CSMC 417

Computer Networks

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Set 2

Spring 2003

Three Components of Computing

Processing
- Speed increasing - cycle time ~ ns
- Parallel processing
- Pipelining at many places in architecture

Storage
- Capacity
- Speed, access time
- density
- Cache, Main, Secondary, Tertiary

Communications

Movement of Information

Local vs. Wide area
Serial vs. Parallel
Distance
- within a chip
- within a board
- within a box
- to peripherals
- within a room, building, campus, metro, world wide

Basics

- Signal
  - Electrical, optical
  - Interpretation of signal as bits, bytes etc.
- Medium
  - Wire
  - Optical
  - Wireless
    - Terrestrial
    - Satellite
- Techniques
  - Point-to-point
  - Circuit Switched
  - Message Switched
  - Packet Switched
  - Cell Switched

Problem
Building a Network

Network That can
- Grow to global proportions
- Support diverse applications
  - Teleconferencing
  - Video on Demand
  - Distributed Computing
  - Digital Libraries

What building blocks should be used ?

What software architecture should it have ?

Computer Networks

Built from general purpose hardware
Not optimized for ONE application
Carry many different types of data
Support a very wide range of applications

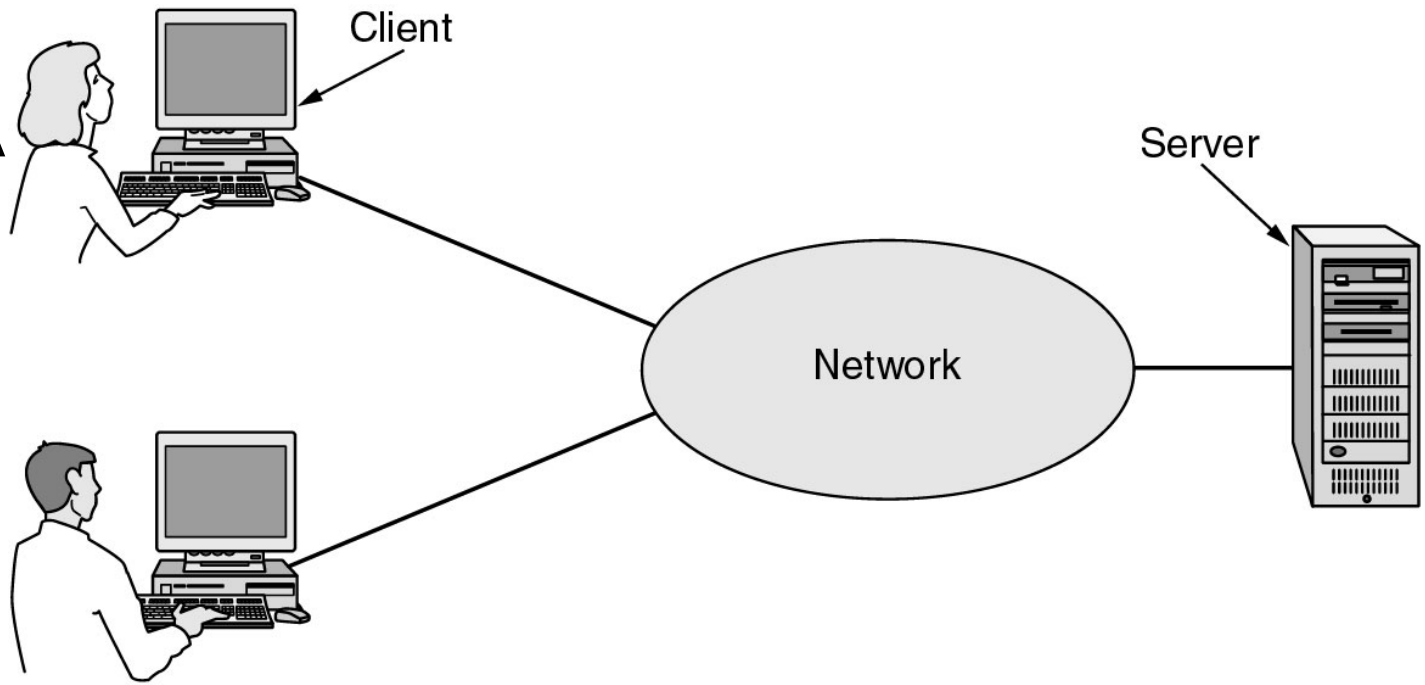
Let us look at the characteristics of some of the applications first

Uses of Computer Networks

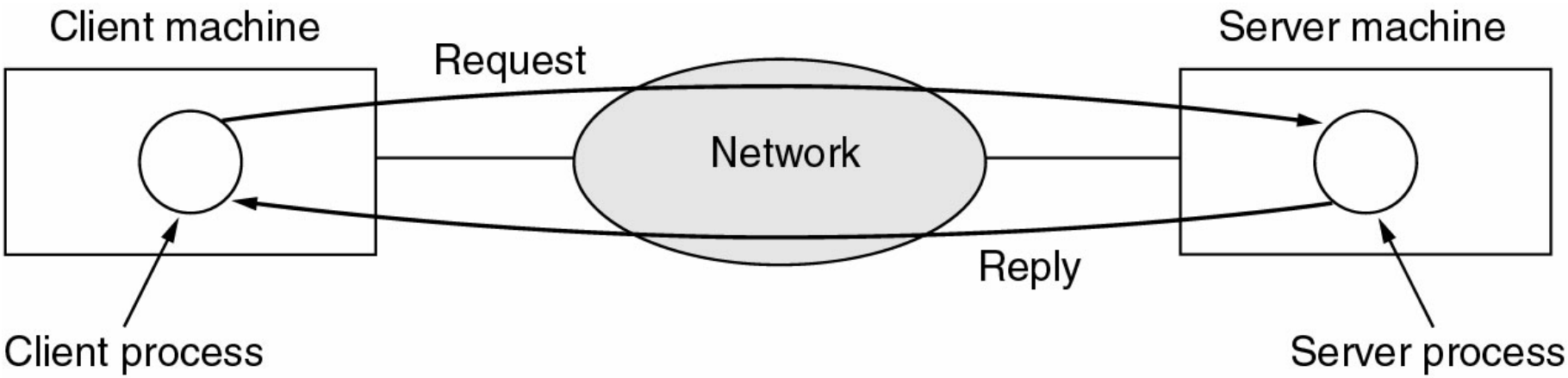
- Business Applications
- Home Applications
- Mobile Users
- Social Issues

Business Applications of Networks

- A



Business Applications of Networks (2)

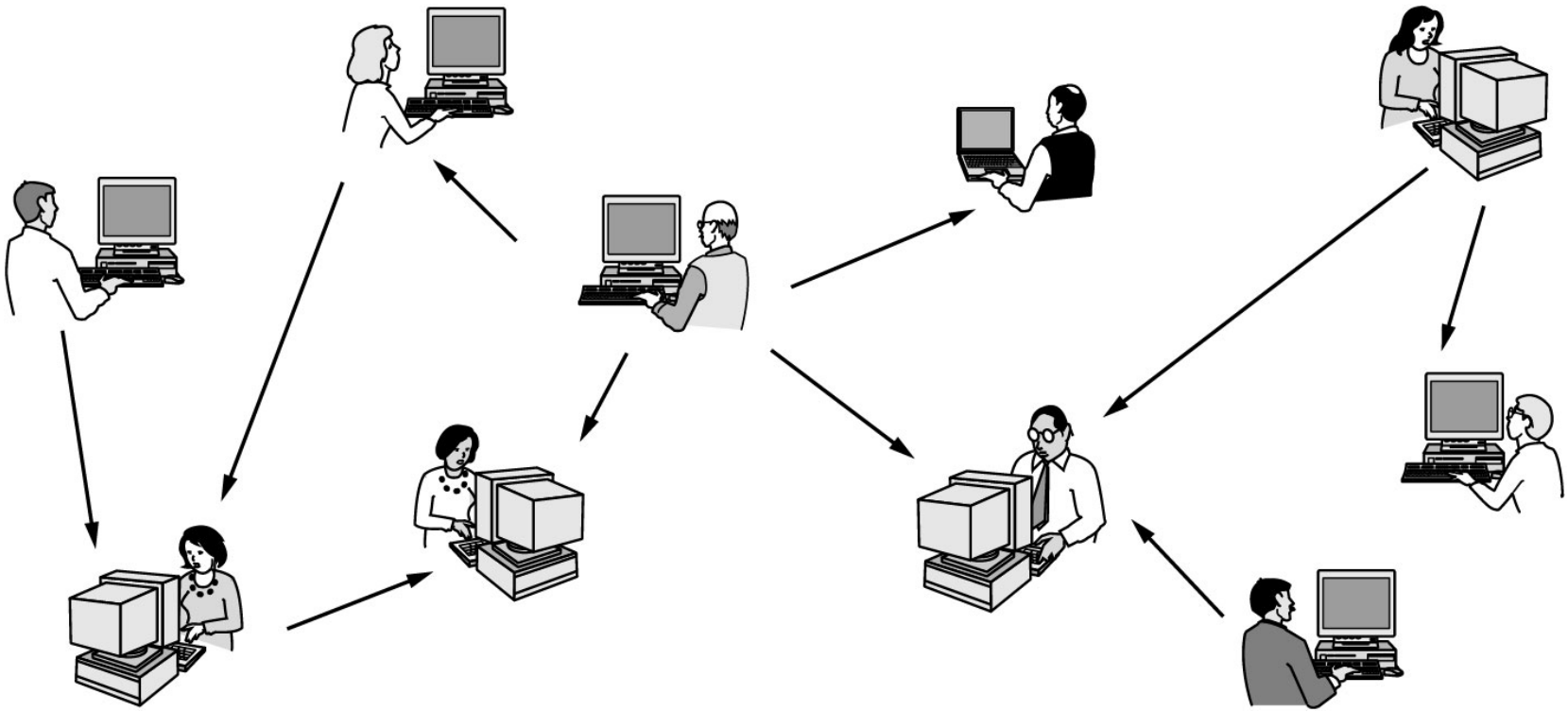


The client-server model involves requests and replies.

Home Network Applications

- Access to remote information
- Person-to-person communication
- Interactive entertainment
- Electronic commerce

Home Network Applications (2)



Home Network Applications (3)

Tag	Full name	Example
B2C	Business-to-consumer	Ordering books on-line
B2B	Business-to-business	Car manufacturer ordering tires from supplier
G2C	Government-to-consumer	Government distributing tax forms electronically
C2C	Consumer-to-consumer	Auctioning second-hand products on-line
P2P	Peer-to-peer	File sharing

Some forms of e-commerce.

Mobile Network Users

Wireless	Mobile	Applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in older, unwired buildings
Yes	Yes	Portable office; PDA for store inventory

Combinations of wireless networks and mobile computing.

Example Applications
FTP

File Transfer Protocol
- Used to move files
  - between machines
- Client Server Mode of Operation

Session Example

```
% ftp
ftp> open ds.internic.net
Connected to ds.internic.net.
 [...]
220 ds.internic.net FTP server ready.
Name (ds.internic.net:bsd):anonymous
331 Guest login ok, send ident as password.
Password:
230 Guest login ok, access restrictions apply.
ftp> cd rfc
250 CWD command successful.
ftp> get rfc-index.txt
200 PORT command successful.
150 Opening ASCII mode data connection
                for rfc-index.txt (245544 bytes).
226 Transfer complete.
local: rfc-index.txt remote: rfc-index.txt
251257 bytes received in 1.2e+02 seconds (2 Kbytes/s)
ftp> close
221 Goodbye.
```

Example Application
World Wide Web

Uses Hyper Text Transfer Protocol (HTTP)
Use Web Browser e.g Mosaic, Netscape etc
Universal Resource Locator (URL)

http://www.cs.umd.edu/projects.html

Open a connection to the web-server at a machine called www.cs.umd.edu and retrieve a file called *projects.html*

A file may contain

- Text
- Image
- Audio
- Video
- Pointers to other files (URLs) - Hypertext links

Example Application
Network Video

Used for multi-party video conferencing

To send you need

- a *Frame Grabber* hardware
- Digitize at a resolution
  - 352 by 240
- pixel using 24 bits of color
  - yield 247.5 K bytes per frame
- Frame Rate
  - 30 /sec or less
  - NV runs at 2 - 3 frames per second

Requirements
Three Perceptions

Network User
- List of services needed
- Guarantee that each message sent will be delivered without error within a certain amount of time.

Network Designer
- Cost-effective design
- Resources are efficiently utilized and fairly allocated

Network Provider
- System easy to administer and manage
- Faults can be easily located
- Accounting of usage

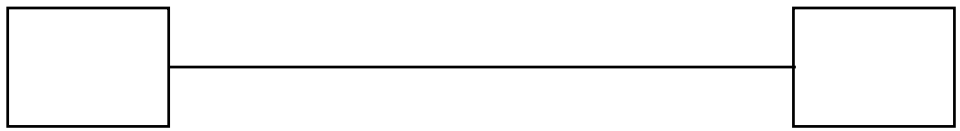
Scalability ?

