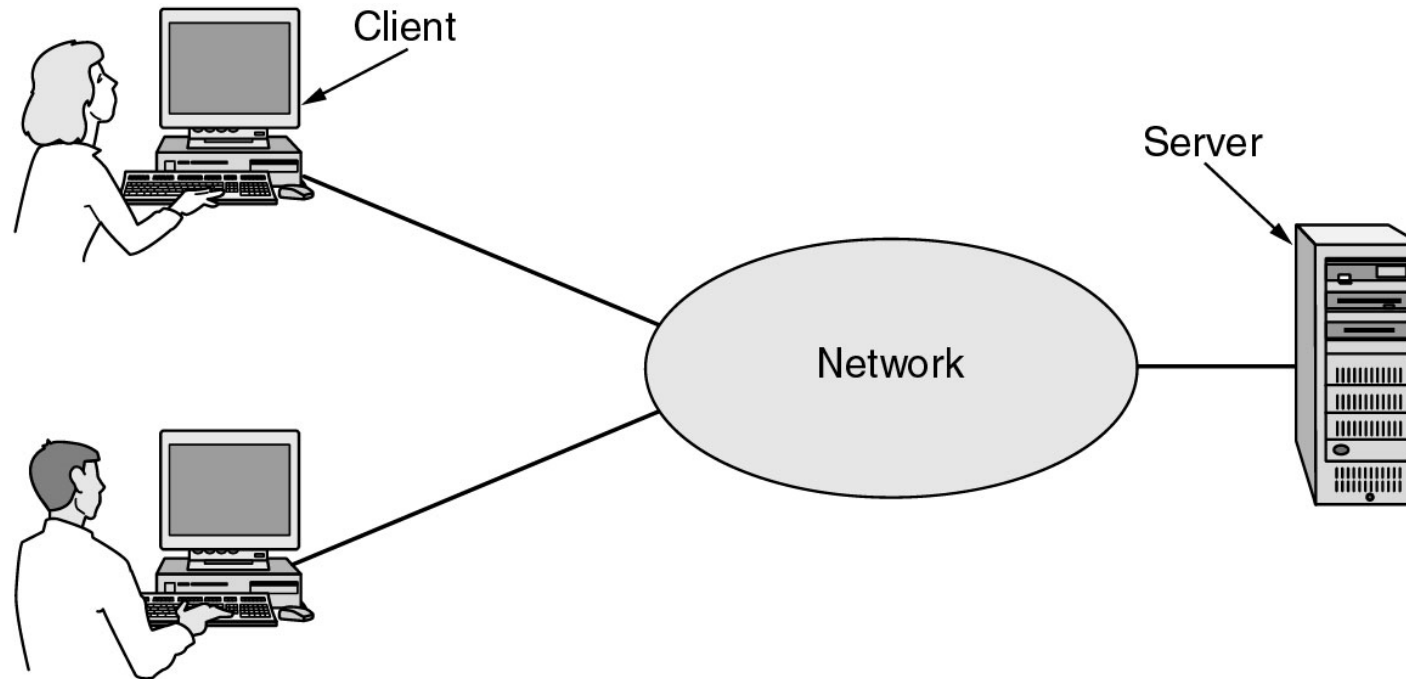# Chapter 2

The Physical Layer
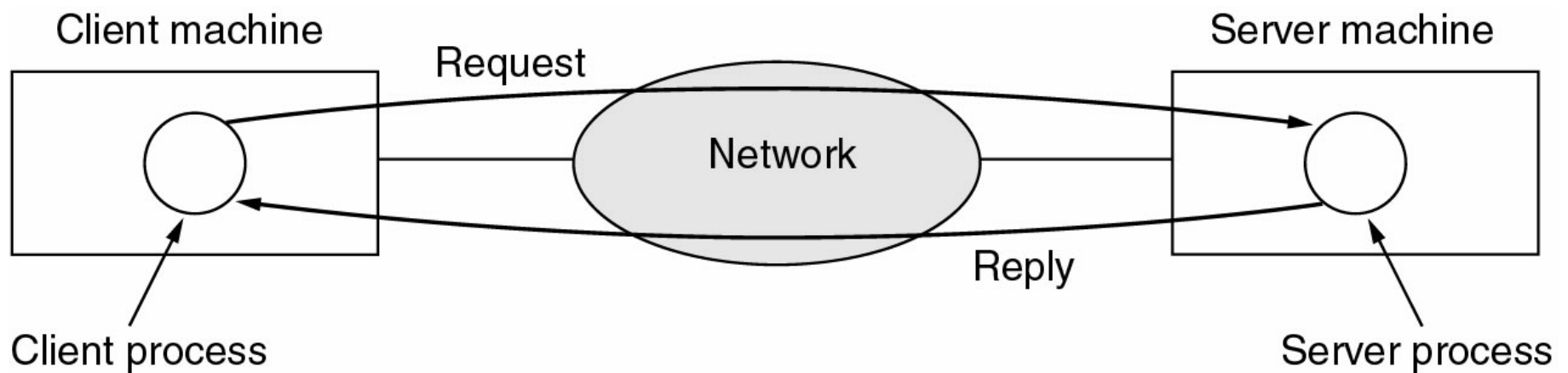
Uses of Computer Networks

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

Business Applications of Networks

a)   A network with two clients and one server.

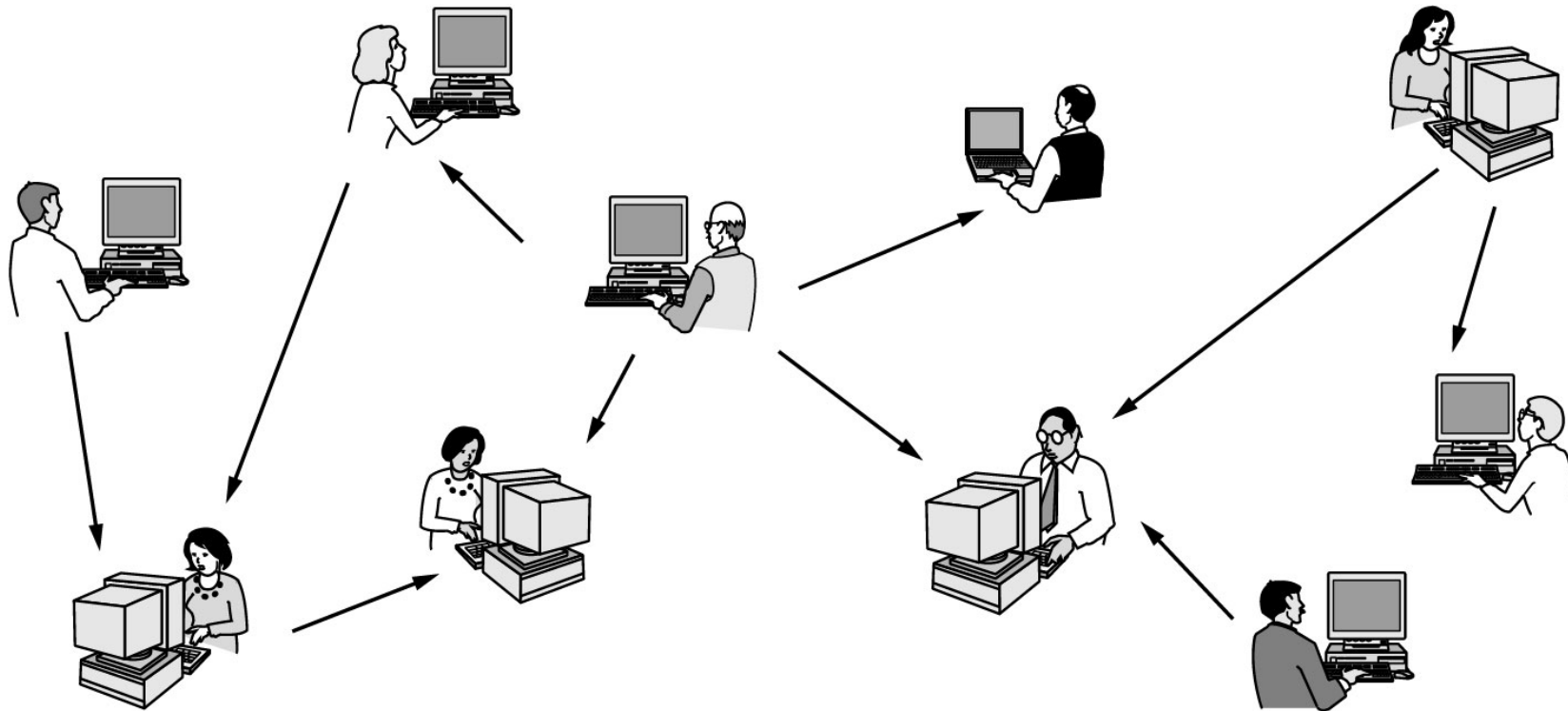# Business Applications of Networks (2)

a) 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)

a) In peer-to-peer system there are no fixed clients and servers.

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

a)   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

a)   Combinations of wireless networks and mobile computing.

Network Hardware

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

Broadcast Networks

a) 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	
100 m	Building	Local area network
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	
1000 km	Continent	Wide area network
10,000 km	Planet	The Internet

a) Classification of interconnected processors by scale.

Local Area Networks
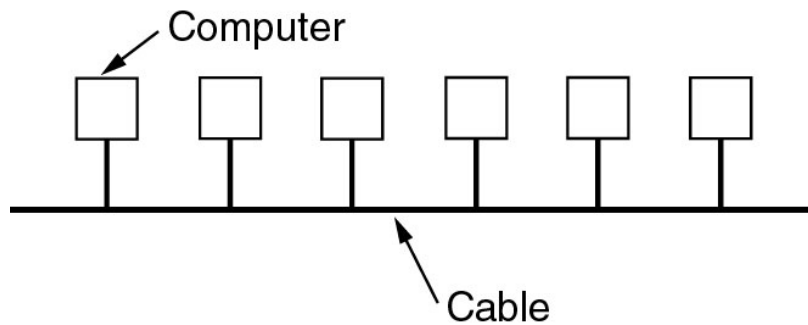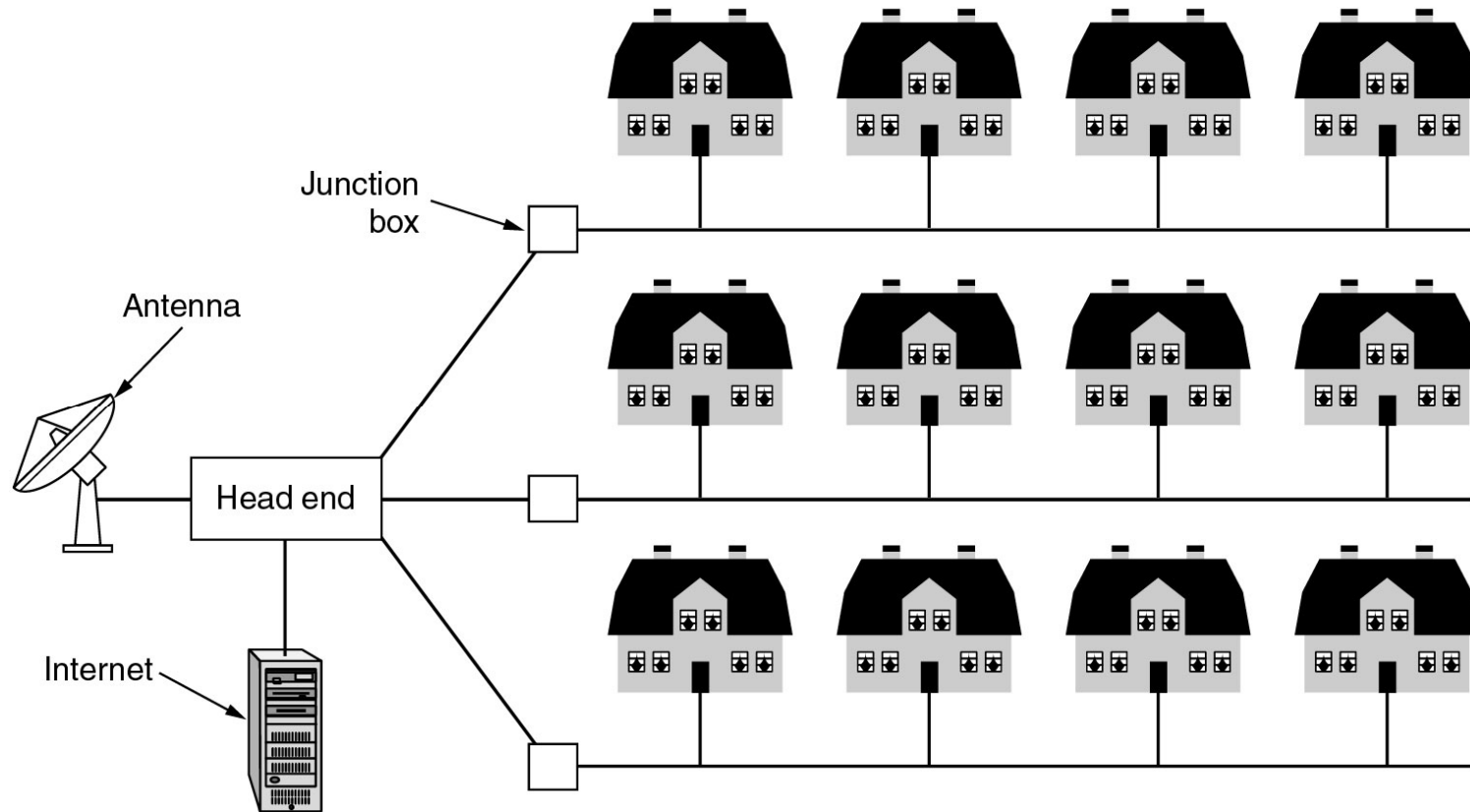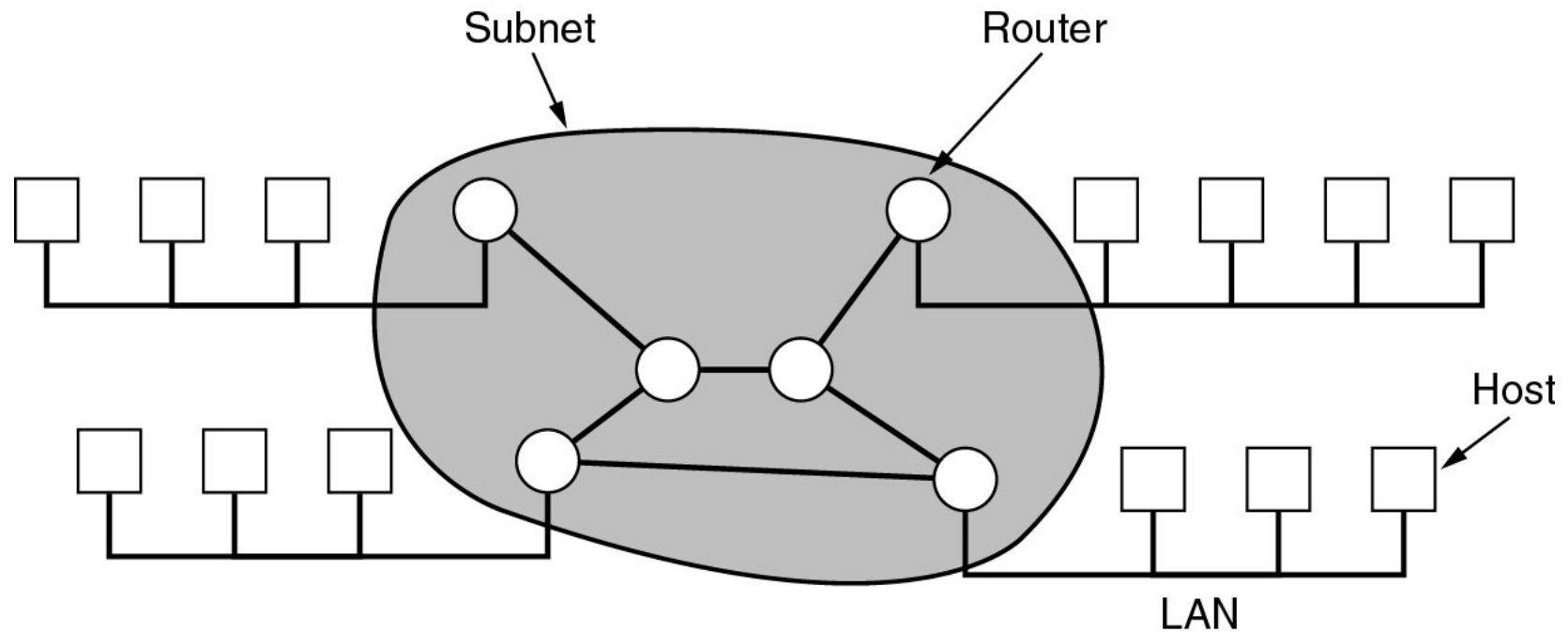

