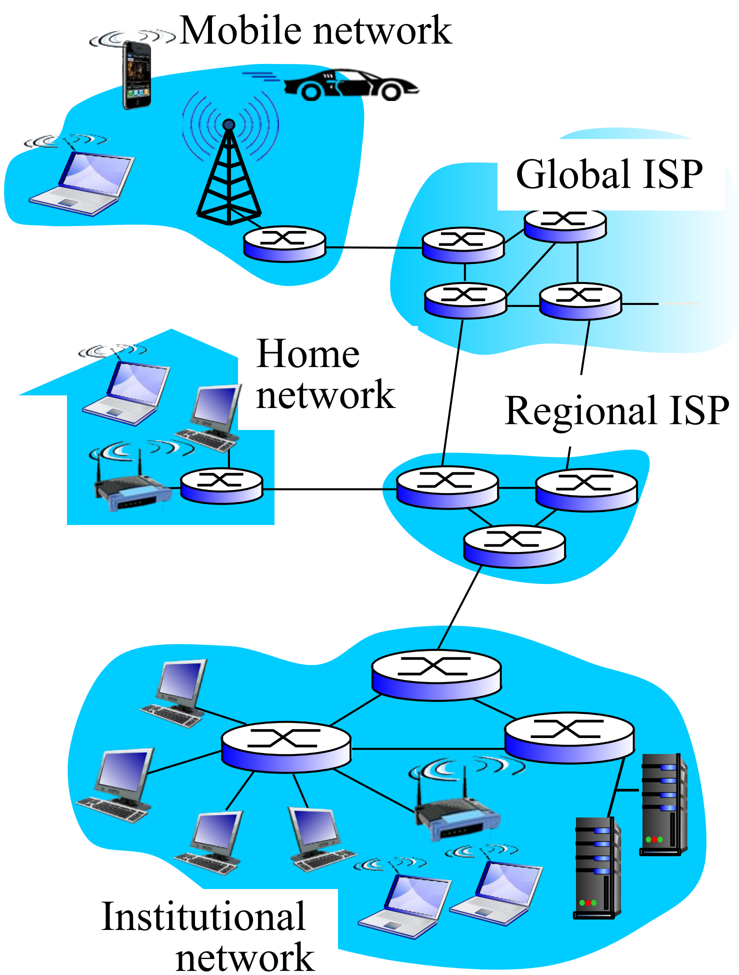
What's the Internet: "Nuts and Bolts" View

- ***Internet:* "network of networks"**
  - Loosely hierarchical
  - Public Internet versus private intranet
- ***Protocols*: control sending, receiving of messages**
  - e.g., TCP, IP, HTTP, FTP, PPP
- Internet standards
  - RFC: Request For Comments
  - IETF: Internet Engineering Task Force



What's the Internet: A Service View

- ***Infrastructure that provides services to applications:***
  - Web, VoIP, email, games, e-commerce, social nets, …
- ***Provides programming interface to apps***
  - Hooks that allow sending and receiving app programs to "connect" to Internet
  - Provides service options, analogous to postal service



What's a Protocol? (1)

Human Protocols:

- "What's the time?"
- "I have a question"
- Introductions

… specific msgs sent

… specific actions taken when msgs received, or other events

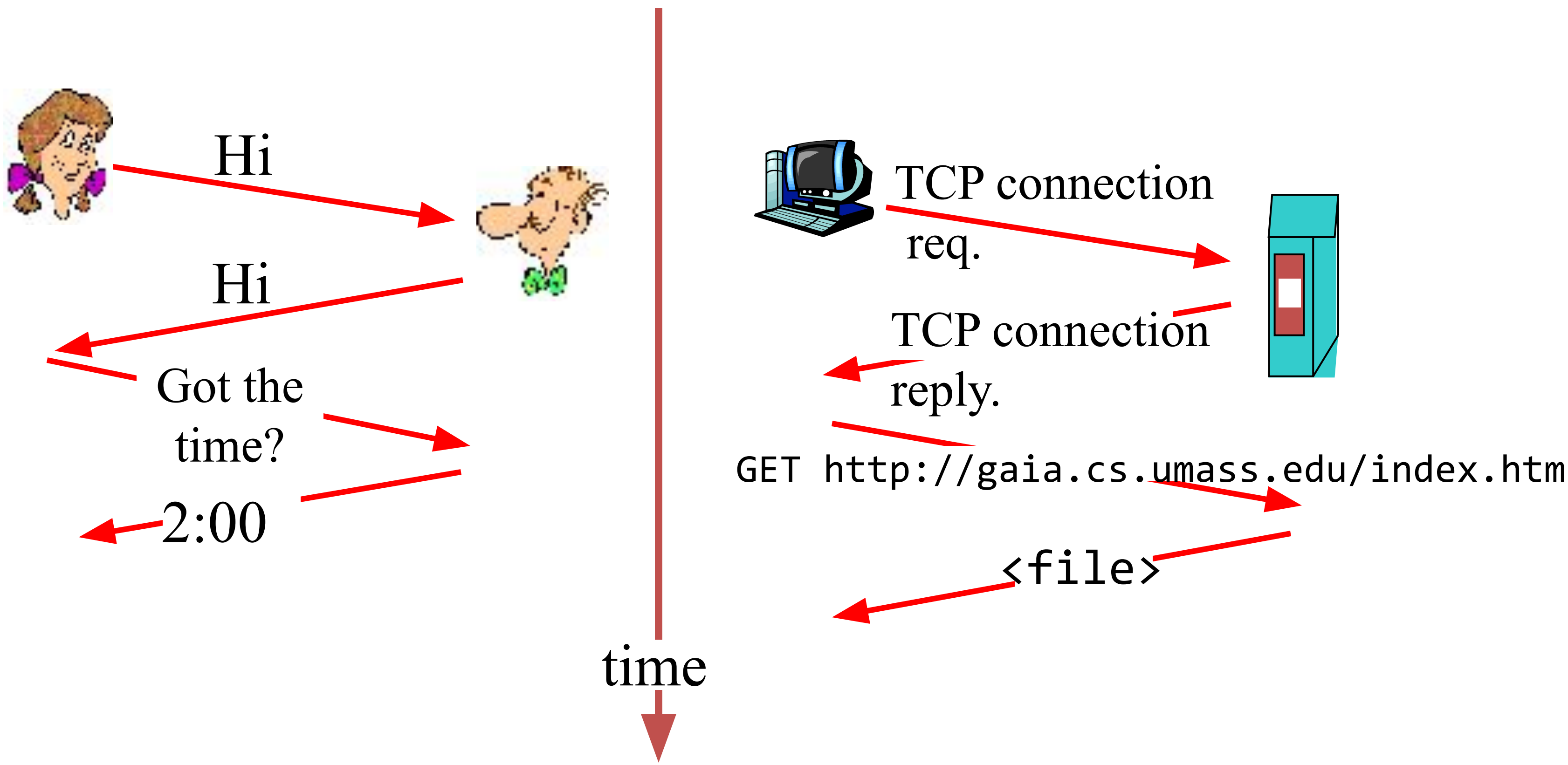
Network Protocols:

- Machines rather than humans
- All communication activity in Internet governed by protocols

Protocols *define* ***format***, ***order*** *of* ***messages sent and received*** *among network entities, and* ***actions taken*** *on message transmission, receipt*

What’s a Protocol? (2)

Human protocol and computer network protocol:



<u>Q:</u> Other human protocols?