Connectivity

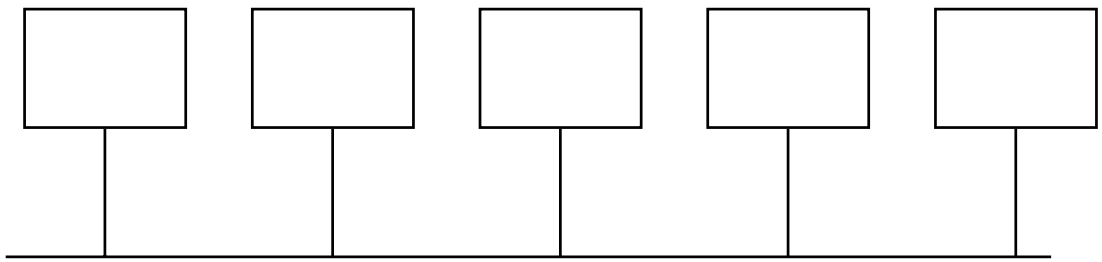
- Link
  - Physical medium used to connect two computers
    - Twisted Pair
    - Cable
    - Fiber
- Nodes
  - Computers links connect

Links

Point-to-point

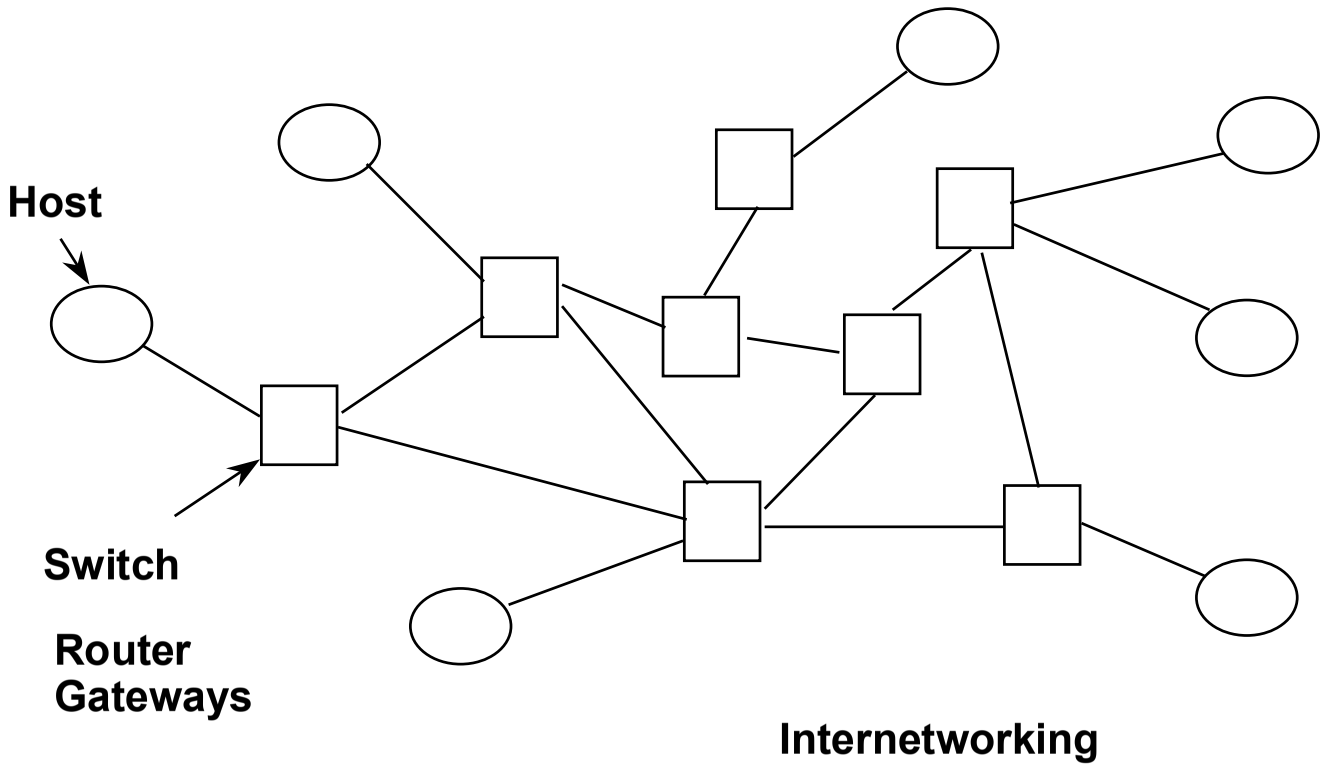


Multiple Access



Switched Network

Circuit Switched
Message/Packet Switched - Store and Forward



Internetworking

Network Hardware

- Local Area Networks
- Metropolitan Area Networks
- Wide Area Networks
- Wireless Networks
- Home Networks
- Internetworks

Broadcast Networks

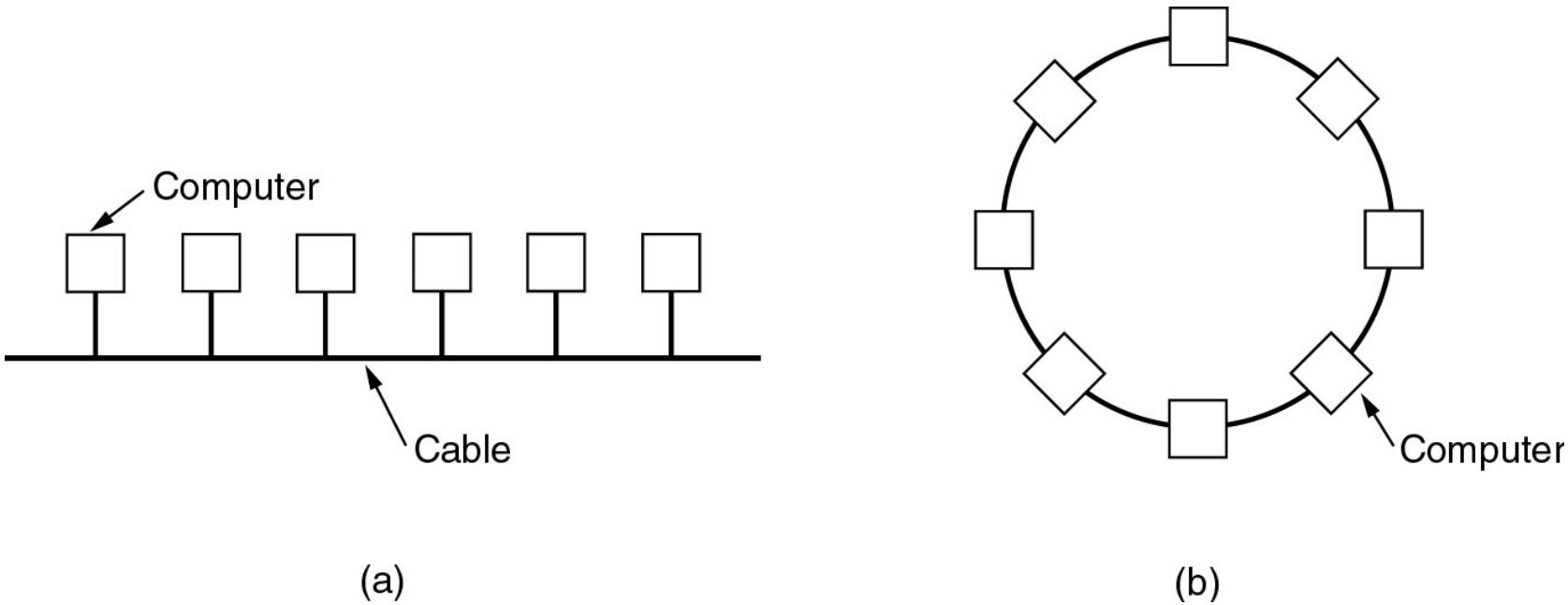
- Types of transmission technology
- Broadcast links
- Point-to-point links

Broadcast Networks (2)

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Classification of interconnected processors by scale.