(a)
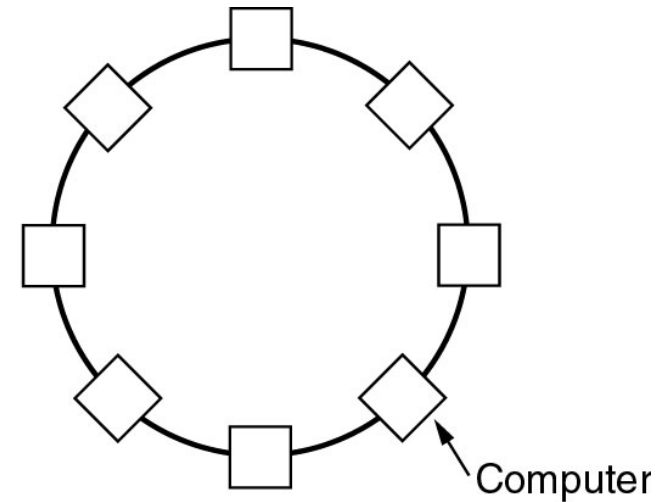
(b)

a)   Two broadcast networks
b)   (a) Bus
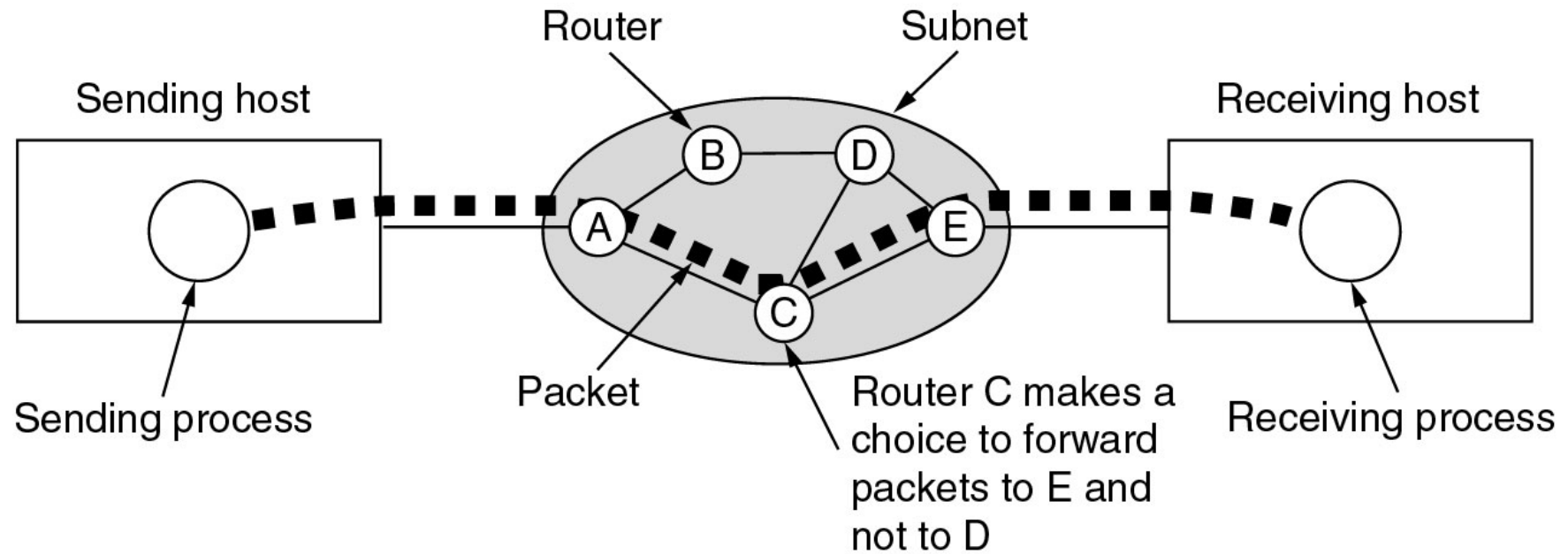c)   (b) Ring

Metropolitan Area Networks

a) A metropolitan area network based on cable TV.

Wide Area Networks

a) Relation between hosts on LANs and the subnet.
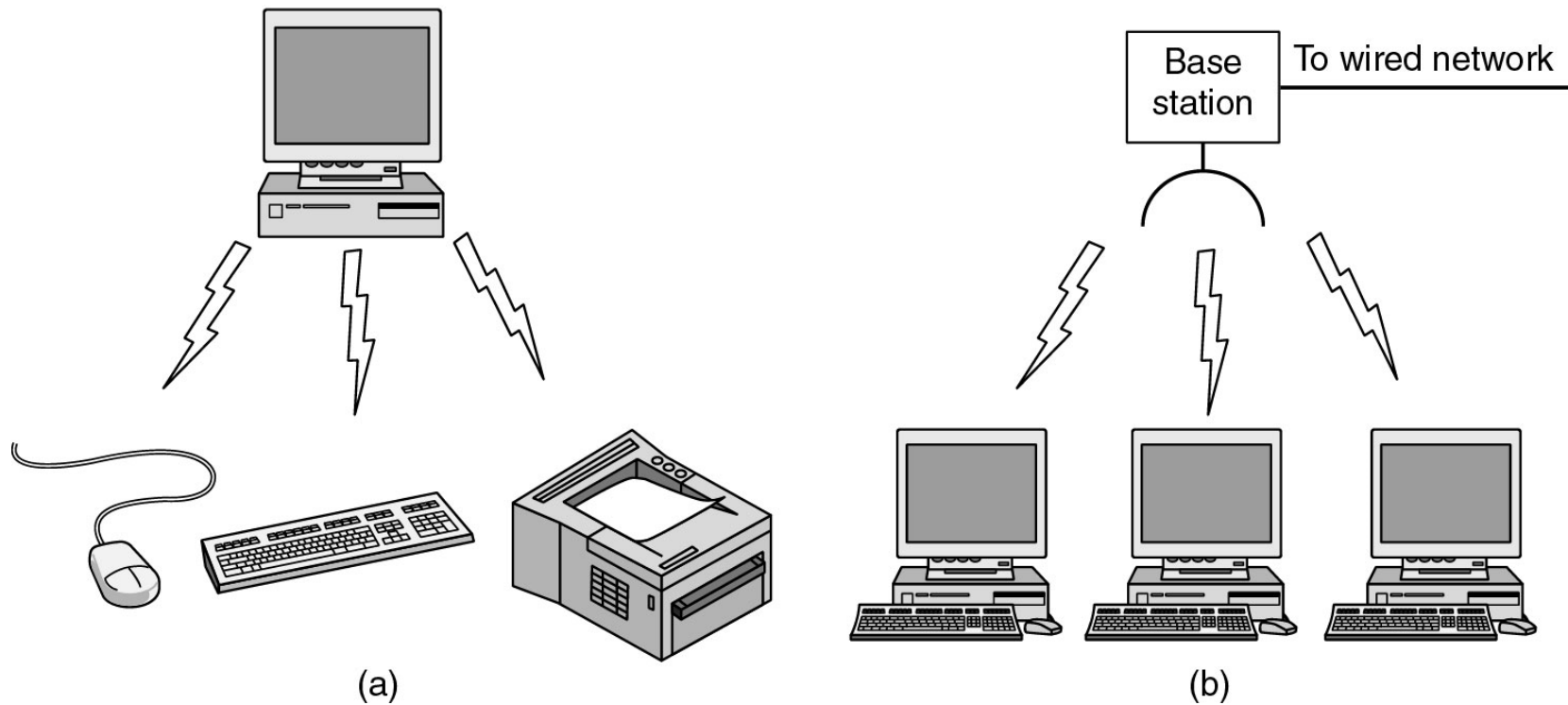
Wide Area Networks (2)

a)   A stream of packets from sender to receiver.
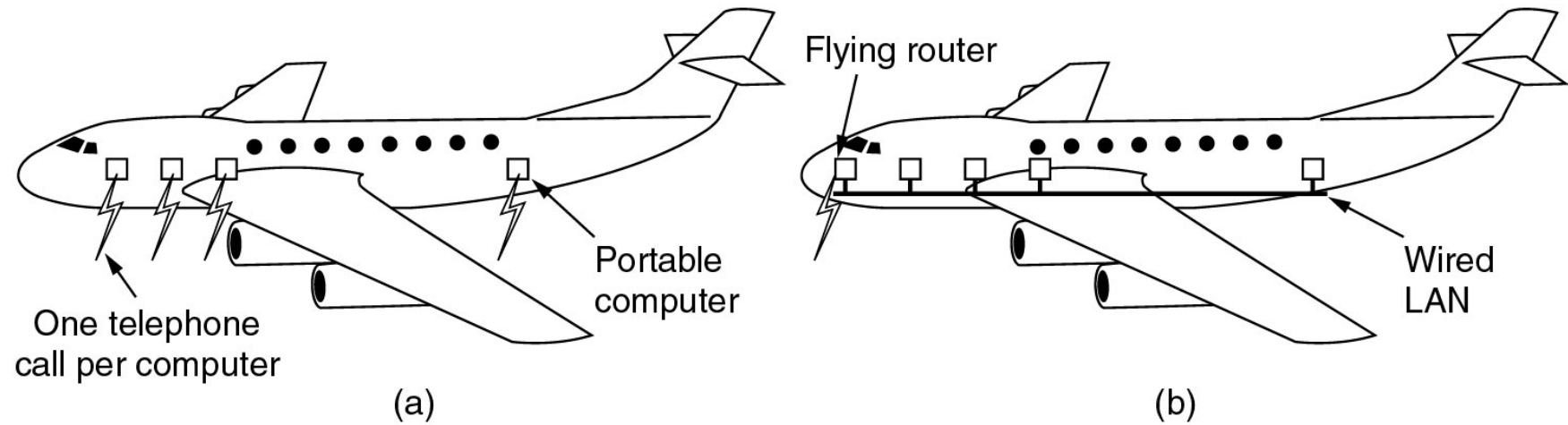
Wireless Networks

a) Categories of wireless networks:

- System interconnection

- Wireless LANs

- Wireless WANs

Wireless Networks (2)

(a)

(b)