Outline

- What is the Internet?
- **Network Edge**
- Network Core
- Delay, Loss, Throughput in Networks
- Protocol Layers, Service Models
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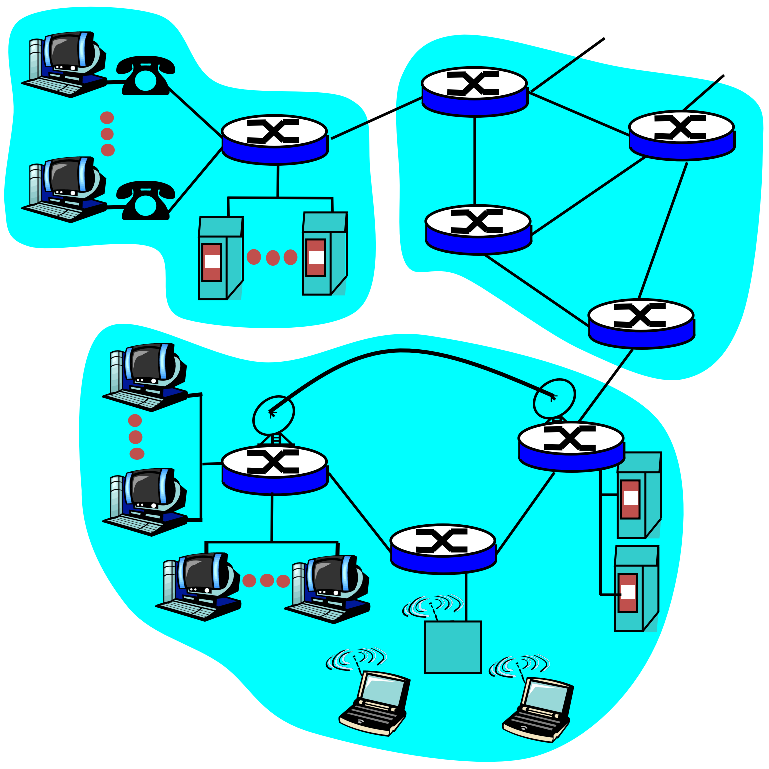
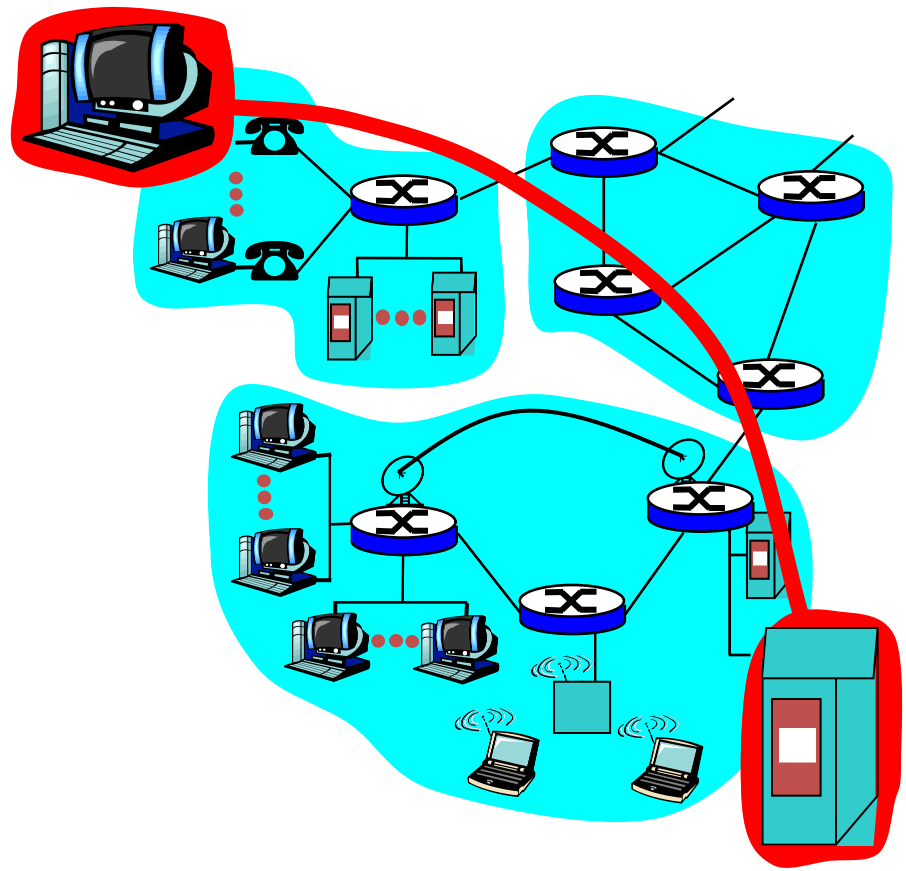
Closer Look at Network Structure

- **Network edge:** Applications and hosts
- **Access networks, physical media:** Wired, wireless communication links
- **Network core:**
  - Routers
  - Network of networks



The Network Edge

- **End systems (hosts):**
  - Run application programs
  - e.g., WWW, email
  - at "edge of network"
- **Client/server model**
  - Client host requests, receives service from server
  - e.g., WWW client (browser)/ server; email client/server
- **Peer-to-peer model:**
  - Host interaction symmetric
  - e.g.: Gnutella, KaZaA



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]: Internet's connectionless service
  - Unreliable data transfer
  - No flow control
  - No congestion control

Apps using TCP:

- HTTP (WWW), FTP (file transfer), Telnet (remote login), SMTP (email)

Apps using UDP:

- Streaming media, teleconferencing, Internet telephony

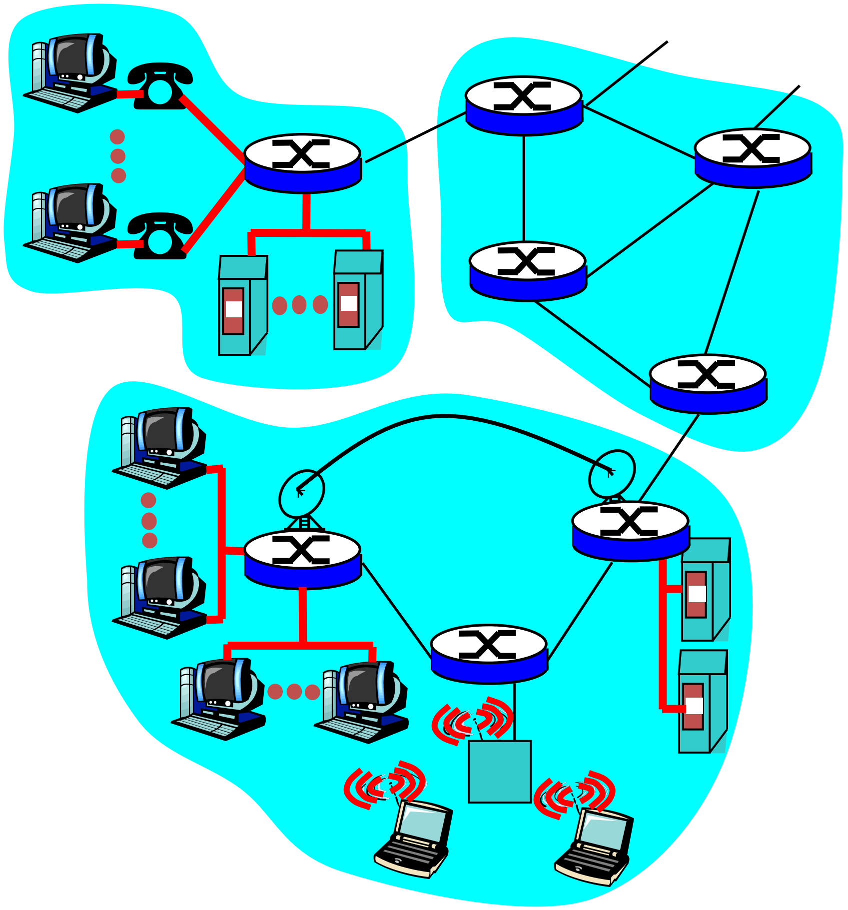
Access Networks and Physical Media

Q: How to connect end systems to edge router?

