Unit I:
Transmission Media and Switching

Guided Media: Twisted-Pair, Coaxial and Fiber-Optic Cable
Unguided Media: Radio Waves, Microwaves, Infrared
IEEE standard and connectors for media. (RJ45, RJ11, BNC, SC/ST etc.)
Circuit-switched Networks: Three Phases, Efficiency, Delay,
Packet switching : Datagram networks, Virtual circuit networks
Brief introduction of Digital Subscriber Line: ADSL, HDSL, SDSL, VDSL (DMT), Cable modem.

Figure 1.1 *Transmission medium and physical layer*

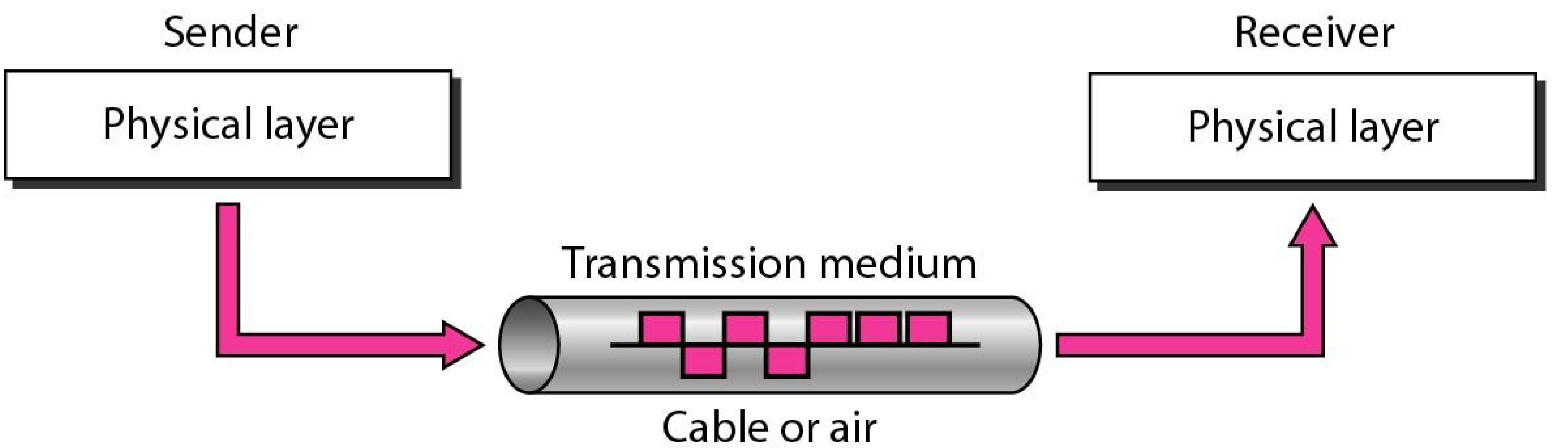
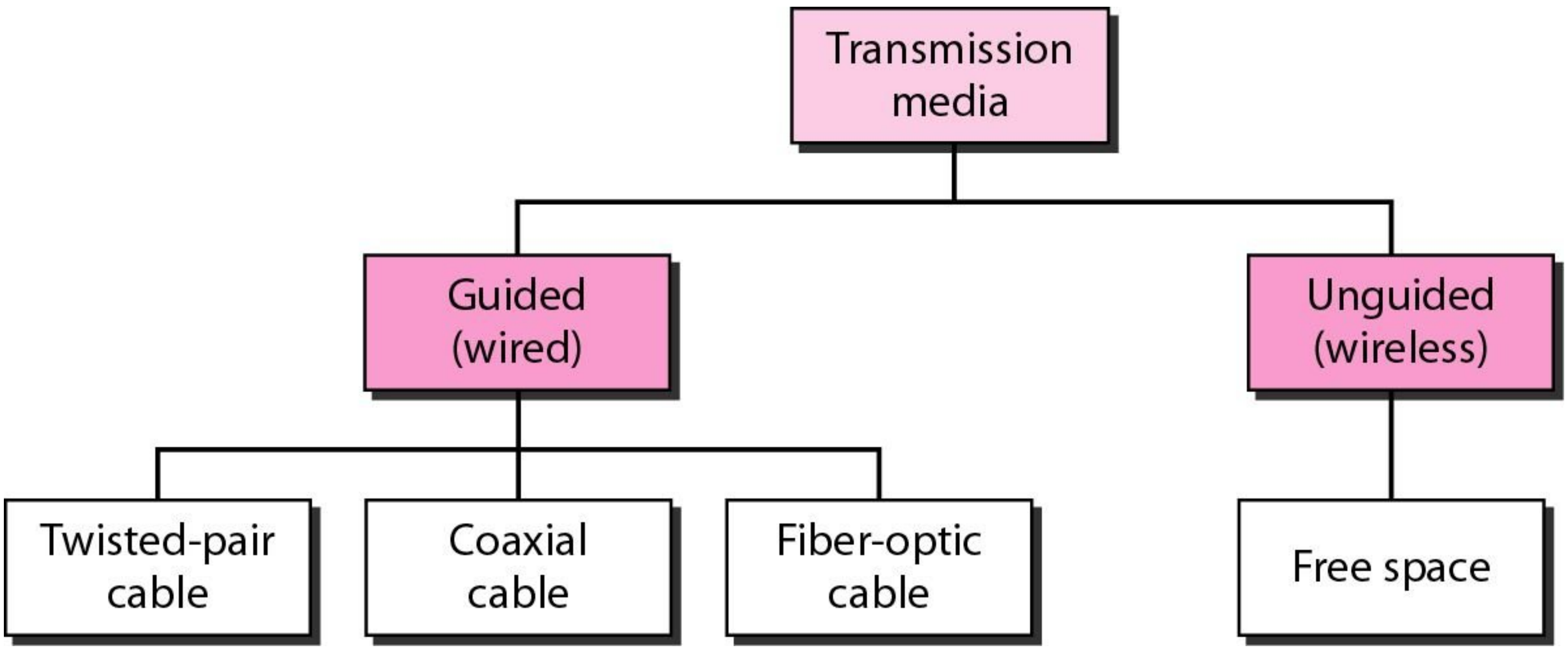