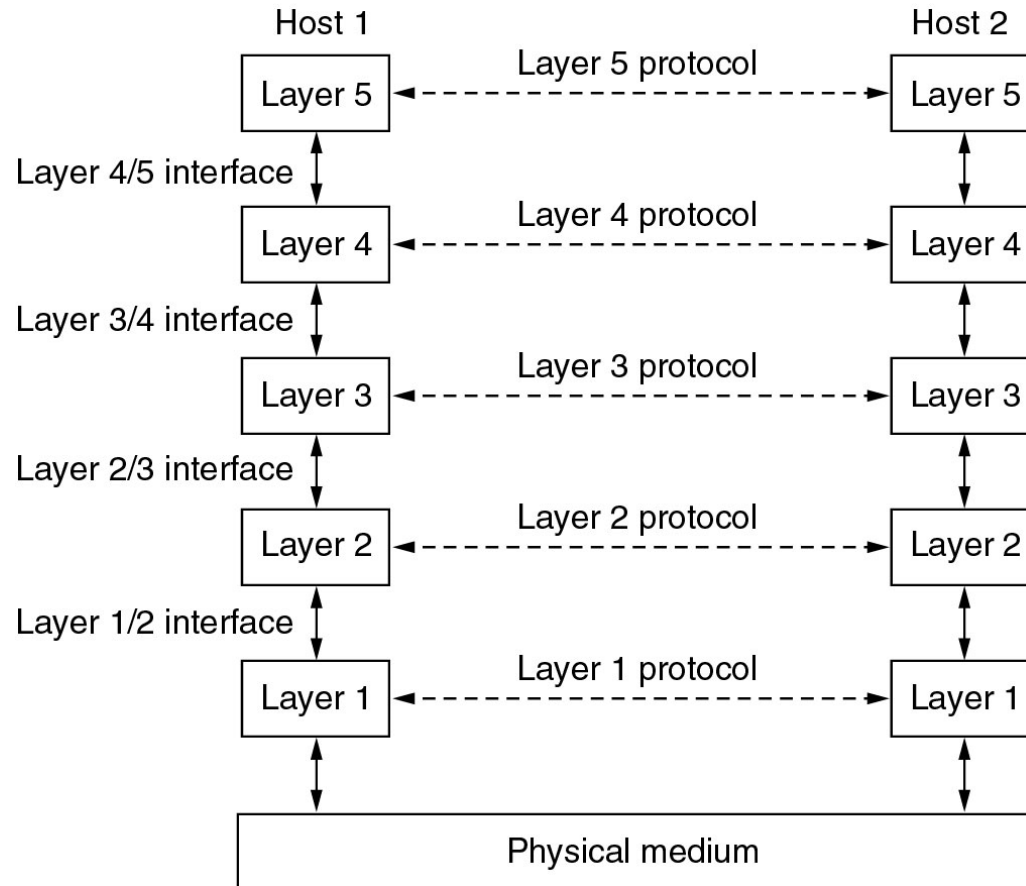a)   (a) Bluetooth configuration
b)   (b) Wireless LAN

Wireless Networks (3)

(a) (b)

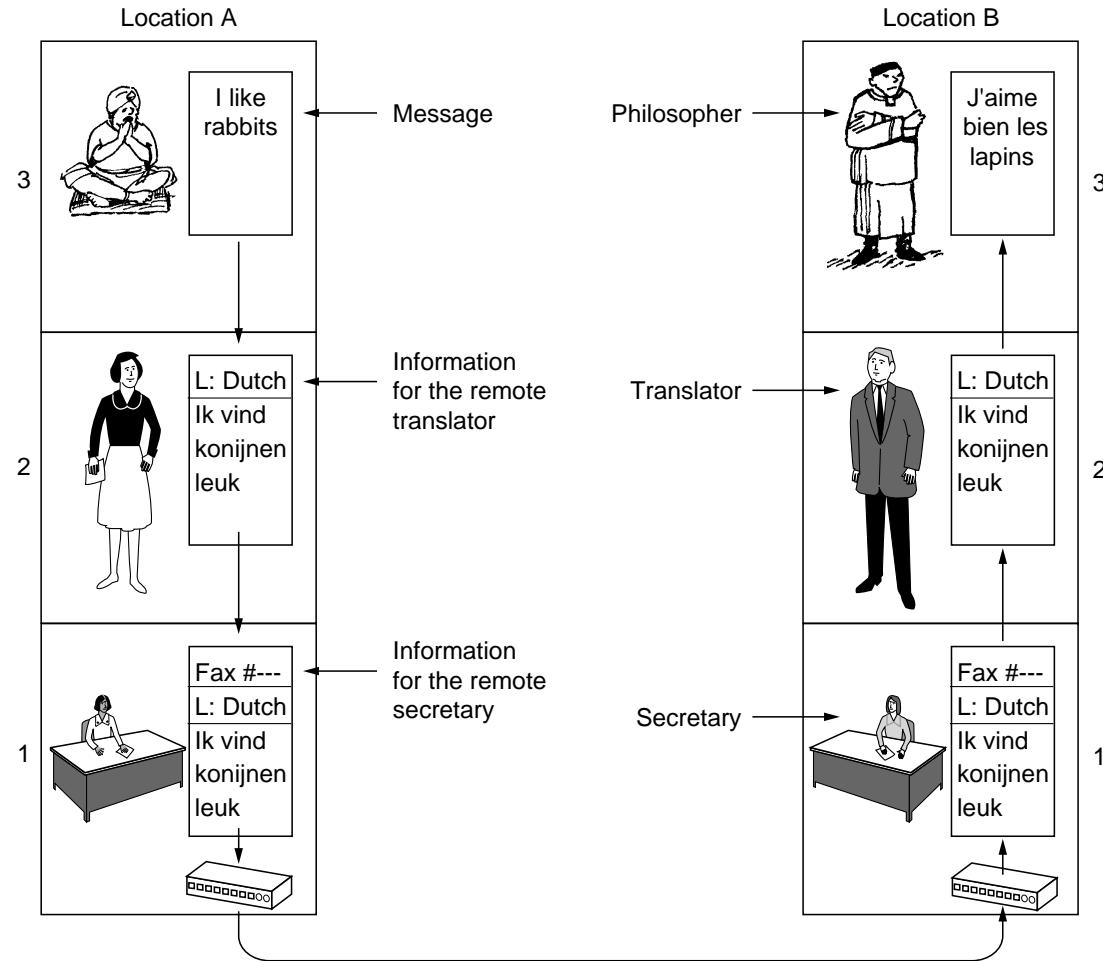a) (a) Individual mobile computers
b) (b) A flying LAN

Network Software
Protocol Hierarchies

a) Layers, protocols, and interfaces.

Protocol Hierarchies (2)

a) The philosopher-translator-secretary architecture.

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

a) 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

a) Five service primitives for implementing a simple connection-oriented service.
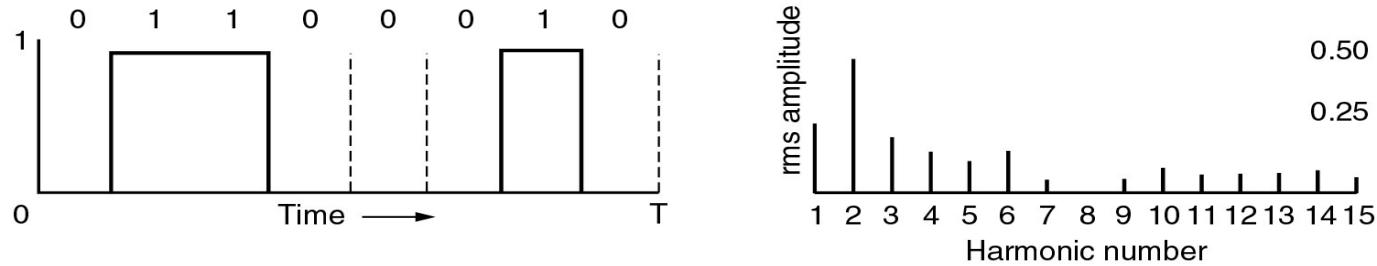
Service Primitives (2)
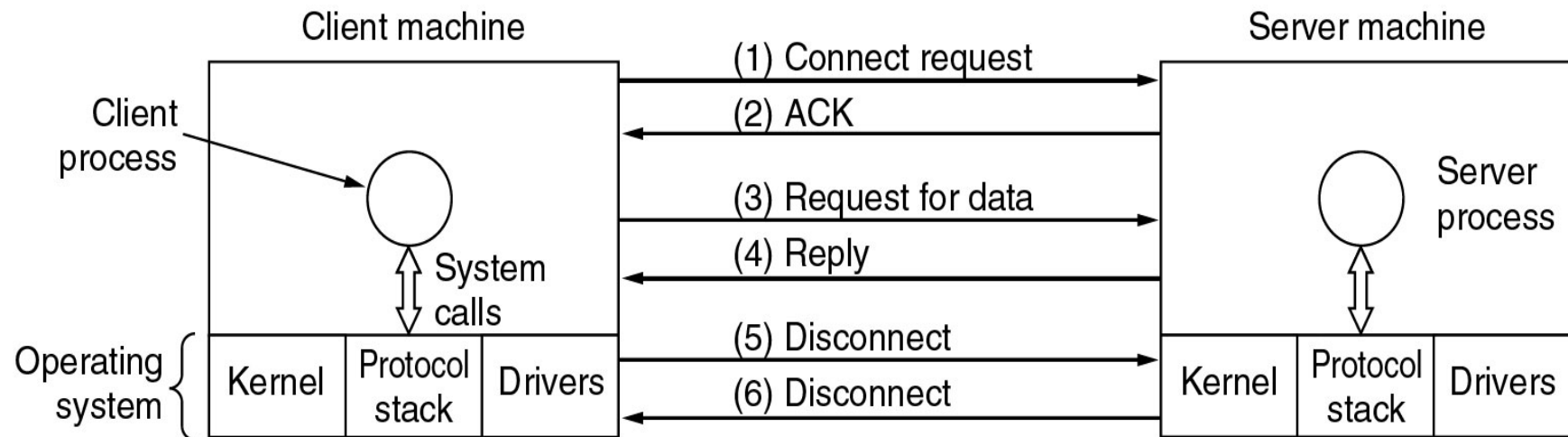
a) Packets sent in a simple client-server interaction on a connection-oriented network.
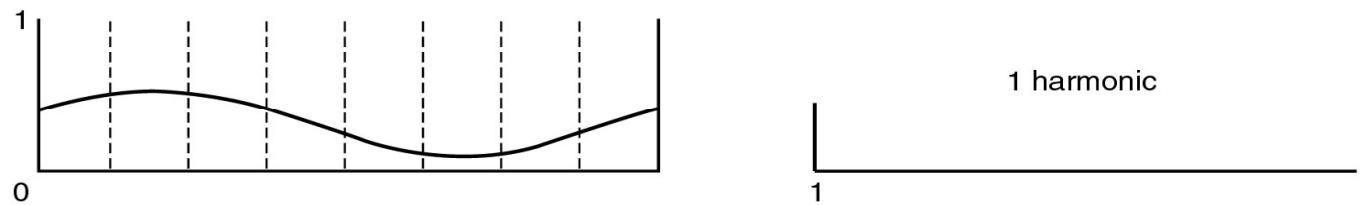
The Theoretical Basis for Data Communication

- Fourier Analysis

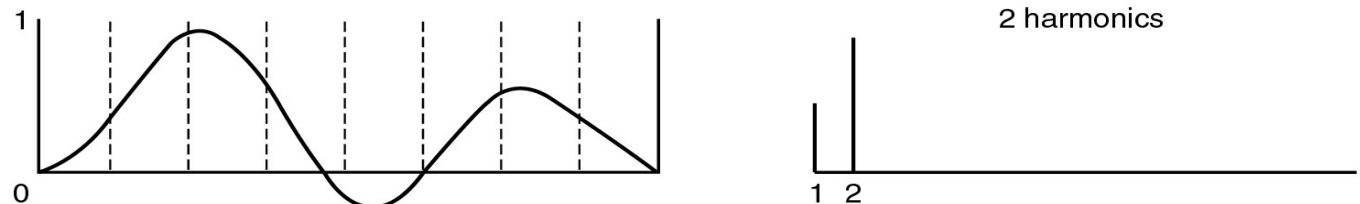- Bandwidth-Limited Signals

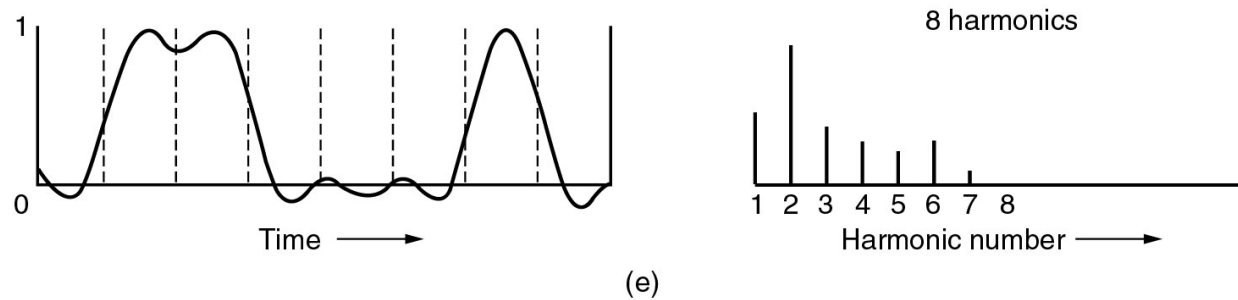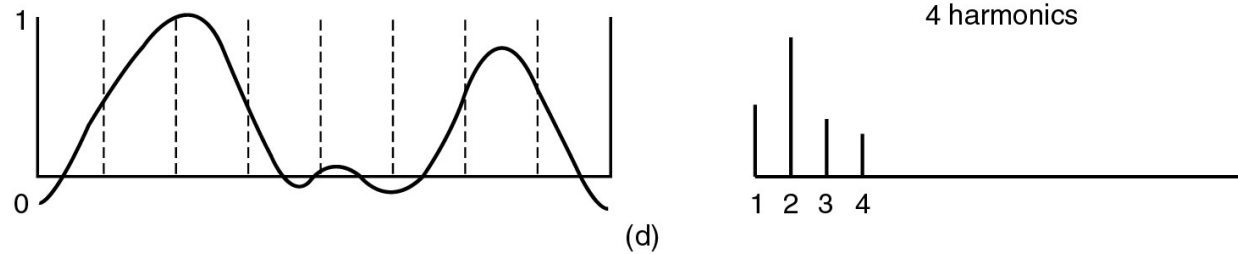- Maximum Data Rate of a Channel

Bandwidth-Limited Signals

A binary signal and its root-mean-square Fourier amplitudes.
(b) – (c) Successive approximations to the original signal.

Bandwidth-Limited Signals (2)

(d) – (e) Successive approximations to the original signal.