- Residential access nets
  - Cable modem
- Institutional access networks (school, company)
  - Local area networks
- Mobile access networks

Physical media

- Coax, fiber
- Radio (e.g., WiFi)



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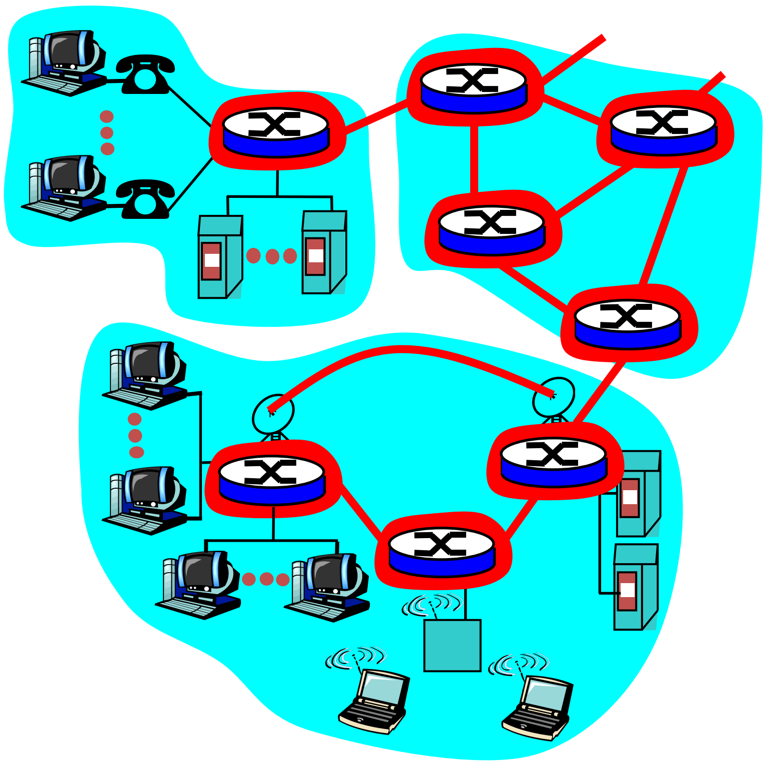
The Network Core

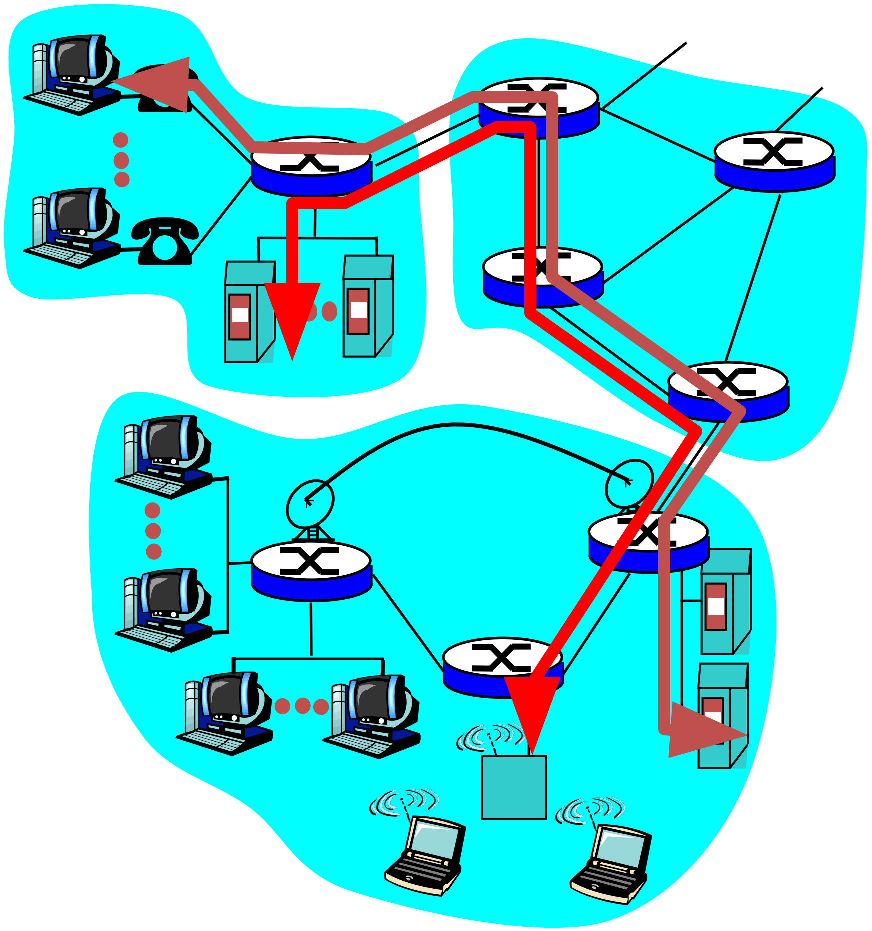
- Mesh of interconnected routers
- ***The*** **fundamental question:** how is data transferred through network?
  - **Circuit switching:** dedicated circuit per call – telephone network
  - **Packet switching:** data sent through network in discrete "chunks"



Network Core: Circuit Switching (1)

End-end resources reserved for "call":

- Link bandwidth, switch capacity
- Dedicated resources: no sharing
- Circuit-like (guaranteed) performance
- Call setup required



Network Core: Circuit Switching (2)

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

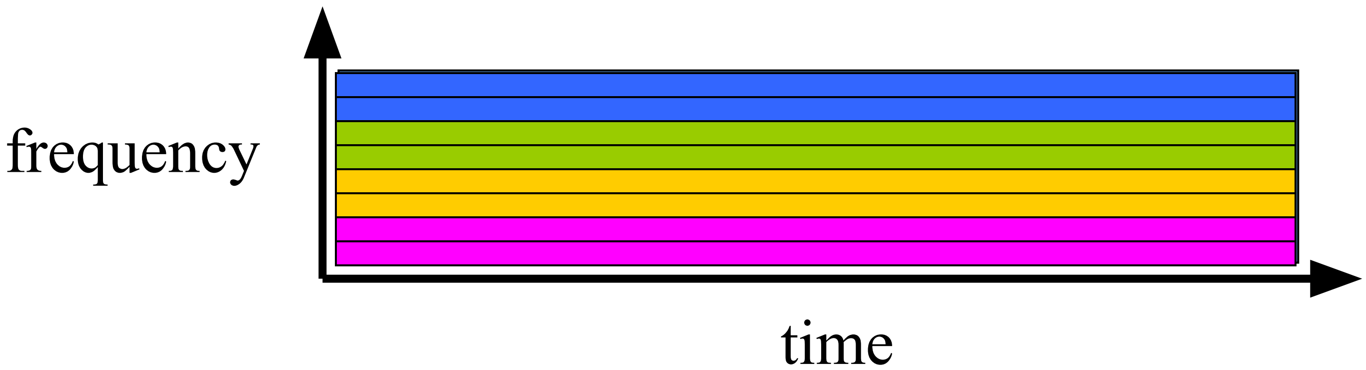
- Pieces allocated to calls
- Resource piece ***idle*** if not used by owning call *(no sharing)*
- Dividing link bandwidth into "pieces"
  - Frequency division
  - Time division

Circuit Switching: FDM and TDM

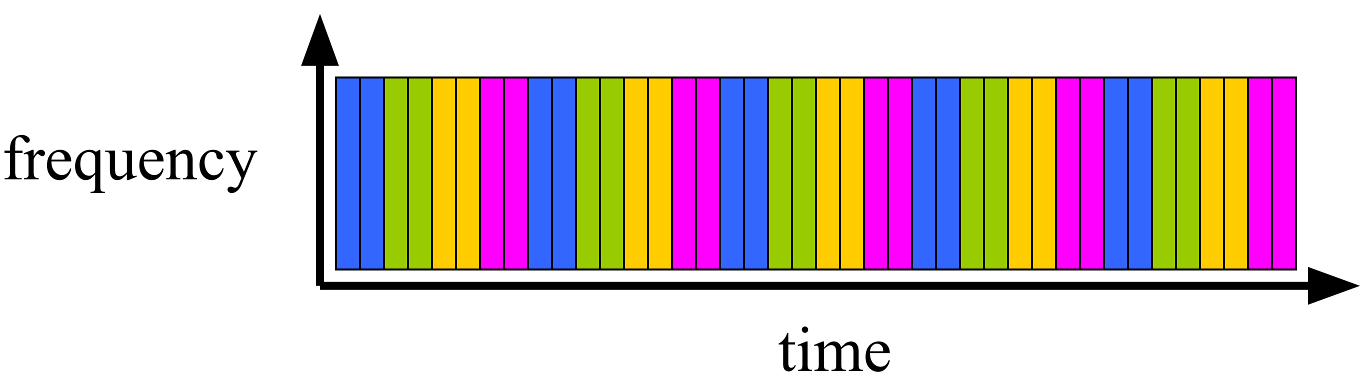
Example:

4 users

FDM



TDM



Network Core: Packet Switching (1)

Each end-end data stream divided into *packets*

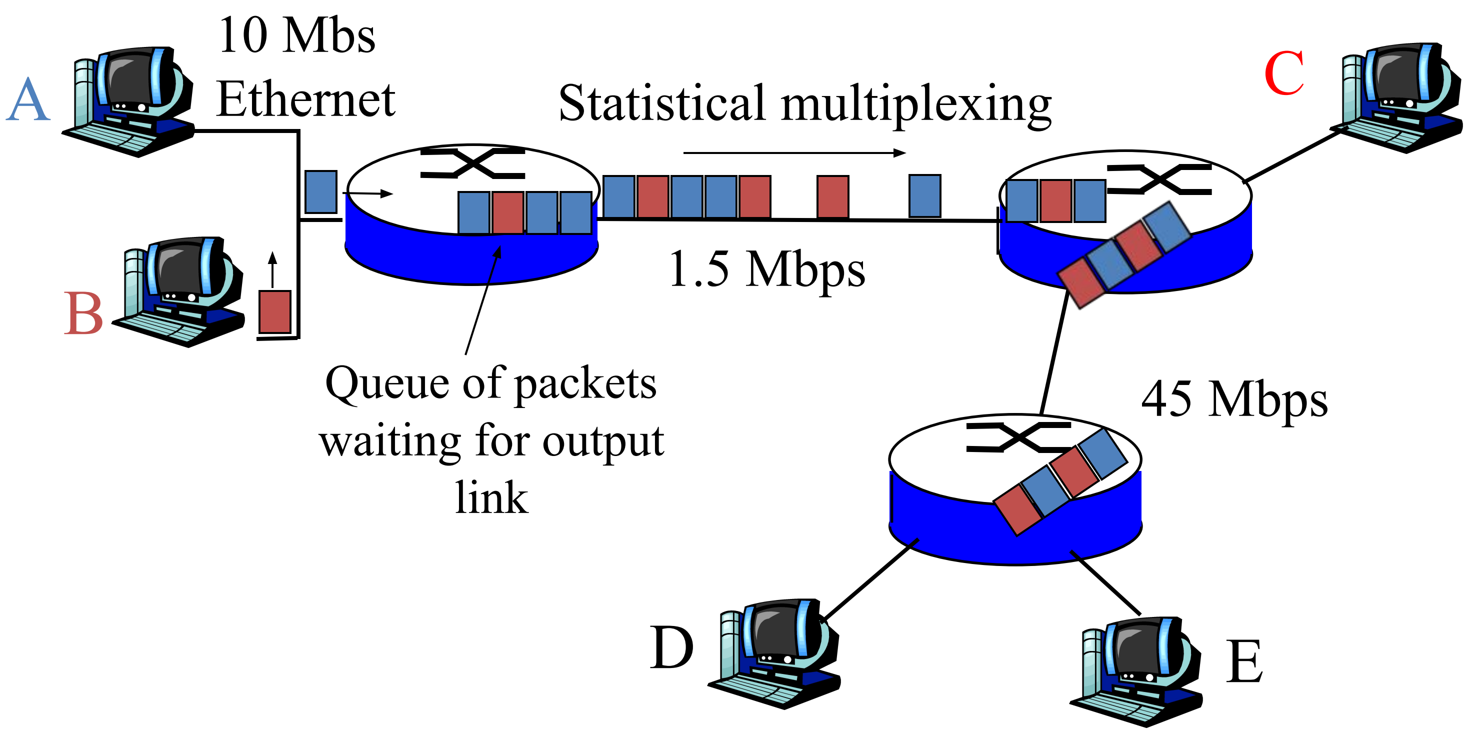
- Users A, B packets *share* network resources
- Each packet uses full link bandwidth
- Resources used *as needed*

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
  - Transmit over link
  - Wait turn at next link

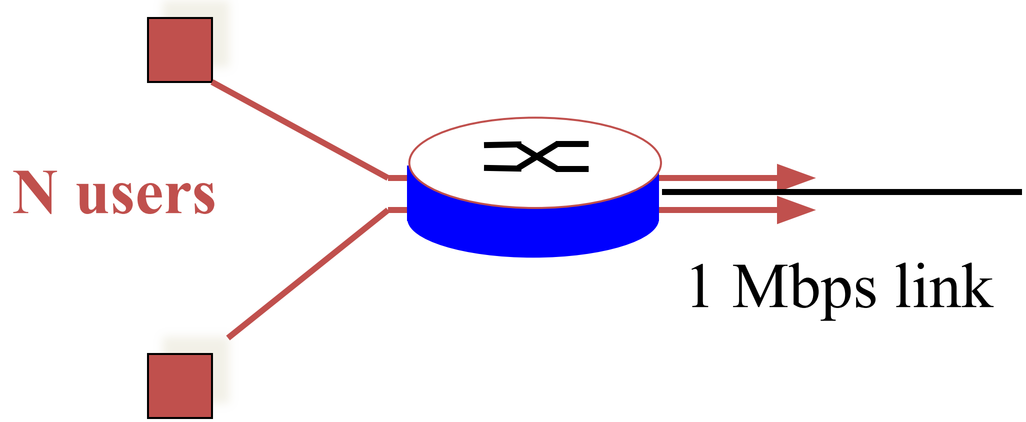
Network Core: Packet Switching (2)



Packet Switching Versus Circuit Switching

Packet switching allows more users to use network!

- 1 Mbit link
- Each user:
  - 100 Kbps when "active"
  - Active 10% of time
- Circuit switching:
  - 10 users
- Packet switching:
  - With 35 users, Probability{>10 active} < .0004