Figure 1.2 *Classes of transmission media*



1-1 GUIDED MEDIA

Guided media, which are those that provide a conduit from one device to another, include twisted-pair cable, coaxial cable, and fiber-optic cable.

Topics discussed in this section:

Twisted-Pair Cable
Coaxial Cable
Fiber-Optic Cable

Figure 1.3 *Twisted-pair cable*

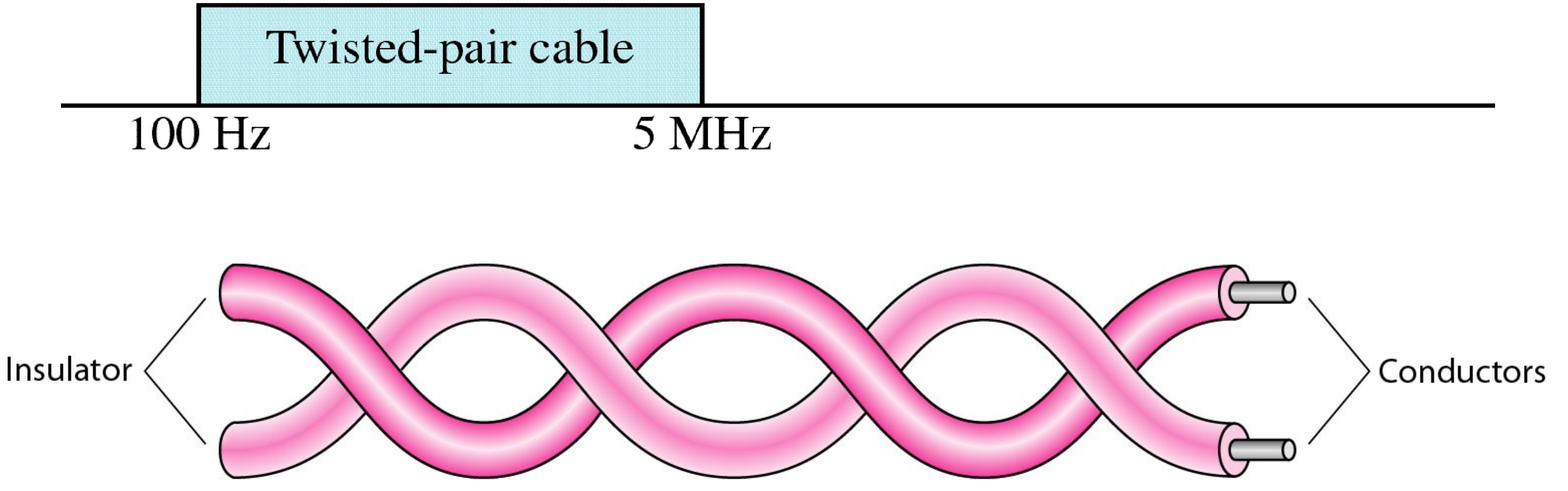


Figure 1.4 *UTP and STP cables*

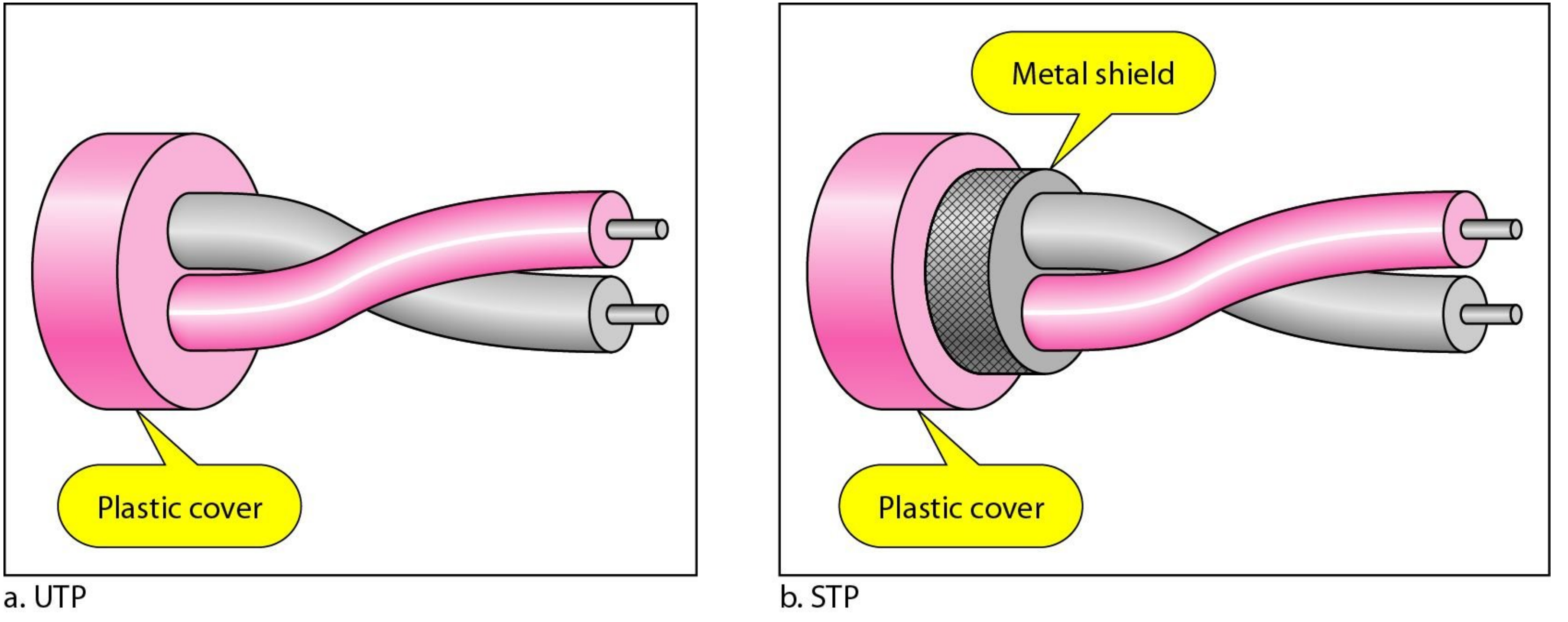


Figure 1-8

Unshielded Twisted-Pair Cable

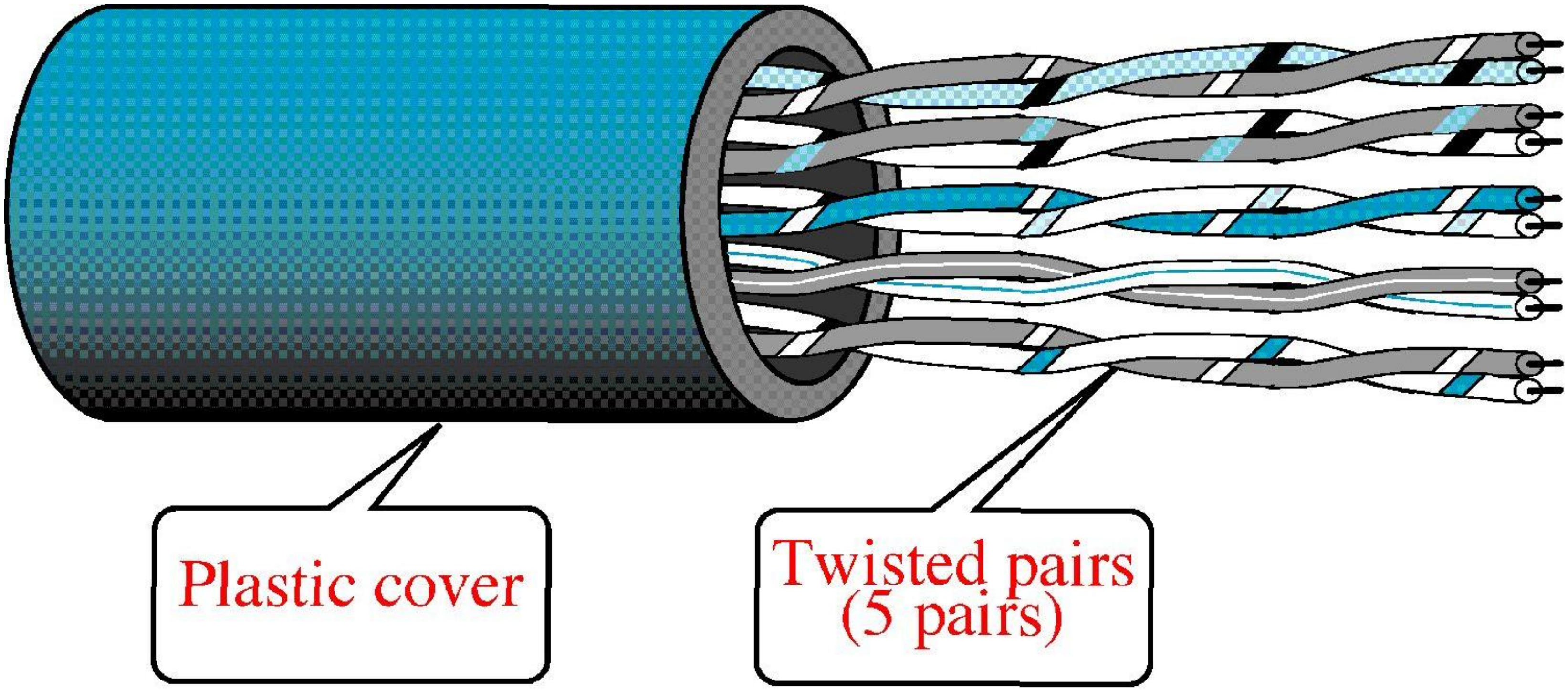