Guided Transmission Data

- Magnetic Media
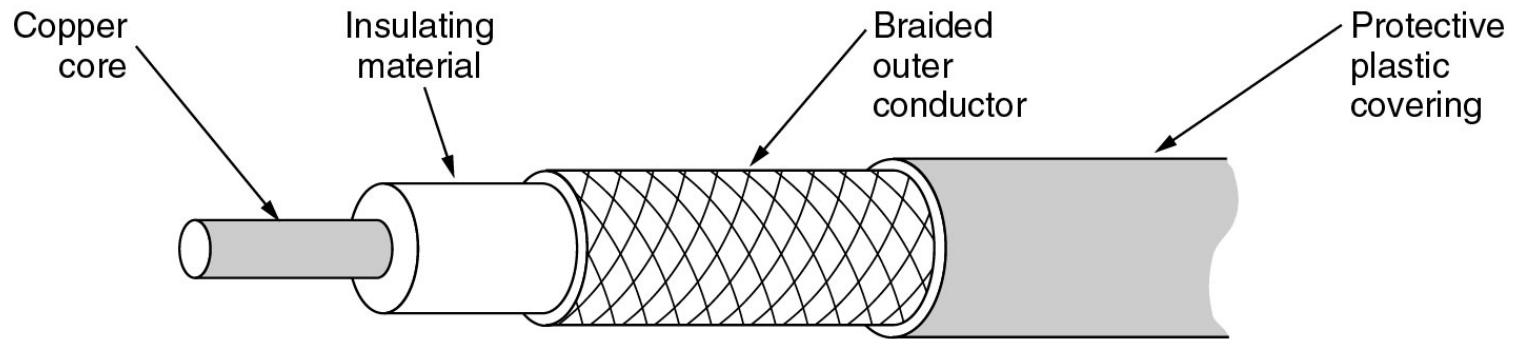- Twisted Pair
- Coaxial Cable
- Fiber Optics

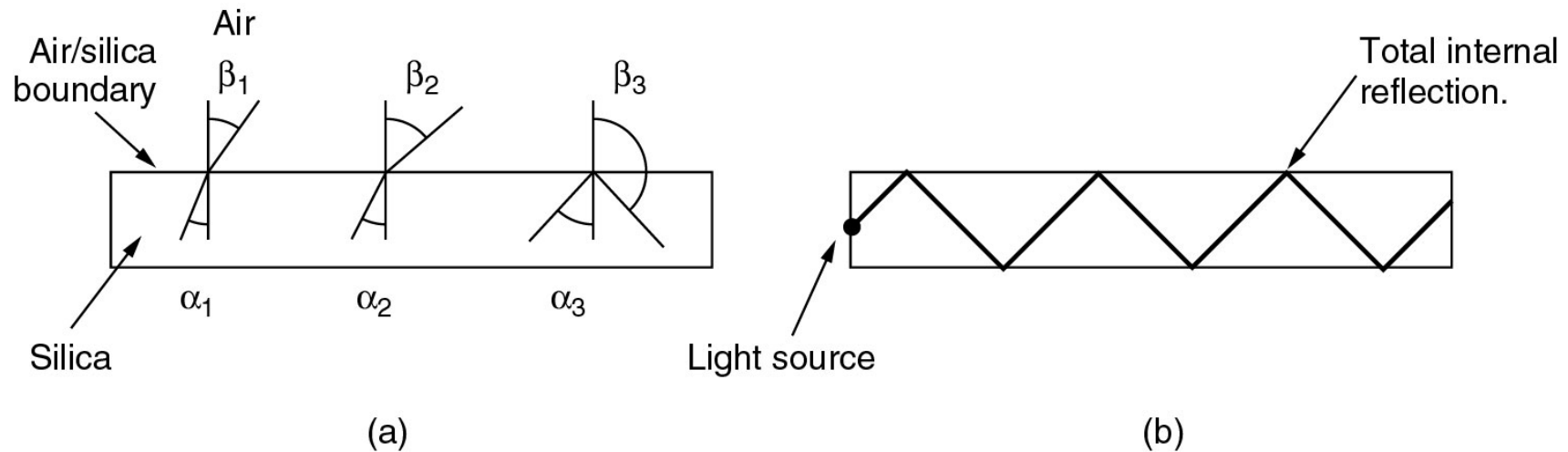# Twisted Pair

(a)

(b)

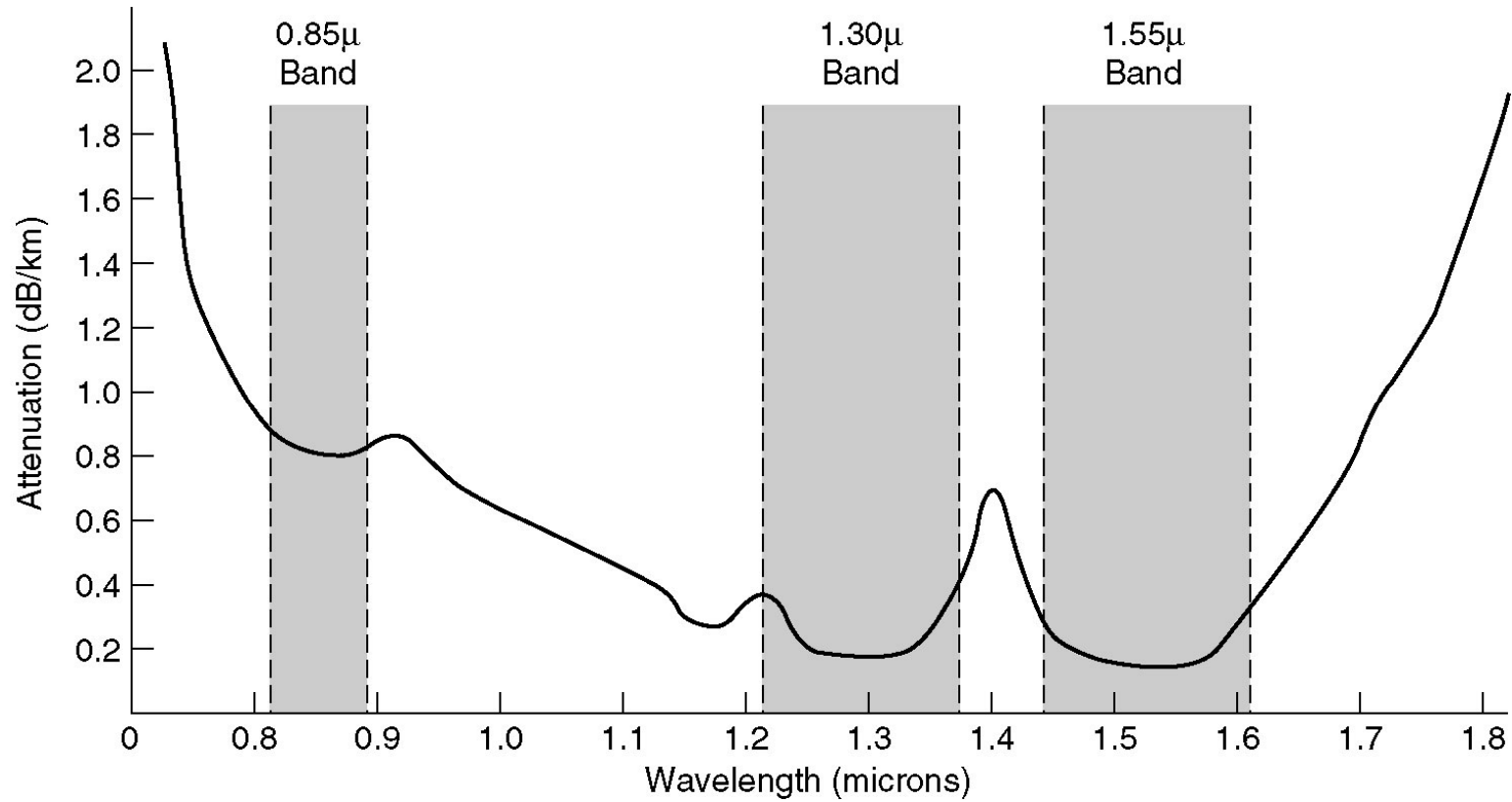(a) Category 3 UTP.
(b) Category 5 UTP.

# Coaxial Cable

A coaxial cable.

Fiber Optics

(a)

(b)

(a) Three examples of a light ray from inside a silica fiber impinging on the air/silica boundary at different angles.

(b) Light trapped by total internal reflection.

Transmission of Light through Fiber

Attenuation of light through fiber in the infrared region.

Fiber Cables

Core
(glass)

Cladding
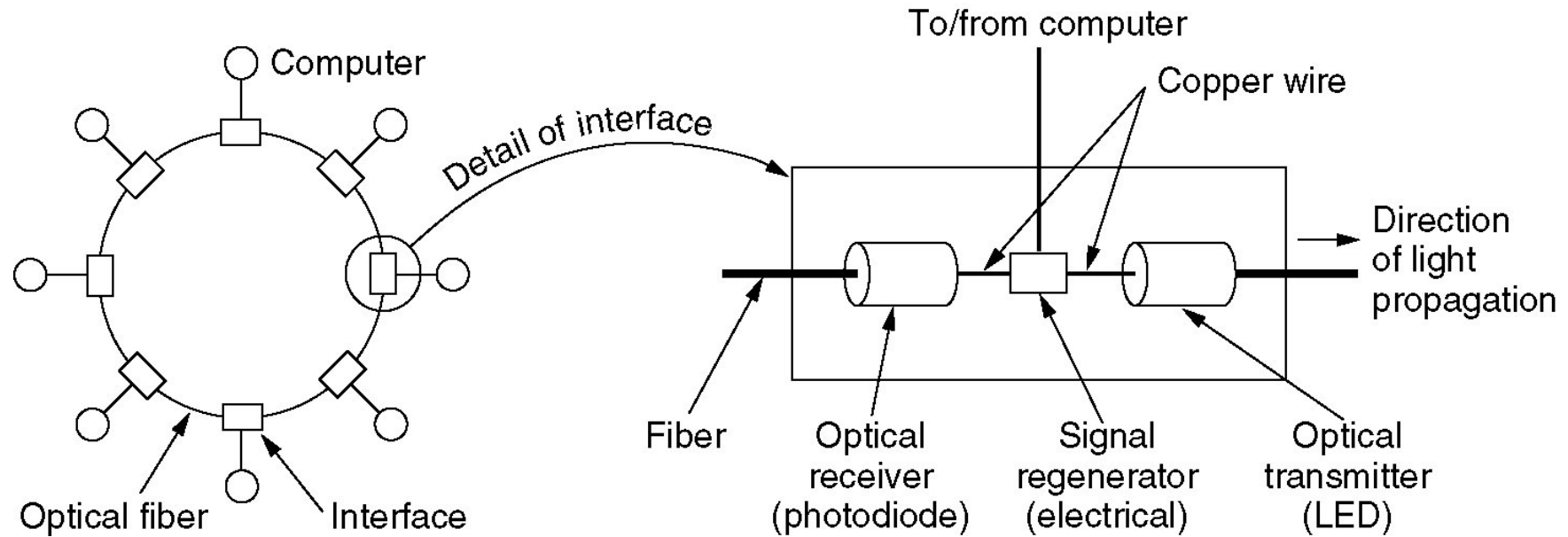(glass)

Jacket
(plastic)

(a)

Sheath

Jacket

Core

Cladding

(b)
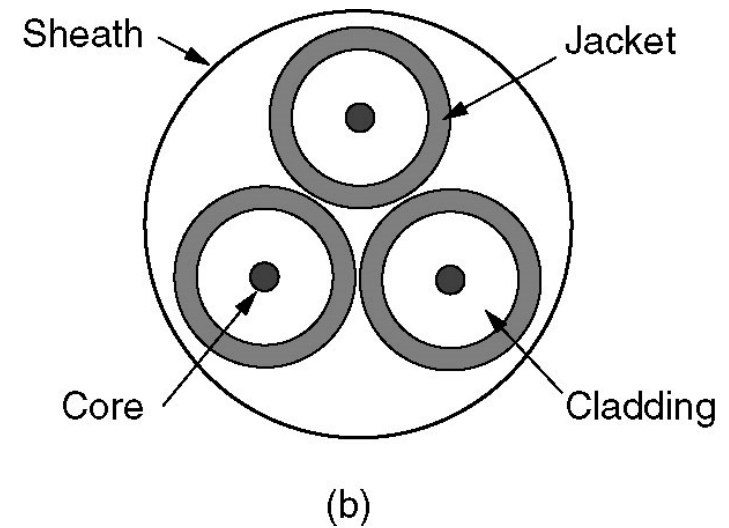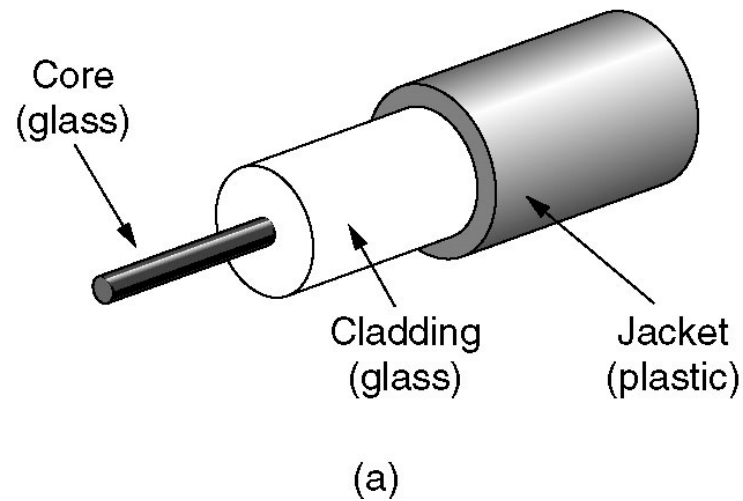
(a) Side view of a single fiber.
(b) End view of a sheath with three fibers.
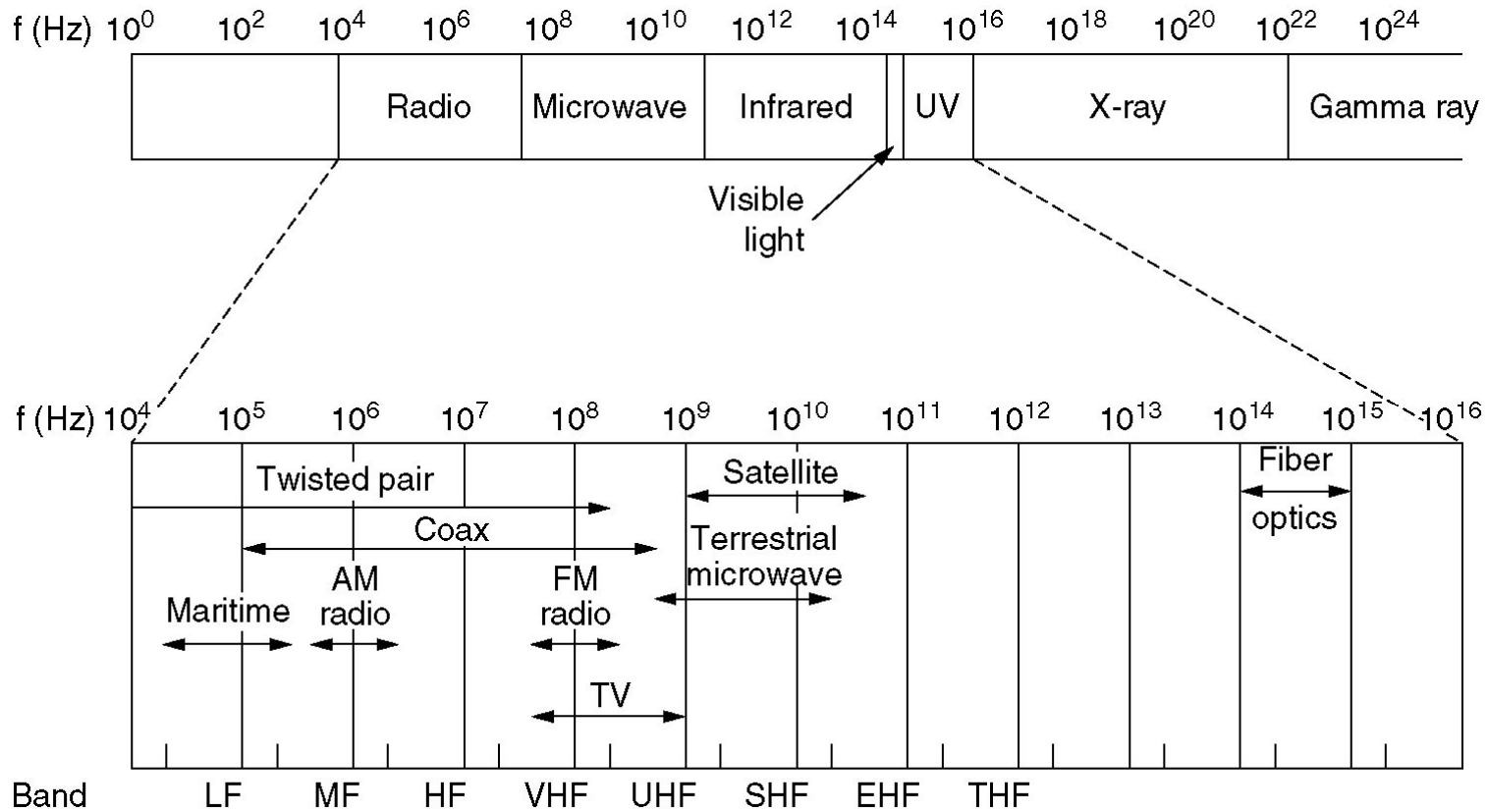
Fiber Optic Networks