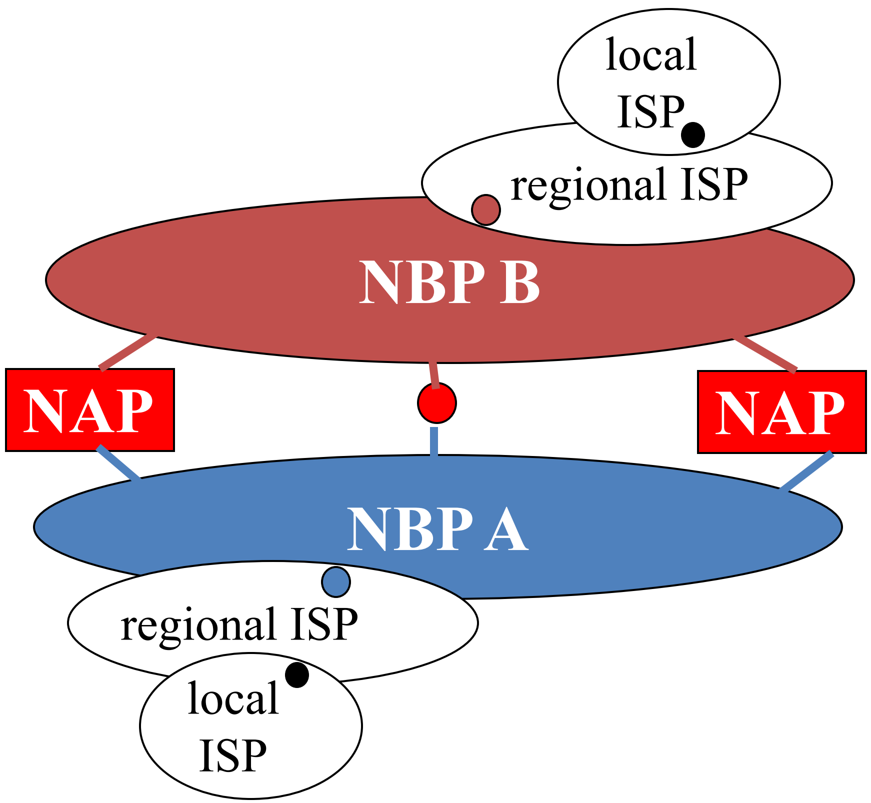


Packet-Switched Networks: Routing

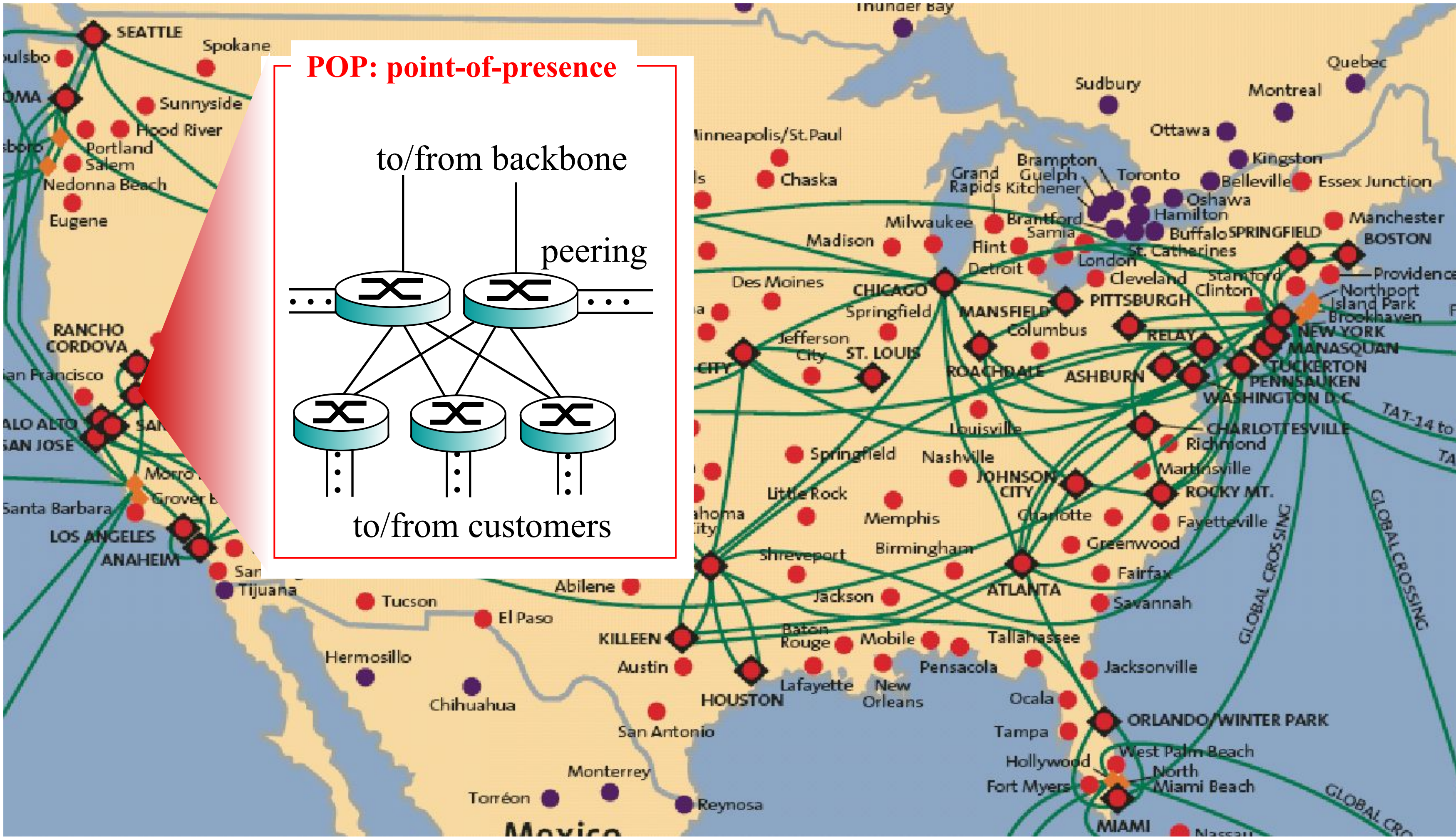
- ***Goal:*** Move packets among routers from source to destination
  - We'll study several path selection algorithms (chapter 4)
- **Datagram network:**
  - *Destination address* determines next hop
  - Routes may change during session
  - Analogy: driving, asking directions
- **Virtual circuit network:**
  - Each packet carries tag (virtual circuit ID), tag determines next hop
  - Fixed path determined at *call setup time*, remains fixed thru call
  - Routers maintain per-call state

Internet Structure: Network of Networks

- Roughly hierarchical
- **National/international backbone providers (NBPs)**
  - e.g. BBN/GTE, Sprint, AT&T, IBM, UUNet
  - Interconnect (peer) with each other privately, or at public Network Access Point (NAPs)
- **Regional ISPs**
  - connect into NBPs
- **Local ISP**, company
  - connect into regional ISPs



National Backbone Provider



Example: Sprint

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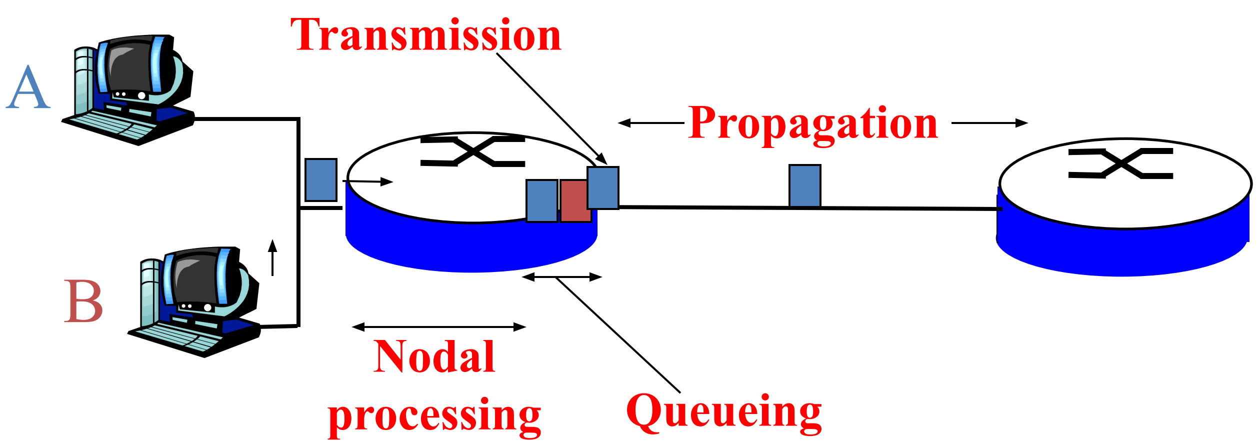
Delay in Packet-Switched Networks (1)

Packets experience **delay** on end-to-end path

- **Four** sources of delay at each hop

- **Nodal processing:**
  - Check bit errors
  - Determine output link
- **Queueing**
  - Time waiting at output link for transmission
  - Depends on congestion level of router



Delay in Packet-Switched Networks (2)

