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PICT, PUNE

Subject: Computer Network
Subject Code: 310244

Examination Scheme:
In Semester Assessment:30
End Semester Assessment:70

Teaching Scheme: **Theory: 3 Hrs/Week**

Vision:

Achieve academic excellence through education in computing and create intellectual, professional manpower to explore higher educational, research and social opportunities.

Mission:

To impart learning by educating students with social awareness, conceptual knowledge and hands on practices using modern tools, FOSS technologies and competency skills there by igniting the young minds for innovative thinking, professional expertise and research.

Course Objective:

- To understand the fundamental concepts of networking standards, protocols and technologies.
- To learn different techniques for framing, error control, flow control and routing.
- To learn different layer protocols in the protocol stacks.
- To understand modern network architectures with respect to design and performance.
- To learn fundamental concepts of Network Security

Course Outcomes:

On completion of the course, student will be able to–

1. **Summarize fundamental concepts of Computer Networks, Architectures, Protocols and Technologies.**
2. **Illustrate the working and functions of data link layer.**
3. **Analyze the working of different routing protocols and mechanisms.**
4. **Implement Client-Server applications using Sockets.**
5. **Illustrate role of application layer with its protocols, Client-Server architectures.**
6. **Comprehend the basics of Network Security**

Syllabus

Unit-I: Introduction to Computer Networks

Unit-II: Data Link Layer

Unit-III: Network Layer

Unit-IV: Transport Layer

Unit-V: Application layer

Unit-VI: Security

References:

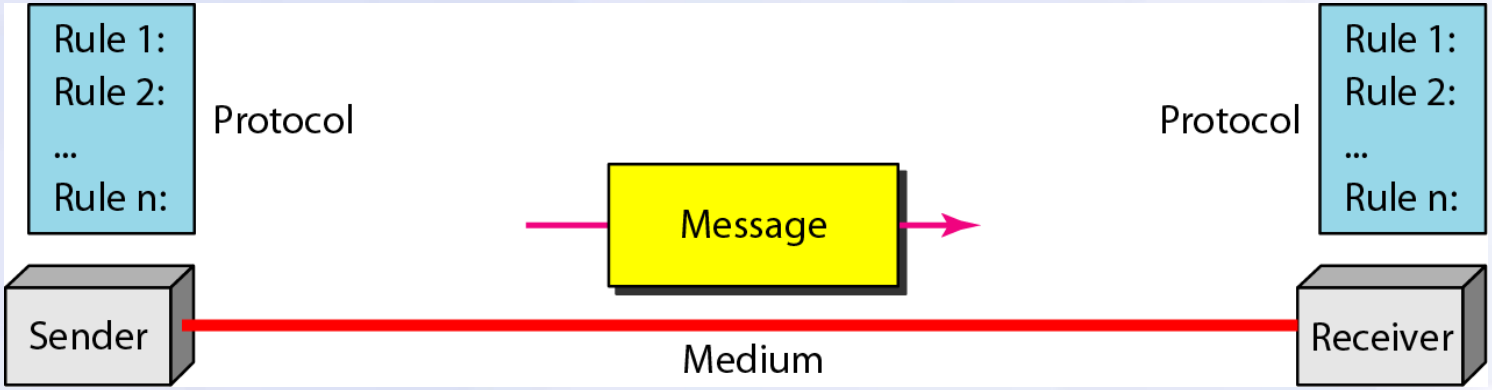
"computer Networking a top down approach", James F. Kurose, keith W. Ross 5th edition,PHI

"Data communications and Networking", Behrouz Forouzan 5th edition,McGraw-Hill

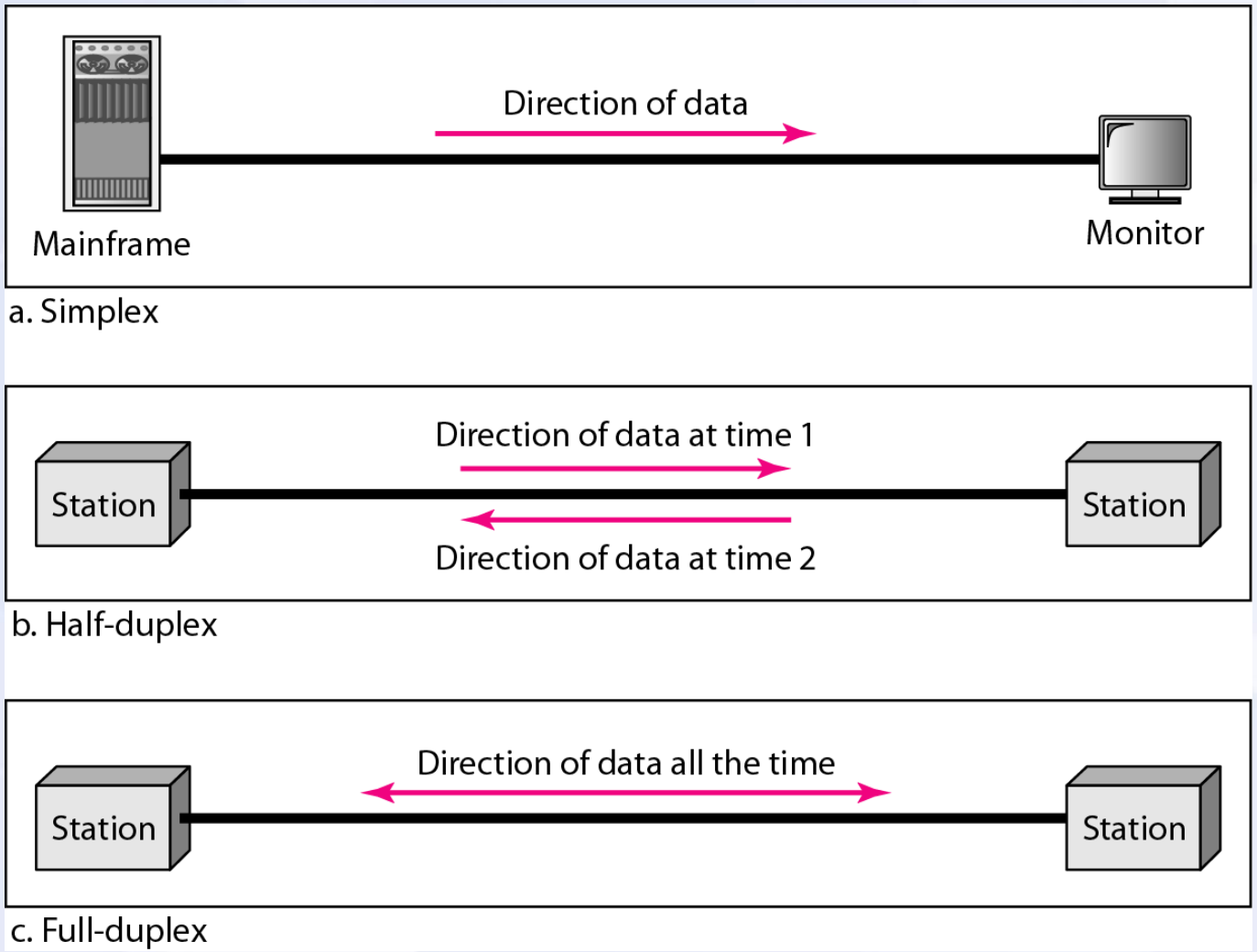
outline

- Data communication system
- What is Computer Network?
- Applications of Computer Networks
- Network types: LAN,WAN,MAN
- Topology
- LAN standards,
- Wireless Networks

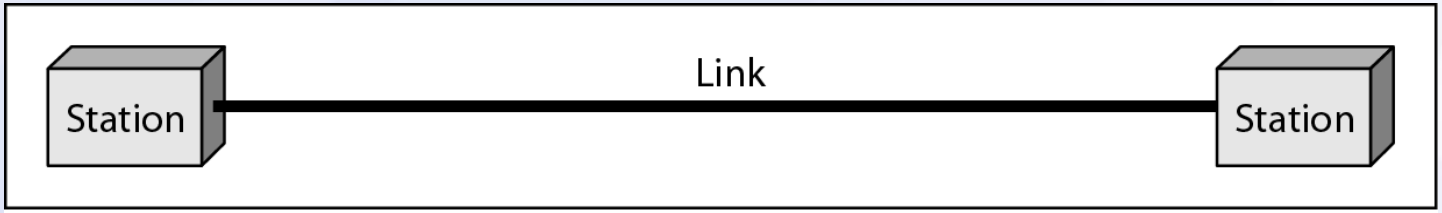
Components of a data communication system



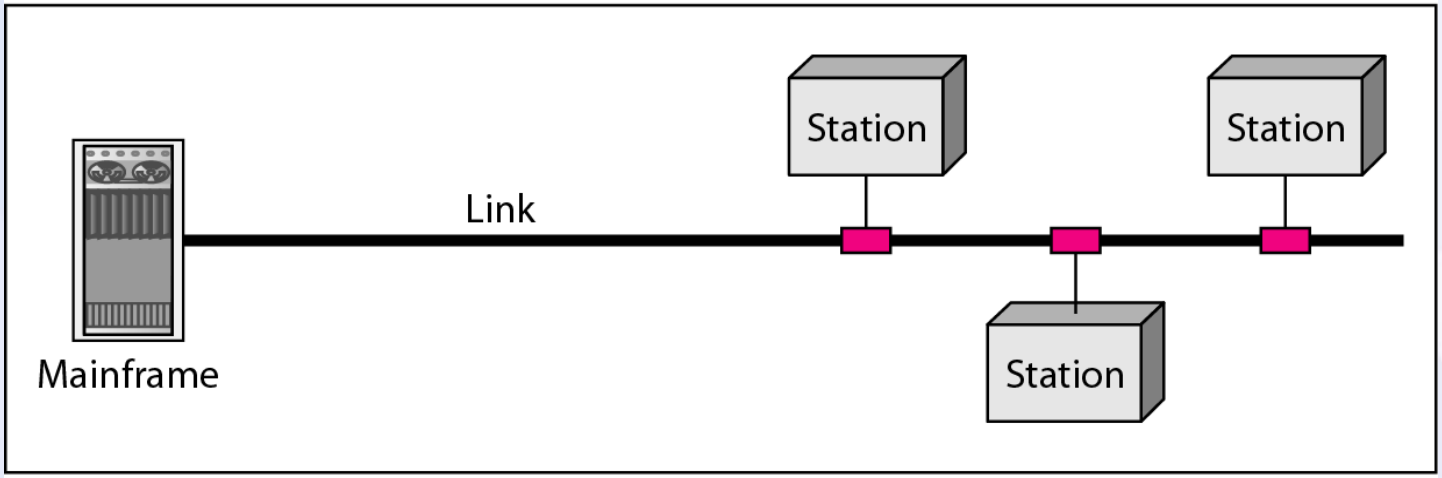
Data flow (simplex, half-duplex, and full-duplex)



Types of connections: point-to-point and multipoint



a. Point-to-point



b. Multipoint

What is Computer Network?

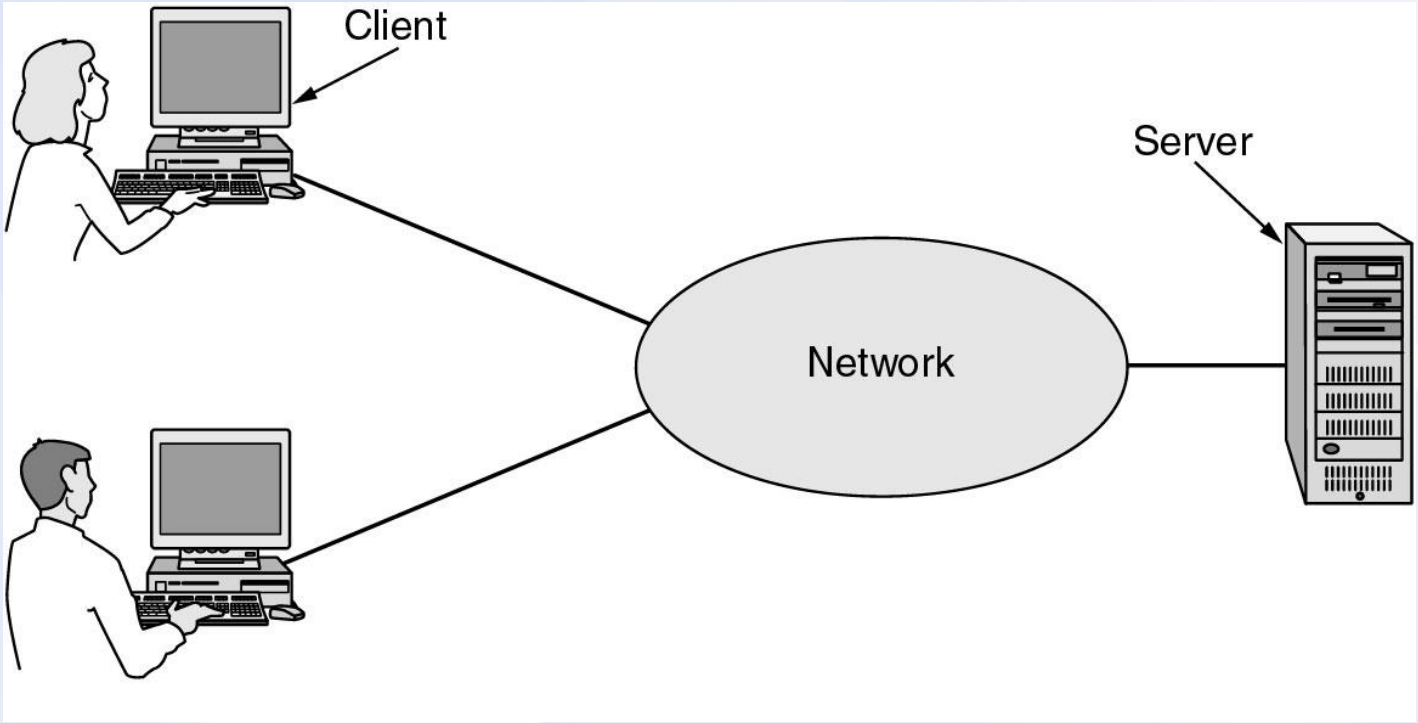
A computer Network is collection of nodes connected using communication links and **capable of sharing resources.**

Characteristics:

- Physical structure (topology, type of connection)
- Performance (throughput ,delay)
- Security
- Reliability

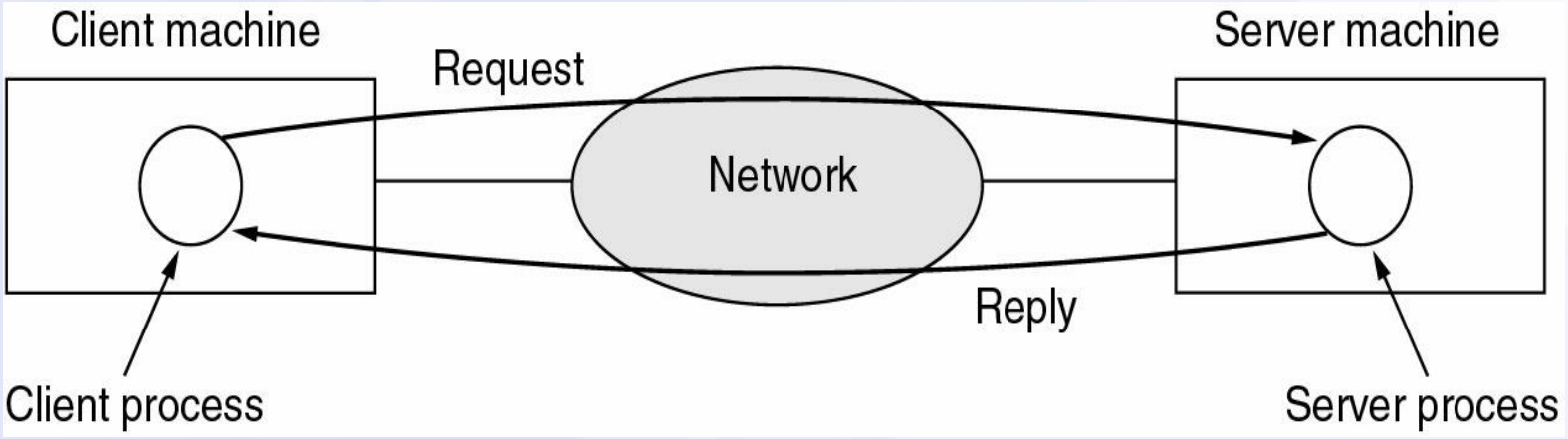
Business Applications of Networks

A network with two clients and one server.