Local Area Networks

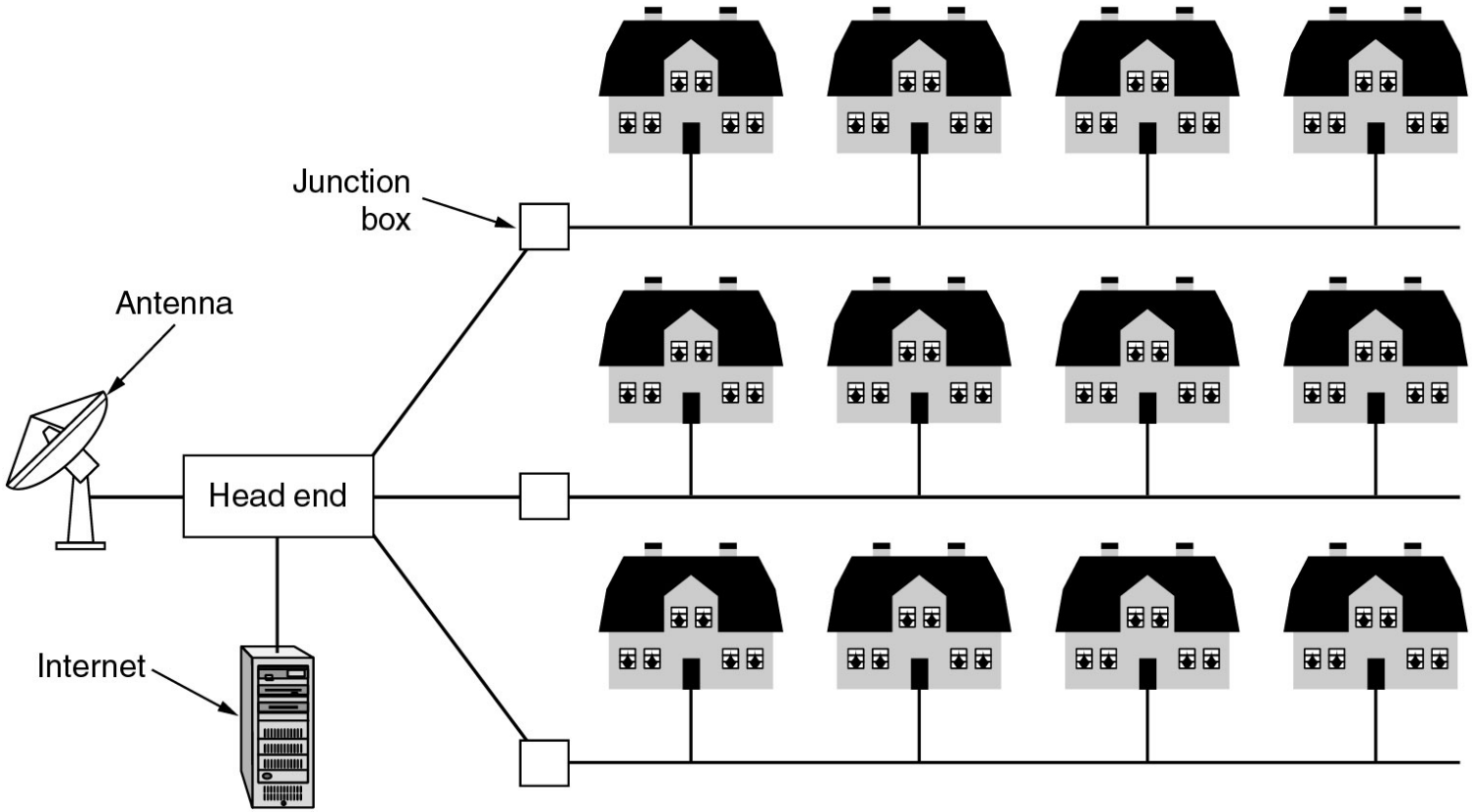


Two broadcast networks

(a) Bus

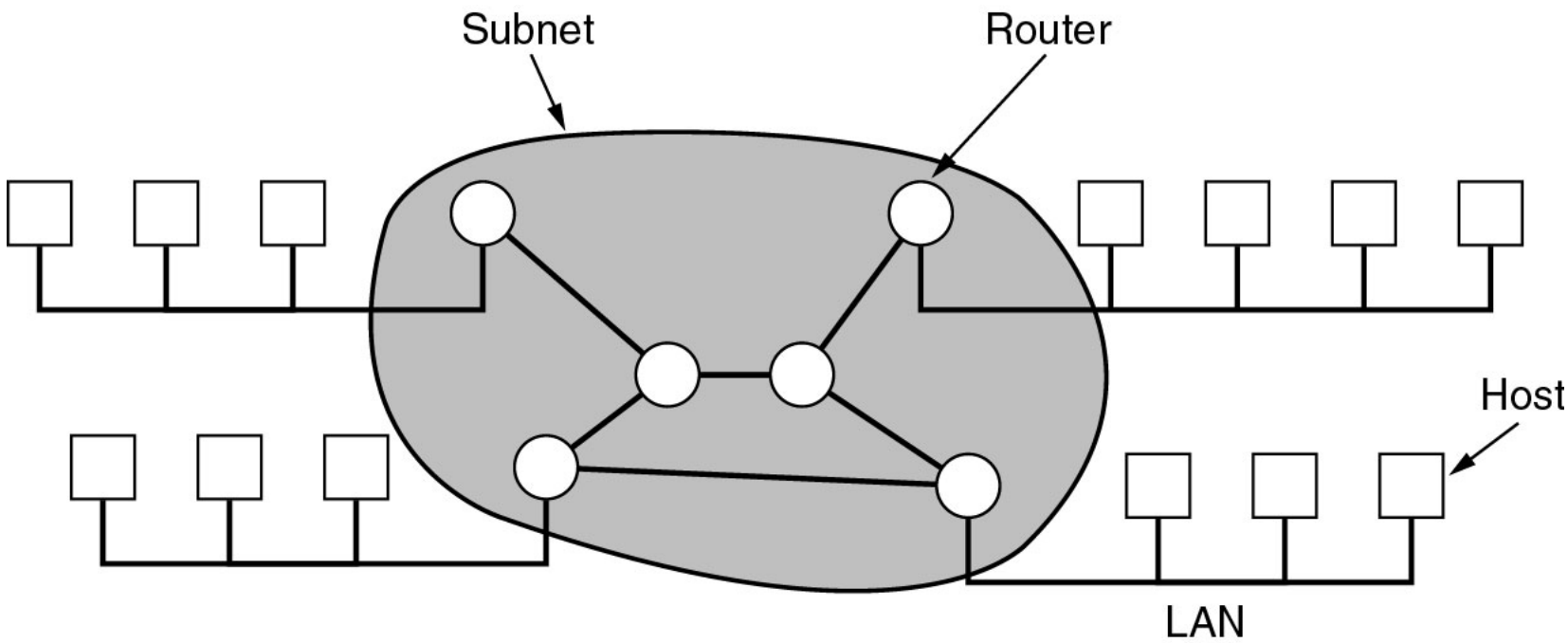
(b) Ring

Metropolitan Area Networks



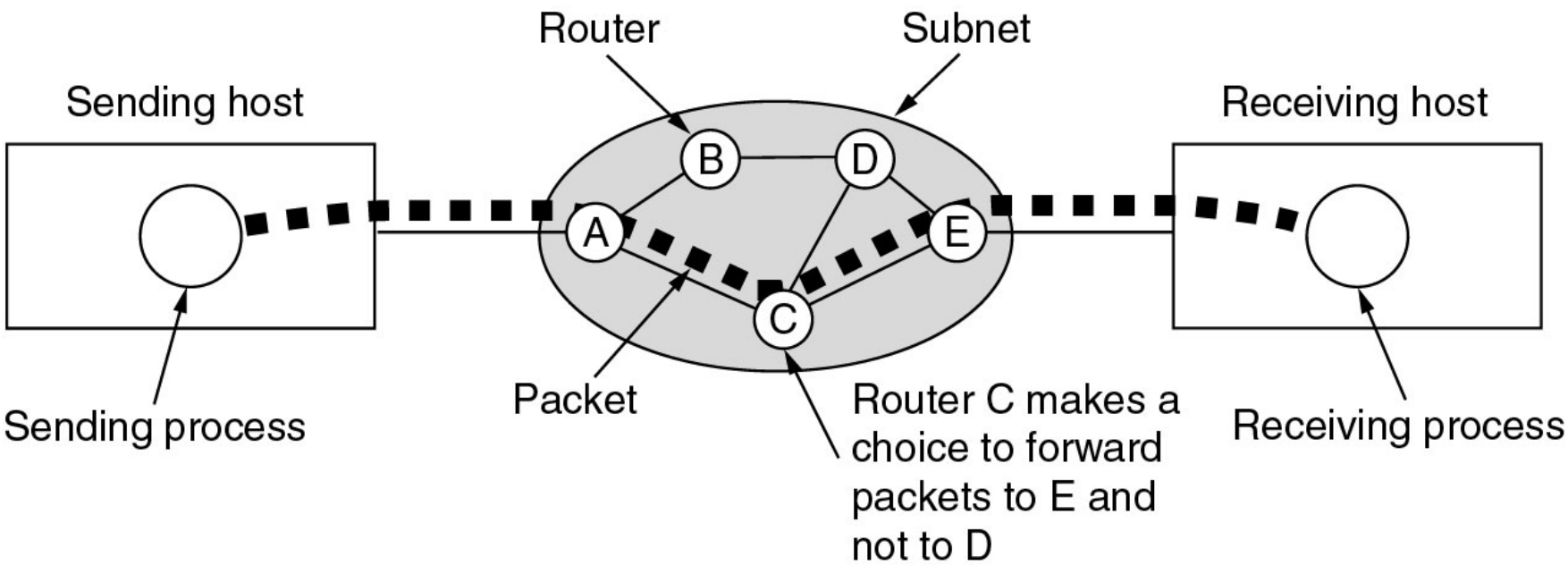
A metropolitan area network based on cable TV.

Wide Area Networks



Relation between hosts on LANs and the subnet.

Wide Area Networks (2)

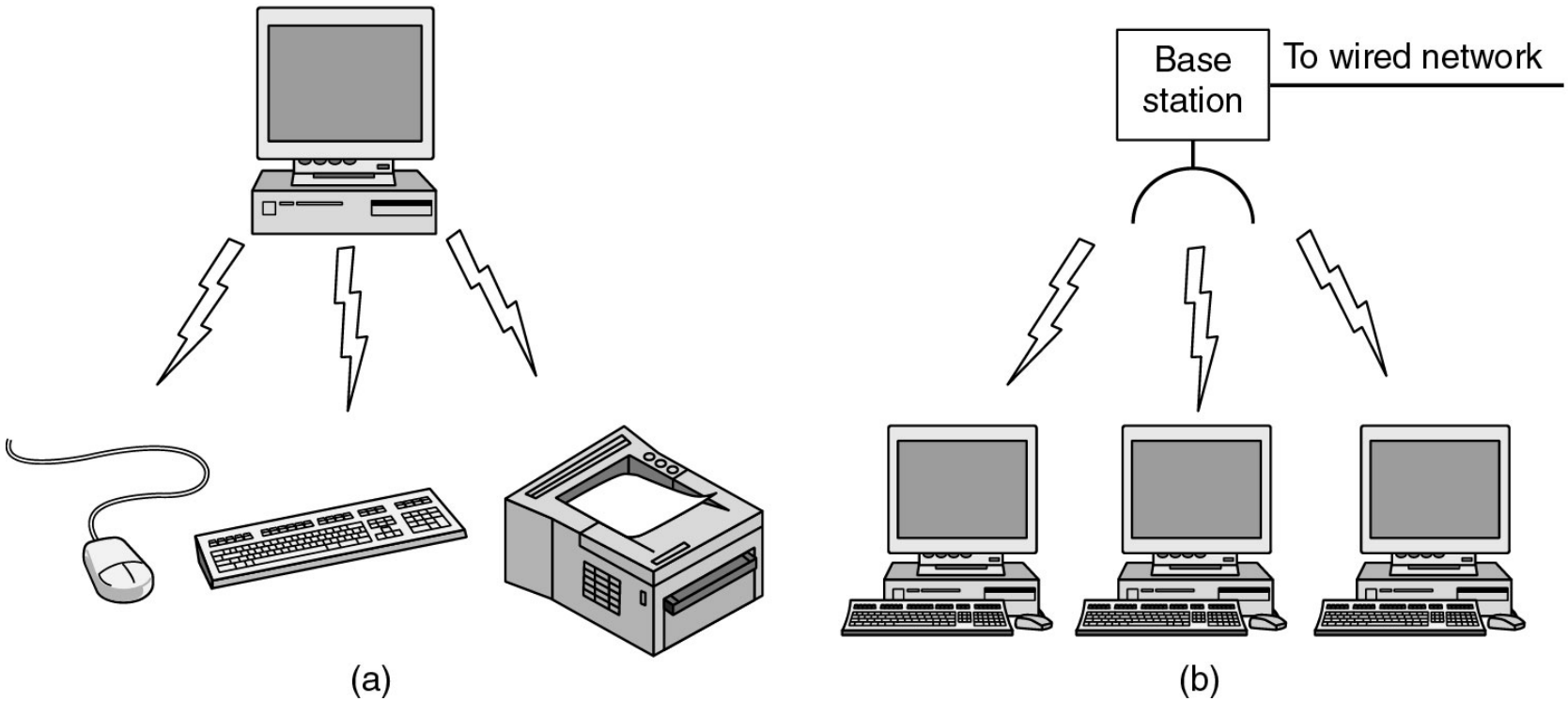


A stream of packets from sender to receiver.

Wireless Networks

- Categories of wireless networks:
- System interconnection
- Wireless LANs
- Wireless WANs

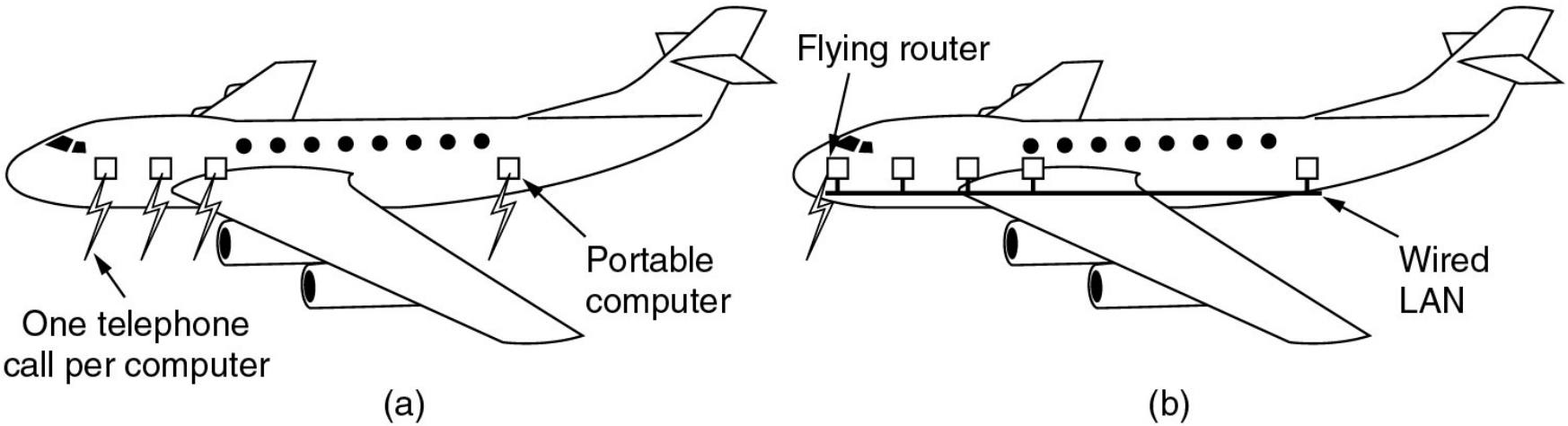
Wireless Networks (2)



(a) Bluetooth configuration

(b) Wireless LAN

Wireless Networks (3)



(a) Individual mobile computers

(b) A flying LAN

Home Network Categories

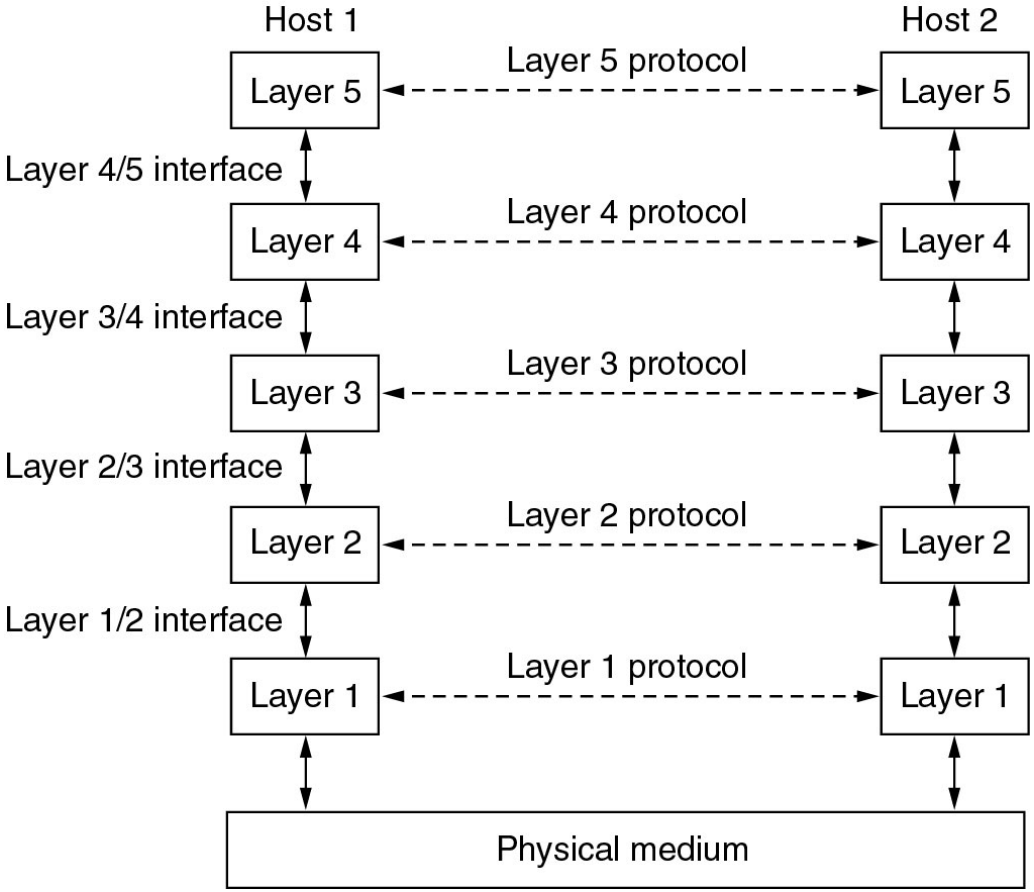
- Computers (desktop PC, PDA, shared peripherals
- Entertainment (TV, DVD, VCR, camera, stereo, MP3)
- Telecomm (telephone, cell phone, intercom, fax)
- Appliances (microwave, fridge, clock, furnace, airco)
- Telemetry (utility meter, burglar alarm, babycam).