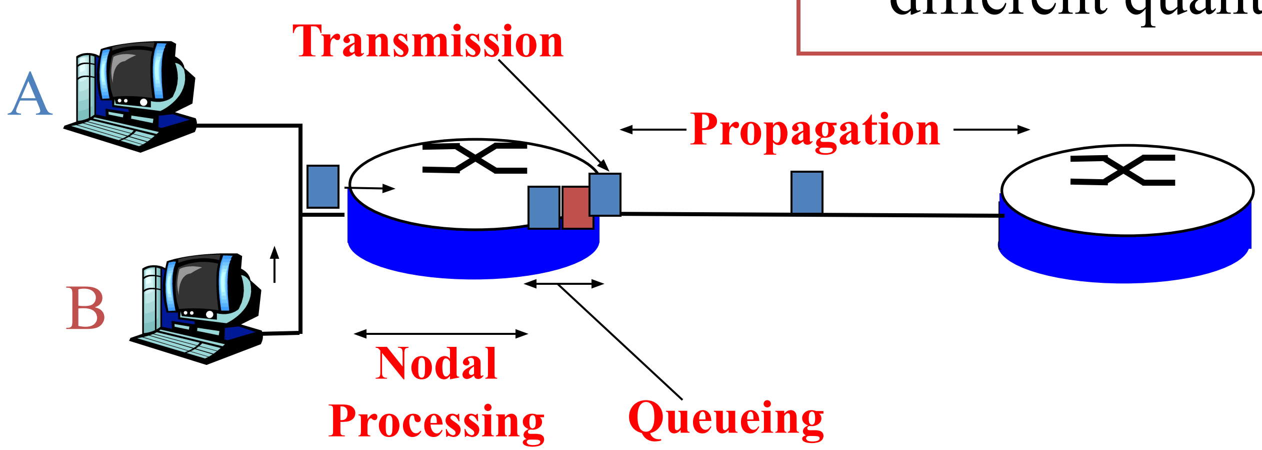
Transmission Delay:

- *R* = Link bandwidth (bps)
- *L* = Packet length (bits)
- Time to send bits into link = L/R

Propagation Delay:

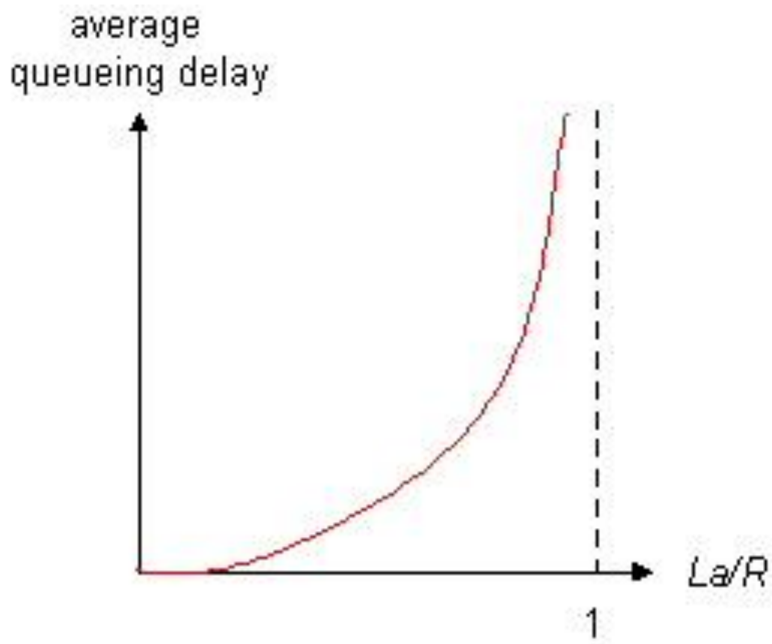
- *d* = Length of physical link
- *s* = propagation speed in medium (~2×10^8 m/sec)
- propagation delay = d/s

Note: *s* and *R* are ***very*** different quantities!



Queueing delay (revisited)

- R = Link bandwidth (bps)
- L = Packet length (bits)
- a = Average packet arrival rate



Traffic intensity = *La*/*R*

- $La/R \sim 0$: Average queueing delay small
- $La/R \rightarrow 1$: Delays become large
- $La/R > 1$: More "work" arriving than can be serviced, average delay infinite!

“Real” Internet Delays and Routes

`traceroute` (or `tracert`): Routers, round-trip delays on source-dest path

Also: `pingplotter`, various Windows programs

```
1  cs-gw (128.119.240.254)  1 ms  1 ms  2 ms
2  border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145)  1 ms  1 ms  2 ms
3  cht-vbns.gw.umass.edu (128.119.3.130)  6 ms 5 ms 5 ms
4  jn1-at1-0-0-19.wor.vbns.net (204.147.132.129)  16 ms 11 ms 13 ms
5  jn1-so7-0-0-0.wae.vbns.net (204.147.136.136)  21 ms 18 ms 18 ms
6  abilene-vbns.abilene.ucaid.edu (198.32.11.9)  22 ms  18 ms  22 ms
7  nycm-wash.abilene.ucaid.edu (198.32.8.46)  22 ms  22 ms  22 ms
8  62.40.103.253 (62.40.103.253)  104 ms 109 ms 106 ms
9  de2-1.de1.de.geant.net (62.40.96.129)  109 ms 102 ms 104 ms
10  de.fr1.fr.geant.net (62.40.96.50)  113 ms 121 ms 114 ms
11  renater-gw.fr1.fr.geant.net (62.40.103.54)  112 ms  114 ms  112 ms
12  nio-n2.cssi.renater.fr (193.51.206.13)  111 ms  114 ms  116 ms
13  nice.cssi.renater.fr (195.220.98.102)  123 ms  125 ms  124 ms
14  r3t2-nice.cssi.renater.fr (195.220.98.110)  126 ms  126 ms  124 ms
15  eurecom-valbonne.r3t2.ft.net (193.48.50.54)  135 ms  128 ms  133 ms
16  194.214.211.25 (194.214.211.25)  126 ms  128 ms  126 ms
17  * * *
18  * * *
19  fantasia.eurecom.fr (193.55.113.142)  132 ms  128 ms  136  ms
```

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Protocol "Layers"

Networks are Complex!

- Many "pieces":
  - Hosts
  - Routers
  - Links of various media
  - Applications
  - Protocols
  - Hardware, software

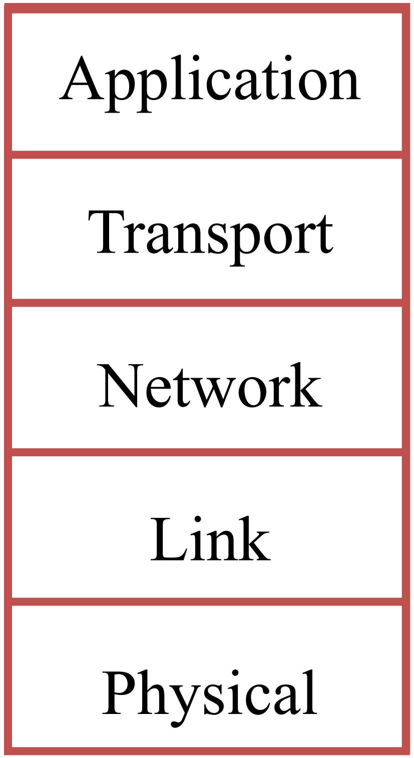
Question:

Is there any hope of *organizing* structure of network?

Or at least our discussion of networks?