A fiber optic ring with active repeaters.
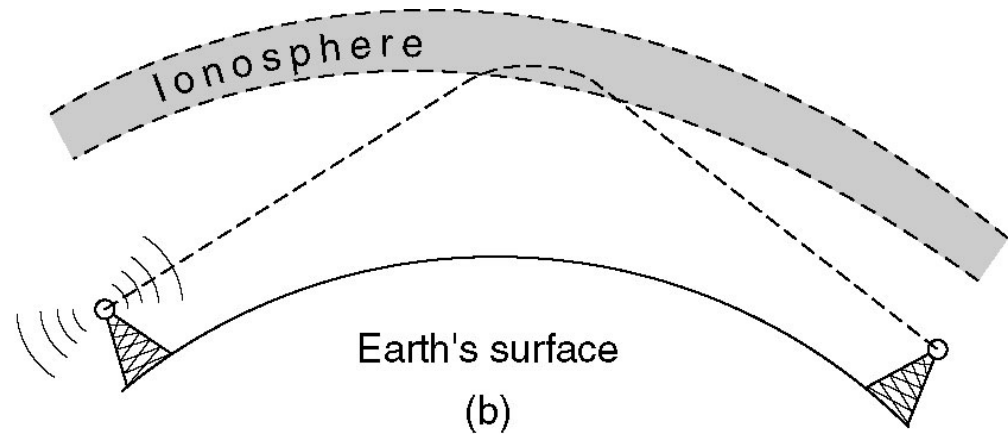
Wireless Transmission
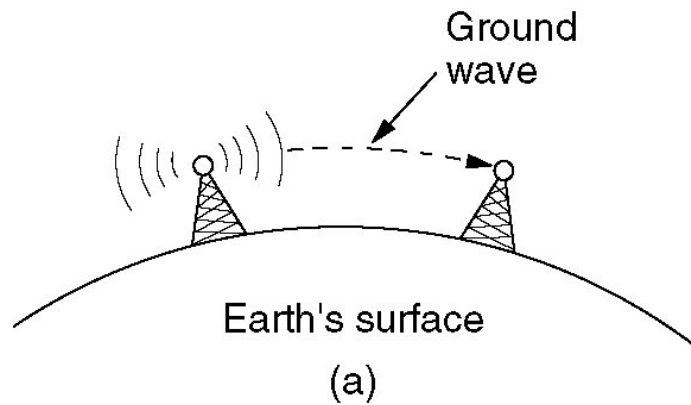
- The Electromagnetic Spectrum

- Radio Transmission

- Microwave Transmission

- Infrared and Millimeter Waves

- Lightwave Transmission

The Electromagnetic Spectrum

The electromagnetic spectrum and its uses for communication.

Radio Transmission

(a) In the VLF, LF, and MF bands, radio waves follow the curvature of the earth.

(b) In the HF band, they bounce off the ionosphere.

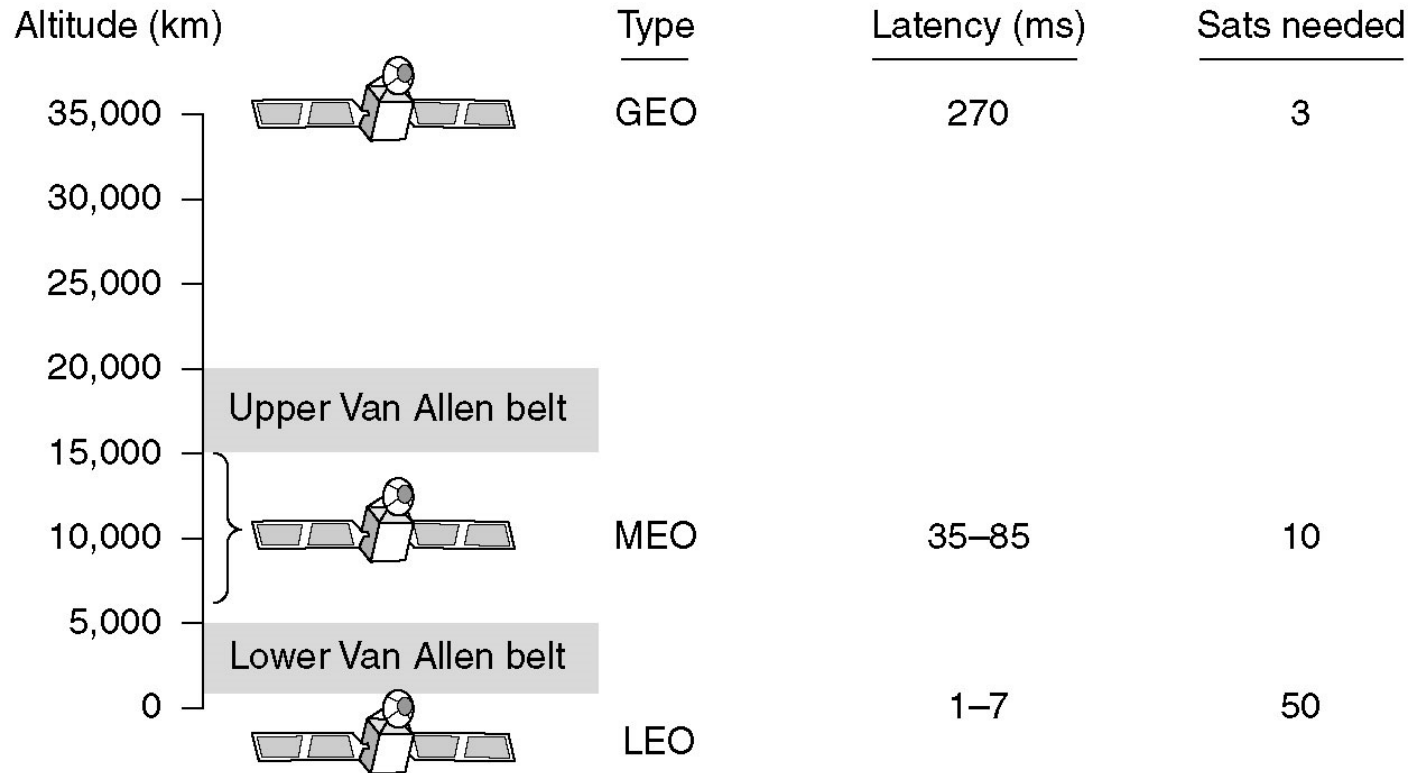# Politics of the Electromagnetic Spectrum
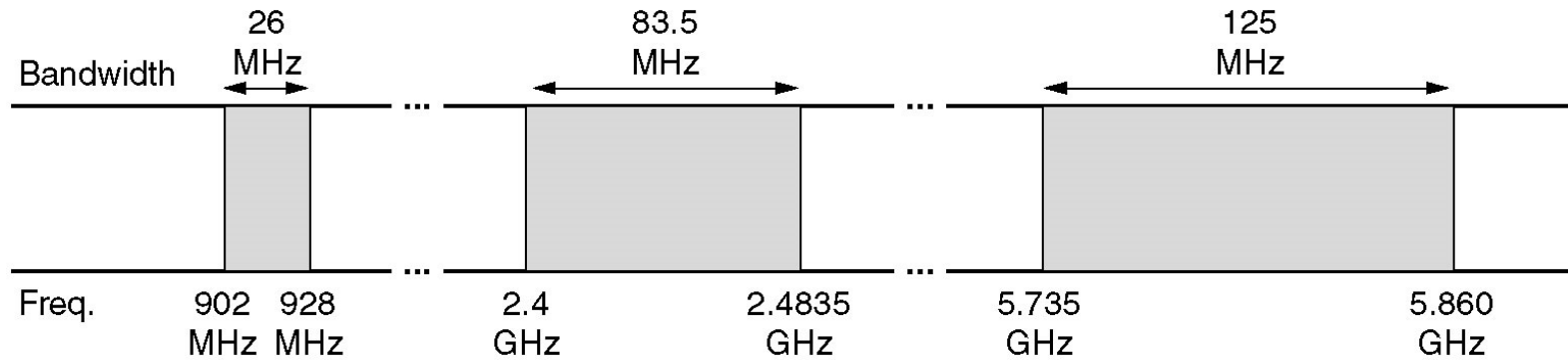
The ISM bands in the United States.

Communication Satellites

- Geostationary Satellites

- Medium-Earth Orbit Satellites

- Low-Earth Orbit Satellites

- Satellites versus Fiber

Communication Satellites

Altitude (km)		Type	Latency (ms)	Sats needed
35,000		GEO	270	3
30,000				
25,000				
20,000				
	Upper Van Allen belt			
15,000				
10,000		MEO	35–85	10
5,000				
	Lower Van Allen belt			
0			1–7	50
		LEO		

Communication satellites and some of their properties,
including altitude above the earth, round-trip delay time
and number of satellites needed for global coverage.

Communication Satellites (2)

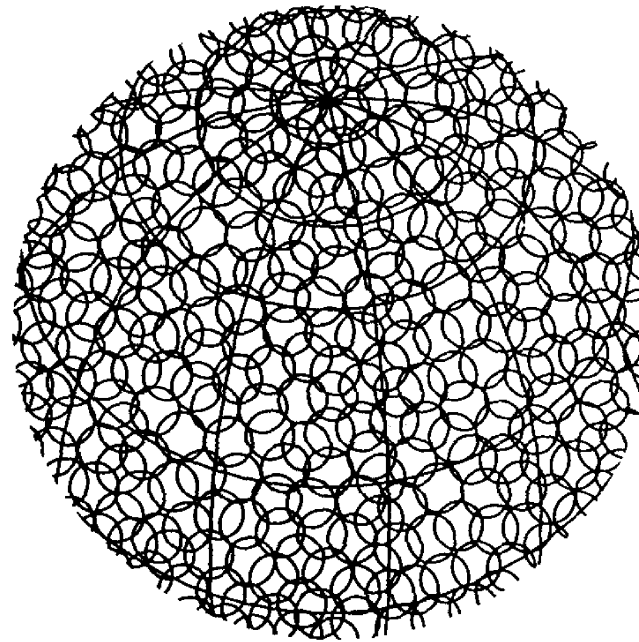| Band	Downlink	Uplink	Bandwidth	Problems
L	1.5 GHz	1.6 GHz	15 MHz	Low bandwidth; crowded
S	1.9 GHz	2.2 GHz	70 MHz	Low bandwidth; crowded
C	4.0 GHz	6.0 GHz	500 MHz	Terrestrial interference
Ku	11 GHz	14 GHz	500 MHz	Rain
Ka	20 GHz	30 GHz	3500 MHz	Rain, equipment cost

The principal satellite bands.
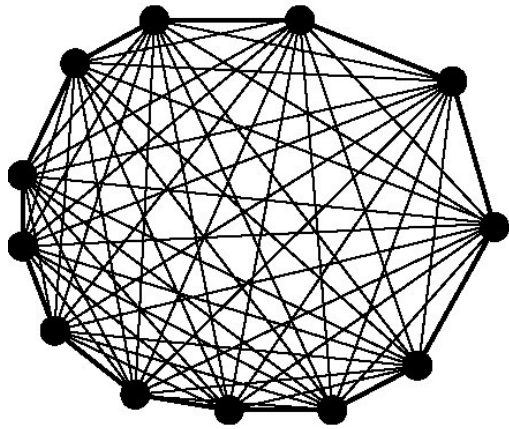
Low-Earth Orbit Satellites
Iridium
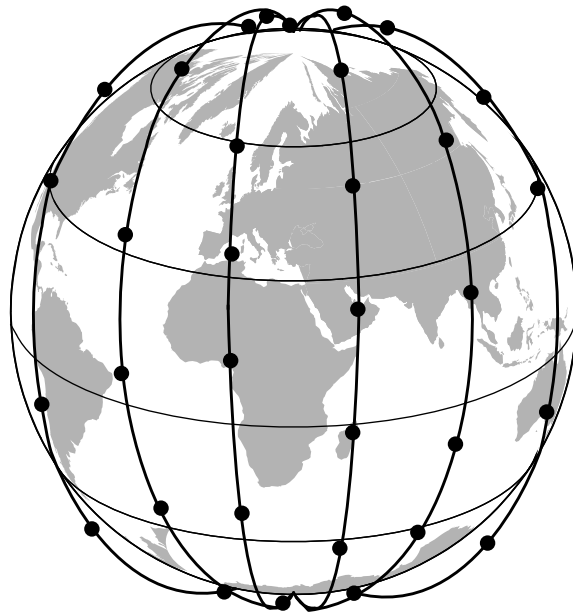
(a)

(b)

(a) The Iridium satellites from six necklaces around the earth.