Network Software

- Protocol Hierarchies
- Design Issues for the Layers
- Connection-Oriented and Connectionless Services
- Service Primitives
- The Relationship of Services to Protocols

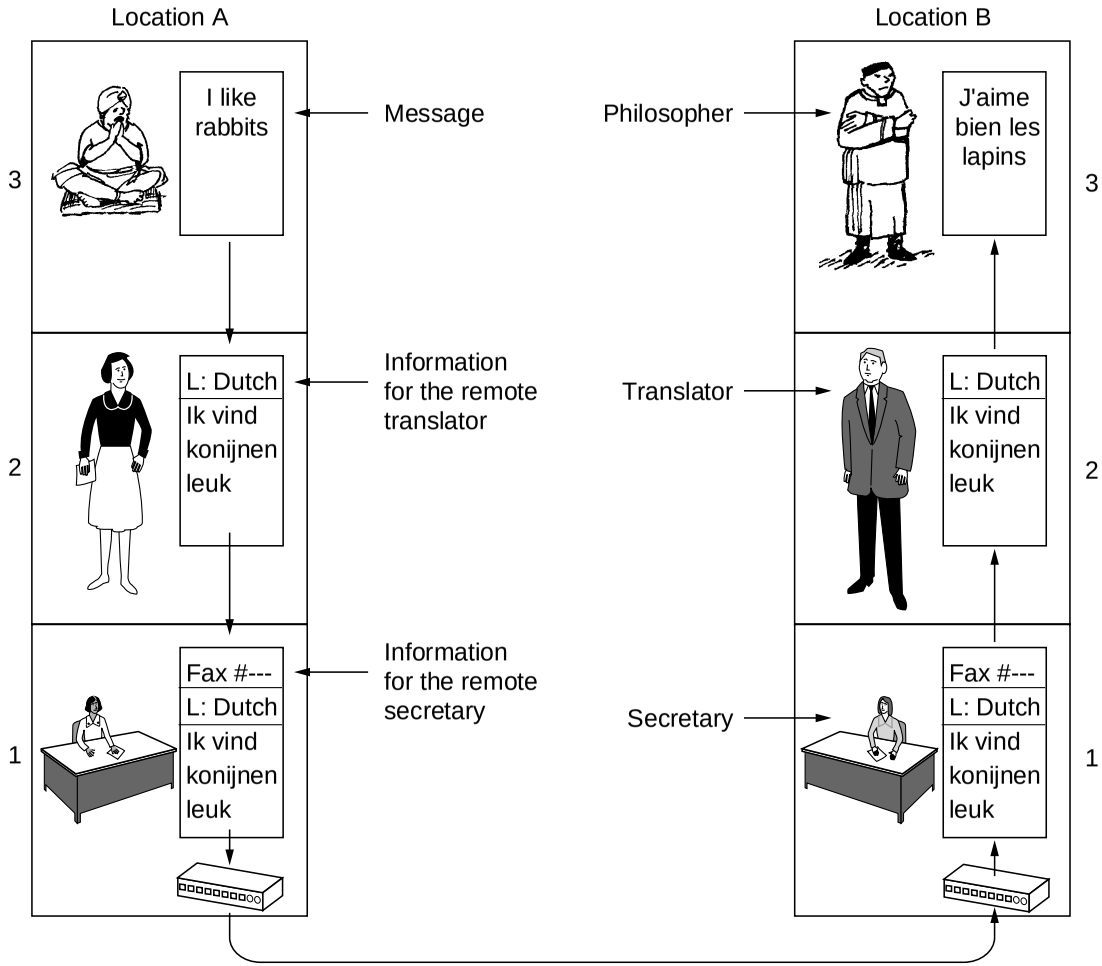
Network Software

Protocol Hierarchies



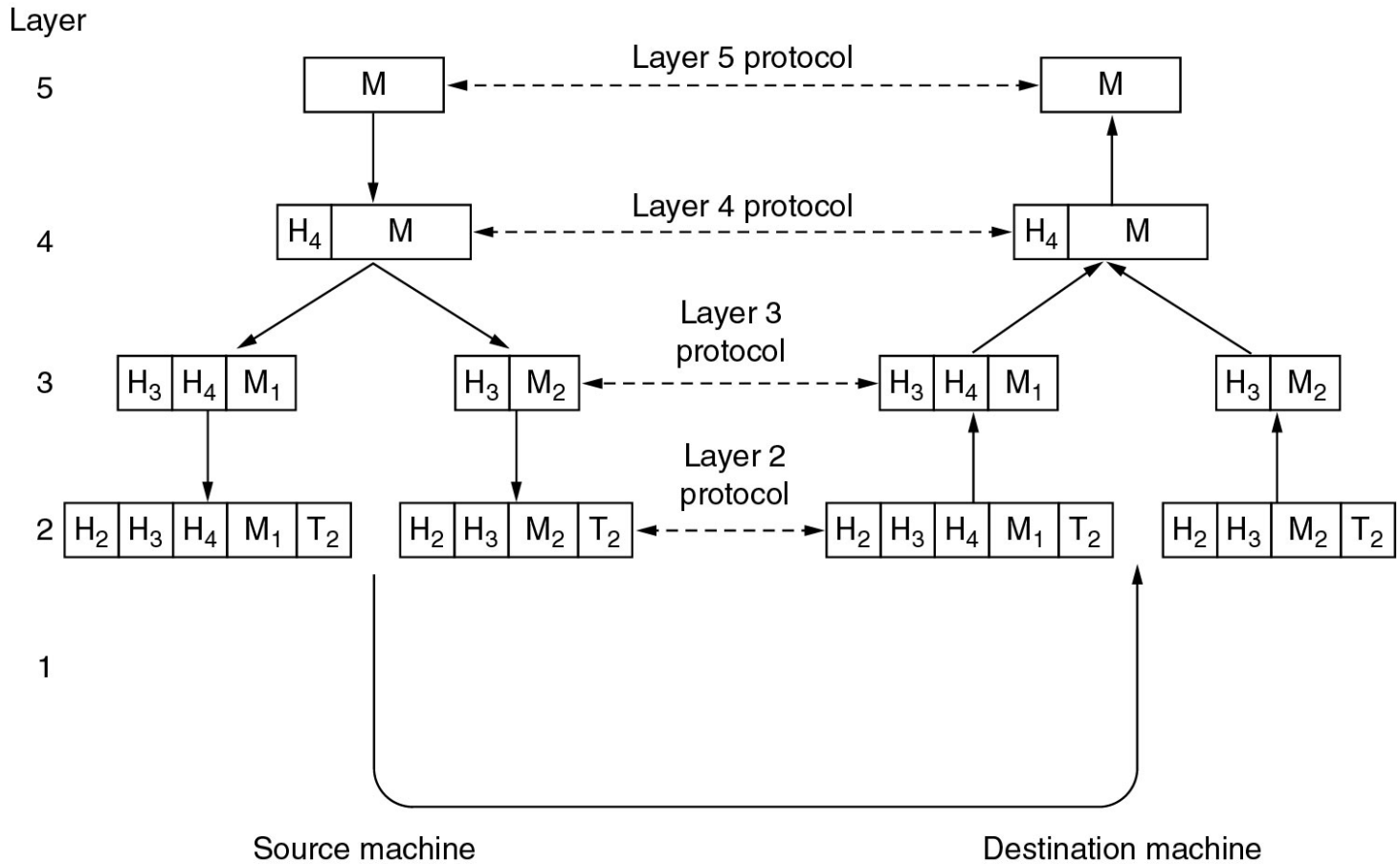
Layers, protocols, and interfaces.

Protocol Hierarchies (2)



The philosopher-translator-secretary architecture.

Protocol Hierarchies (3)



Example information flow supporting virtual communication in layer 5.

Design Issues for the Layers

- Addressing
- Error Control
- Flow Control
- Multiplexing
- Routing

Connection-Oriented and Connectionless Services

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Remote login
	Unreliable connection	Digitized voice
Connectionless	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Registered mail
	Request-reply	Database query

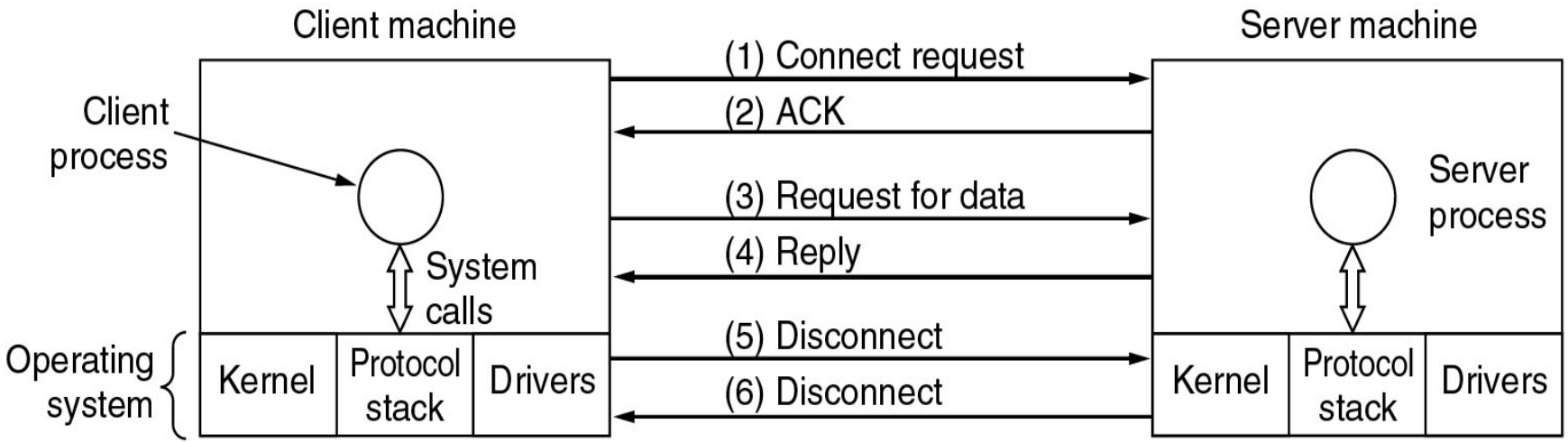
Six different types of service.

Service Primitives

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Five service primitives for implementing a simple connection-oriented service.

Service Primitives (2)



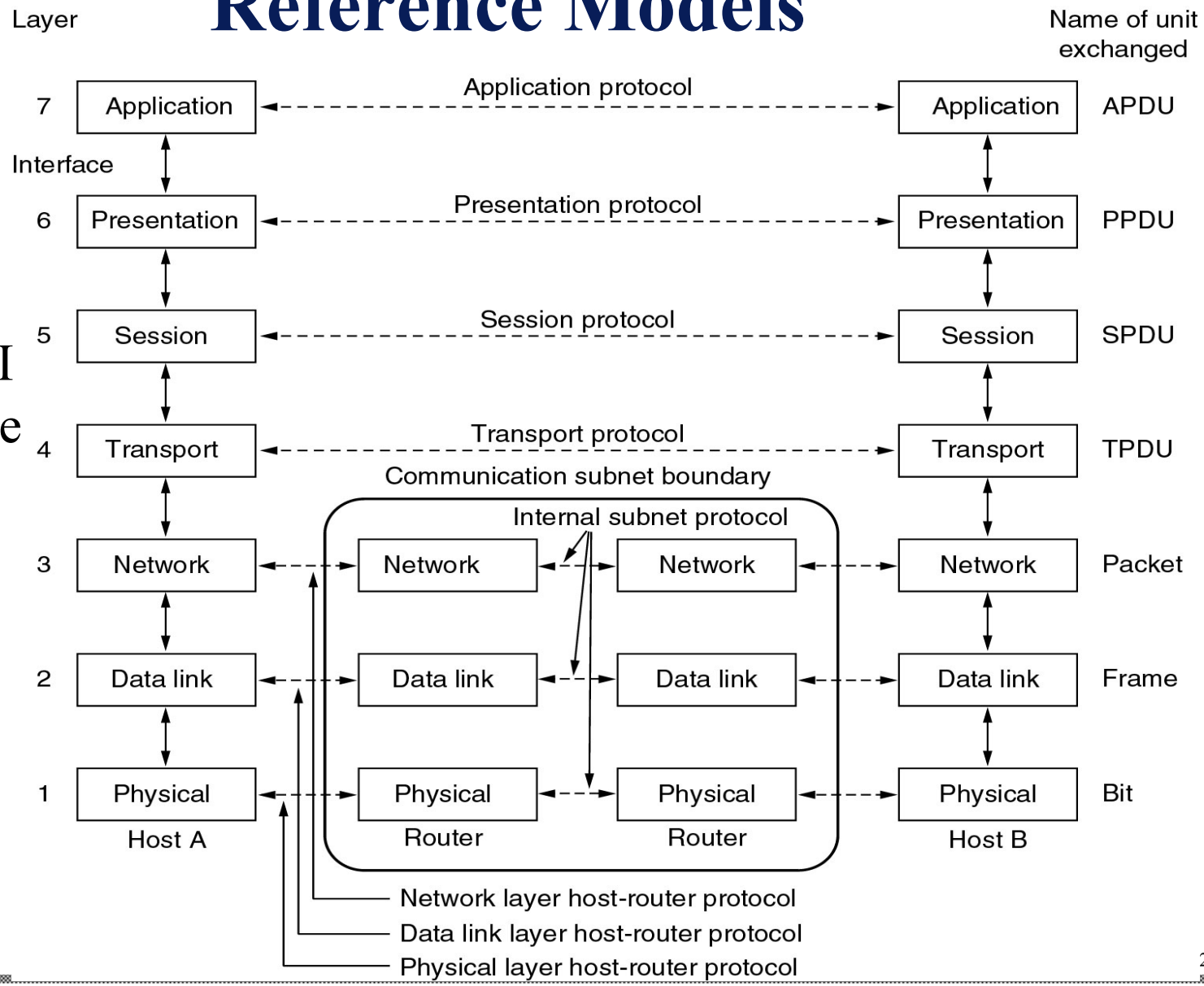
Packets sent in a simple client-server interaction on a connection-oriented network.