Applications of Computer Networks

Client server Business Applications



Access to remote information

Person-to-person communication

Interactive entertainment

Electronic commerce

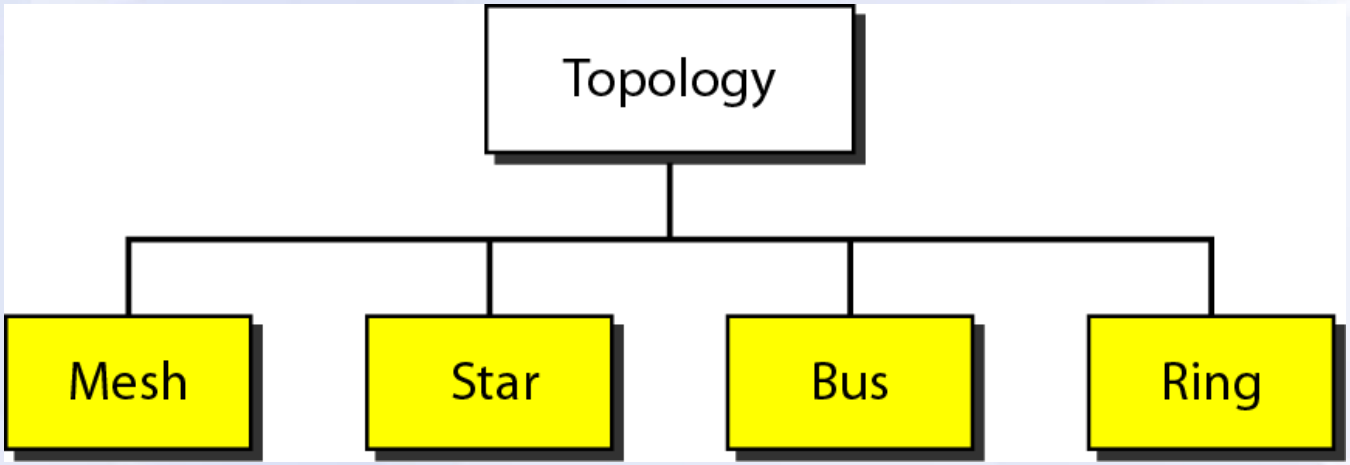
Types of Networks

- Local Area Networks (LAN)
- Metropolitan Area Networks(MAN)
- Wide Area Networks(WAN)
- Wireless Networks
- Internet

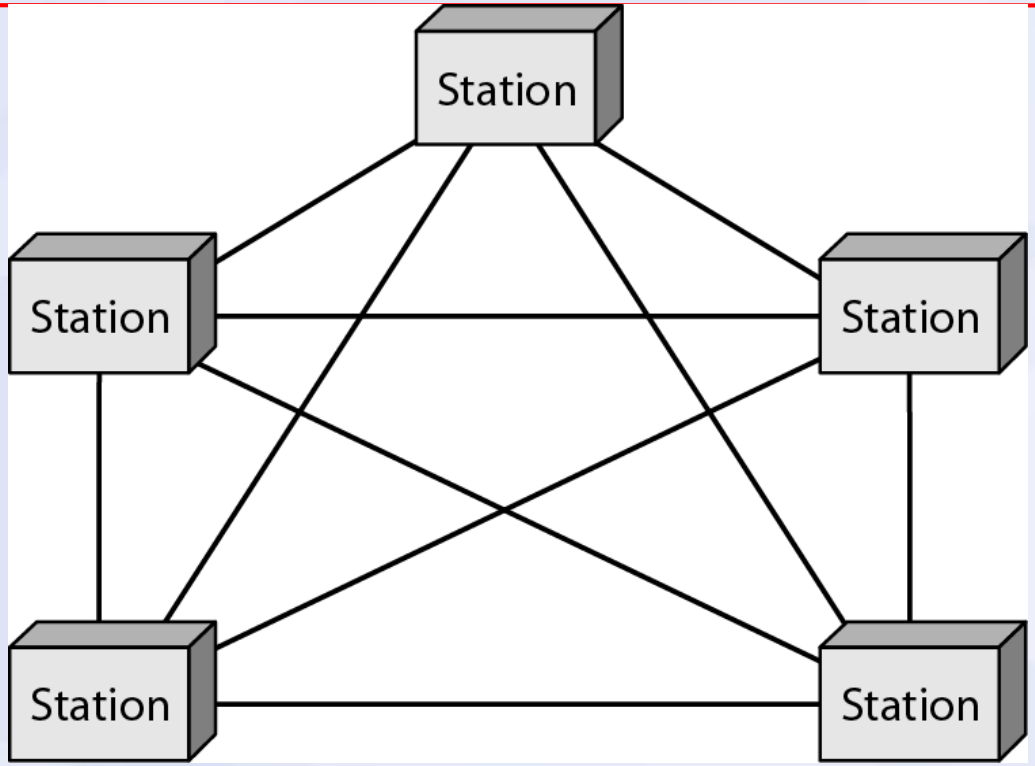
Terminology

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

Categories of topology

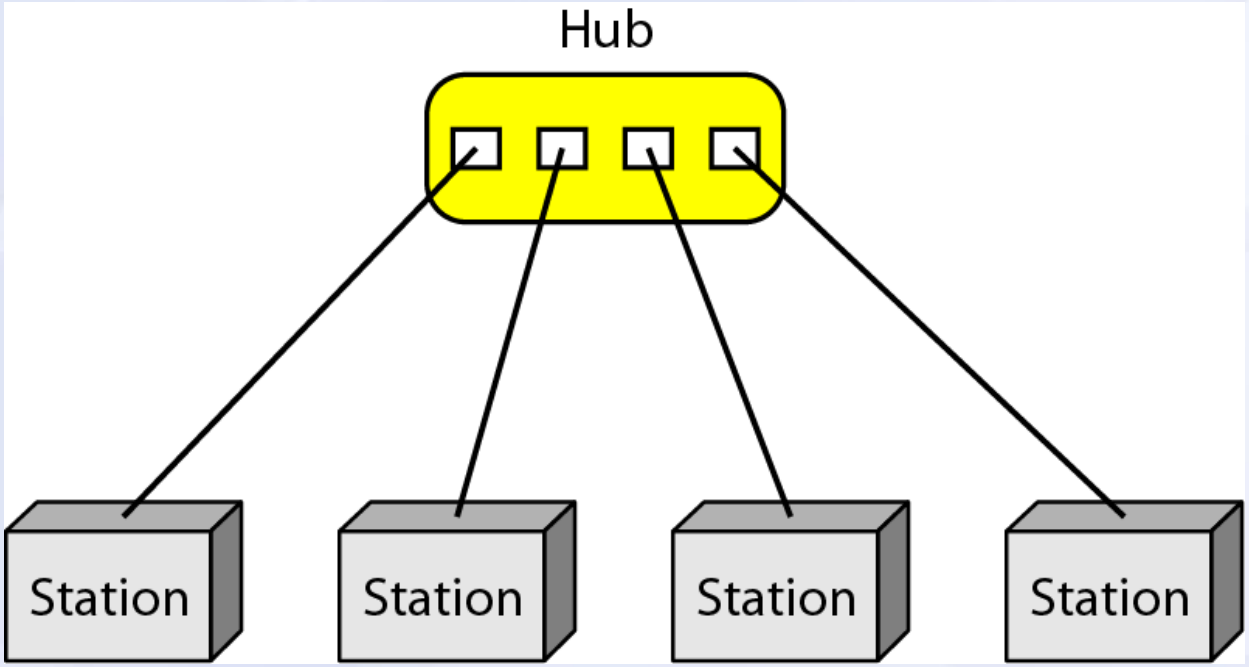


A fully connected mesh topology (five devices)



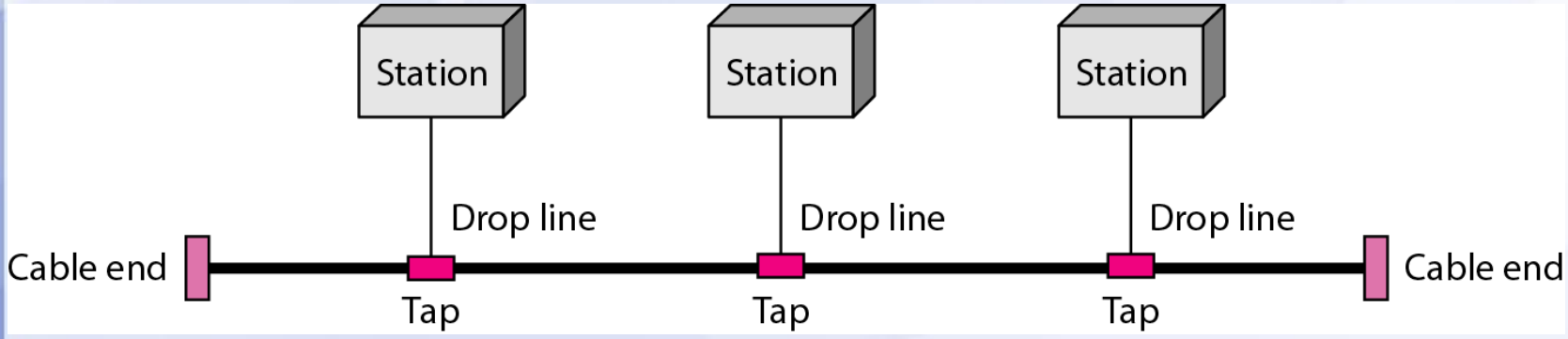
Some WANs, most notably the Internet, employ mesh routing.

A star topology connecting four stations



Devices typically connect to the hub with Unshielded Twisted Pair (UTP) Ethernet.

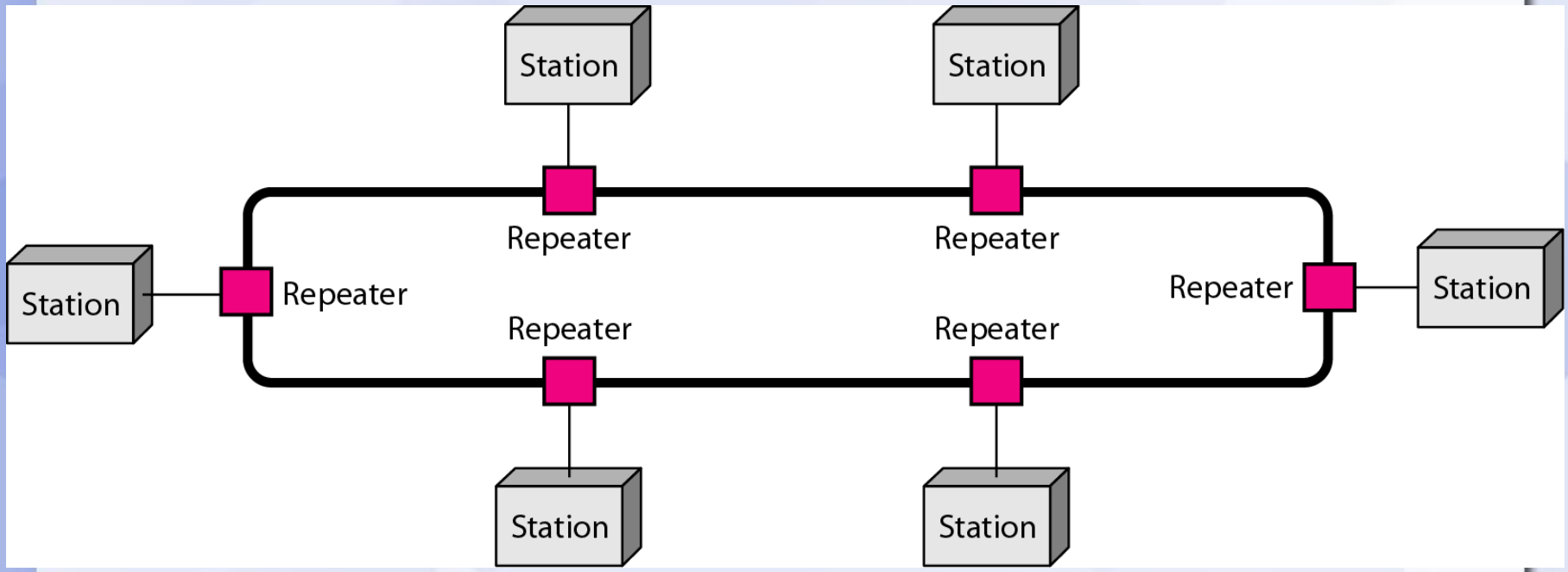
A bus topology connecting three stations



use a common backbone to connect all devices.

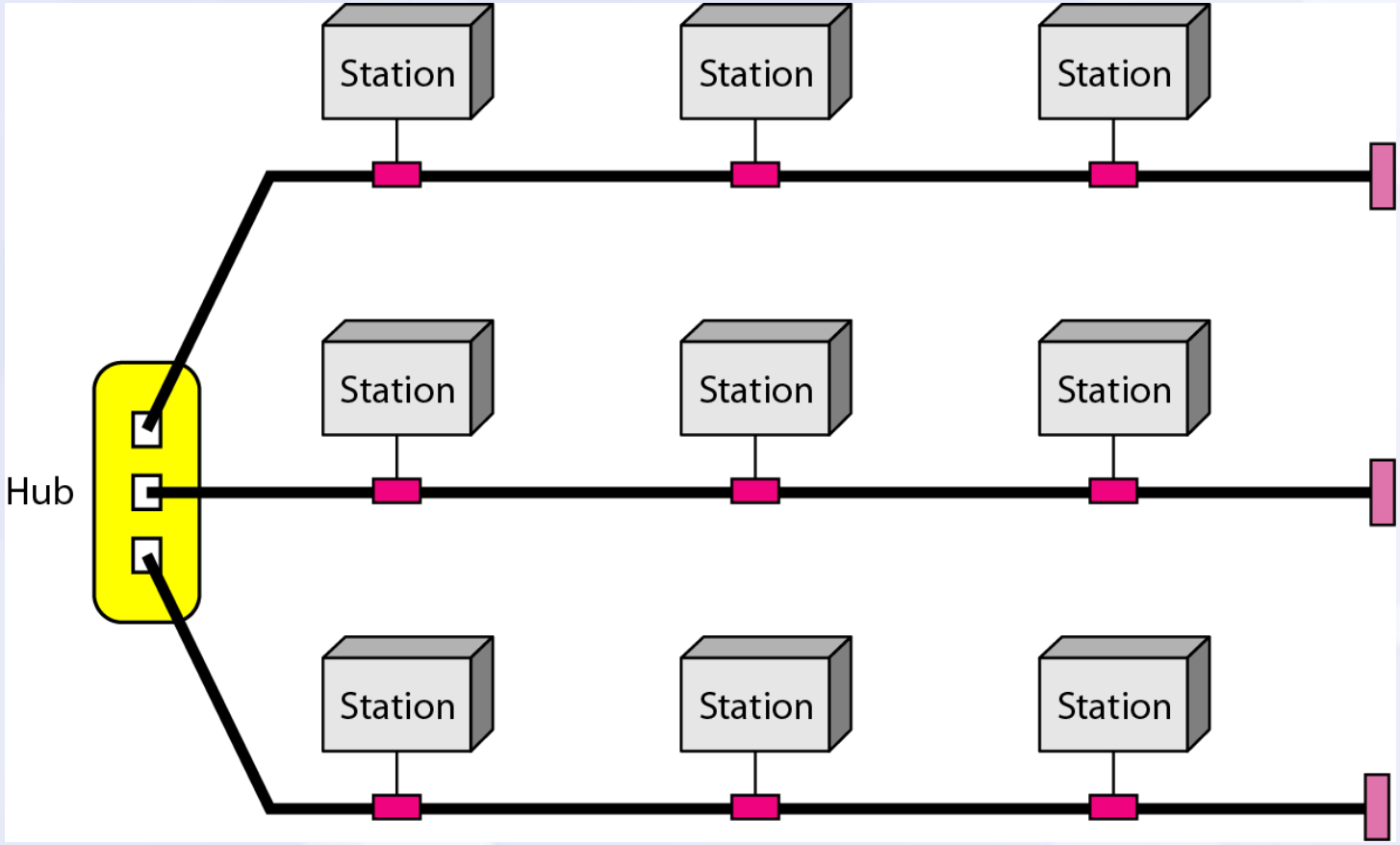
10Base-2 ("ThinNet") and 10Base-5 ("ThickNet") both were popular Ethernet cabling options many years ago for bus topologies.

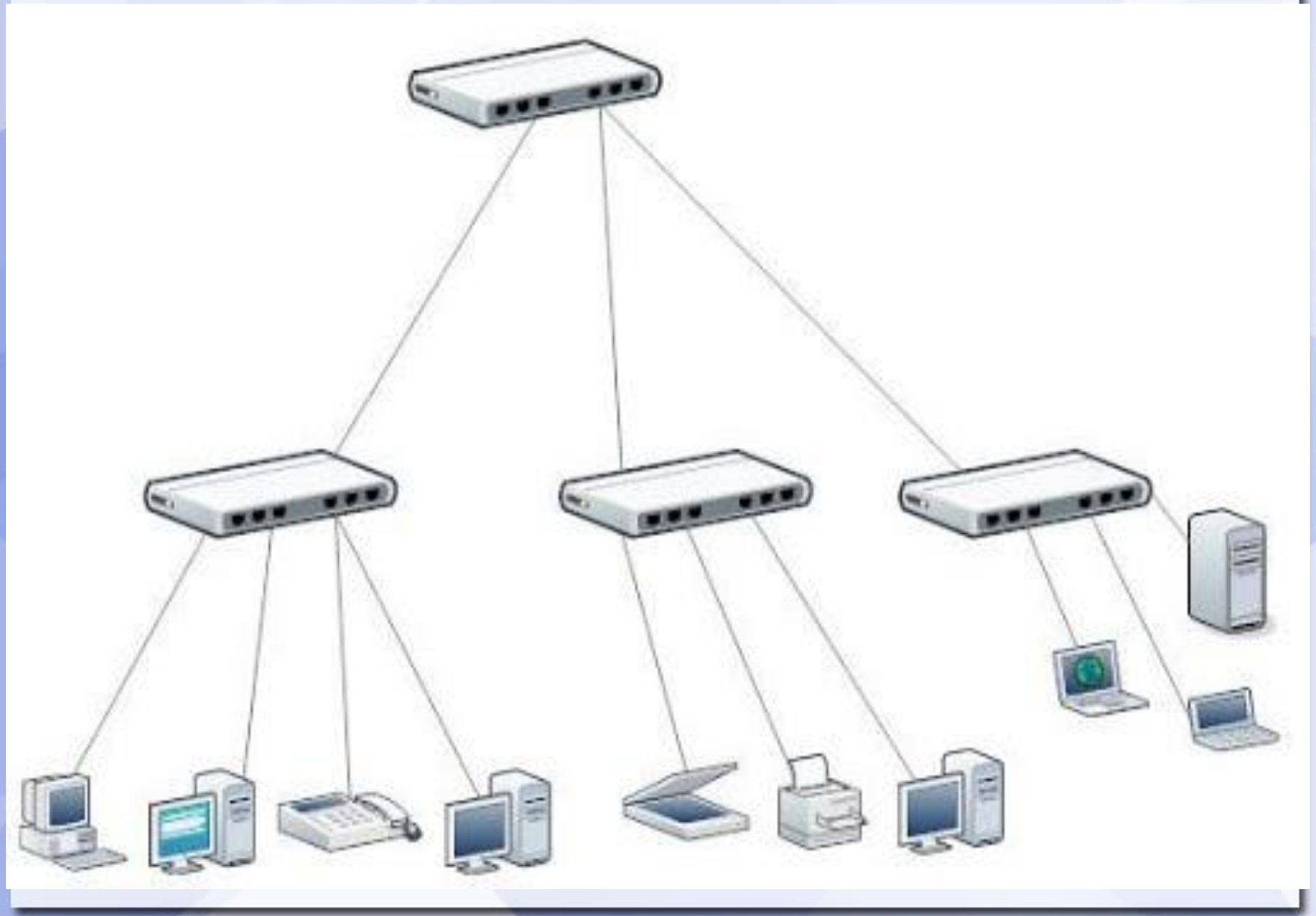
A ring topology connecting six stations



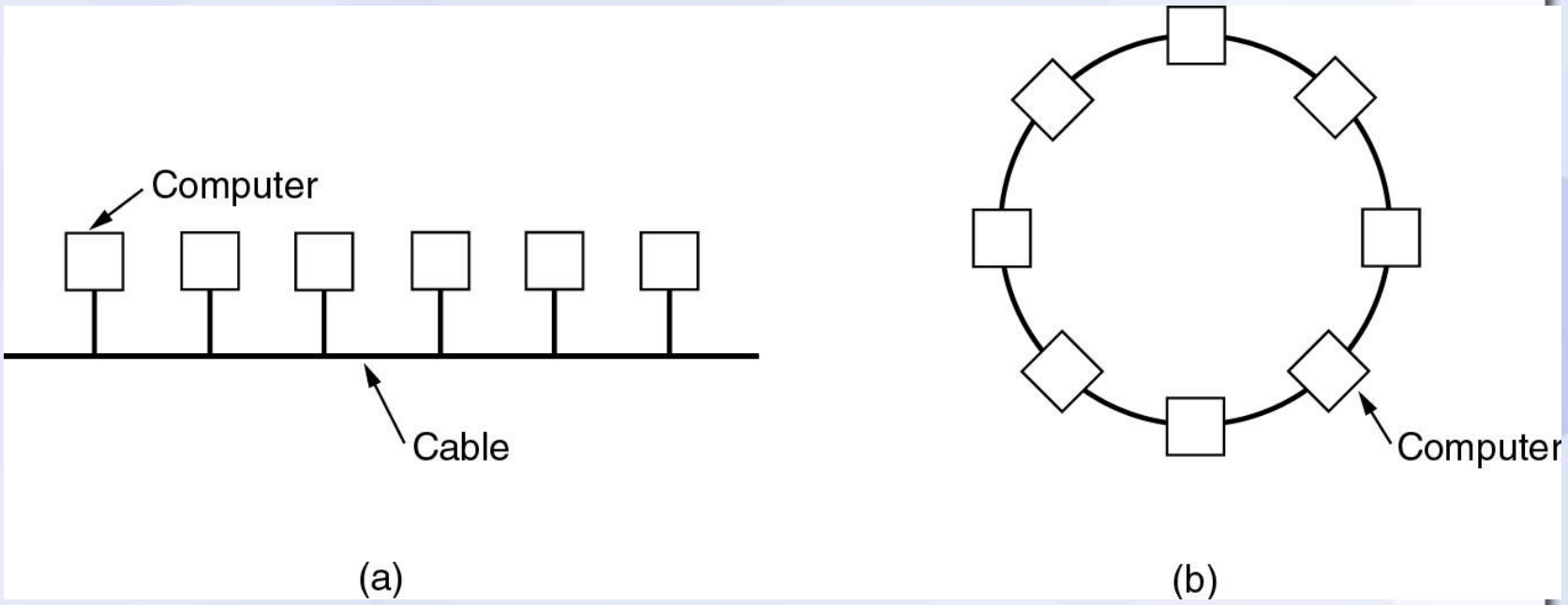
Typically uses FDDI, SONET, or Token Ring technology.