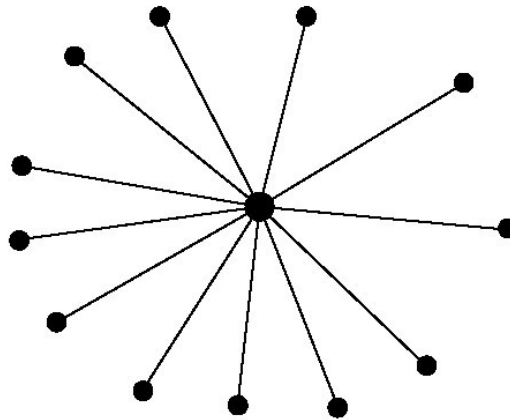(b) 1628 moving cells cover the earth.

Public Switched Telephone System

- Structure of the Telephone System

- The Politics of Telephones

- The Local Loop: Modems, ADSL and Wireless
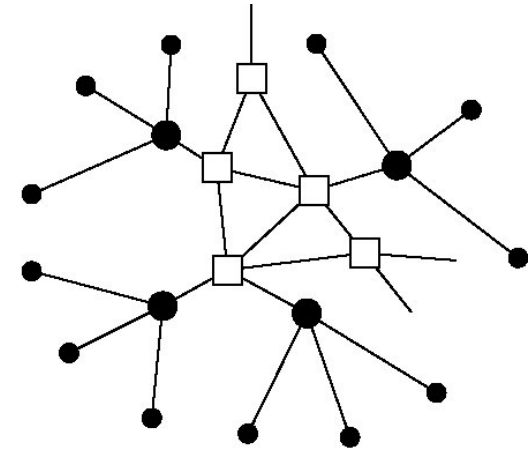
- Trunks and Multiplexing

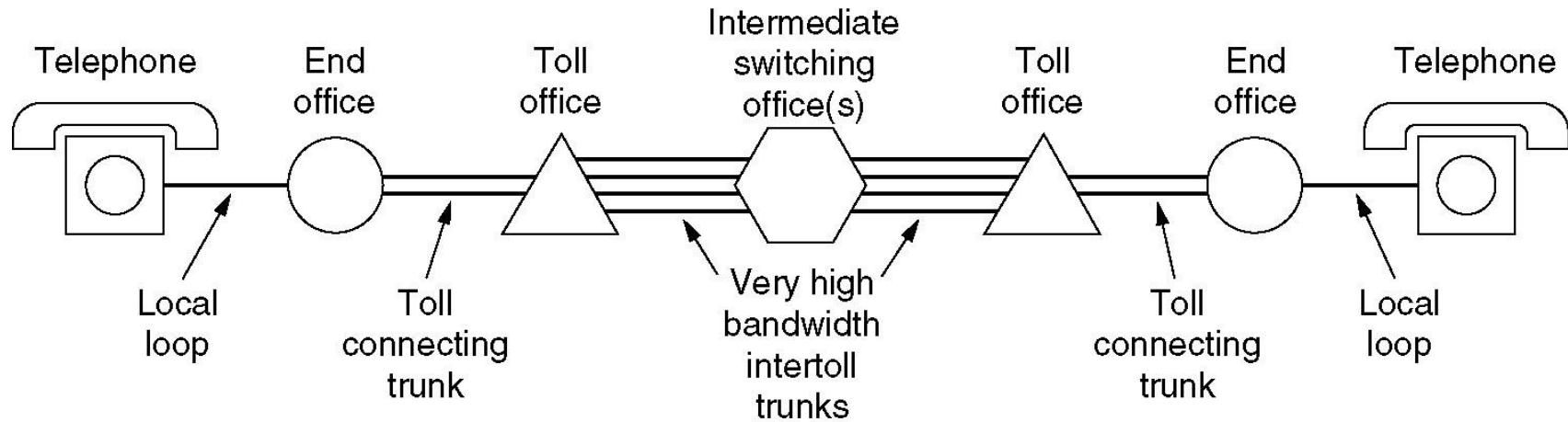- Switching

Structure of the Telephone System

(a)   (b)   (c)

(a) Fully-interconnected network.
(b) Centralized switch.
(c) Two-level hierarchy.

Structure of the Telephone System (2)

A typical circuit route for a medium-distance call.

# Major Components of the Telephone System

- Local loops
  - Analog twisted pairs going to houses and businesses

- Trunks
  - Digital fiber optics connecting the switching offices

- Switching offices
  - Where calls are moved from one trunk to another

The Local Loop: Modems, ADSL, and Wireless
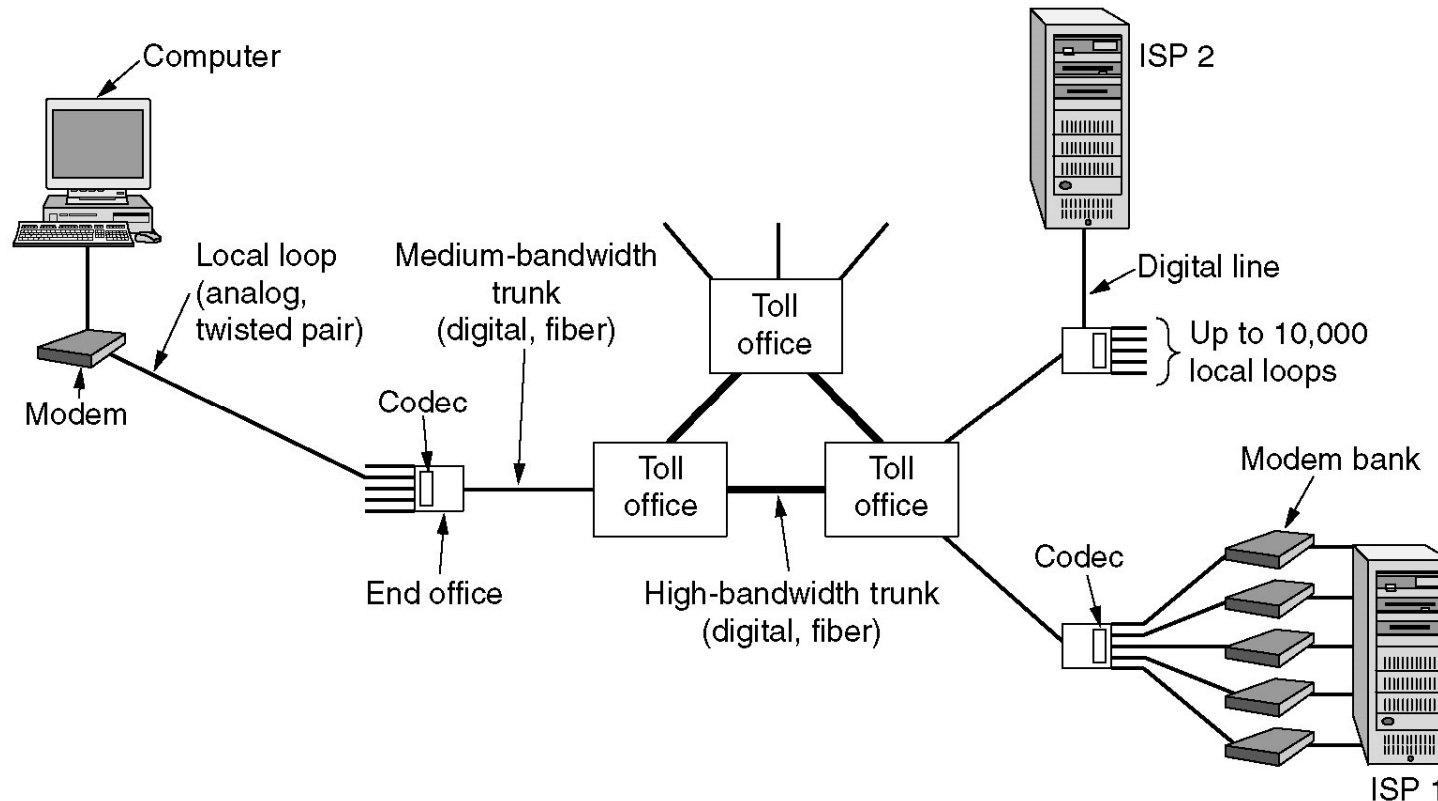
The use of both analog and digital transmissions for a computer to computer call. Conversion is done by the modems and codecs.

Modems

(a) A binary signal   (c) Frequency modulation
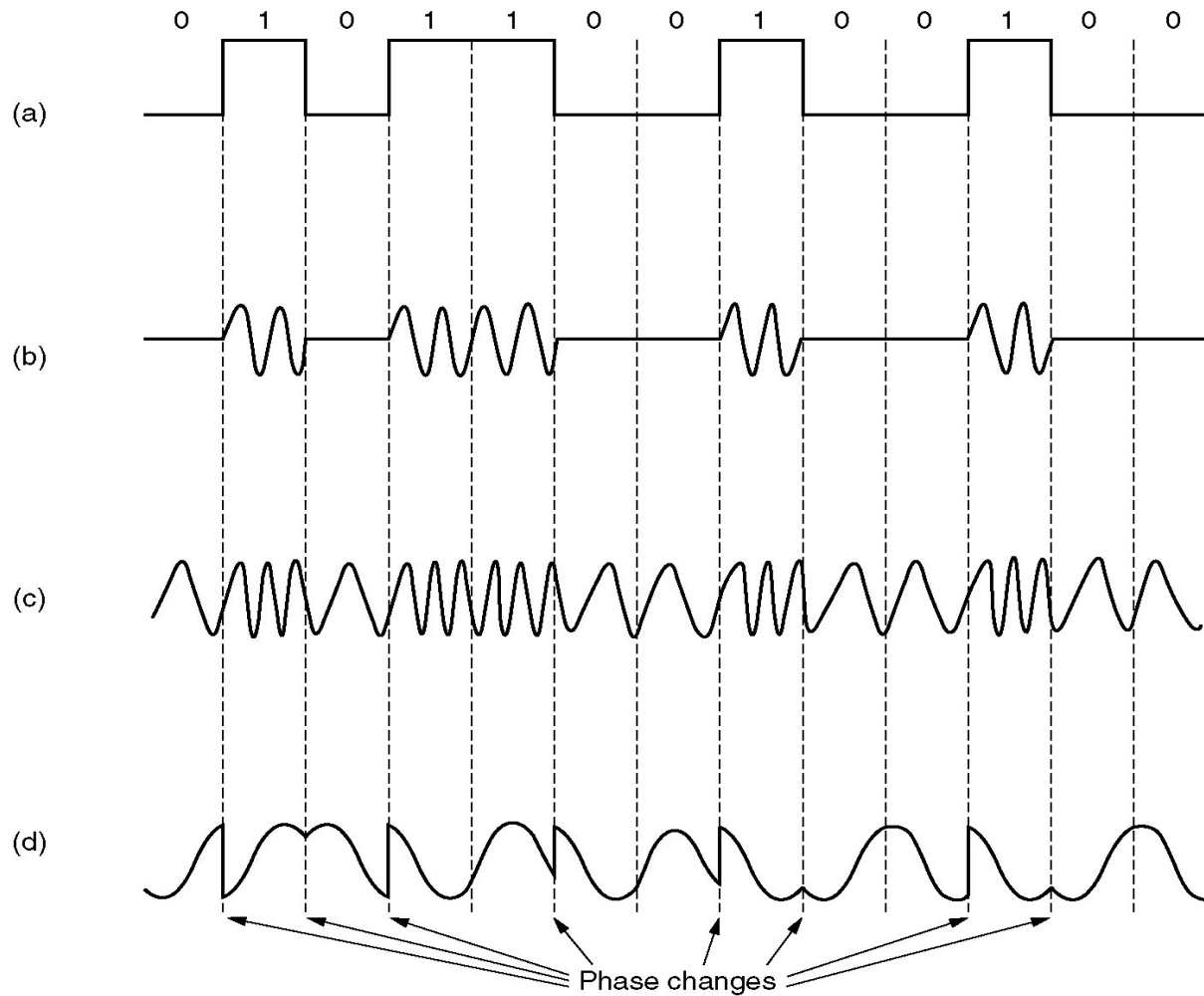
(b) Amplitude modulation   (d) Phase modulation