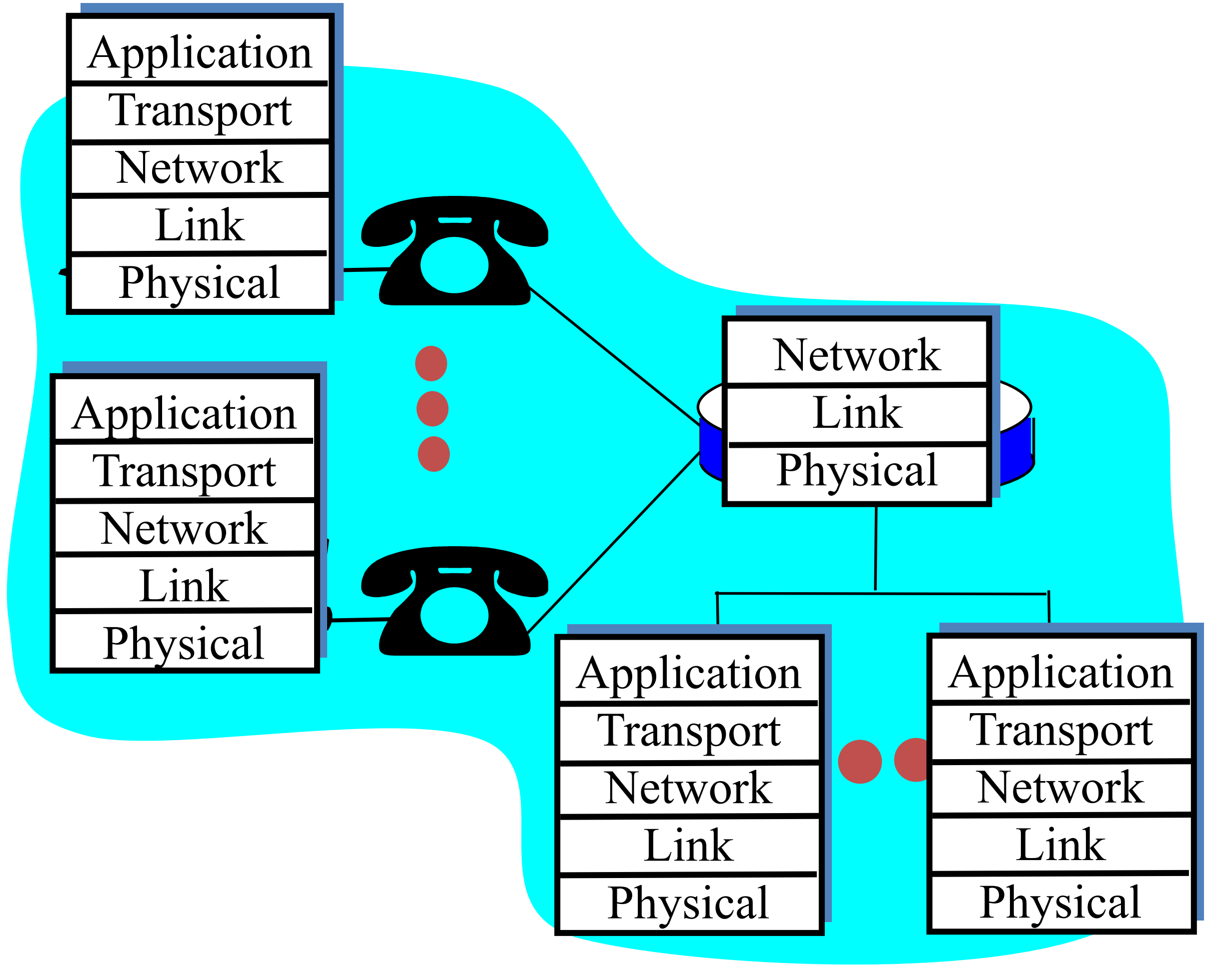
Internet Protocol Stack

- **Application:** supporting network applications
  - FTP, SMTP, HTTP
- **Transport:** host-host data transfer
  - TCP, UDP
- **Network:** routing of datagrams from source to destination
  - IP, routing protocols
- **Link:** data transfer between neighboring network elements
  - PPP, Ethernet
- **Physical:** bits “on the wire”, “over the air”



Layering: Logical Communication (1)

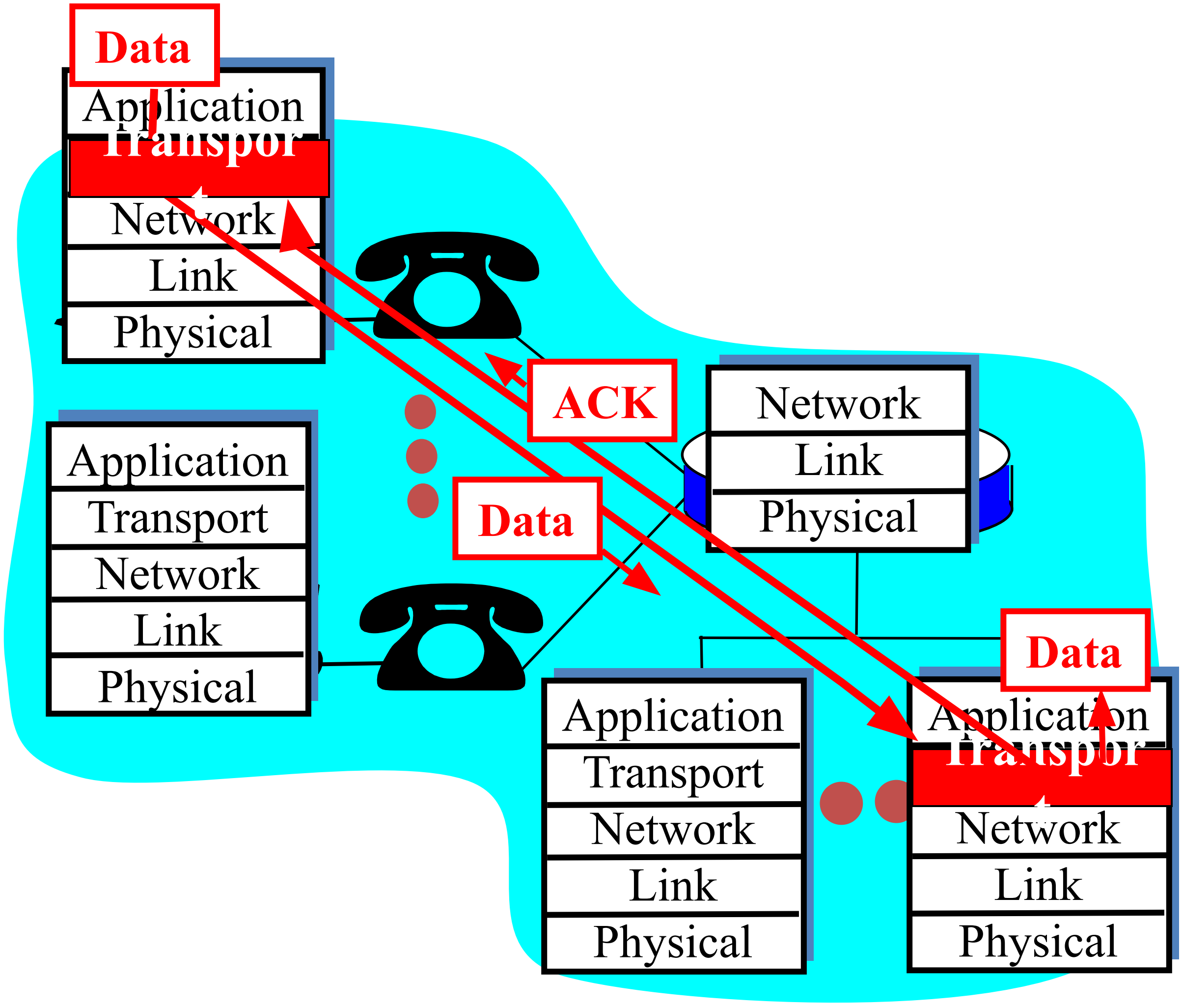
Each layer:
- Distributed
- "Entities" implement layer functions at each node
- Entities perform actions, exchange messages with peers