A hybrid topology: a star backbone with three bus networks





Local Area Networks



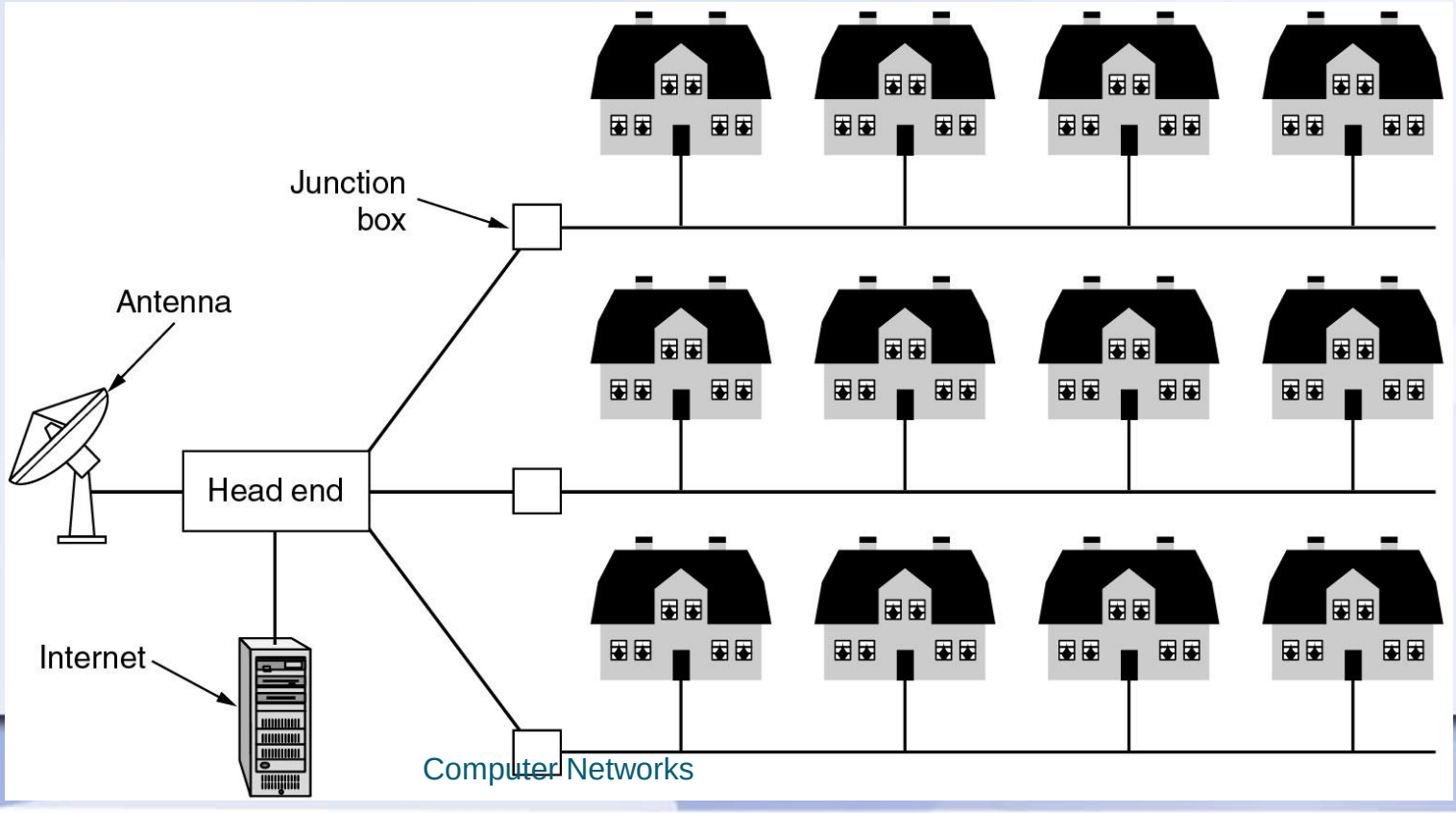
Two broadcast networks

(a) Bus 10base2 and 10base5

(b) Ring FDDI SONET

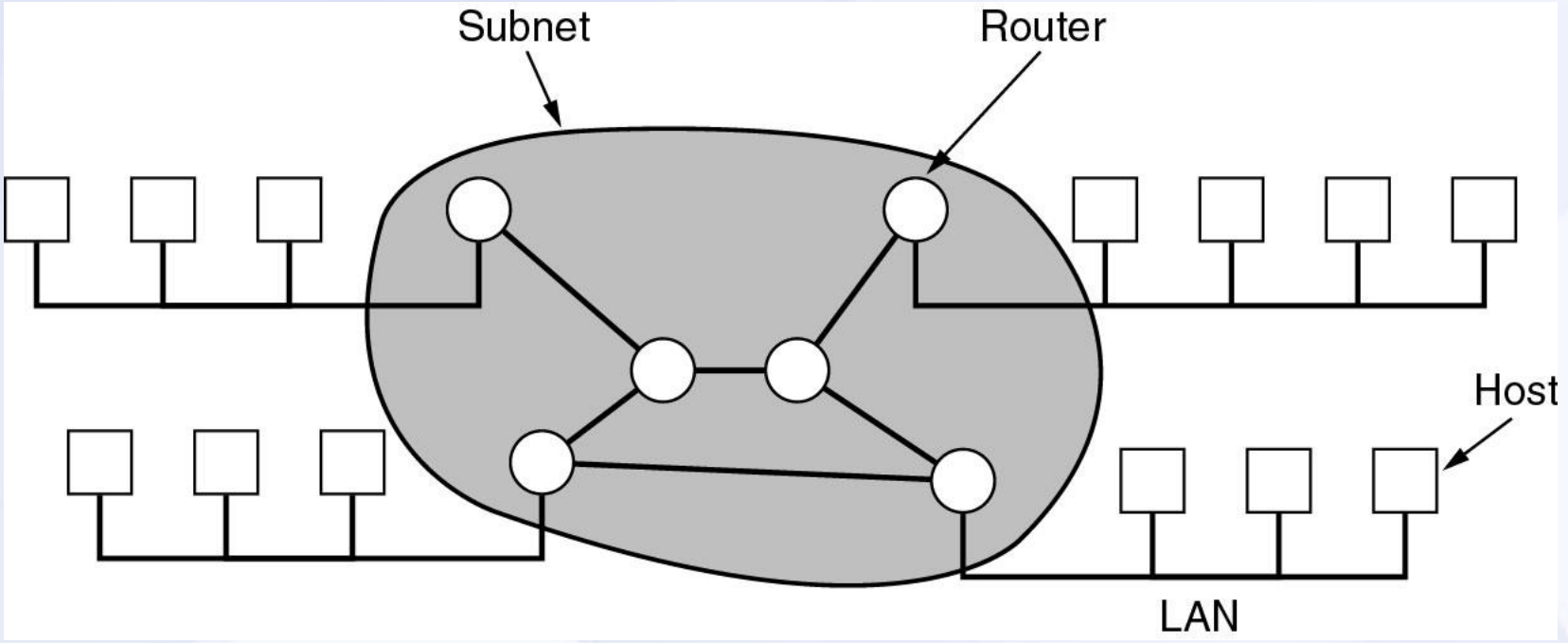
Metropolitan Area Networks

A metropolitan area network based on cable TV.



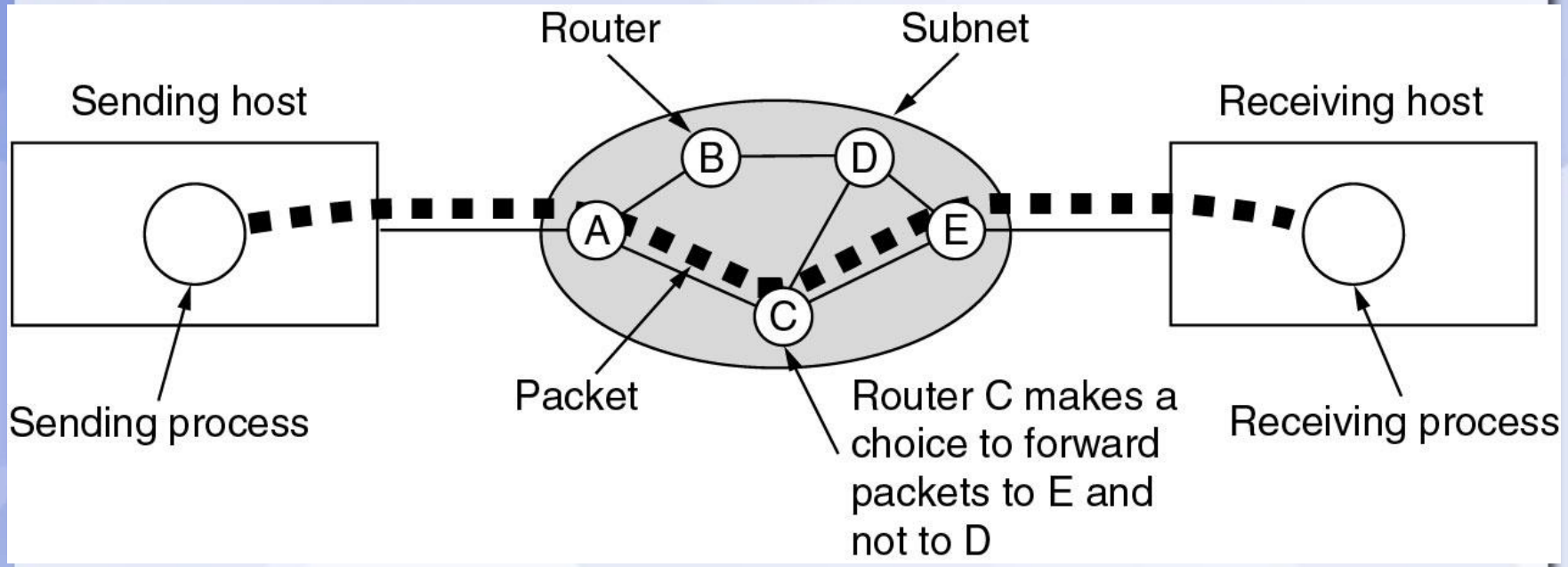
Wide Area Networks

Relation between hosts on LANs and the subnet.



Wide Area Networks (2)

A stream of packets from sender to receiver.



Wireless Networks

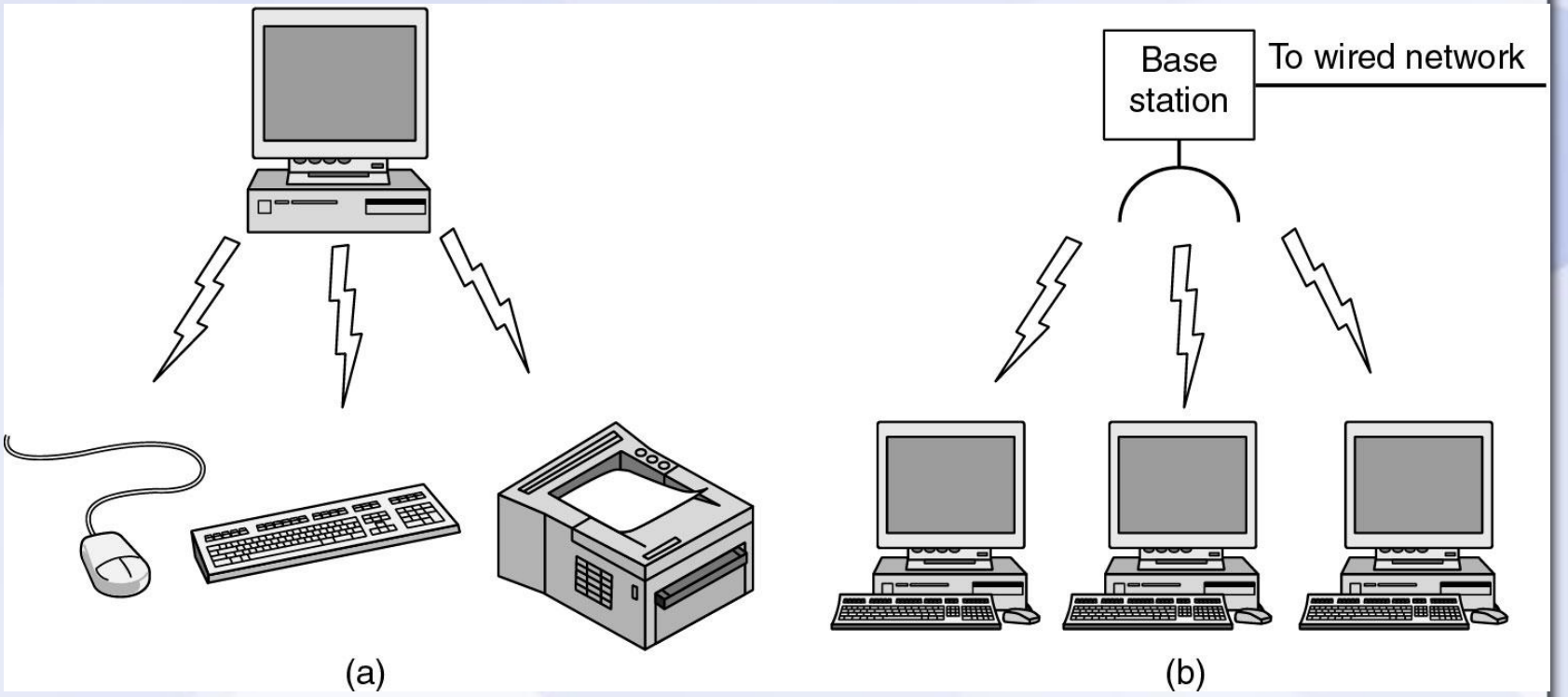
Categories of wireless networks:

- System interconnection
- Wireless LANs
- Wireless WANs

Wireless Networks

(a) Bluetooth configuration(PAN)

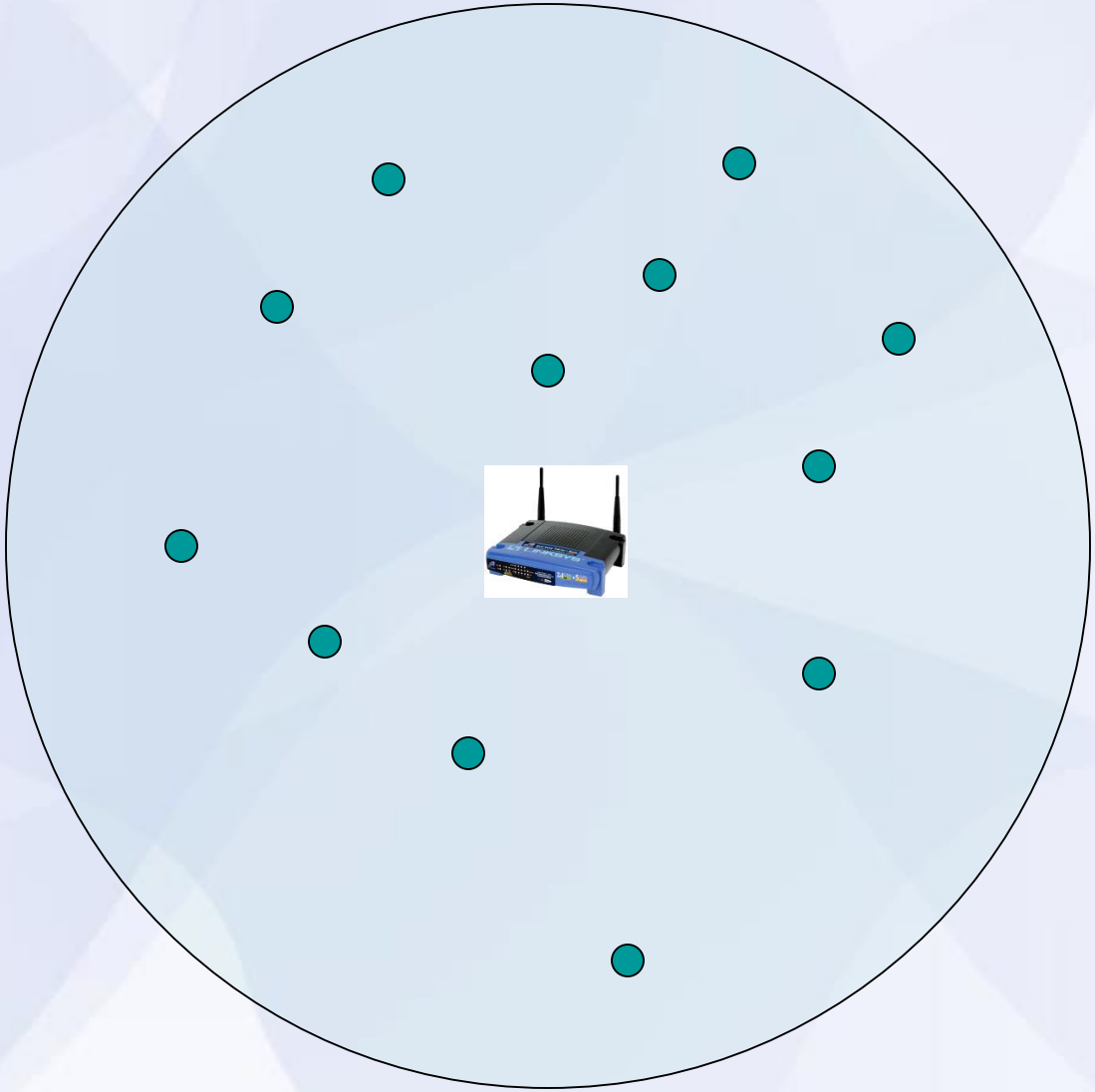
(b) Wireless LAN



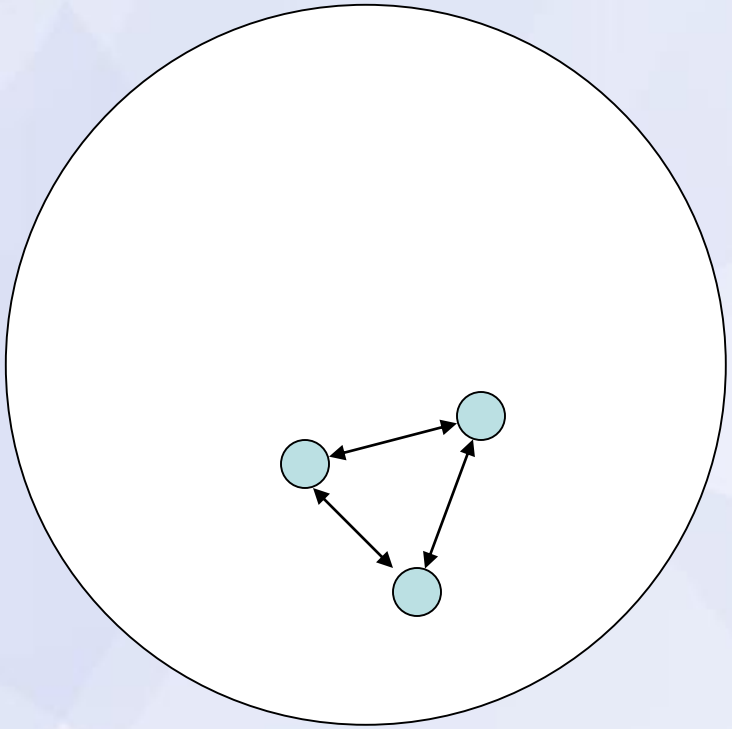
Infrastructure Access

- Access Points:
  - Provide infrastructure access to mobile users
  - Cover a fixed area
  - Wired into LAN