Reference Models

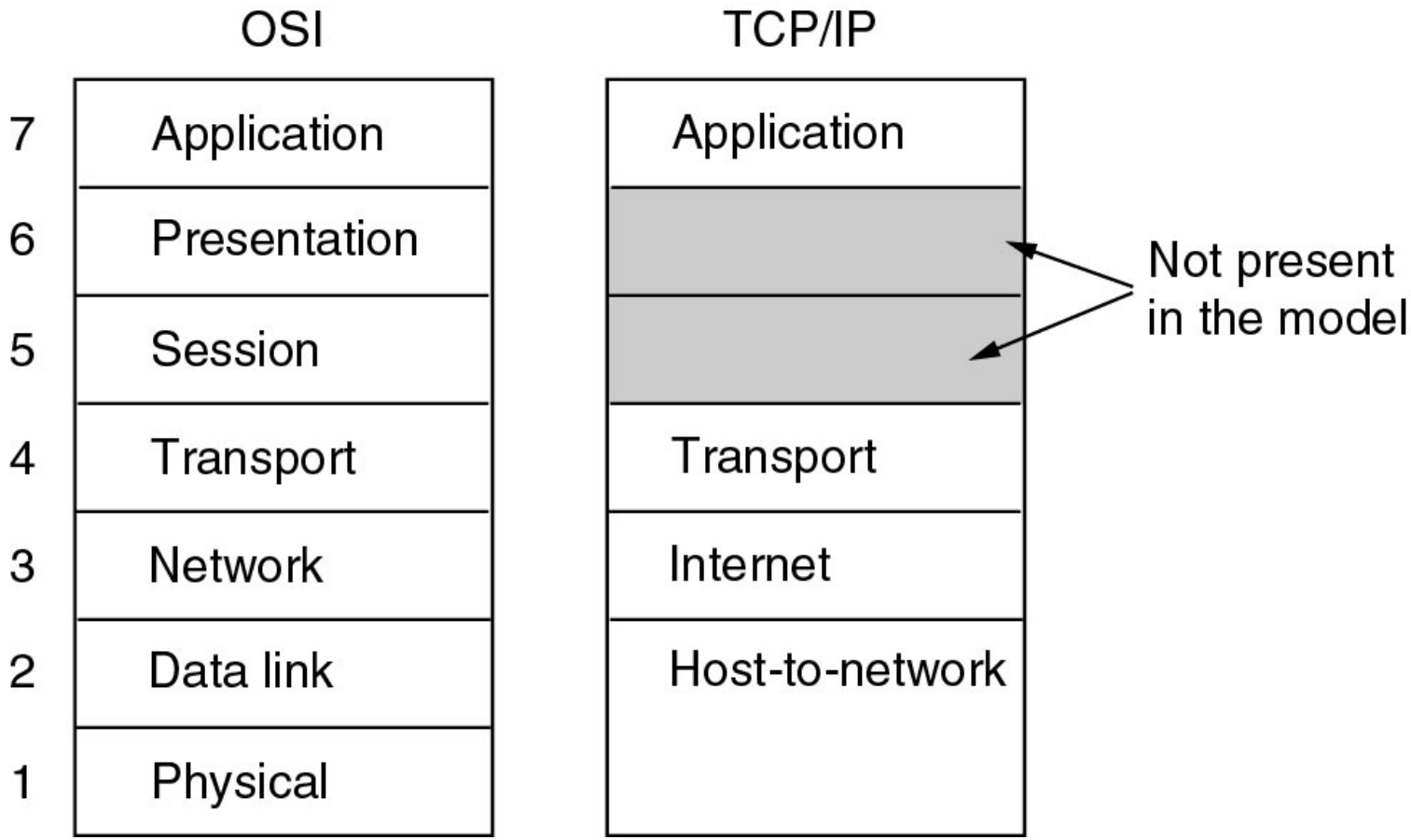
- The OSI Reference Model
- The TCP/IP Reference Model
- A Comparison of OSI and TCP/IP
- A Critique of the OSI Model and Protocols
- A Critique of the TCP/IP Reference Model

Reference Models

The OSI reference model.

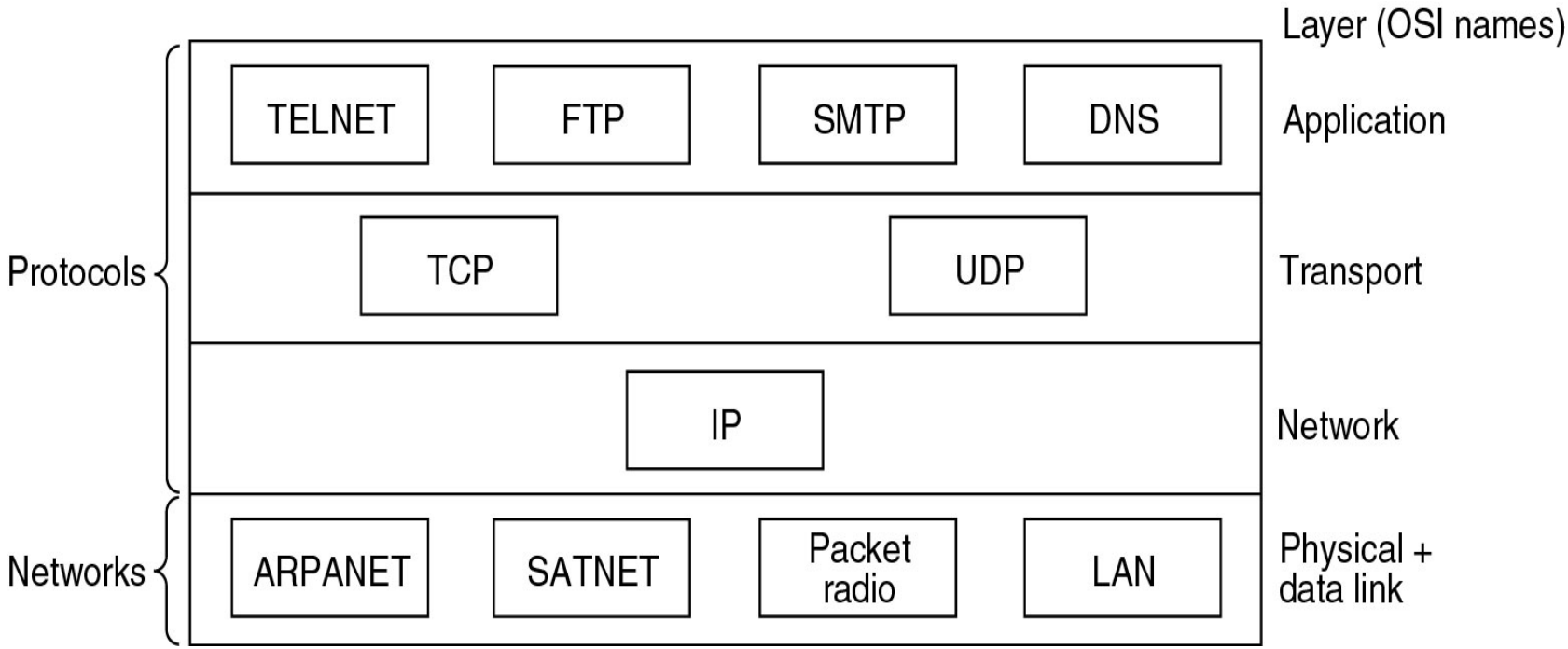


Reference Models (2)



The TCP/IP reference model.

Reference Models (3)



Protocols and networks in the TCP/IP model initially.

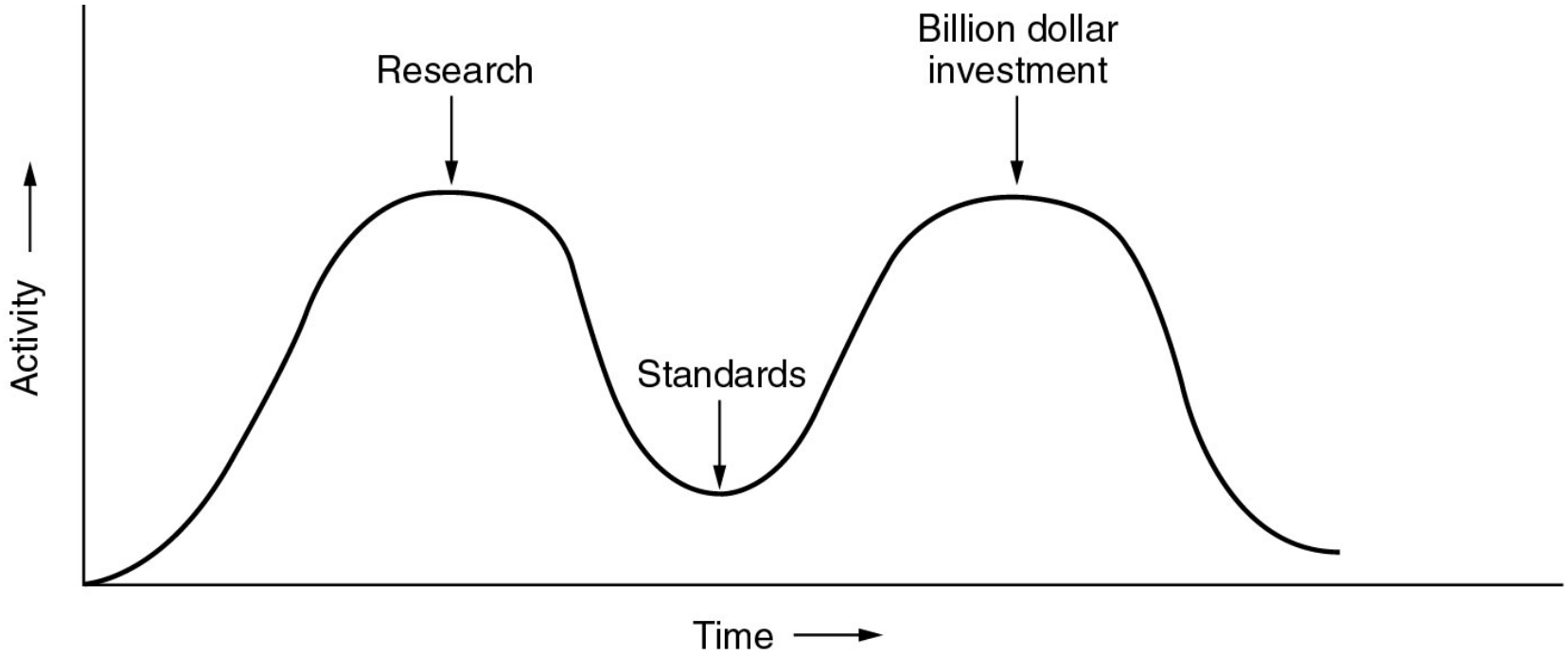
Comparing OSI and TCP/IP Models

- Concepts central to the OSI model
- Services
- Interfaces
- Protocols

A Critique of the OSI Model and Protocols

- Why OSI did not take over the world
- Bad timing
- Bad technology
- Bad implementations
- Bad politics

Bad Timing

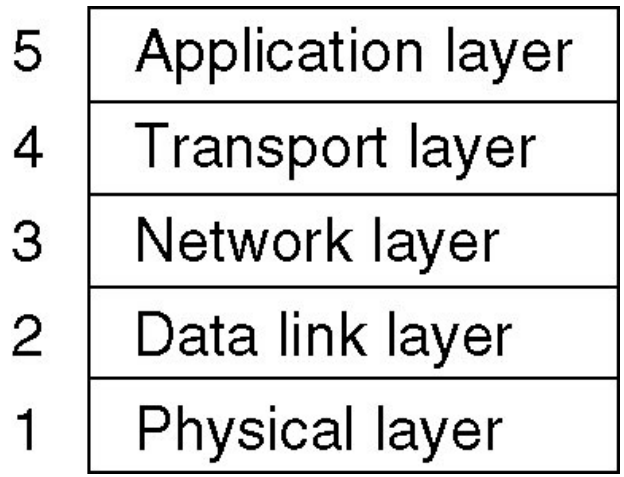


The apocalypse of the two elephants.