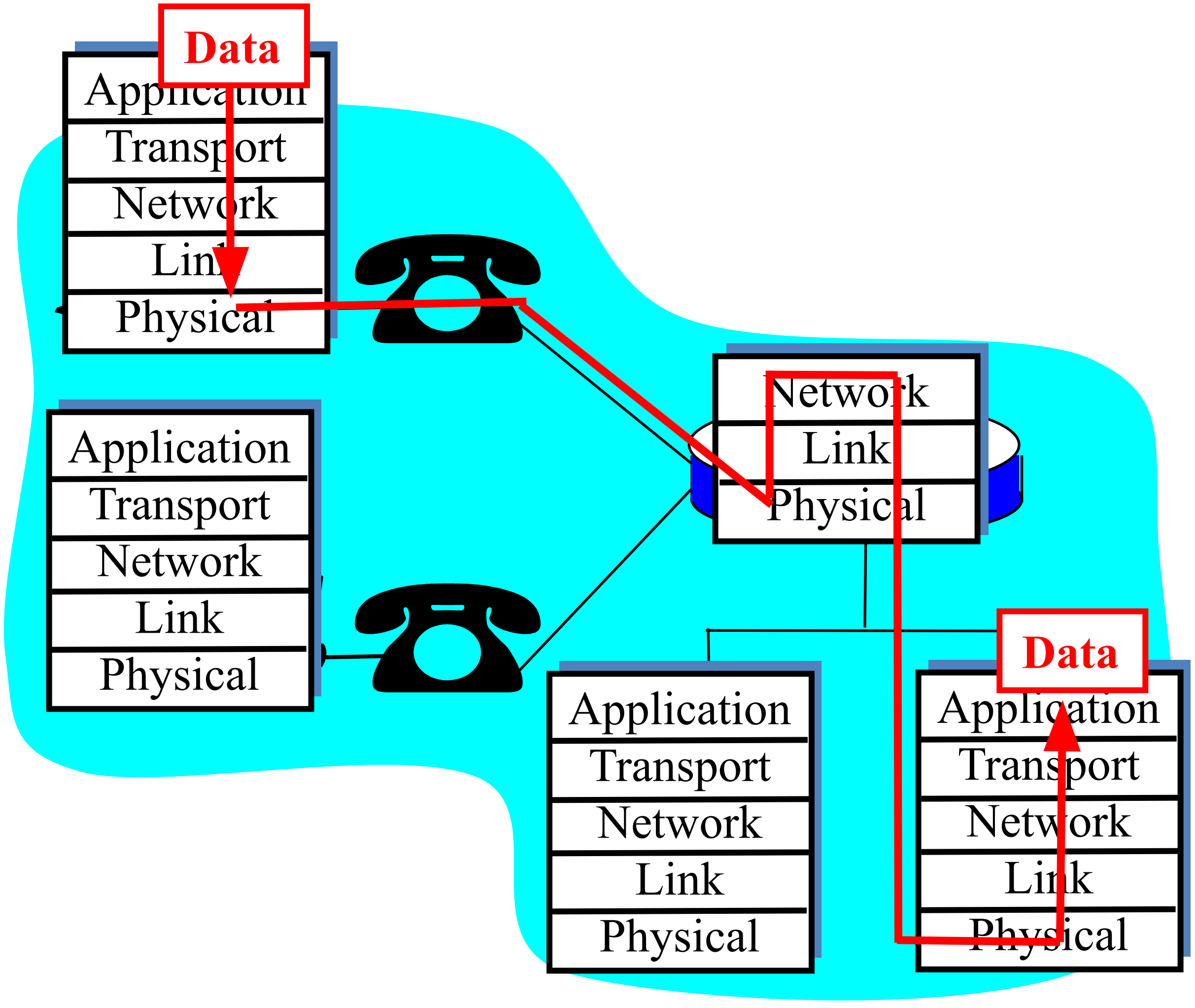
Layering: *Logical* Communication (2)

E.g.: Transport layer

- Take data from app
- Add addressing, reliability check info to form "datagram"
- Send datagram to peer
- Wait for peer to ack receipt
- Analogy: post office



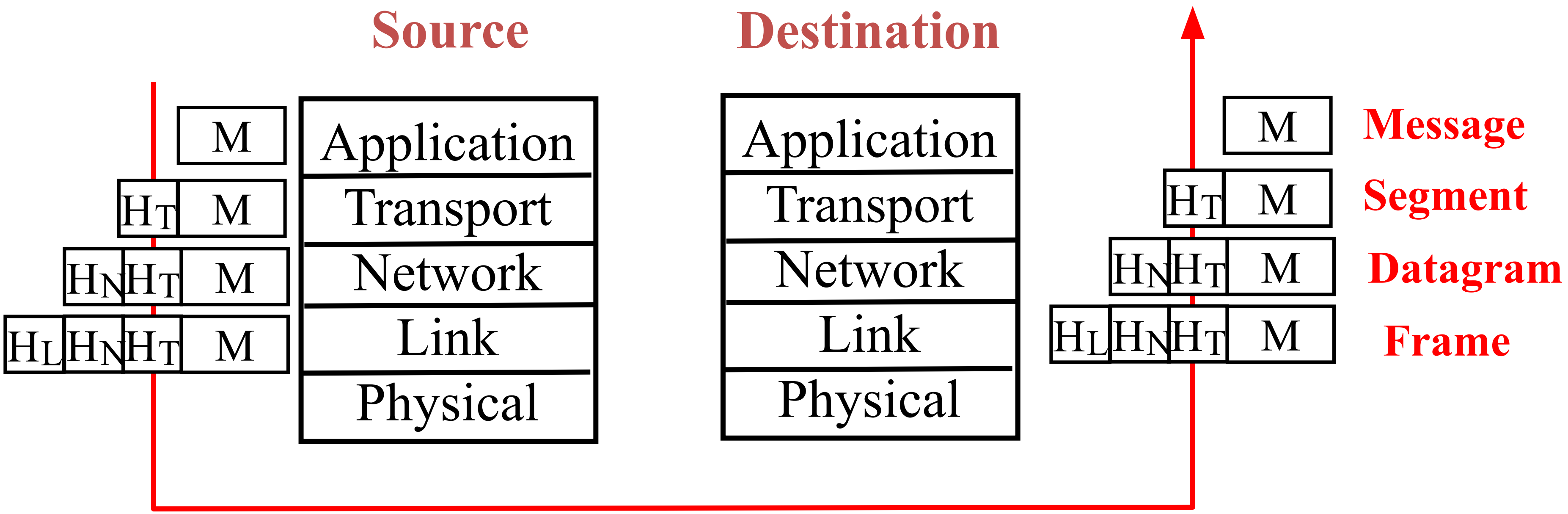
Layering: Physical Communication



Protocol Layering and Data

Each layer takes data from above

- Adds header information to create new data unit
- Passes new data unit to layer below



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- **History**

Internet History (1)

1961–1972: Early packet-switching principles

- **1961:** Kleinrock – queueing theory shows effectiveness of packet-switching
- **1964:** Baran – packet-switching in military nets
- **1967:** ARPAnet conceived by Advanced Research Projects Agency
- **1969:** First ARPAnet node operational
- **1972**:
  - ARPAnet demonstrated publicly
  - NCP (Network Control Protocol) first host-host protocol
  - First e-mail program
  - ARPAnet has 15 nodes

Internet History (2)

1972–1980: Internetworking, new and proprietary nets

- **1970:** ALOHAnet satellite network in Hawaii
- **1973:** Metcalfe's PhD thesis proposes Ethernet
- **1974:** Cerf and Kahn - architecture for interconnecting networks
- **late 70s:** Proprietary architectures: DECnet, SNA, XNA
- **late 70s:** Switching fixed length packets (ATM precursor)
- **1979:** ARPAnet has 200 nodes

Cerf and Kahn's internetworking principles:

- Minimalism, autonomy - no internal changes required to interconnect networks
- Best effort service model
- Stateless routers
- Decentralized control

Define today's Internet architecture

Internet History (3)

1980–1990: New protocols, a proliferation of networks

- **1983:** Deployment of TCP/IP
- **1982:** SMTP e-mail protocol defined
- **1983:** DNS defined for name-to-IP-address translation
- **1985:** FTP protocol defined
- **1988:** TCP congestion control

- New national networks: Csnet, BITnet, NSFnet, Minitel
- 100,000 hosts connected to confederation of networks

Internet History (4)

1990s: Commercialization, the WWW

- **Early 1990's:** ARPAnet decommissioned
- **1991:** NSF lifts restrictions on commercial use of NSFnet (decommissioned, 1995)
- **Early 1990s:** WWW
  - hypertext [Bush 1945, Nelson 1960s]
  - HTML, http: Berners-Lee
  - 1994: Mosaic, later Netscape
  - Late 1990s: commercialization of the WWW

Late 1990's:

- Est. 50 million computers on Internet
- Est. 100 million+ users
- Backbone links running at 1 Gbps

Introduction: Summary

Covered a "ton" of material!

- Internet overview
- What's a protocol?
- Network edge, core, access network
  - Packet switching versus circuit switching
- Performance: loss, delay
- Layering and service models
- Backbones, NAPs, ISPs
- History

You now have:

- Context, overview, "feel" of networking
- More depth, detail *later* in course