Infrastructure Access



Peer to Peer Ad Hoc Mode



LAN Standards

Local Area Networks

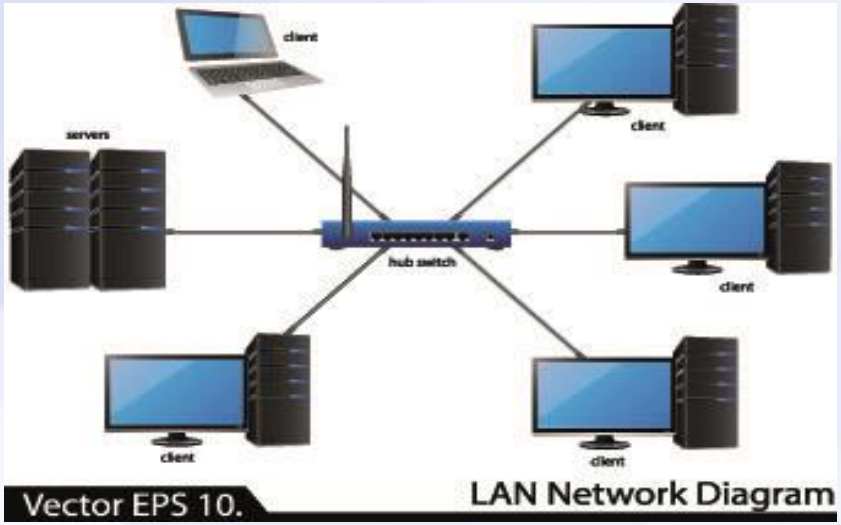
802 standards

Ethernet 802.3

Wireless 802.11

LAN (Local Area Networks)

- A LAN is a computer network that covers a small area (home, office, building, campus)
  - a few kilometers
- LANs have higher data rates (10Mbps to 40Gbps) as compared to WANs



802 standards

- **IEEE 802.1 -** High-Level Interface. It provides for LAN management and bridging standards.
- **IEEE 802.2 -** Logical Link Control
- A Data Link layer standard used with IEEE 802.3, 802.4 and 802.5 standards.
- **IEEE 802.3 -** Carrier Sense Multiple Access with Collision Detection
- A Physical layer standard specifying a linear bus LAN with a CSMA/CD access method commonly associated with Ethernet and Fast Ethernet.
- **IEEE 802.4 -** Token-bus
- A Physical layer standard specifying a token-passing access method on a bus topology.

- **IEEE 802.5 - Token-ring**
- A Physical layer standard specifying a token-passing access method on a ring topology.

IEEE 802.6 - Metropolitan Area Network (MAN)

Describes a topology known as Distributed Queue Dual Bus (DQDB). This topology consists of two parallel runs of cable to link devices over a metropolitan (city-sized) area. The transmission medium is usually optical fiber and transmission speed in the range of 100 Mbps.

- **IEEE 802.7 -** Broadband Technology The IEEE technical advisory group for broadband LANs.

- **IEEE 802.8 - Fiber Optics**
- The IEEE technical advisory group for optical fiber LANs. This committee provides technical advice to other subcommittees on optical fiber networks as alternatives to existing copper-based networks.
- **IEEE 802.9 - Integrated Services LAN**
- The IEEE committee working on the integration of voice, data and video traffic over other 802 LANs.
- **IEEE 802.10 - LAN Security**
- The IEEE technical advisory group for security. This group is working on the definition of a standard security model that will operate over a variety of networks. It incorporates both authentication and encryption methods.

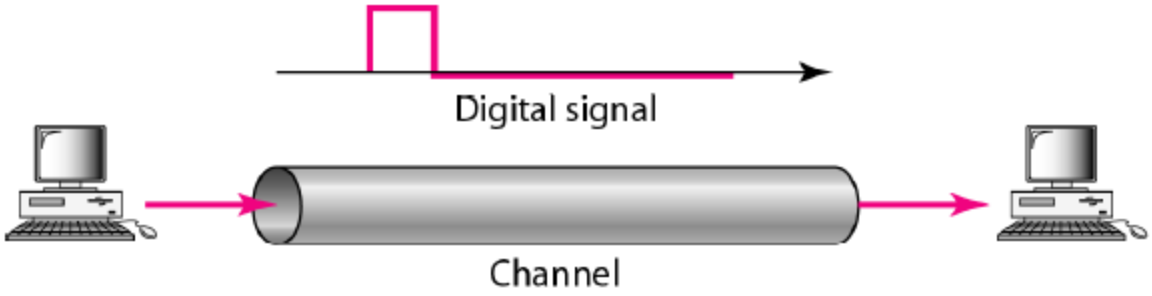
- **IEEE 802.11 – Wireless**
- This group is working on the standardization of media such as spread-spectrum radio, narrowband radio, infrared and transmission over power lines.

- **IEEE 802.12 - Demand Priority**
- The IEEE committee charged with the standard for 100 Mbps Ethernet using a
- Demand Priority access method, commonly referred to as 100VG-AnyLAN.

Transmission of Digital Signals

- *Baseband transmission*
- *Broadband transmission*

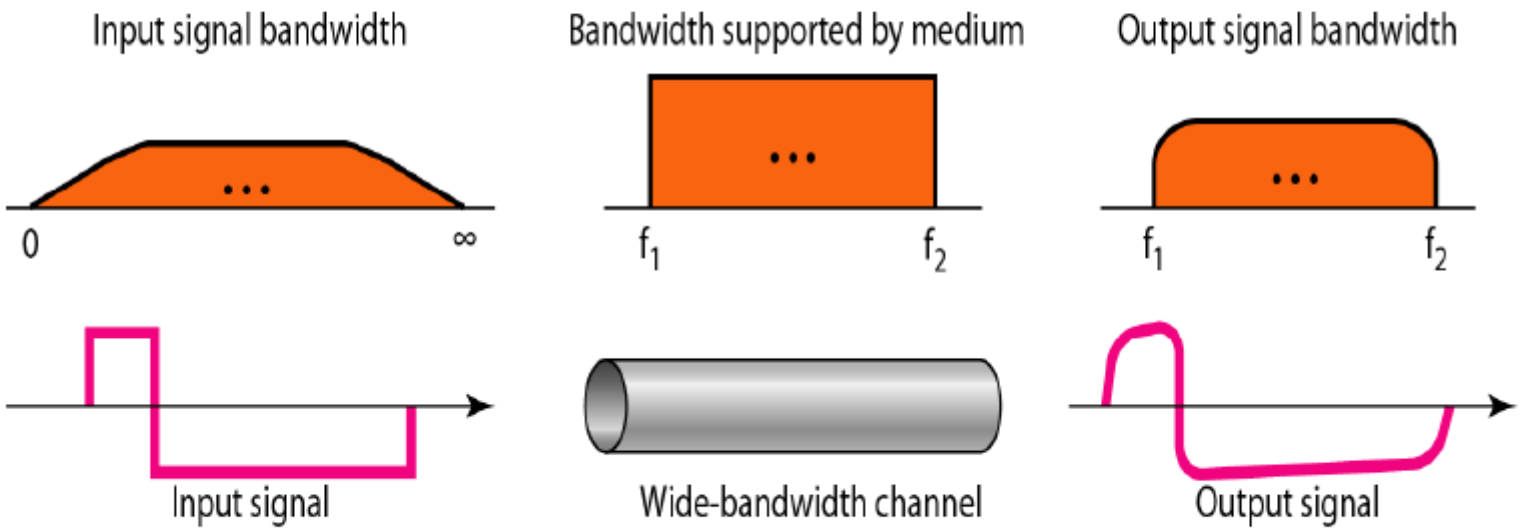
Baseband transmission is sending digital signals without converting them to analog signals.



A digital signal is a composite analog signal with an *infinite* bandwidth.

Low-pass channels with wide bandwidth

Figure 3.20 *Baseband transmission using a dedicated medium*



Baseband transmission of a digital signal that preserves the shape of the digital signal is possible only if we have a low-pass channel with an infinite or very wide bandwidth.

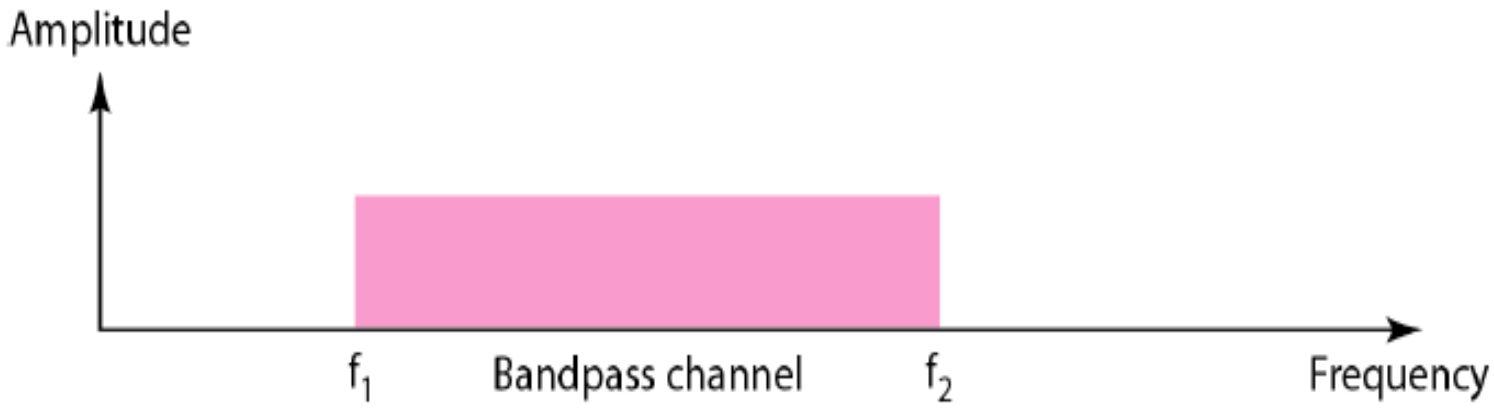
A LAN uses dedicated channel where the entire bandwidth of the medium is used as one single channel.
In a bus topology LAN with multipoint connections, only two stations can communicate with each other at each moment in time (timesharing); the other stations need to refrain from sending data.
In a star topology LAN, the entire channel between each station and the hub is used for communication between these two entities.

Broadband transmission

Digital signal → analog signal for transmission using modulation

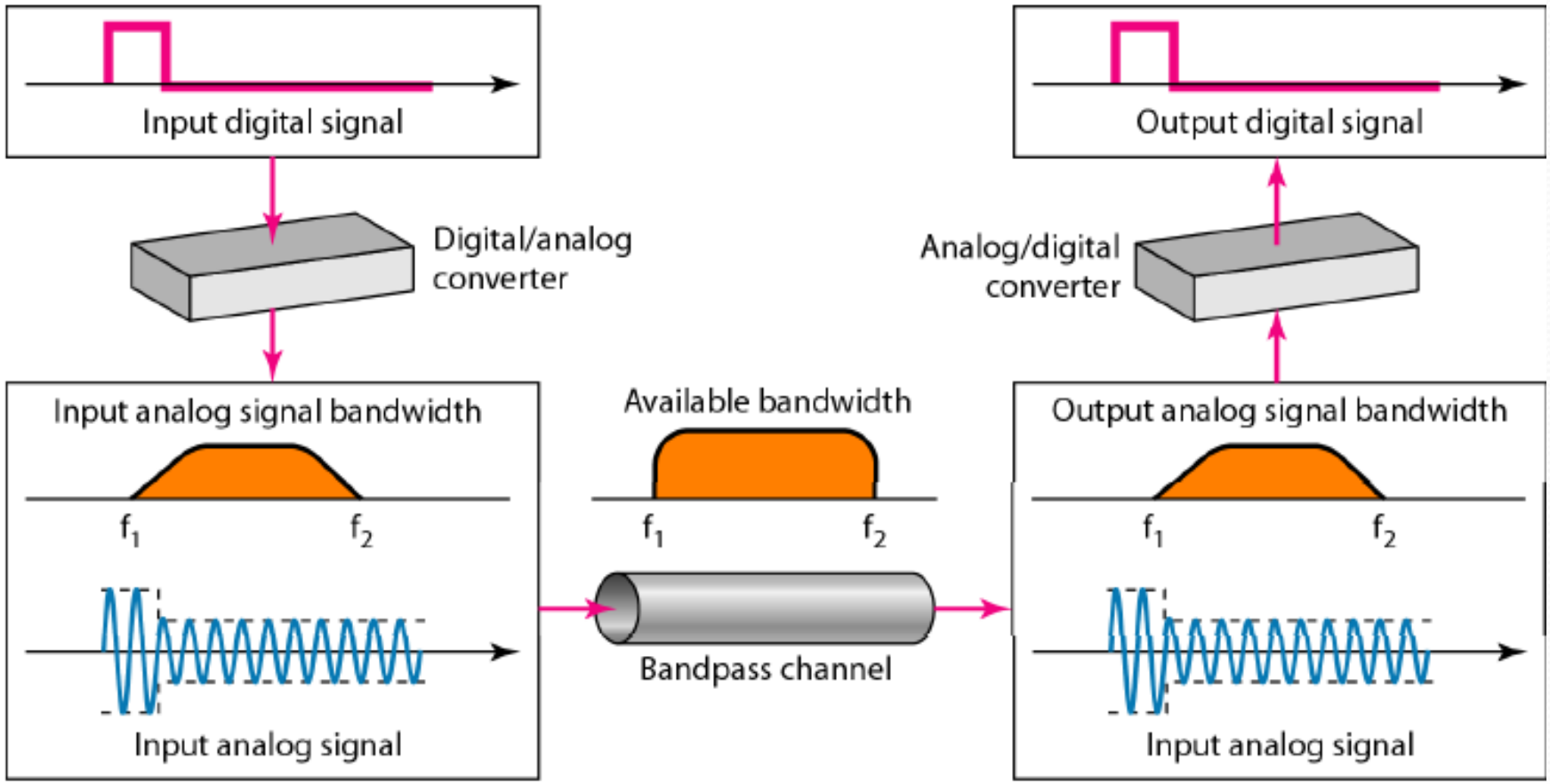
Modulation uses bandpass channels.

Figure 3.23 *Bandwidth of a bandpass channel*



If the available channel is a **bandpass** channel, we cannot send the digital signal directly to the channel; we need to convert the digital signal to an analog signal before transmission.