A Critique of the TCP/IP Reference Model

- Problems:
- Service, interface, and protocol not distinguished
- Not a general model
- Host-to-network “layer” not really a layer
- No mention of physical and data link layers
- Minor protocols deeply entrenched, hard to replace

Hybrid Model

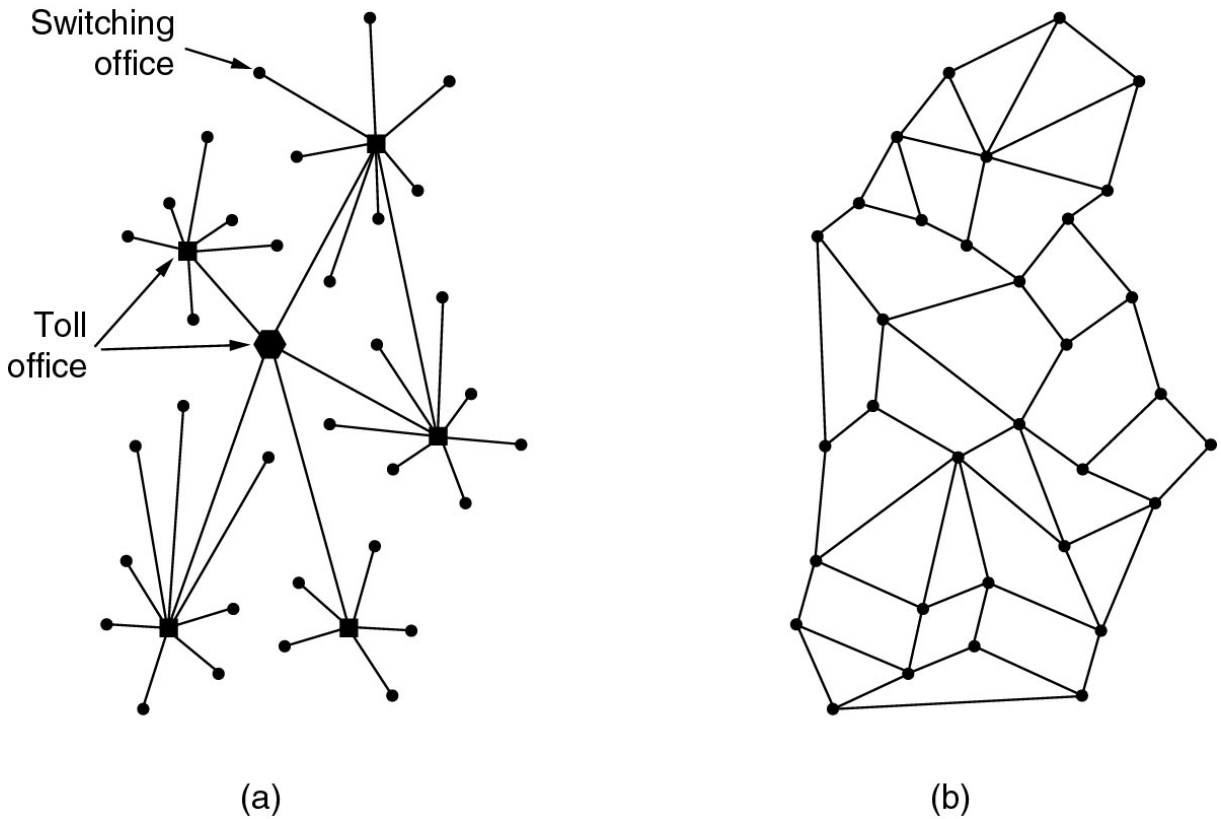


The hybrid reference model to be used in this course.

Example Networks

- The Internet
- Connection-Oriented Networks:
  X.25, Frame Relay, and ATM
- Ethernet
- Wireless LANs: 802:11

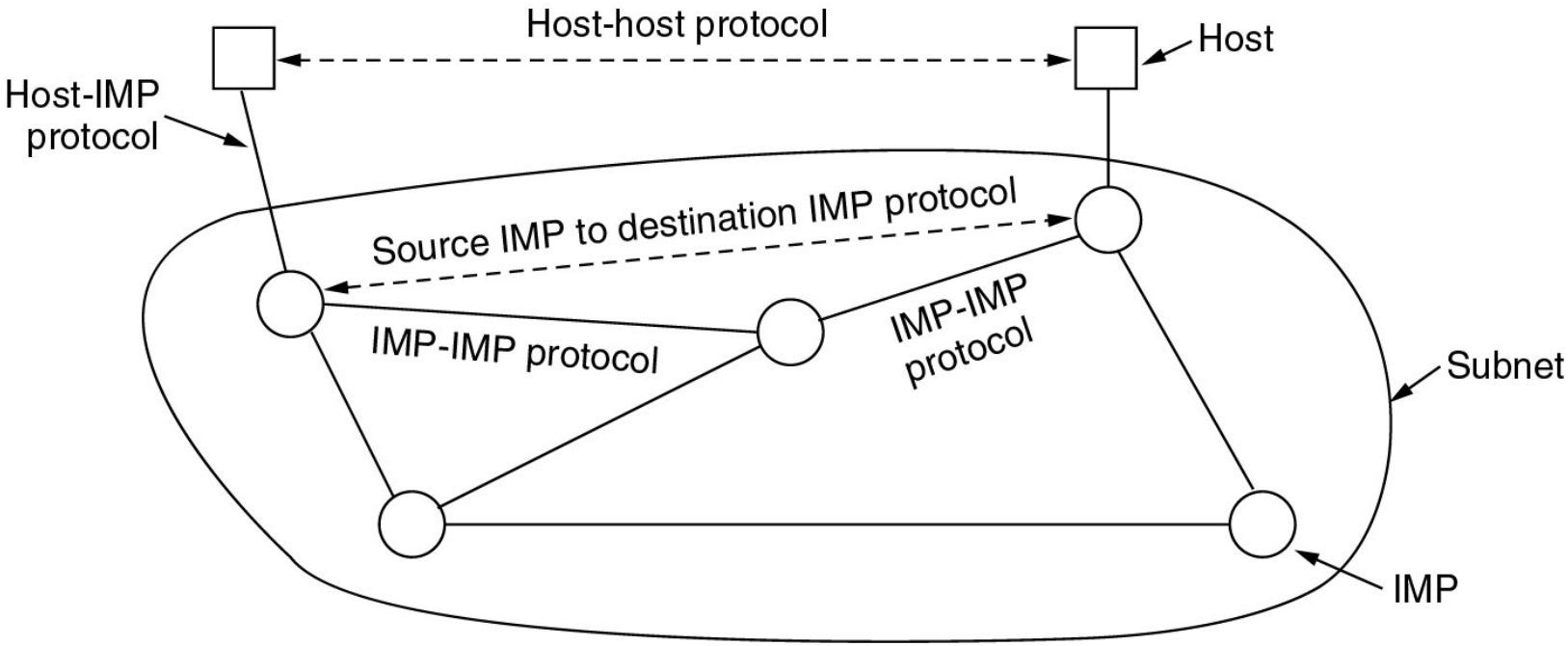
The ARPANET



(a) Structure of the telephone system.

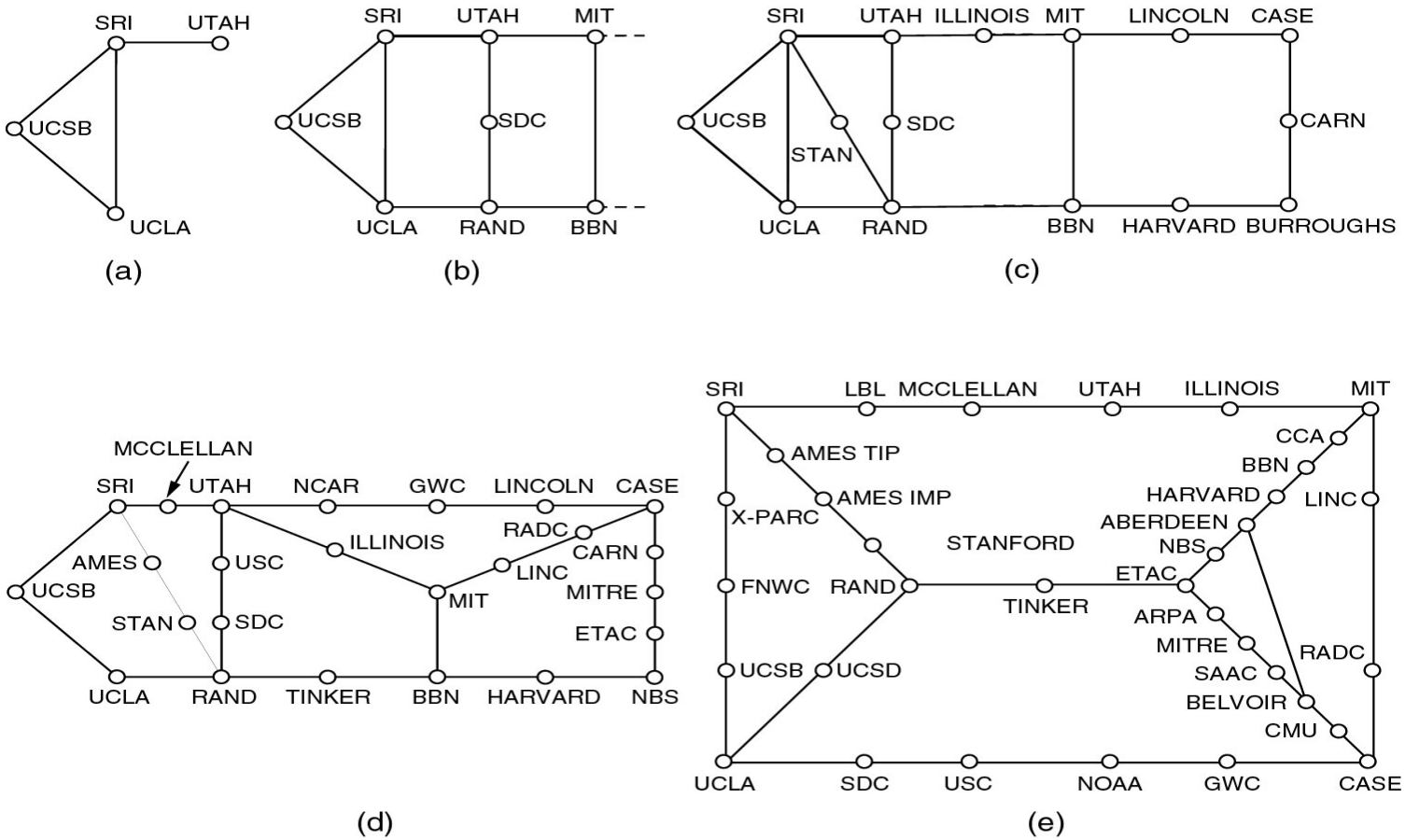
(b) Baran's proposed distributed switching system.

The ARPANET (2)



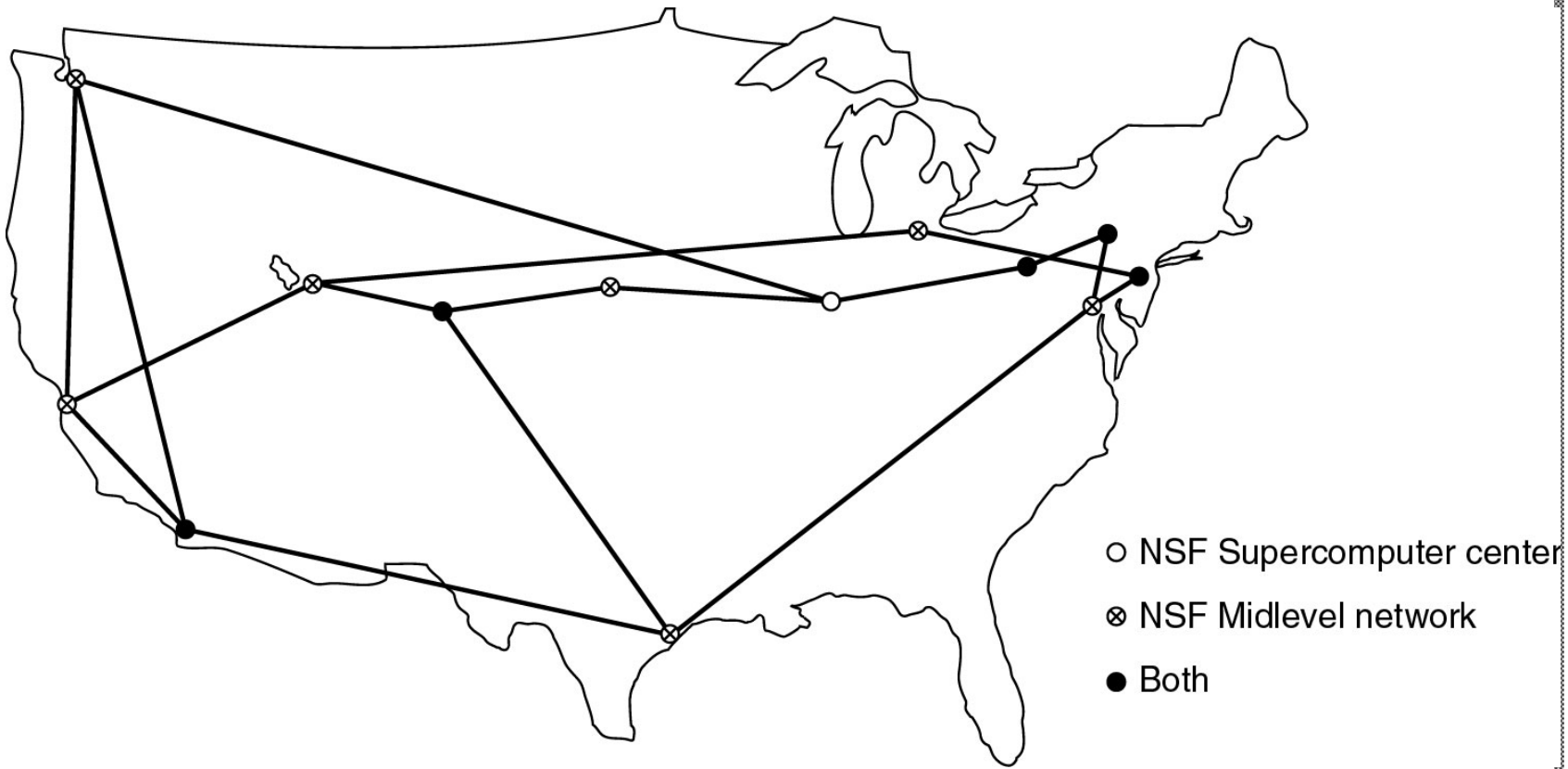
The original ARPANET design.