Modems (2)
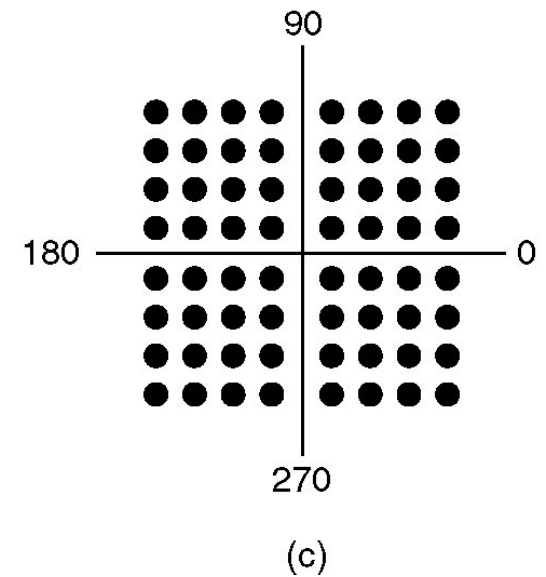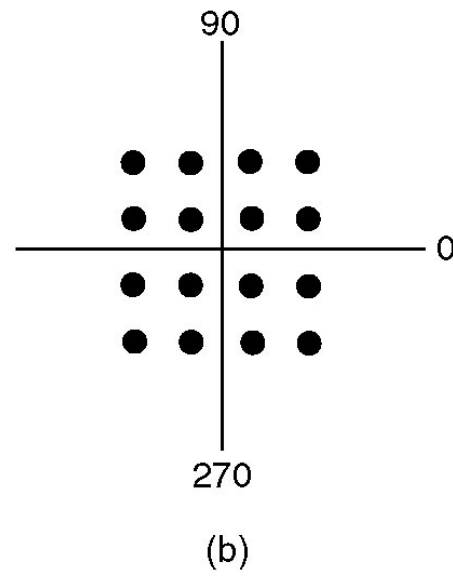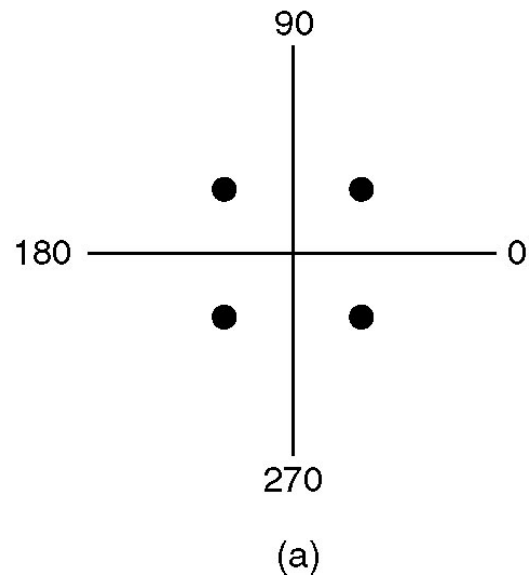
(a) QPSK.
(b) QAM-16.
(c) QAM-64.

Modems (3)
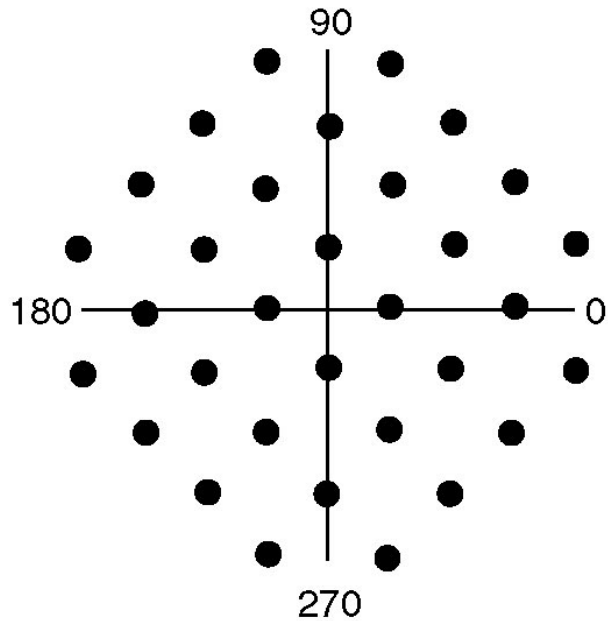
(a)
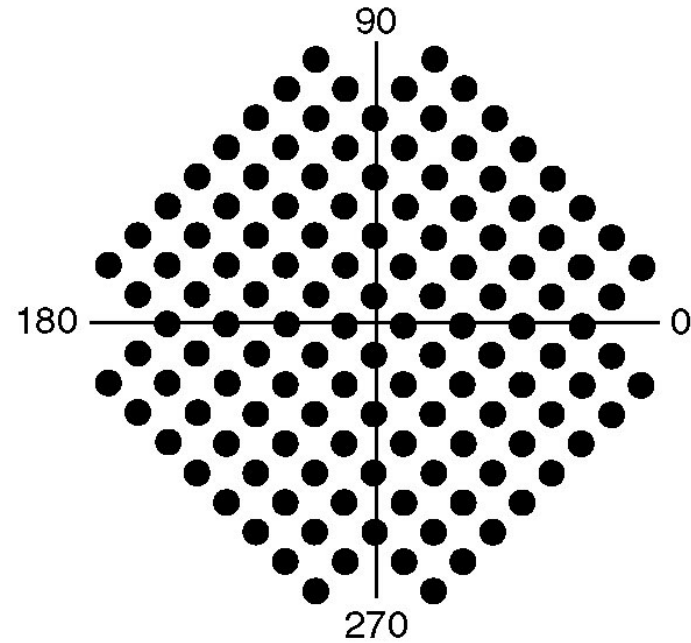
(b)

(a) V.32 for 9600 bps.
(b) V32 bis for 14,400 bps.

Wireless Local Loops
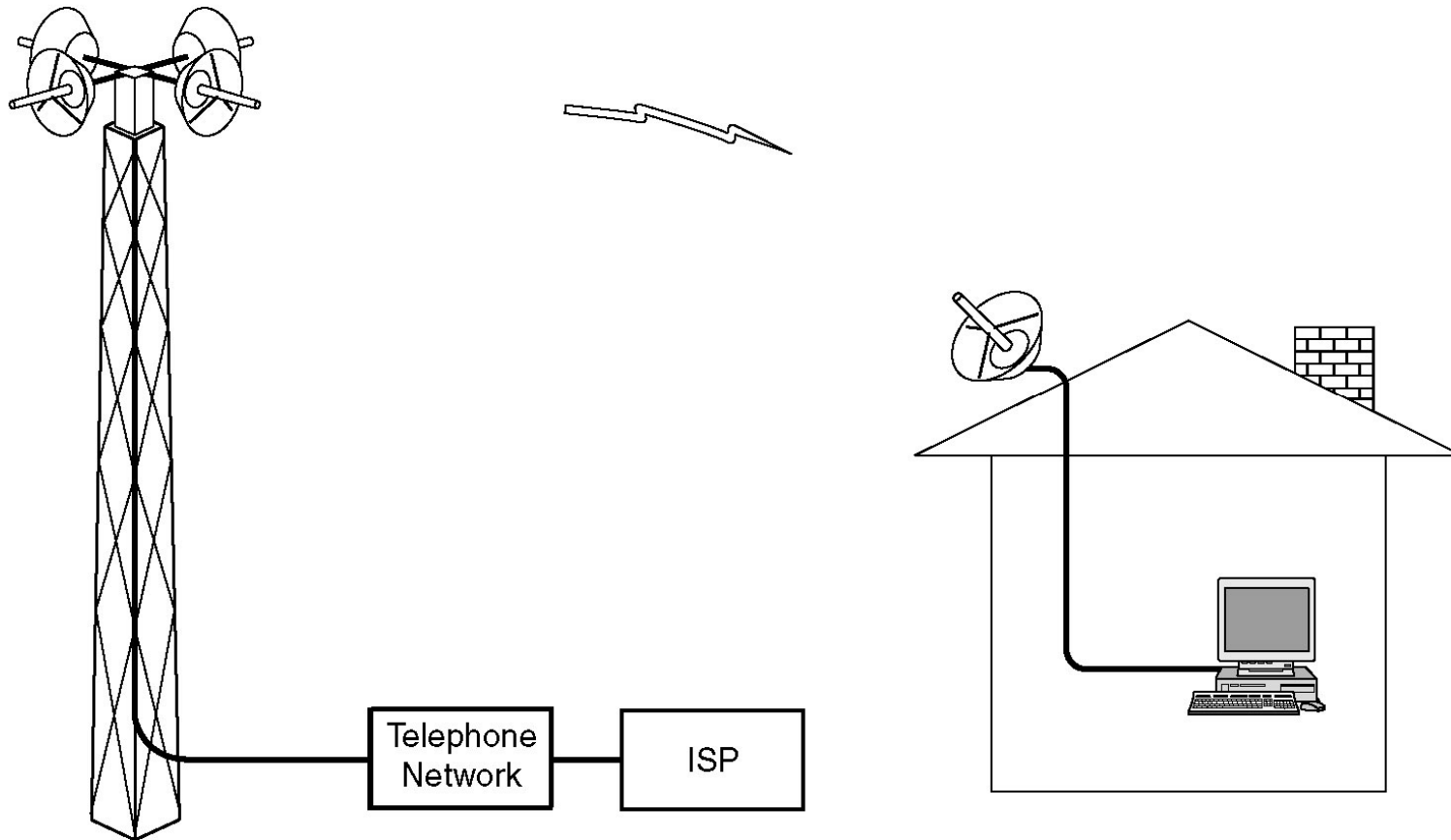
Architecture of an LMDS system.

Frequency Division Multiplexing

(a) The original bandwidths.

(b) The bandwidths raised in frequency.

(b) The multiplexed channel.

Time Division Multiplexing

The T1 carrier (1.544 Mbps).

Time Division Multiplexing (3)
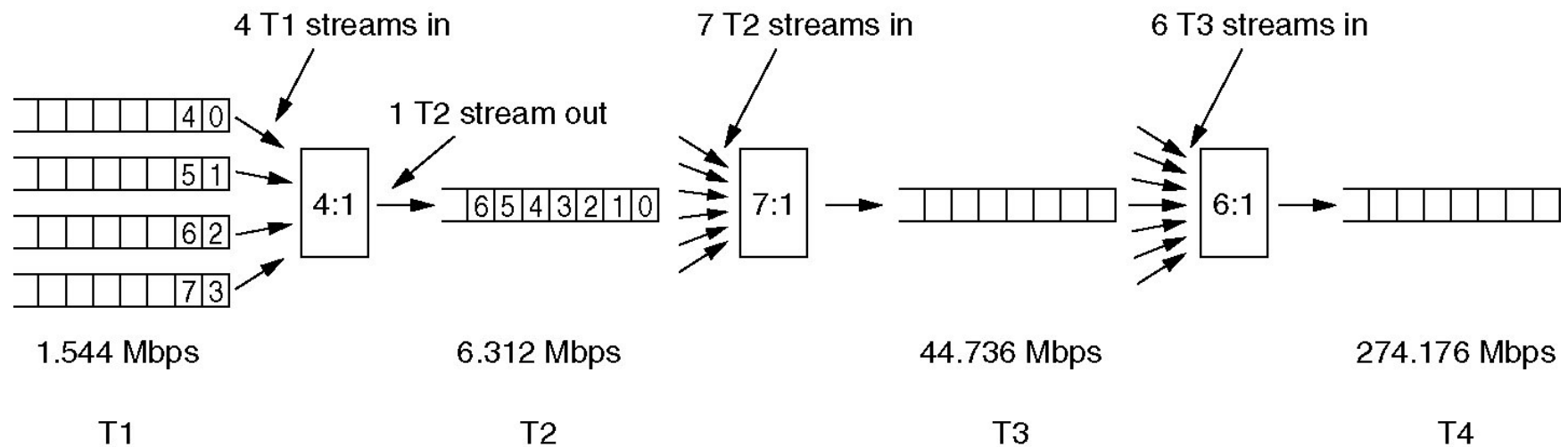
Multiplexing T1 streams into higher carriers.

Circuit Switching
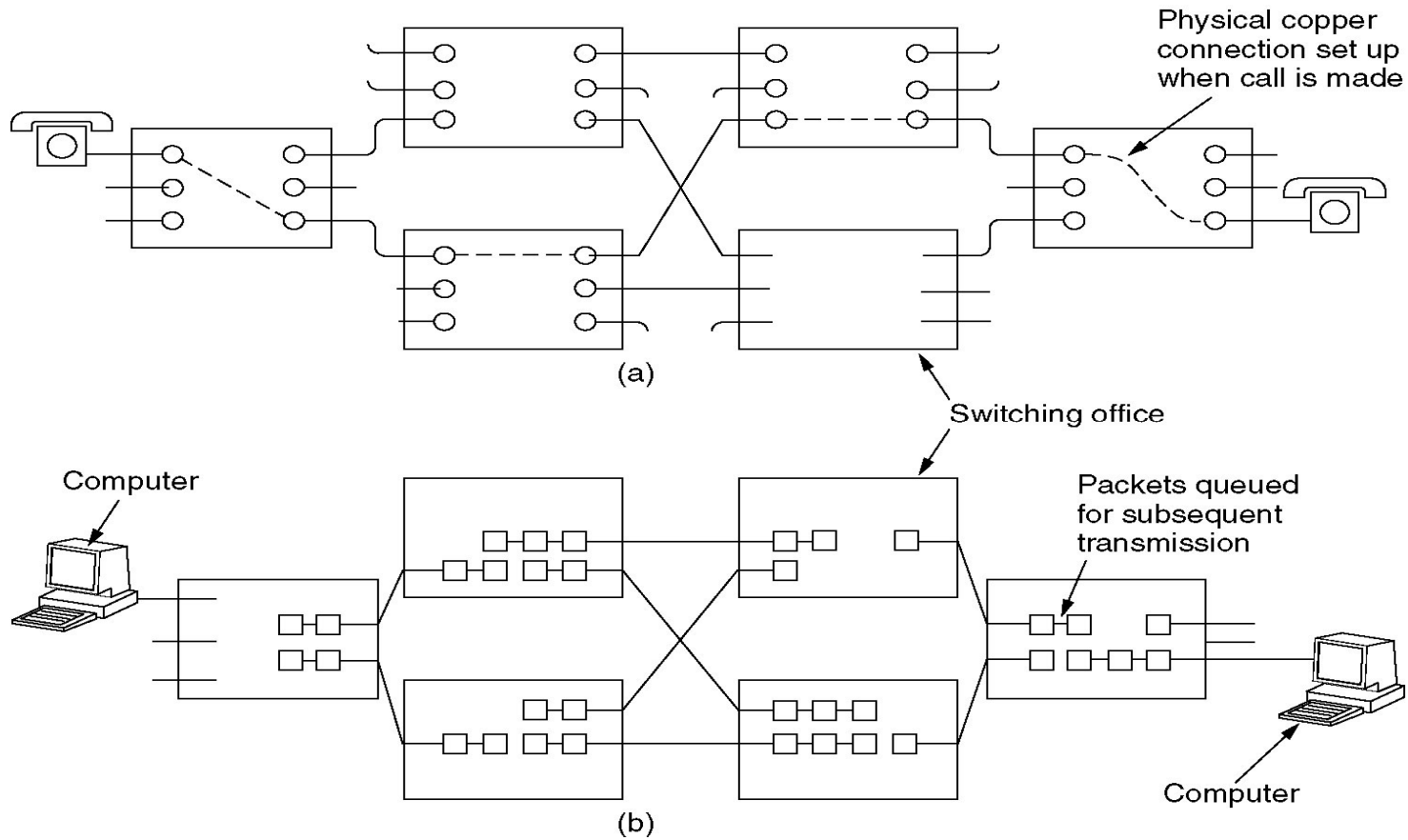
(a) Circuit switching.
(b) Packet switching.