Figure 3.24 *Modulation of a digital signal for transmission on a bandpass channel*



Important terms related to data communication

Bit rate: No. Of bits sent from source to destination in one sec. (bps)

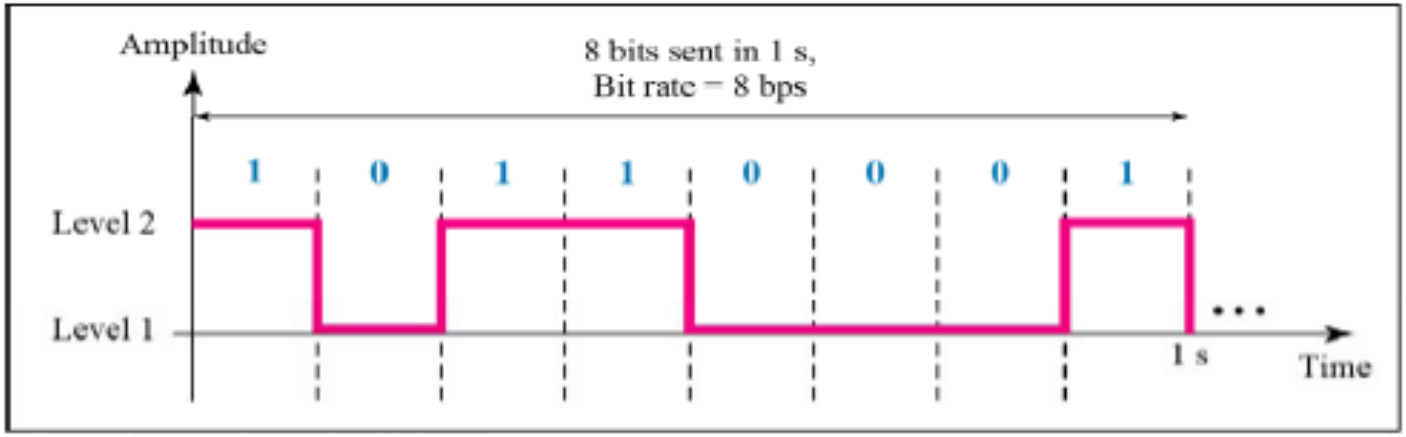
Baud rate: No. Of signal elements sent from source to destination in one sec.(Baud per sec)

Bandwidth of a channel:

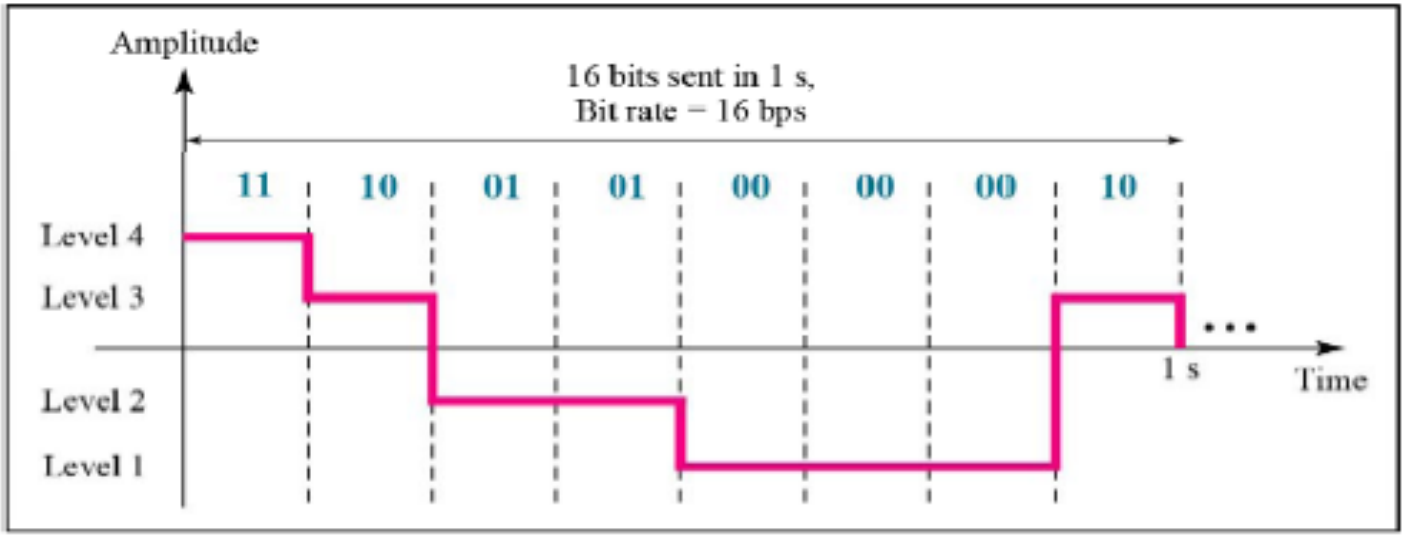
number of bits can be sent in one second. also measured in Hz(frequency range supported for transmission)

Delay:

Two digital signals: one with two signal levels and the other with four signal levels



a. A digital signal with two levels

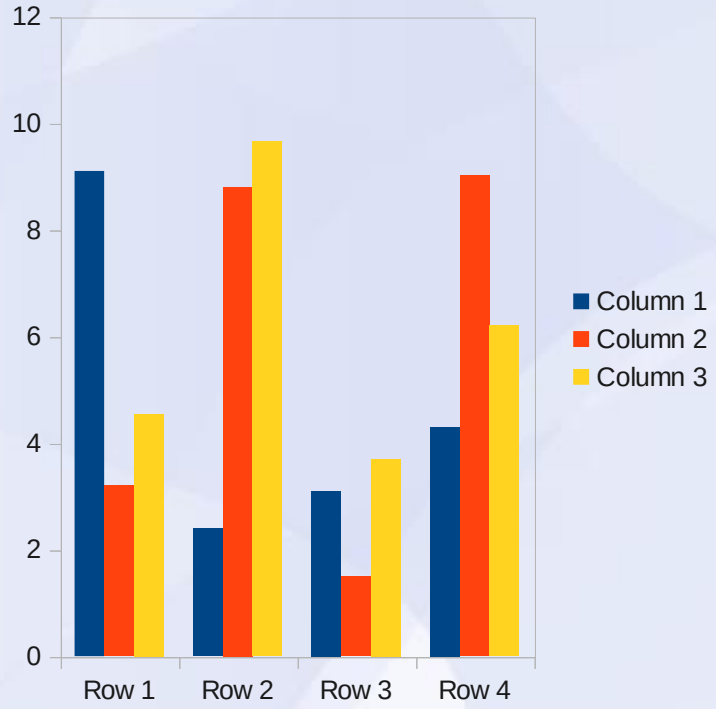


b. A digital signal with four levels

Reference models:

ISO-OSI Model (International System Organization- Open System Interconnection)

TCP/IP(Transmission Control Protocol-Internet Protocol)


12
10
8
6
4
2
0
Row 1
Row 2
Row 3
Row 4
Column 1
Column 2
Column 3

Why layering???

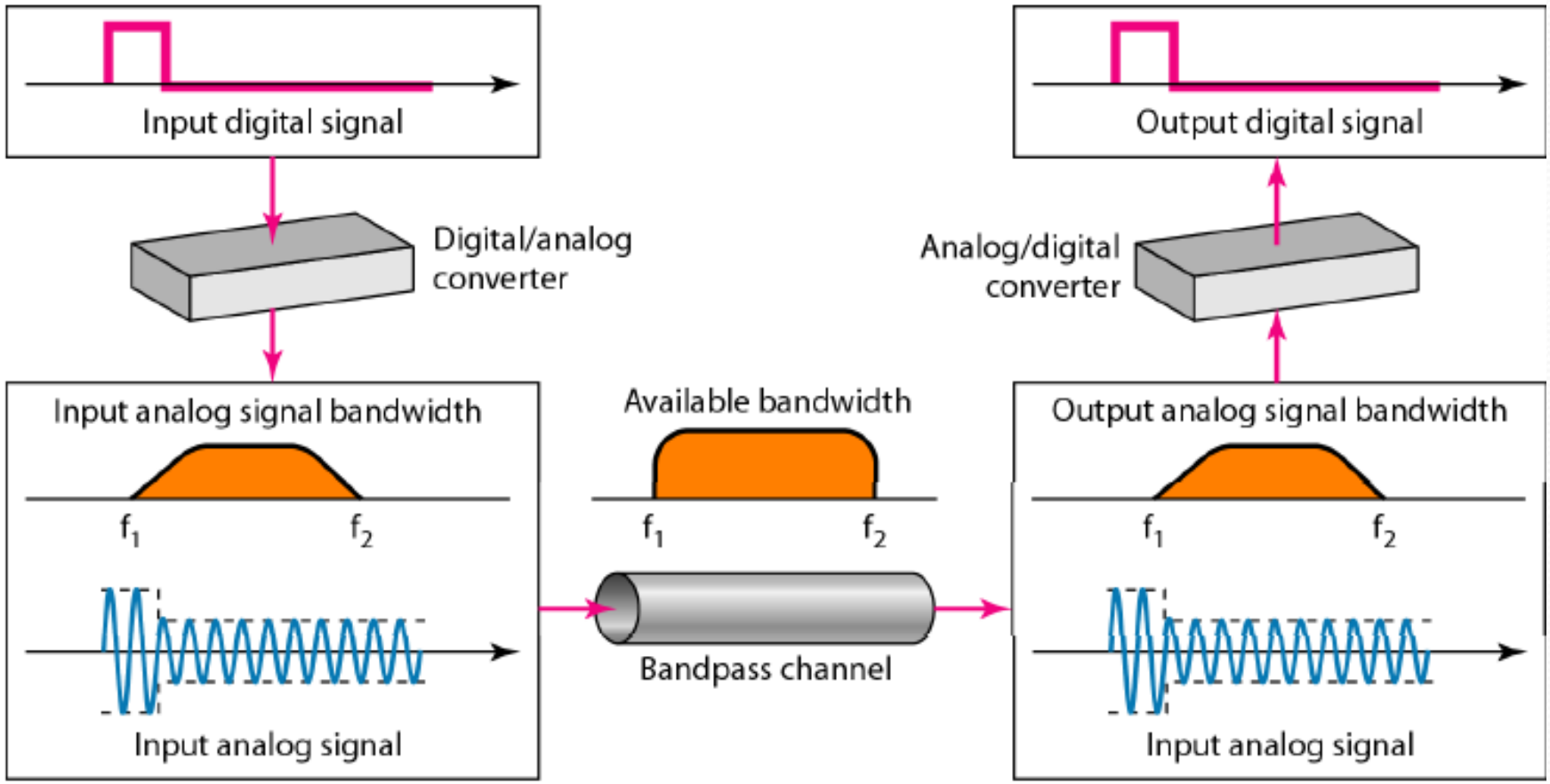
1.To make the design process easy by breaking unmanageable tasks into several smaller and manageable tasks (by divide-and-conquer approach).

2. Modularity and clear interfaces, so as to provide comparability between the different providers' components.

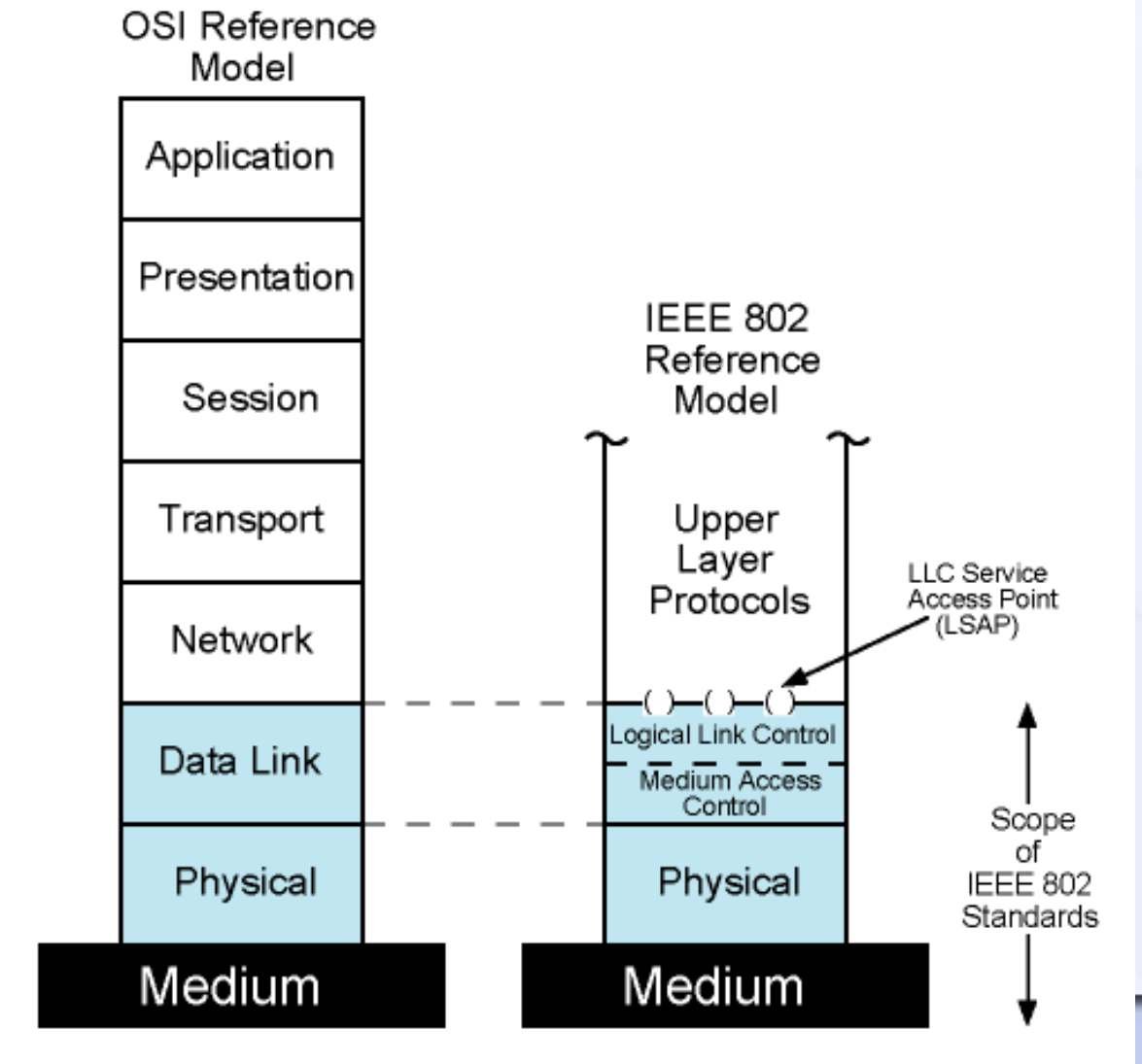
3. Ensure independence of layers, so that implementation of each layer can be changed or modified without affecting other layers.

4. Each layer can be analyzed and tested independently of all other layers.

Figure 3.24 *Modulation of a digital signal for transmission on a bandpass channel*



IEEE 802 Protocol Layers vs. OSI Model



Ethernet 802.3

- **10 Mbps (Standard Ethernet)**

—IEEE 802.3

—10base5(2500m extendable ,thick Ethernet,coaxial cable bus topology)

—10base2(thin Ethernet,bus topology, thin coaxial cable)

—10baseT(2 pairs of twisted pair,star topology,max 100m)

—IEEE 802.3ae

Ethernet 802.3

- **100 Mbps(Fast Ethernet)**

—IEEE 802.3u

- **1 Gbps (Gigabit Ethernet)**

—IEEE 802.3ab

—Uses all 4 pairs of the RJ-45 cable

- **10 Gbps**

100Mbps (Fast Ethernet)

- Provides low cost data rate of 100Mbps and compatible with standard ethernet
  - **100BaseT4**
    - to use voice grade cat 3 cables
    - 3 pairs in each direction with 33.3 Mbps on each using a ternary signalling scheme (8B6T = 8 bits map to 6 trits)
  - **100Base-X**
    - Unidirectional data rate of 100 Mbps
    - 4B/5B blocking coding
    - Uses two links (one for transmit, one for receive)
    - Two types: 100Base-TX and 100Base-FX

- **100Base-TX**

— STP or cat5 UTP (one pair in each direction)
— Maximum cable length 100m
— 4B/5B block coding scheme
— at 125 Mhz with special encoding that has 20% overhead

- **100Base-FX**

— Optical fiber (one at each direction)
— NRZ-I coding scheme
— Maximum cable length 100m

Fast Ethernet - Details

- Same message format as 10 Mbps Ethernet
- Fast Ethernet may run in full duplex mode
  - So effective data rate per user becomes 200 Mbps
  - Full duplex mode requires star topology with switches

- In fact, shared medium no longer exists when switches are used
  - no collisions, thus CSMA/CD algorithm no longer needed
  - but stations still use CSMA/CD and same message format is used for backward compatibility reasons

Gigabit Ethernet

- Strategy same as Fast Ethernet

—New medium and transmission specification

—Retains CSMA/CD protocol and frame format

—Compatible with 10 and 100 Mbps Ethernet

- Why gigabit Ethernet?

— 10/100 Mbps load from end users creates increased traffic on backbones

  - so gigabit Ethernet is meaningful for backbones

Gigabit Ethernet – Physical

- 1000Base-SX

—2 wires ,one for sending and one for receiving

—NRZ and 8B/10B block coding schemes are used

—Short wavelength, multimode fiber

—Maximum length 550m

- 1000Base-LX

—Long wavelength, Multi or single mode fiber

—2 wire implementation

—Maximum cable length 5000m

- 1000Base-CX

—A special STP (<25m) ,one for each direction

—NRZ and 8B/10B block coding schemes are used

—Maximum Length of cable 25m

- 1000Base-T

—4 pairs, cat5 UTP (bidirectional)

—100 m

A Perspective of IEEE 802 Standards in Network Communication

802.2

802.3
802.4
802.5
802.12

802.1 applies to both.

802 Layers - Medium Access Control & Logical Link Control

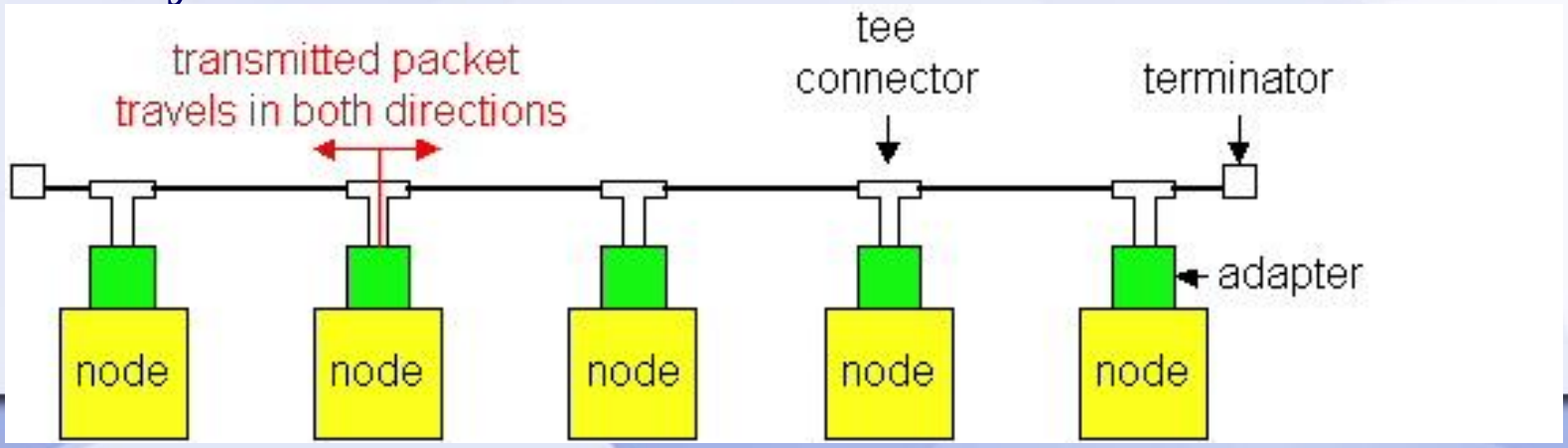
- OSI layer 2 (Data Link) is divided into two in IEEE 802
  - Logical Link Control (LLC) layer
  - Medium Access Control (MAC) layer
    - LLC layer
  - Interface to higher levels
  - flow control
  - Based on classical Data Link Control Protocols (so we will cover later)
    - MAC layer
  - Prepare data for transmission
  - Error detection
  - Address recognition
  - Govern access to transmission medium
    - Not found in traditional layer 2 data link control

IEEE 802 Layers - Physical

- Signal encoding/decoding
- Preamble generation/removal
  - for synchronization
- Bit transmission/reception
- Specification for topology and transmission medium

Media Access

- **Ethernet and Wi-Fi are both "multi-access" technologies**
  - Broadcast medium, shared by many hosts
  - Simultaneous transmissions will result in collisions
- **Media Access Control (MAC) protocol required**
  - Rules on how to share medium
- **The Data Link Layer is divided into two Part MAC Media Access Control) Sublayer and LLC (Logic Link Control) Sublayer**



MAC Protocols

1.Contention-Based MAC

- No control.
- Stations try to acquire the medium.
- Distributed in nature.

Example :

ALOHA and Slotted ALOHA,CSMA,CSMA/CD.

2.Round-robin based MAC:

token-based protocols.

Token bus.

Token ring.