The ARPANET (3)



Growth of the ARPANET (a) December 1969. (b) July 1970. (c) March 1971. (d) April 1972. (e) September 1972.

NSFNET

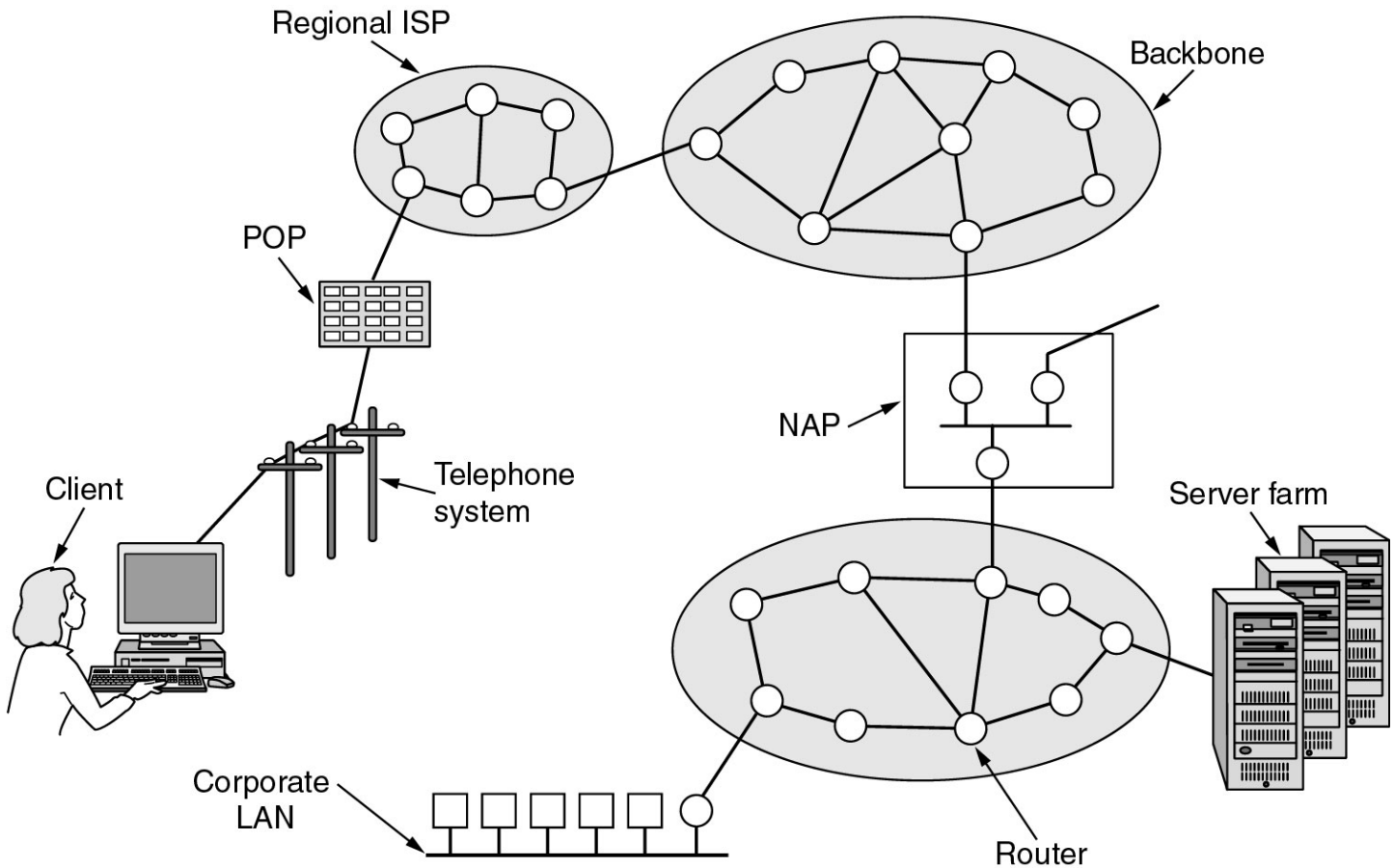


The NSFNET backbone in 1988.

Internet Usage

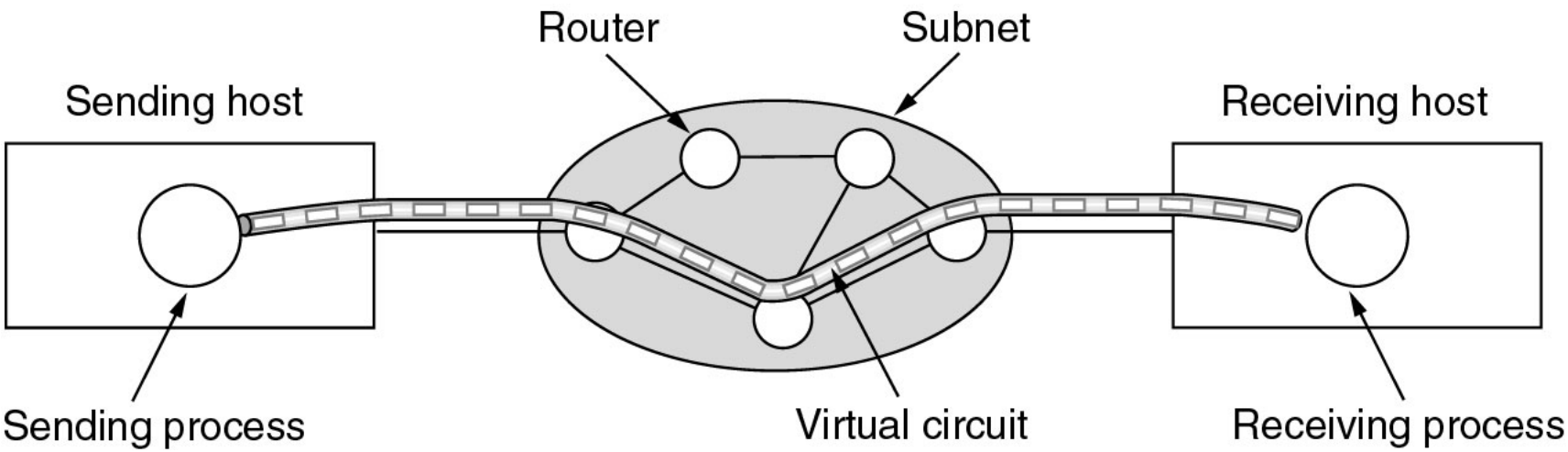
- Traditional applications (1970 – 1990)
- E-mail
- News
- Remote login
- File transfer

Architecture of the Internet



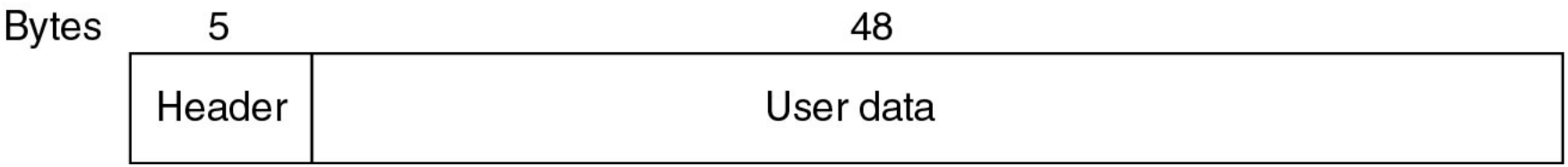
Overview of the Internet.

ATM Virtual Circuits



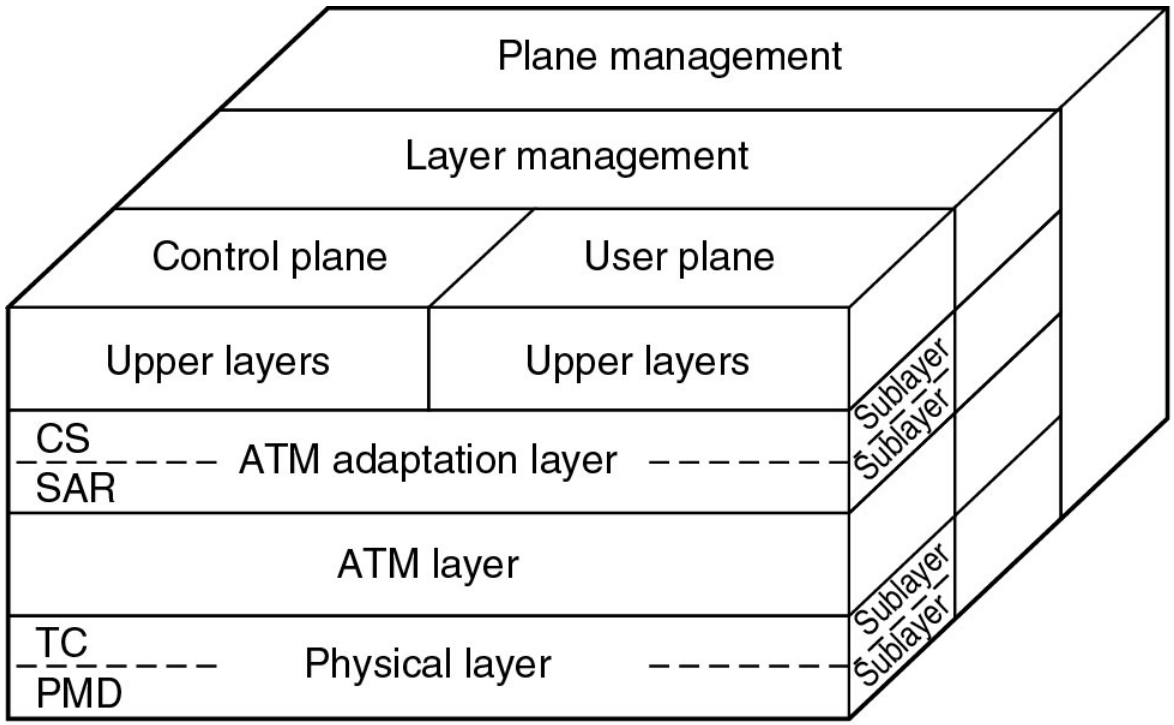
A virtual circuit.

ATM Virtual Circuits (2)



An ATM cell.

The ATM Reference Model



CS: Convergence sublayer
SAR: Segmentation and reassembly sublayer
TC: Transmission convergence sublayer
PMD: Physical medium dependent sublayer

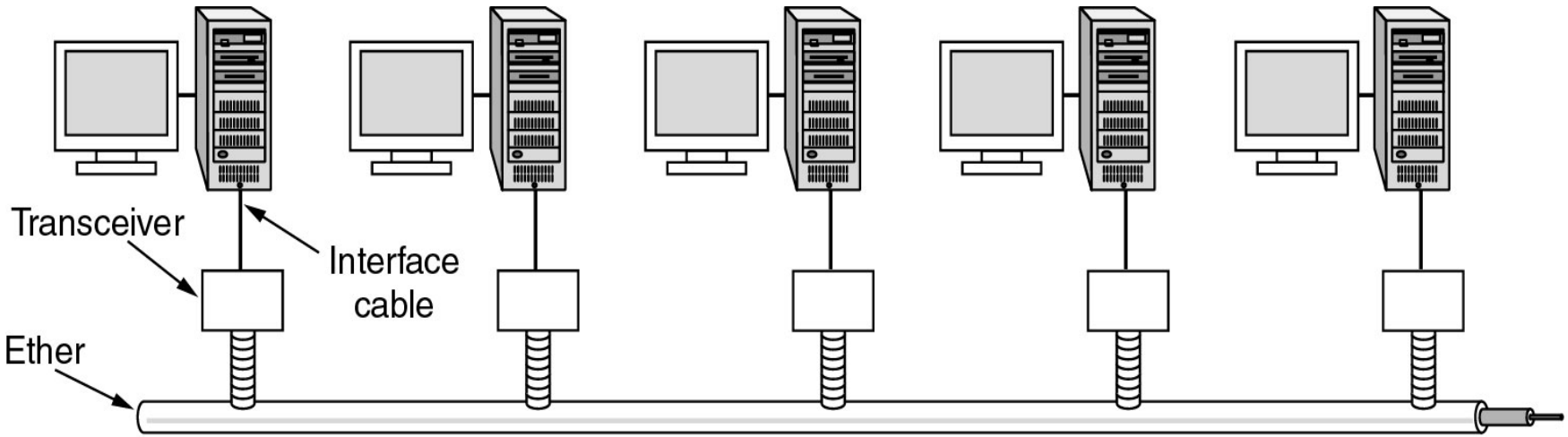
The ATM reference model.