Packet Switching

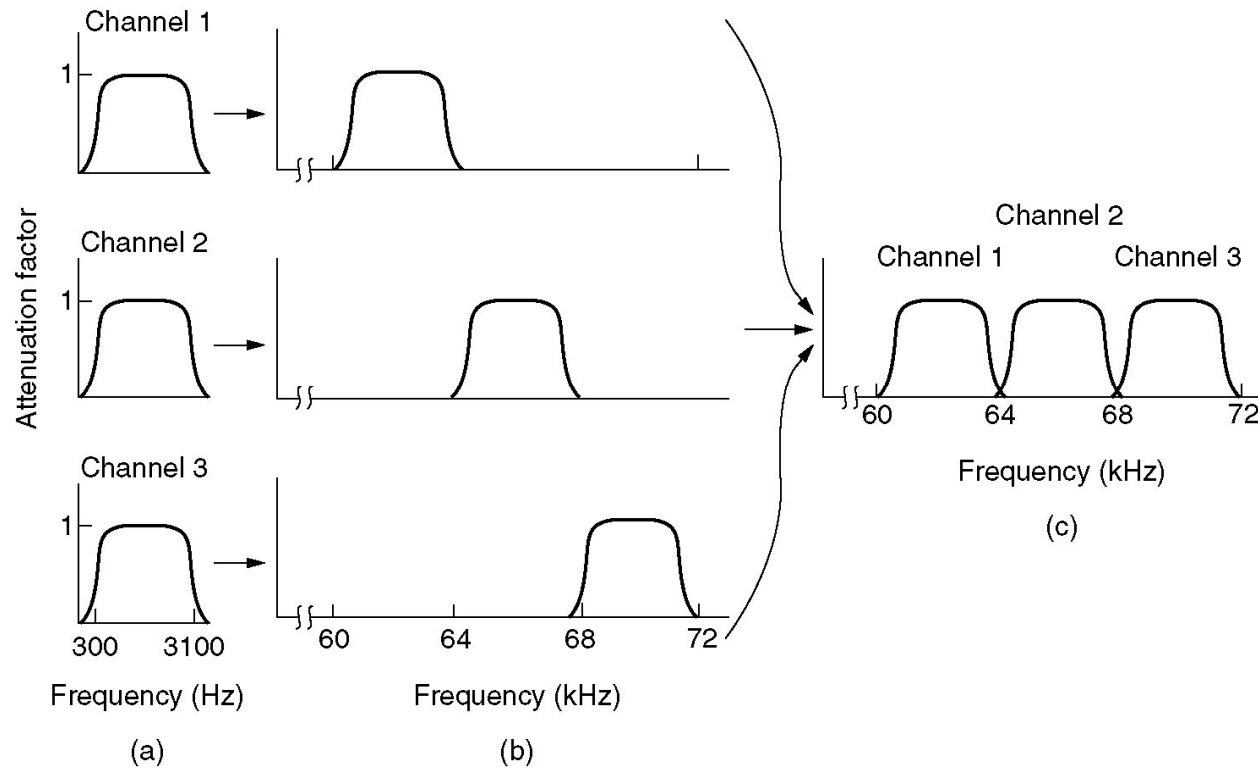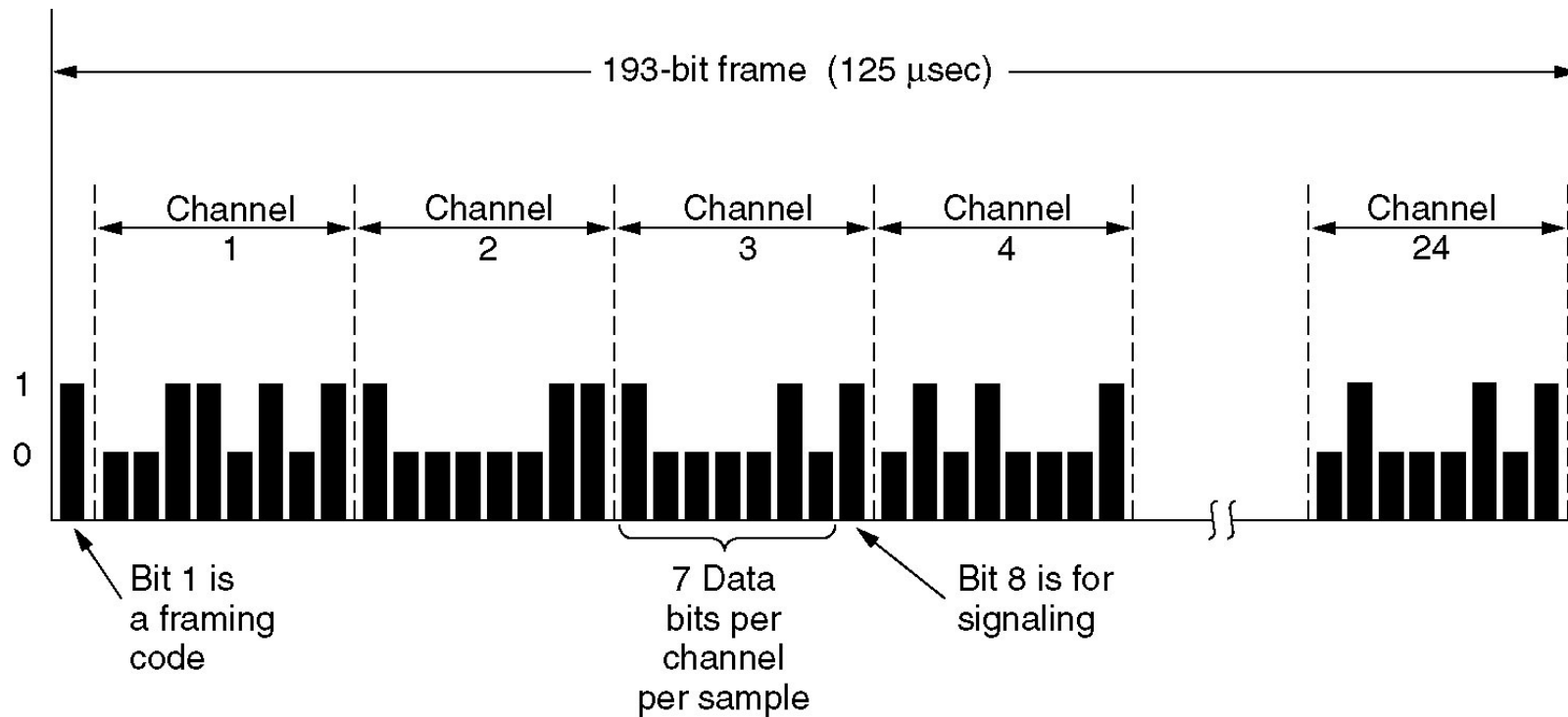| Item	Circuit-switched	Packet-switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
When can congestion occur	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

A comparison of circuit switched and packet-switched networks.

The Mobile Telephone System

- First-Generation Mobile Phones: Analog Voice

- Second-Generation Mobile Phones: Digital Voice

- Third-Generation Mobile Phones: Digital Voice and Data

Advanced Mobile Phone System
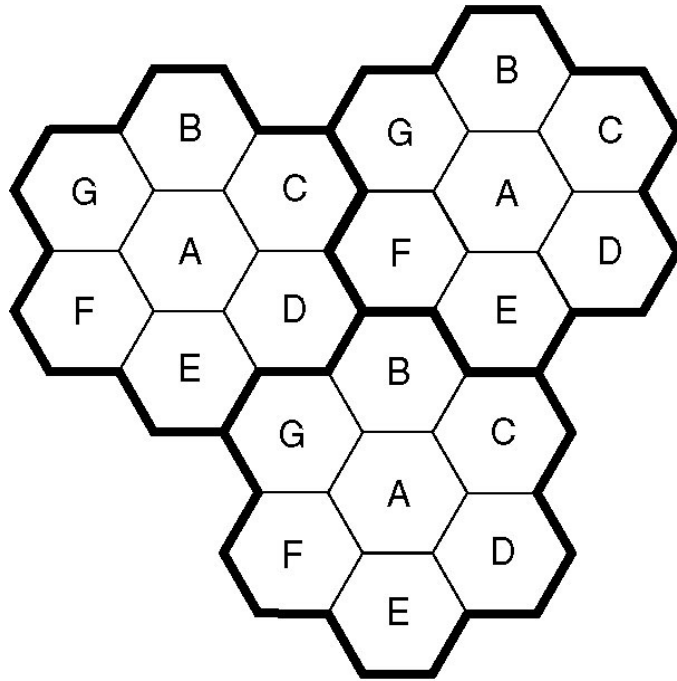
(a)

(b)

(a) Frequencies are not reused in adjacent cells.

(b) To add more users, smaller cells can be used.

CDMA – Code Division Multiple Access

A: 0 0 0 1 1 0 1 1   A: (−1 −1 −1 +1 +1 −1 +1 +1)
B: 0 0 1 0 1 1 1 0   B: (−1 −1 +1 −1 +1 +1 +1 −1)
C: 0 1 0 1 1 1 0 0   C: (−1 +1 −1 +1 +1 +1 −1 −1)
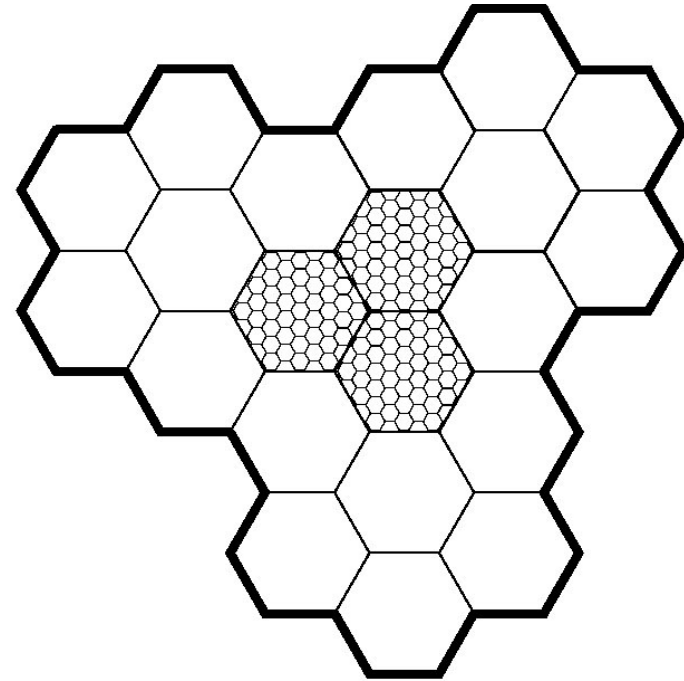D: 0 1 0 0 0 0 1 0   D: (−1 +1 −1 −1 −1 −1 +1 −1)

         (a)   (b)

Six examples:

$$
\begin{array}{llll}
-\ -\ 1\ - & \mathbf{C} & S_1 = (−1\ +1\ −1\ +1\ +1\ +1\ −1\ −1) \\
-\ 1\ 1\ - & \mathbf{B} + \underline{\mathbf{C}} & S_2 = (−2\ \ 0\ \ \ 0\ \ \ 0\ +2\ +2\ \ \ 0\ −2) \\
1\ 0\ -\ - & \mathbf{A} + \underline{\mathbf{B}} & S_3 = (\ \ 0\ \ \ 0\ −2\ +2\ \ \ 0\ −2\ \ \ 0\ +2) \\
1\ 0\ 1\ - & \mathbf{A} + \mathbf{B} + \mathbf{C} & S_4 = (−1\ +1\ −3\ +3\ +1\ −1\ −1\ +1) \\
1\ 1\ 1\ 1 & \mathbf{A} + \mathbf{B} + \mathbf{C} + \mathbf{D} & S_5 = (−4\ \ \ 0\ −2\ \ \ 0\ +2\ \ \ 0\ +2\ −2) \\
1\ 1\ 0\ 1 & \mathbf{A} + \mathbf{B} + \overline{\mathbf{C}} + \mathbf{D} & S_6 = (−2\ −2\ \ \ 0\ −2\ \ \ 0\ −2\ +4\ \ \ 0)
\end{array}
$$

                                 (c)

$S_1 \bullet C = (1\ +1\ +1\ +1\ +1\ +1\ +1\ +1)/8 = 1$
$S_2 \bullet C = (2\ +0\ +0\ +0\ +2\ +2\ +0\ +2)/8 = 1$
$S_3 \bullet C = (0\ +0\ +2\ +2\ +0\ −2\ +0\ −2)/8 = 0$
$S_4 \bullet C = (1\ +1\ +3\ +3\ +1\ −1\ +1\ −1)/8 = 1$
$S_5 \bullet C = (4\ +0\ +2\ +0\ +2\ +0\ −2\ +2)/8 = 1$
$S_6 \bullet C = (2\ −2\ +0\ −2\ +0\ −2\ −4\ +0)/8 = −1$

                       (d)

(a) Binary chip sequences for four stations
(b) Bipolar chip sequences
(c) Six examples of transmissions
(d) Recovery of station C's signal