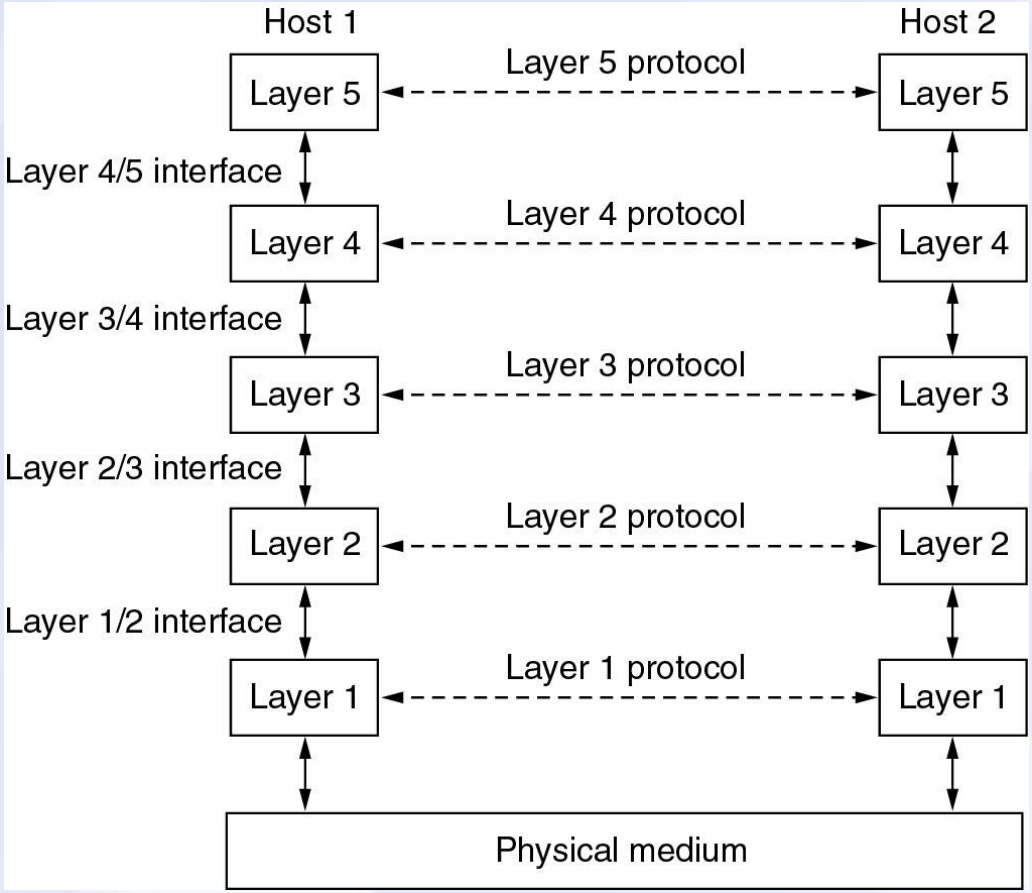
What is 802.11?

- A family of wireless LAN (WLAN) specifications developed by a working group at the Institute of Electrical and Electronic Engineers (IEEE)
- Defines standard for WLANs using the following four technologies
  - Frequency Hopping Spread Spectrum (FHSS)
  - Direct Sequence Spread Spectrum (DSSS)
  - Infrared (IR)
  - Orthogonal Frequency Division Multiplexing (OFDM)
- Versions: 802.11a, 802.11b, 802.11g, 802.11e, 802.11f, 802.11i

Network Software

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

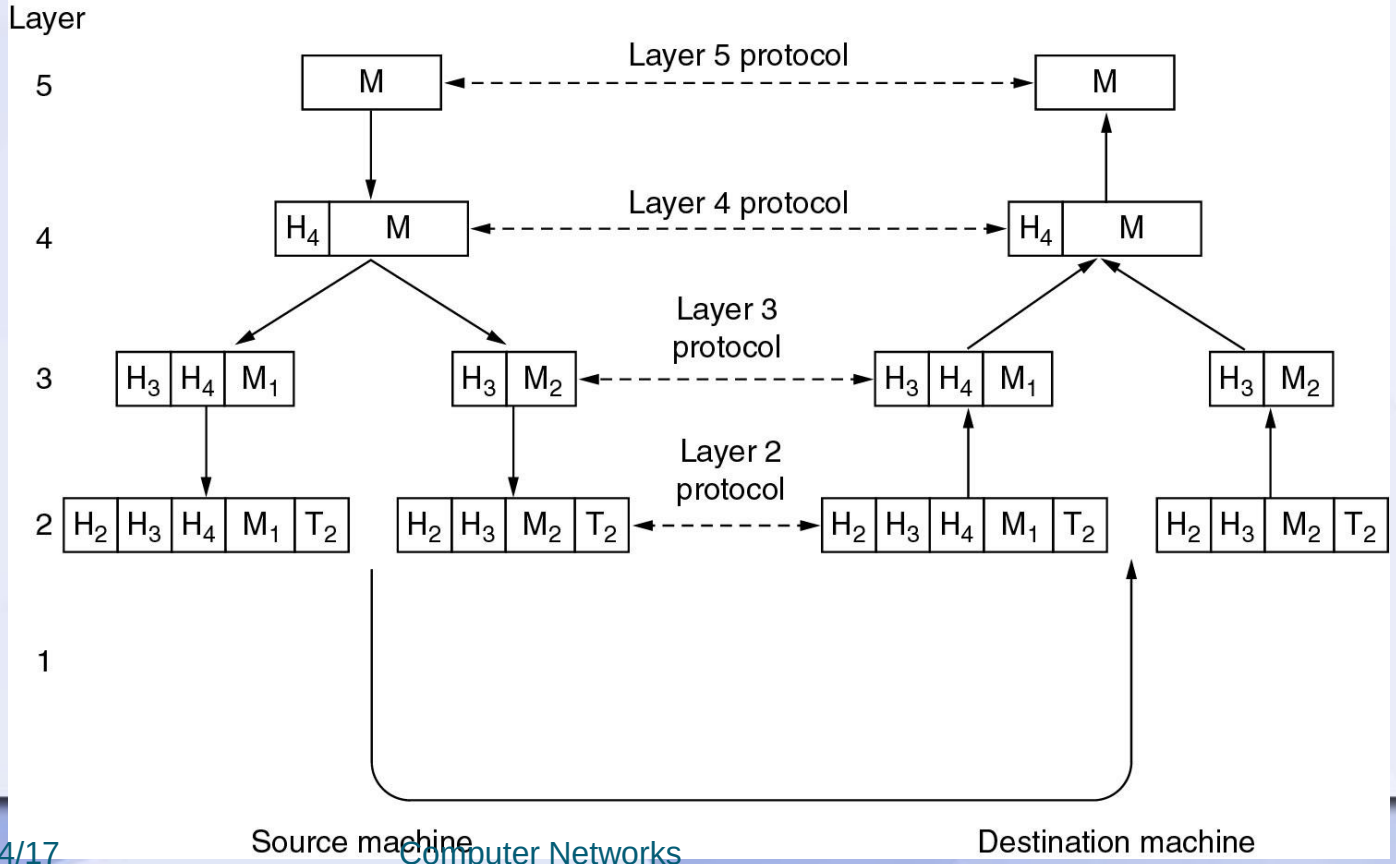
Network Software
Protocol Hierarchies



Layers, protocols, and interfaces.

Protocol Hierarchies (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

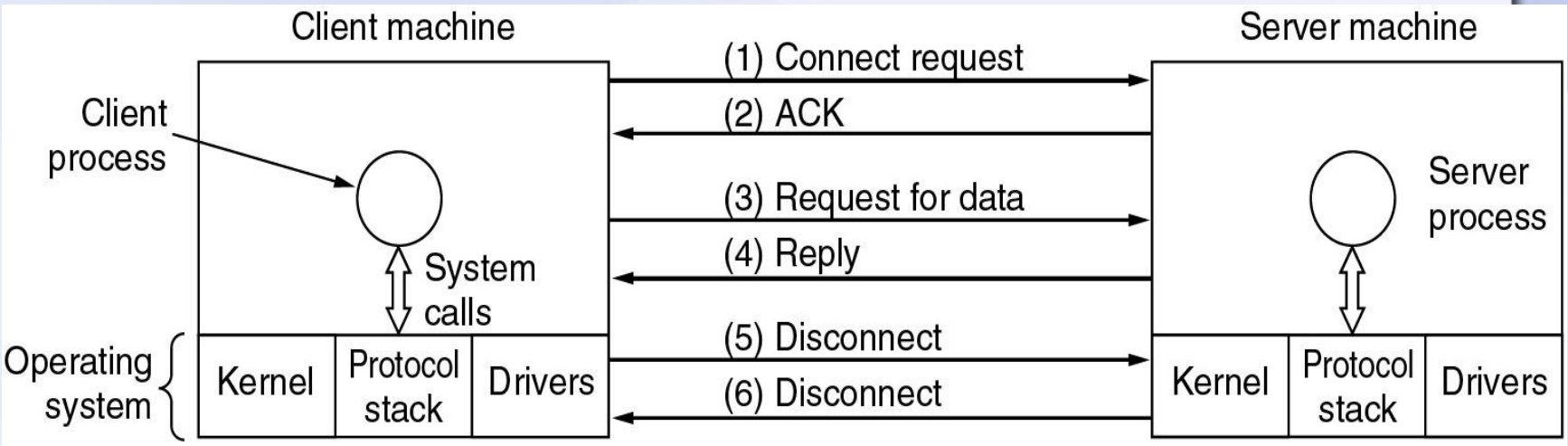
	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Remote login
	Unreliable connection	Digitized voice
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Registered mail
	Request-reply	Database query

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

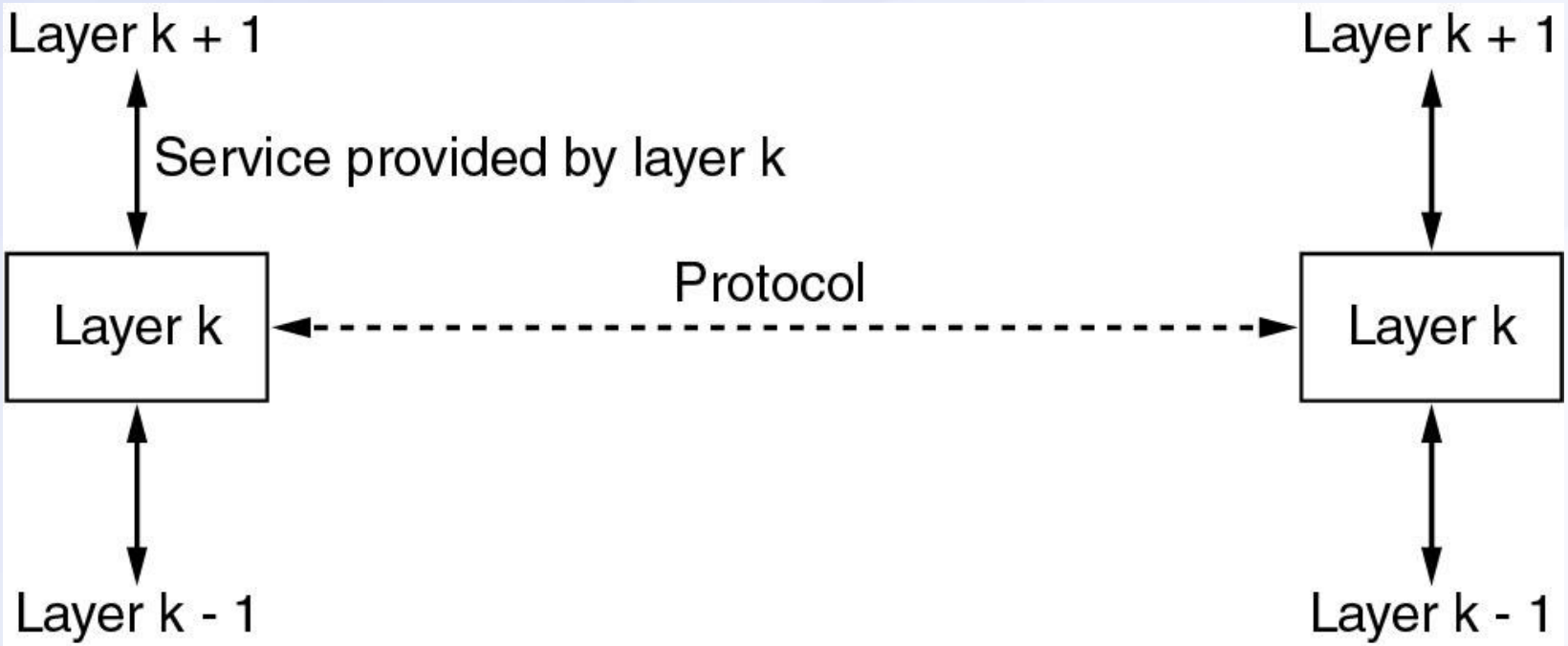
Service Primitives (2)

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



Services to Protocols Relationship

The relationship between a service and a protocol.

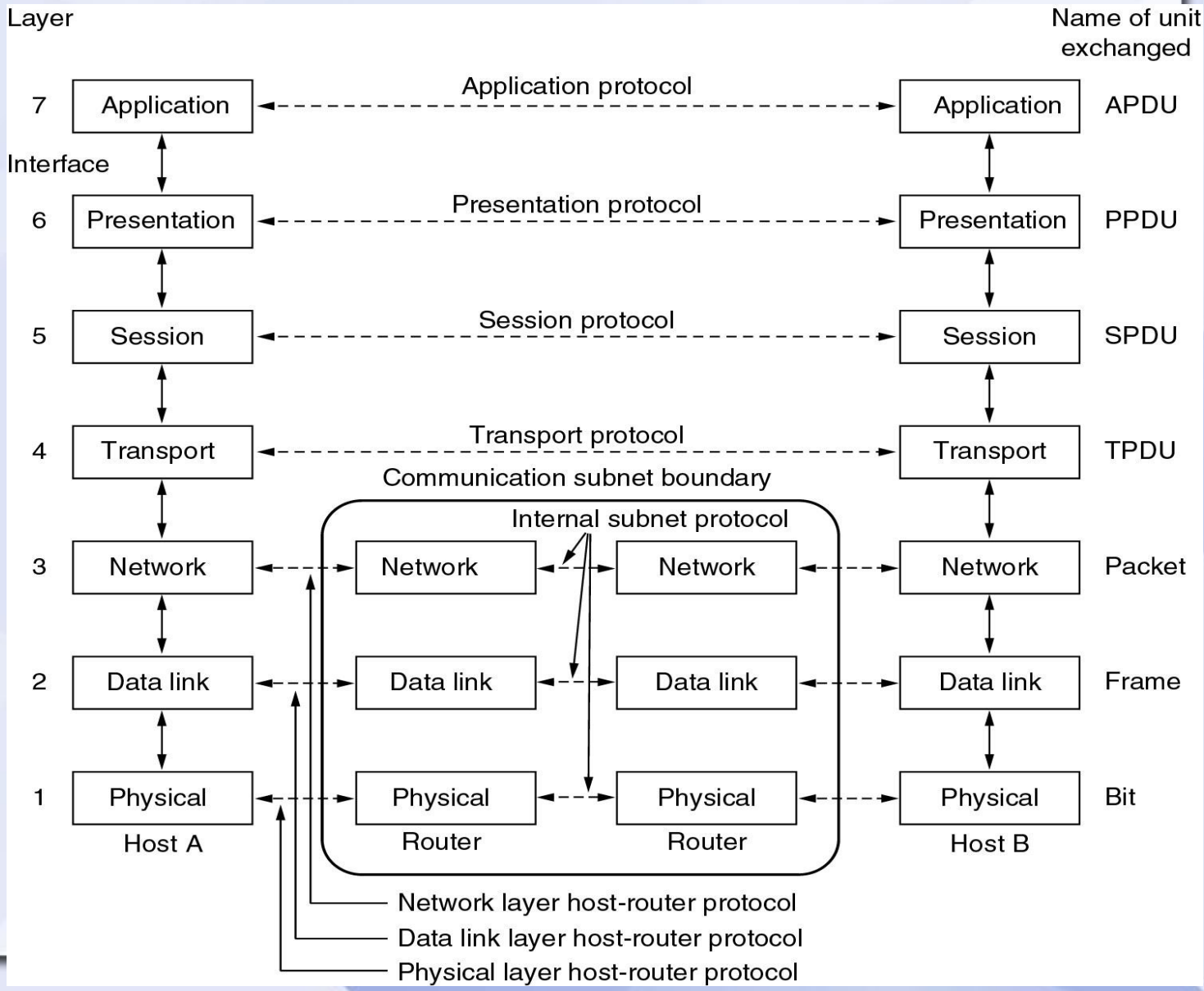


Reference Models

- 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

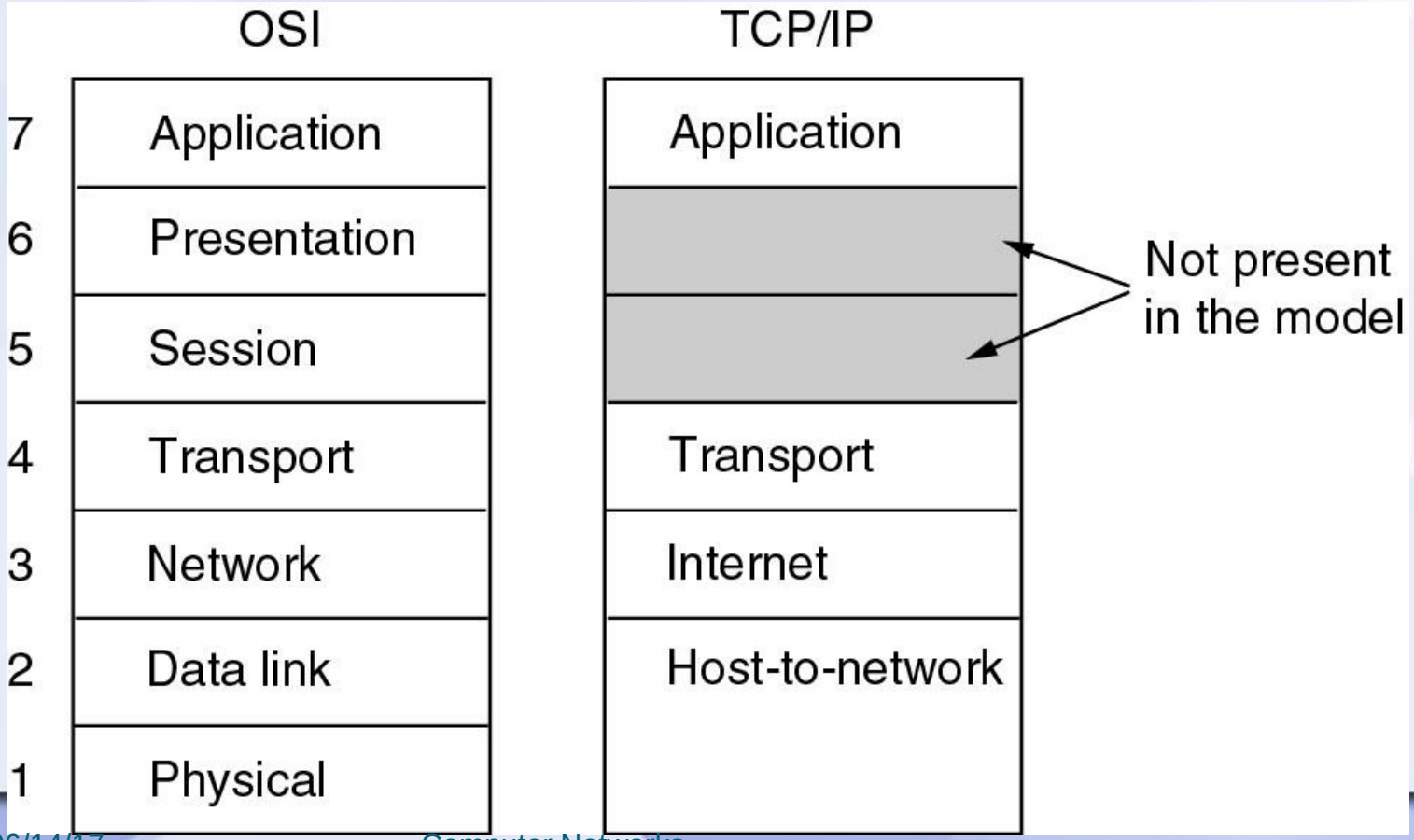
Reference Models

The OSI reference model.