The ATM Reference Model (2)

OSI layer	ATM layer	ATM sublayer	Functionality
3/4	AAL	CS	Providing the standard interface (convergence)
		SAR	Segmentation and reassembly
2/3	ATM		Flow control Cell header generation/extraction Virtual circuit/path management Cell multiplexing/demultiplexing
2	Physical	TC	Cell rate decoupling Header checksum generation and verification Cell generation Packing/unpacking cells from the enclosing envelope Frame generation
1		PMD	Bit timing Physical network access

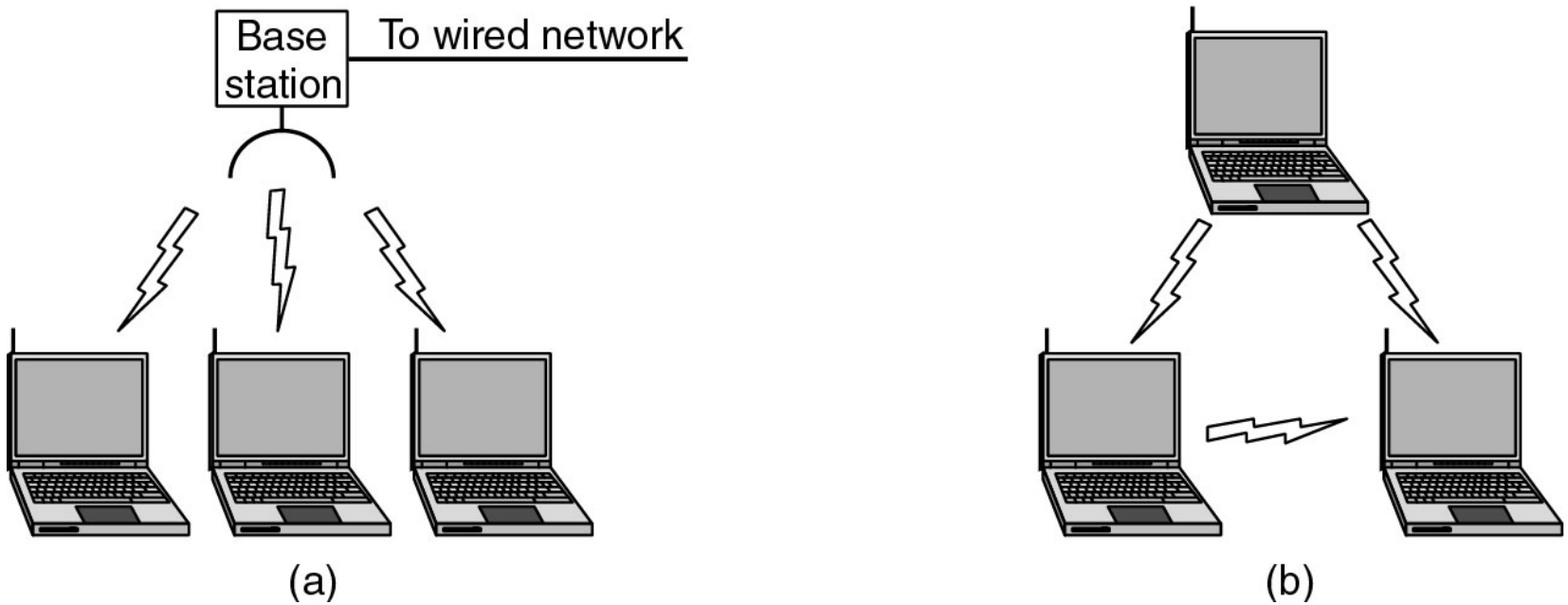
The ATM layers and sublayers and their functions.

Ethernet



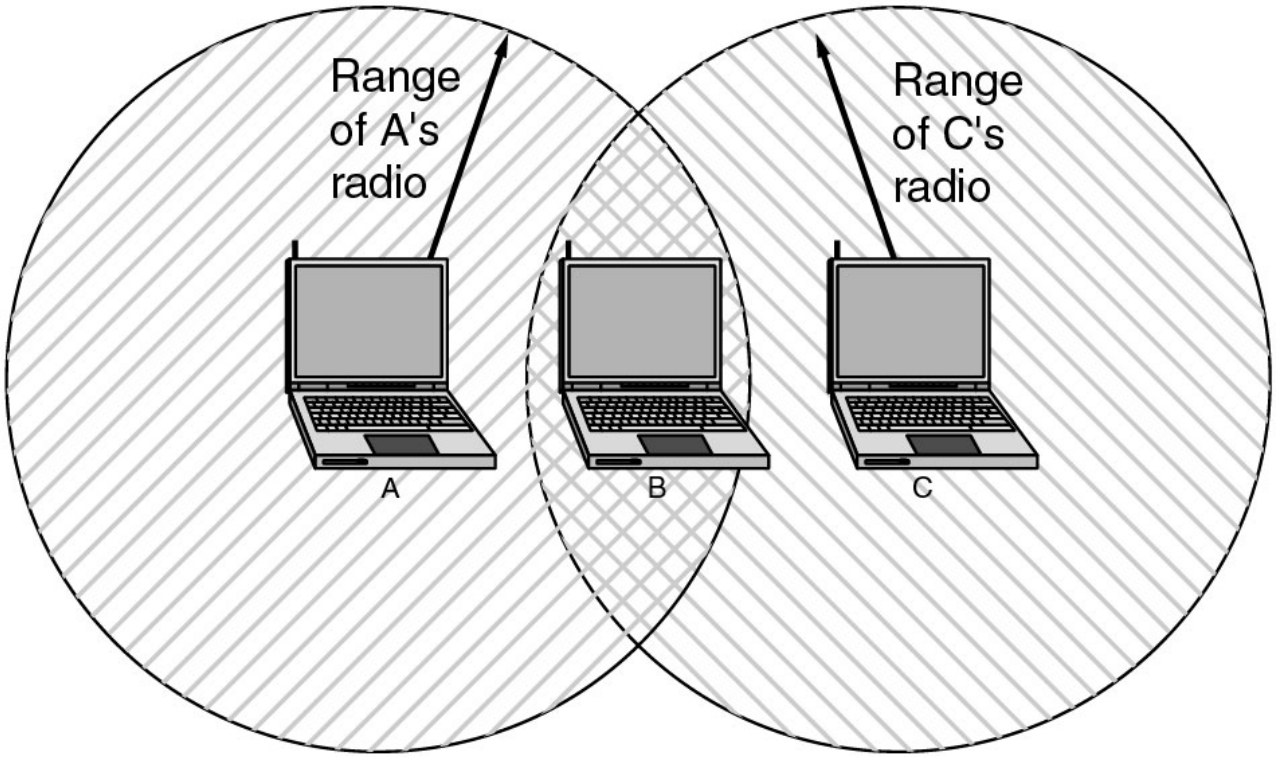
Architecture of the original Ethernet.

Wireless LANs



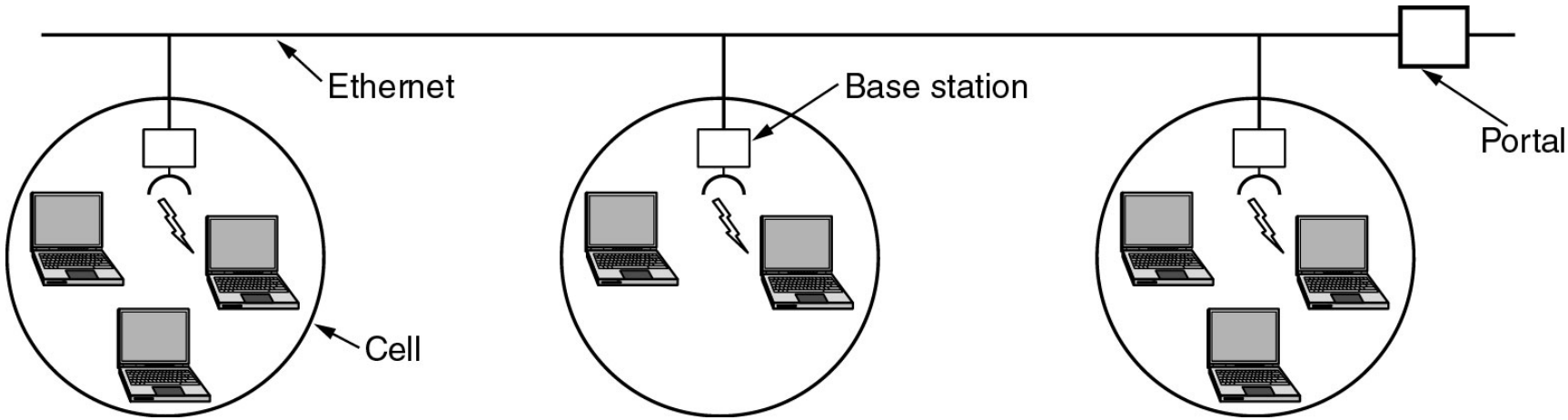
- (a) Wireless networking with a base station.
- (b) Ad hoc networking.

Wireless LANs (2)



The range of a single radio may not cover the entire system.

Wireless LANs (3)



A multicell 802.11 network.

Network Standardization

- Who's Who in the Telecommunications World
- Who's Who in the International Standards World
- Who's Who in the Internet Standards World

ITU

- **Main sectors**
  - Radiocommunications
  - Telecommunications Standardization
  - Development
- **Classes of Members**
  - National governments
  - Sector members
  - Associate members
  - Regulatory agencies

IEEE 802 Standards

Number	Topic
802.1	Overview and architecture of LANs
802.2 ↓	Logical link control
802.3 *	Ethernet
802.4 ↓	Token bus (was briefly used in manufacturing plants)
802.5	Token ring (IBM's entry into the LAN world)
802.6 ↓	Dual queue dual bus (early metropolitan area network)
802.7 ↓	Technical advisory group on broadband technologies
802.8 †	Technical advisory group on fiber optic technologies
802.9 ↓	Isochronous LANs (for real-time applications)
802.10 ↓	Virtual LANs and security
802.11 *	Wireless LANs
802.12 ↓	Demand priority (Hewlett-Packard's AnyLAN)
802.13	Unlucky number. Nobody wanted it
802.14 ↓	Cable modems (defunct: an industry consortium got there first)
802.15 *	Personal area networks (Bluetooth)
802.16 *	Broadband wireless
802.17	Resilient packet ring

The 802 working groups. The important ones are marked with *. The ones marked with ↓ are hibernating. The one marked with † gave up.

Metric Units

Exp.	Explicit	Prefix	Exp.	Explicit	Prefix
10^{-3}	0.001	milli	10^{3}	1,000	Kilo
10^{-6}	0.000001	micro	10^{6}	1,000,000	Mega
10^{-9}	0.000000001	nano	10^{9}	1,000,000,000	Giga
10^{-12}	0.000000000001	pico	10^{12}	1,000,000,000,000	Tera
10^{-15}	0.000000000000001	femto	10^{15}	1,000,000,000,000,000	Peta
10^{-18}	0.000000000000000001	atto	10^{18}	1,000,000,000,000,000,000	Exa
10^{-21}	0.000000000000000000001	zepto	10^{21}	1,000,000,000,000,000,000,000	Zetta
10^{-24}	0.000000000000000000000001	yocto	10^{24}	1,000,000,000,000,000,000,000,000	Yotta

The principal metric prefixes.

Reliability

Reliable delivery of messages

Three classes of failures

- Bit Level
  - Bursty
  - one in 10^6 or 10^7 on copper cable and
  - one in 10^{12} or 10^{14} on optical Fiber
- Packet Level
  - Lost due to
    - uncorrectable bit errors
    - buffer overflow
    - Software errors
- Node and Link Level
  - Due to
    - Hardware or software failures

Performance

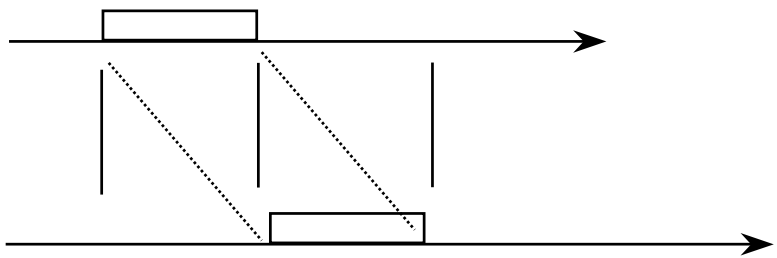
Bandwidth

- Number of bits transmitted in certain period of time
- Example 10 million bits per second
  - Bit time is 0.1 μs
- Easy to talk about the bandwidth of a link
- Throughput
  - often used to refer to what is actually achieved

Performance

Latency

- How long it takes a single bit to propagate from one end to the other end of the network
  - Transcontinental latency is 24 ms
- Has three components
  - Speed of light propagation delay
  - Time it takes to transmit a unit of data
  - Queuing delays
- RTT - Round Trip Time



Latency

Latency = Propagation + Transmit + Queue
Propagation = Distance / Speed of light
Transmit = Size / Bandwidth

Performance Implications

Client sends one byte message and receives one byte message
- Assuming to serious computation is involved
- Performance is dominated by latency and not bandwidth
  - Cross County Channel RTT - 100 ms
  - In a room RTT - 1 ms
  - on 1 Mbps transmit time = 8 μs
  - on 100 Mbps transmit time = 0.08 μs

Fetch 25 MB image data
- Bandwidth of channel dominates
  - at 10 Mbps takes 20 seconds

CPU vs. Communication Speeds

Consider CPU with 800 MIPS
Communication with 100 ms RTT across 5000 miles
If CPU sits idle for 100 ms
    implies it lost 80 million instructions
    or 16,000 instructions per mile of travel

Delay- Bandwidth Product

May treat a channel as a pipe

- length - delay
- bandwidth - diameter

Dealy bandwidth product gives the volume measure

- Number of bits it holds

A transcontinental channel with one-way latency of 50 ms and bandwidth of 45 Mbps holds 2.25 million bits or 280KB !!

Performance Needs of Application

Request/Response Channels
- Faster is better
- How much ?

Video
- 128KB frames at 30 frames/sec = 32 Mbps

Average Vs Peak Bandwidth Requirement

Jitter Requirements

Compression
- Lossless
- Lossy