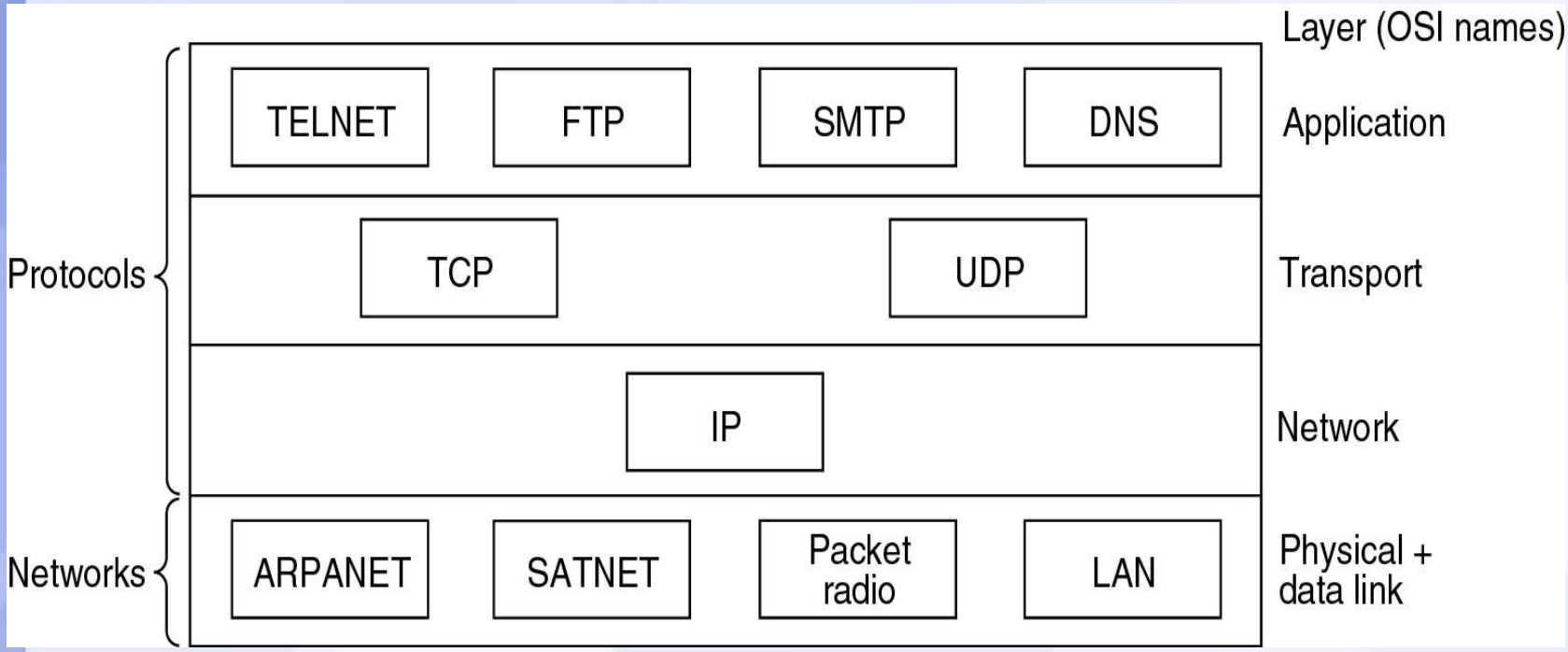
Reference Models (2)

The TCP/IP reference model.



Reference Models (3)

Protocols and networks in the TCP/IP model initially.



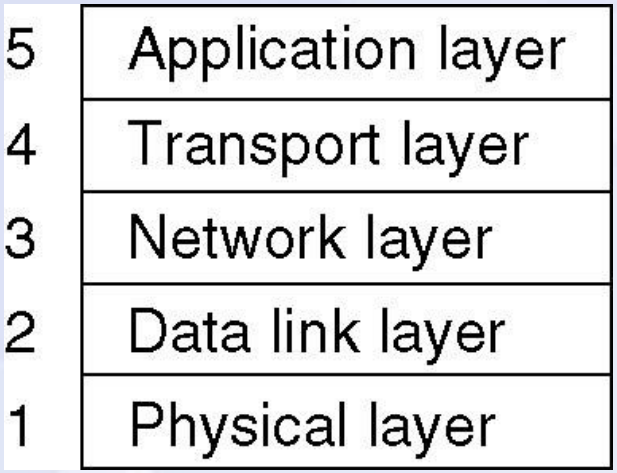
Comparing OSI and TCP/IP Models

Concepts central to the OSI model

- Services
- Interfaces
- Protocols

Hybrid Model

The hybrid reference model to be used in this book.



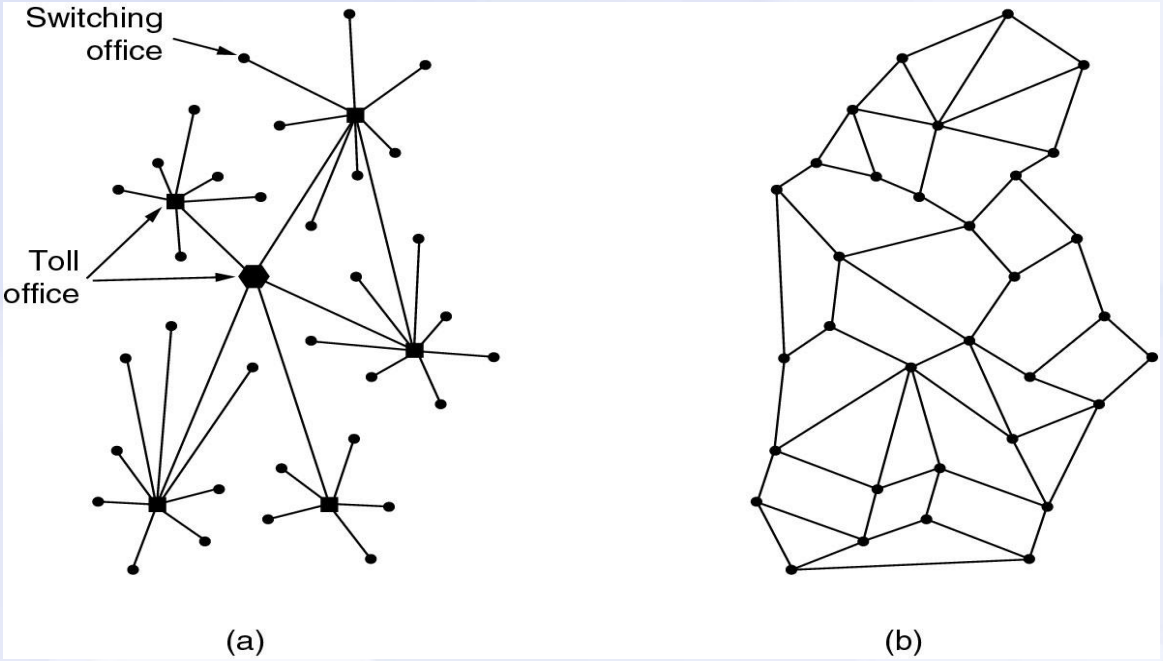
Example Networks

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

The ARPANET

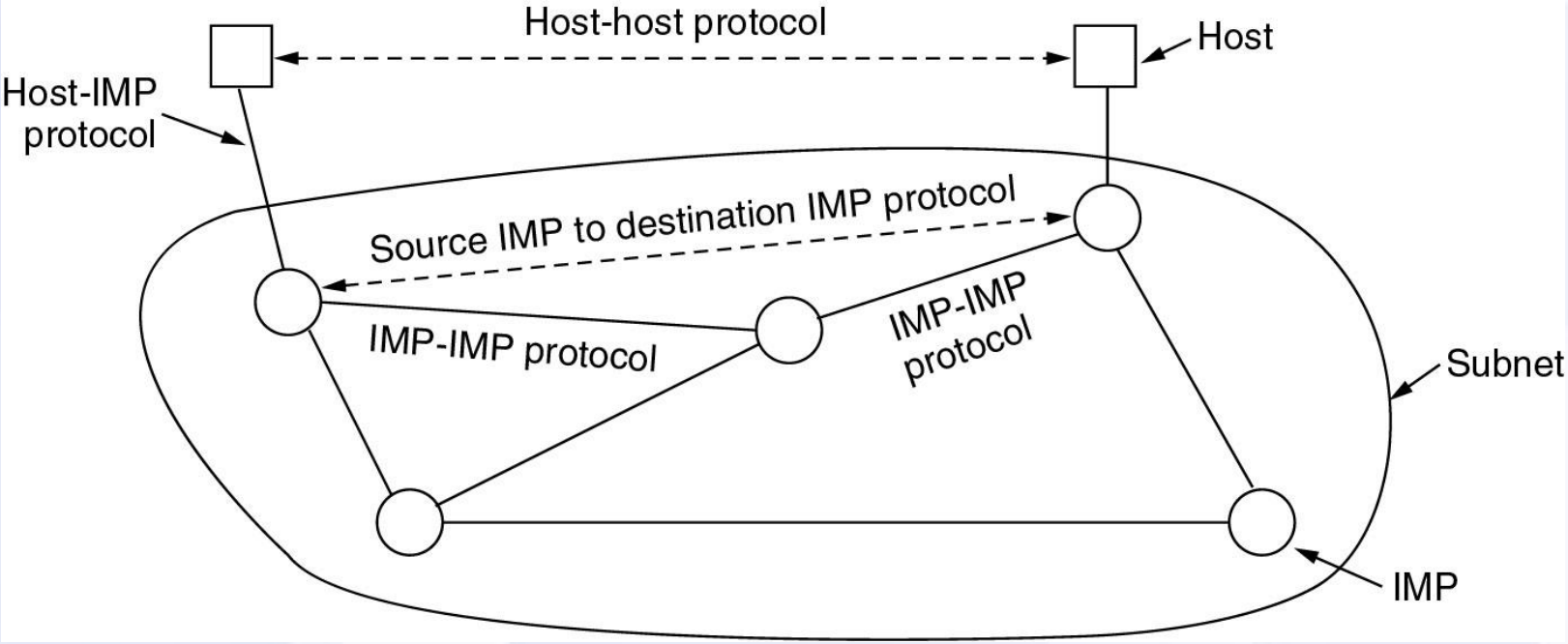
(a) Structure of the telephone system.

(b) Baran's proposed distributed switching system.

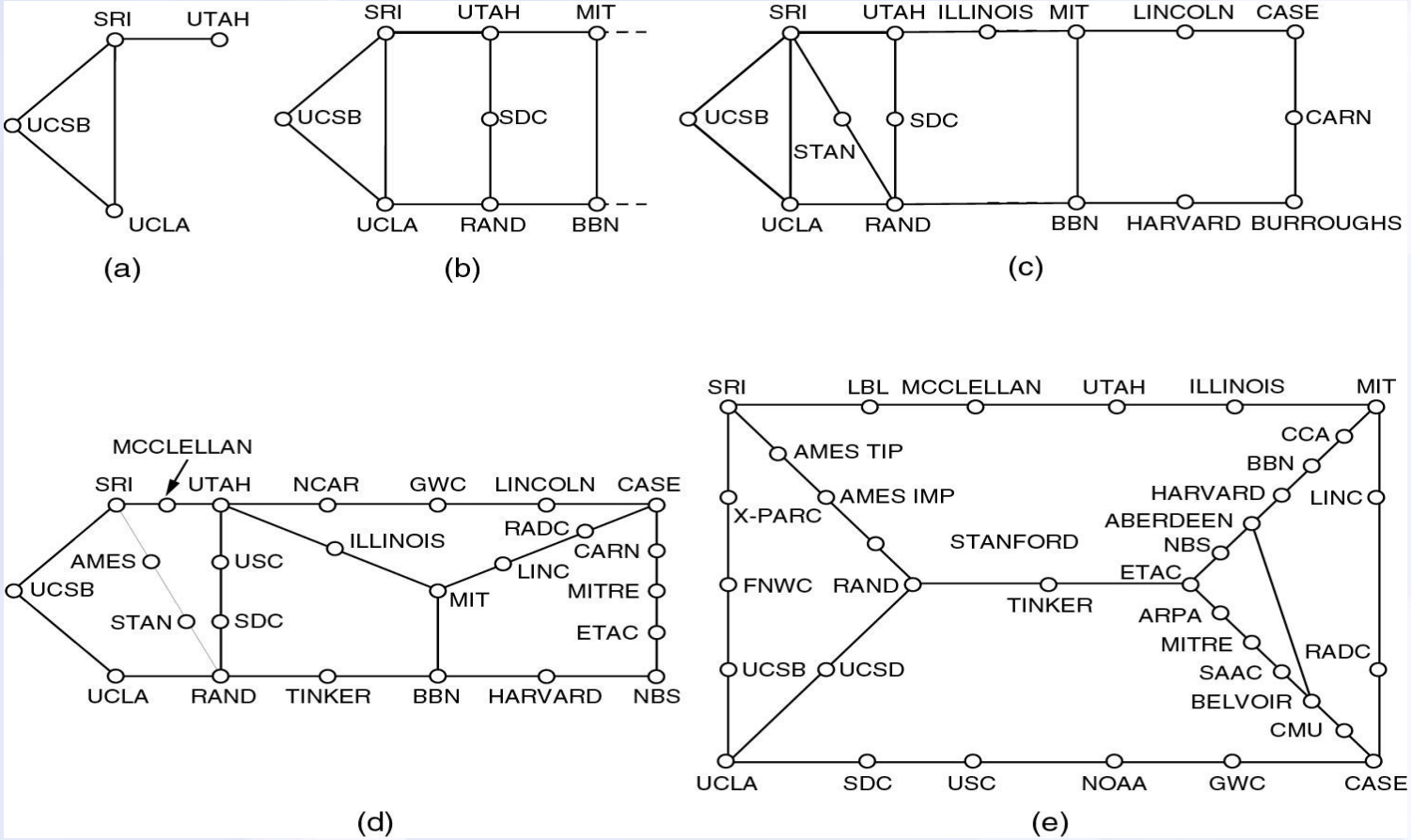


The ARPANET (2)

The original ARPANET design.



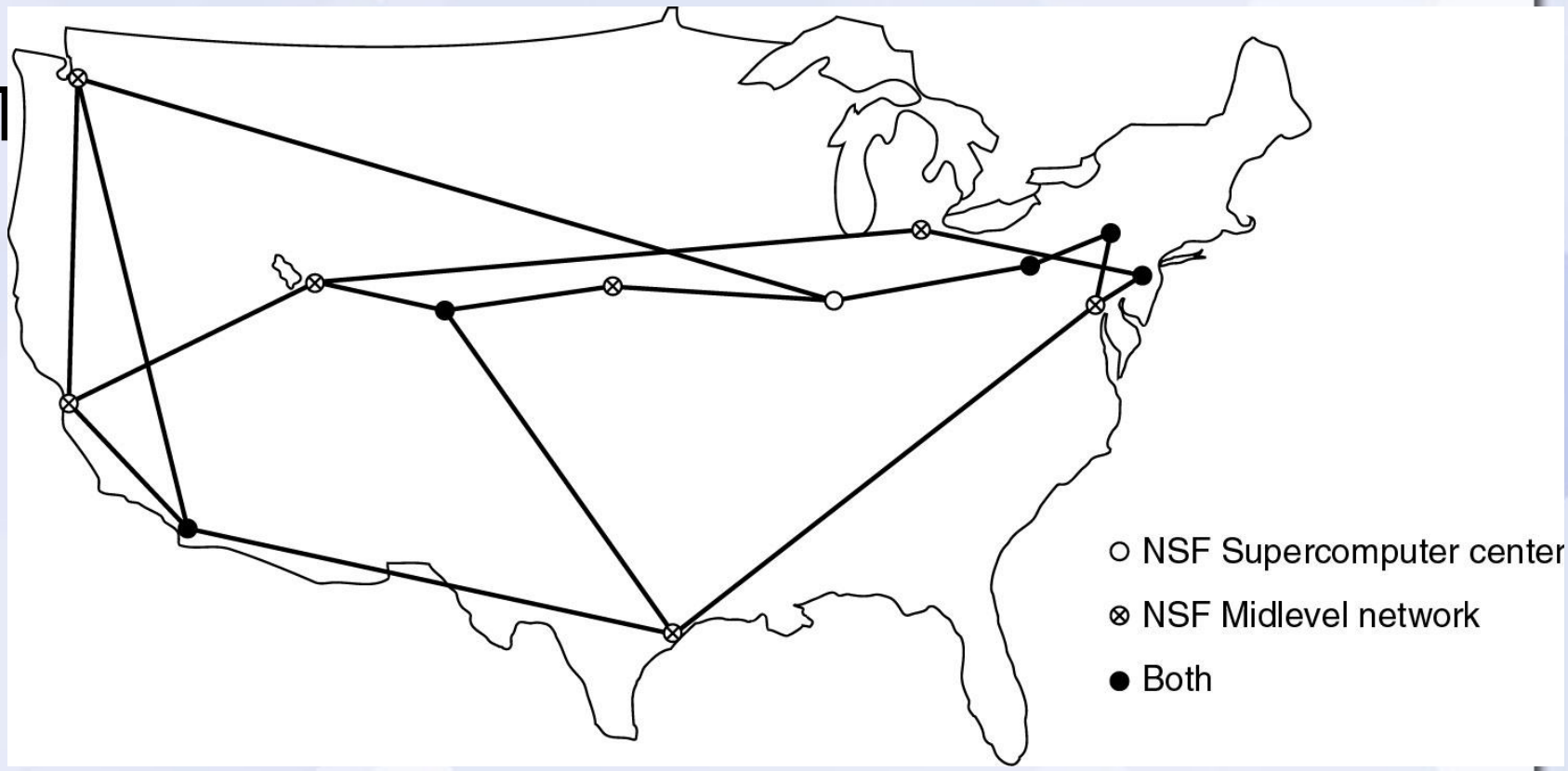
The ARPANET (3)



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

NSFNET

T



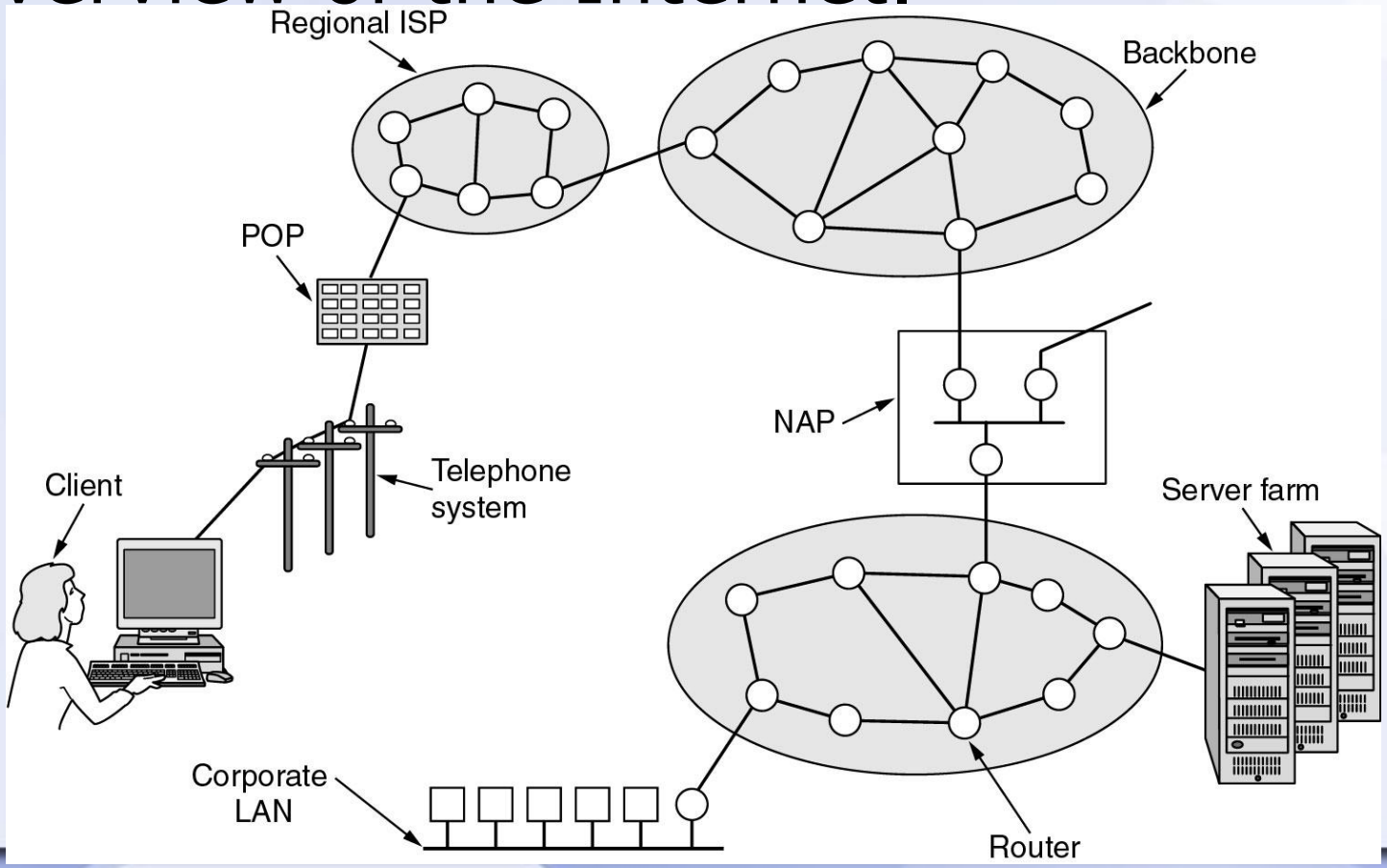
Internet Usage

Traditional applications (1970 – 1990)

- E-mail
- News
- Remote login
- File transfer

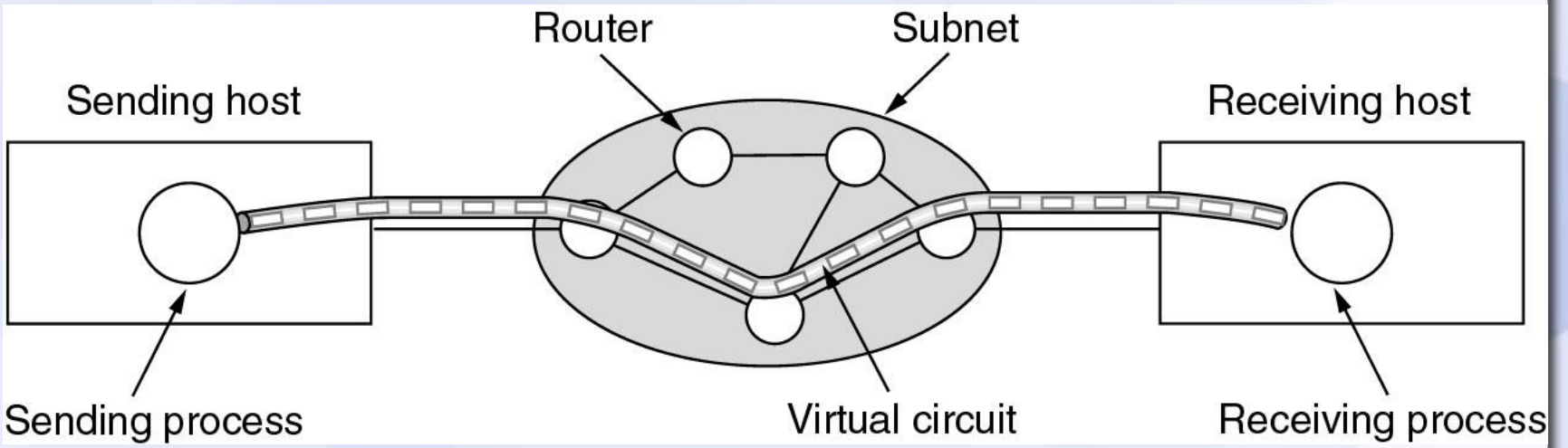
Architecture of the Internet

Overview of the Internet.



ATM Virtual Circuits

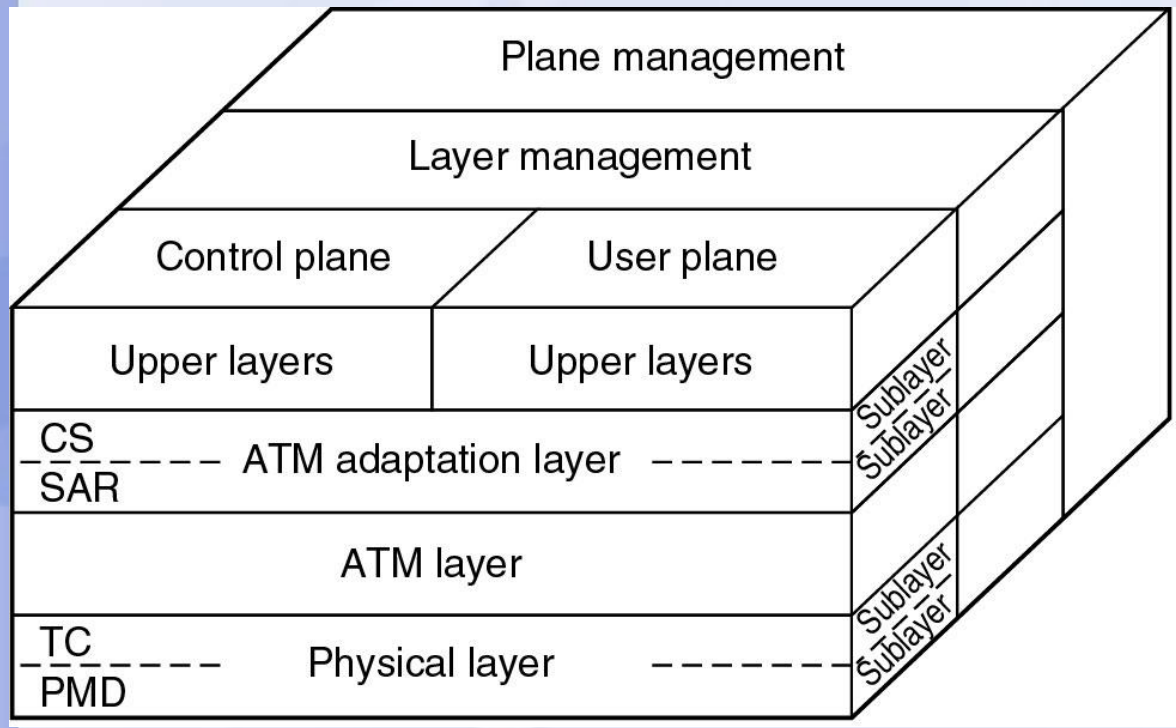
A virtual circuit.



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

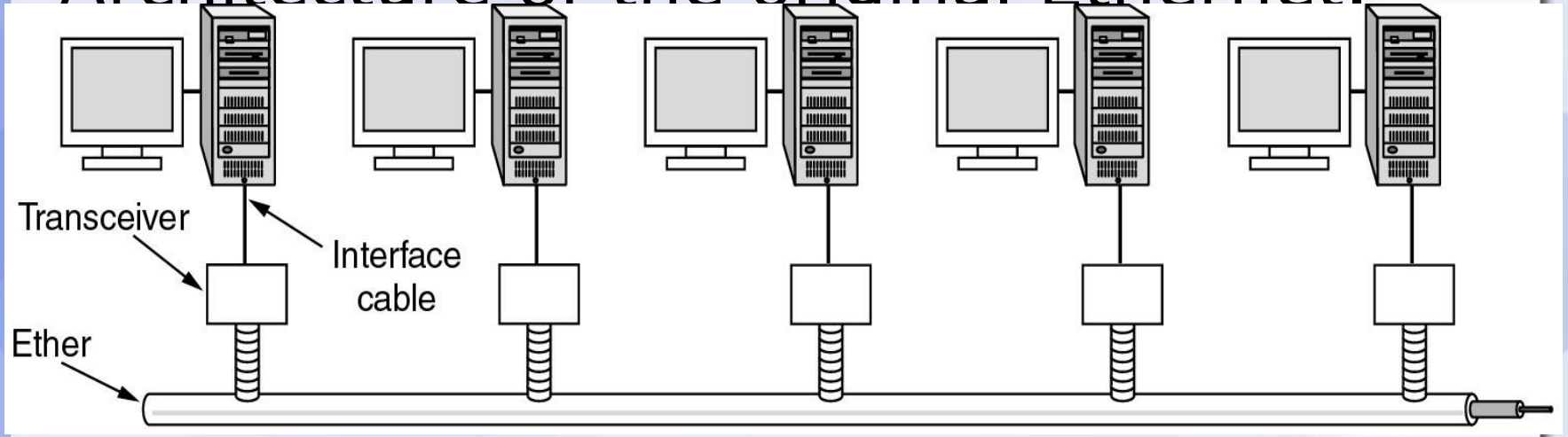
The ATM Reference Model (2)

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

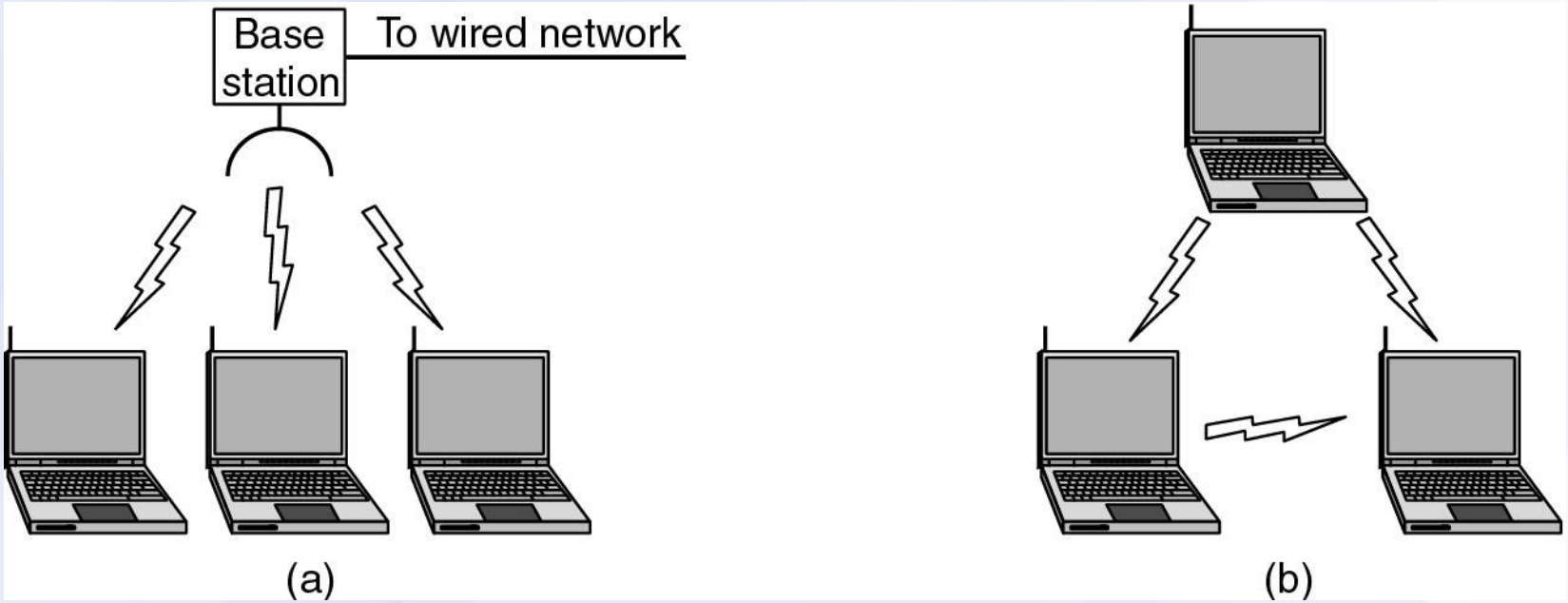
The ATM layers and sublayers and their functions.

Ethernet

Architecture of the original Ethernet.



Wireless LANs

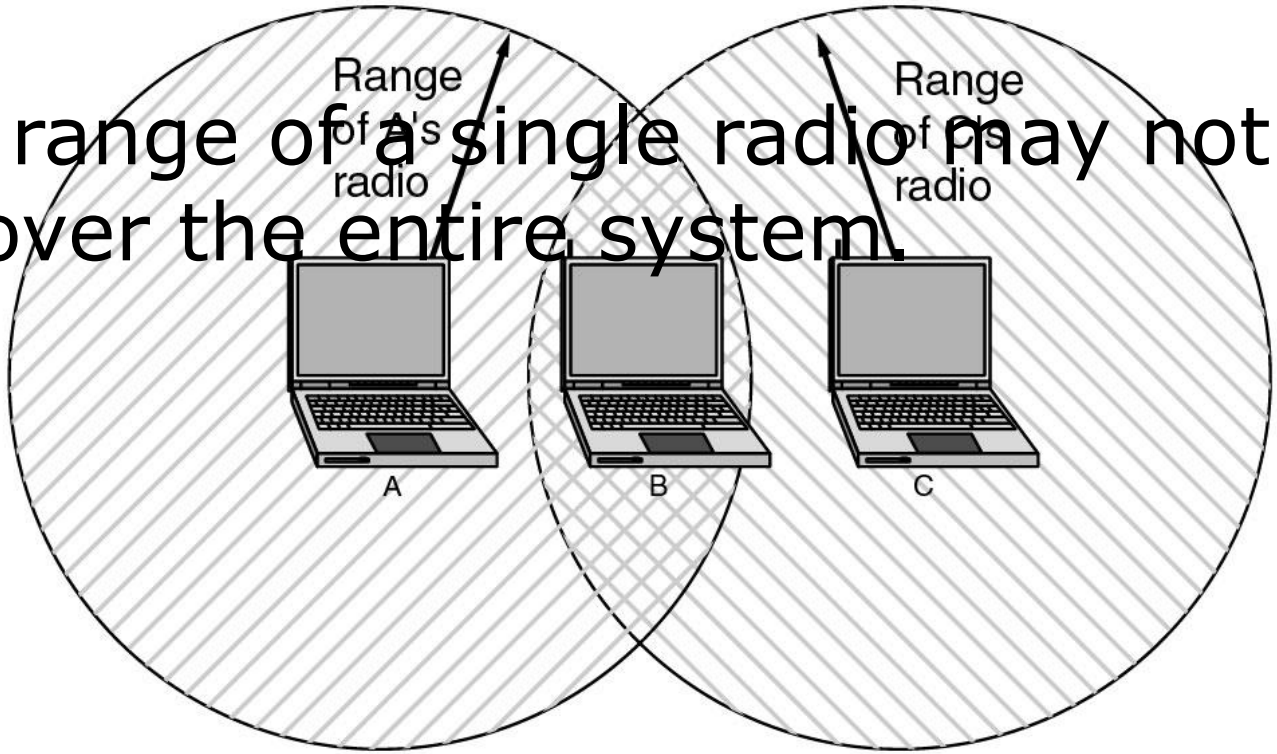


(a) Wireless networking with a base station.

(b) Ad hoc networking.

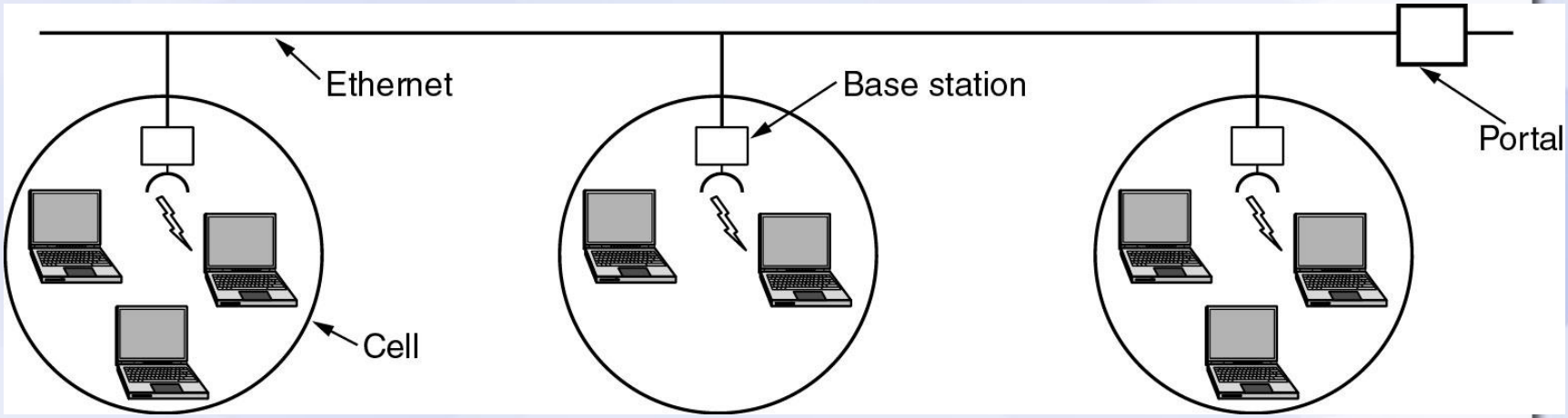
Wireless LANs (2)

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.