Figure 1-10

Shielded Twisted-Pair Cable

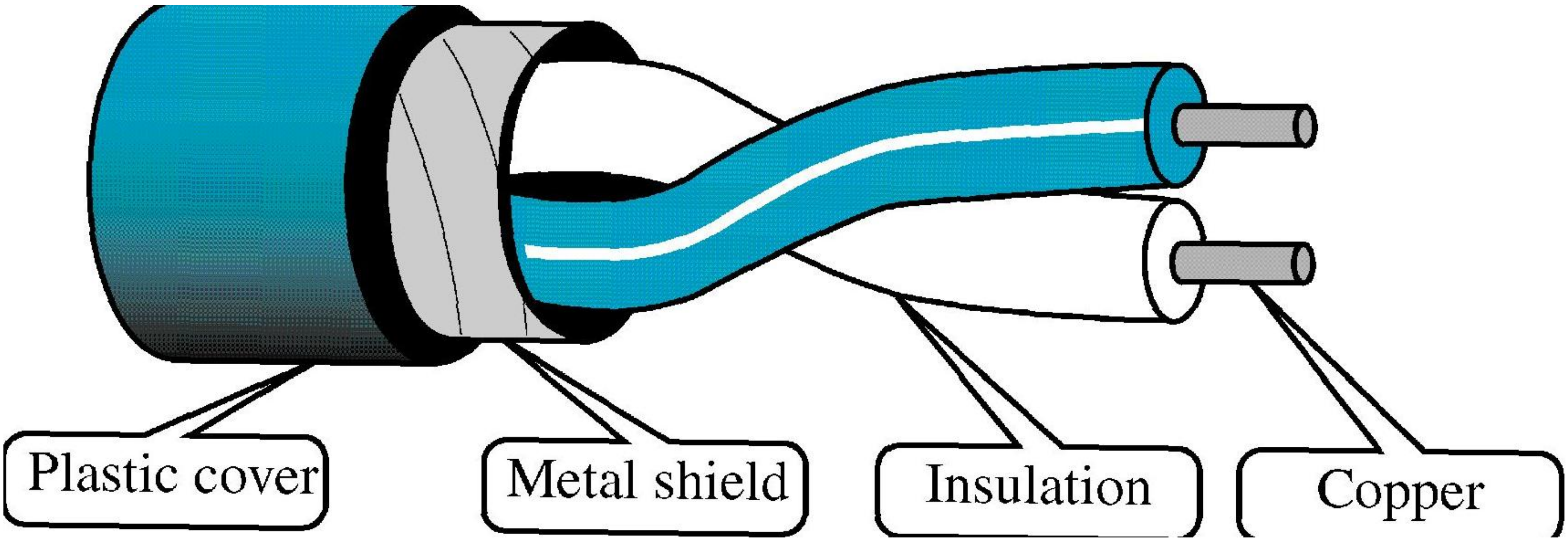


Table 1.1 *Categories of unshielded twisted-pair cables*

Category	*Specification*	*Data Rate (Mbps)*	*Use*
1	Unshielded twisted-pair used in telephone	< 0.1	Telephone
2	Unshielded twisted-pair originally used in T-lines	2	T-1 lines
3	Improved CAT 2 used in LANs	10	LANs
4	Improved CAT 3 used in Token Ring networks	20	LANs
5	Cable wire is normally 24 AWG with a jacket and outside sheath	100	LANs
5E	An extension to category 5 that includes extra features to minimize the crosstalk and electromagnetic interference	125	LANs
6	A new category with matched components coming from the same manufacturer. The cable must be tested at a 200-Mbps data rate.	200	LANs
7	Sometimes called SSTP (shielded screen twisted-pair). Each pair is individually wrapped in a helical metallic foil followed by a metallic foil shield in addition to the outside sheath. The shield decreases the effect of crosstalk and increases the data rate.	600	LANs

Figure 1.5 *UTP connector*

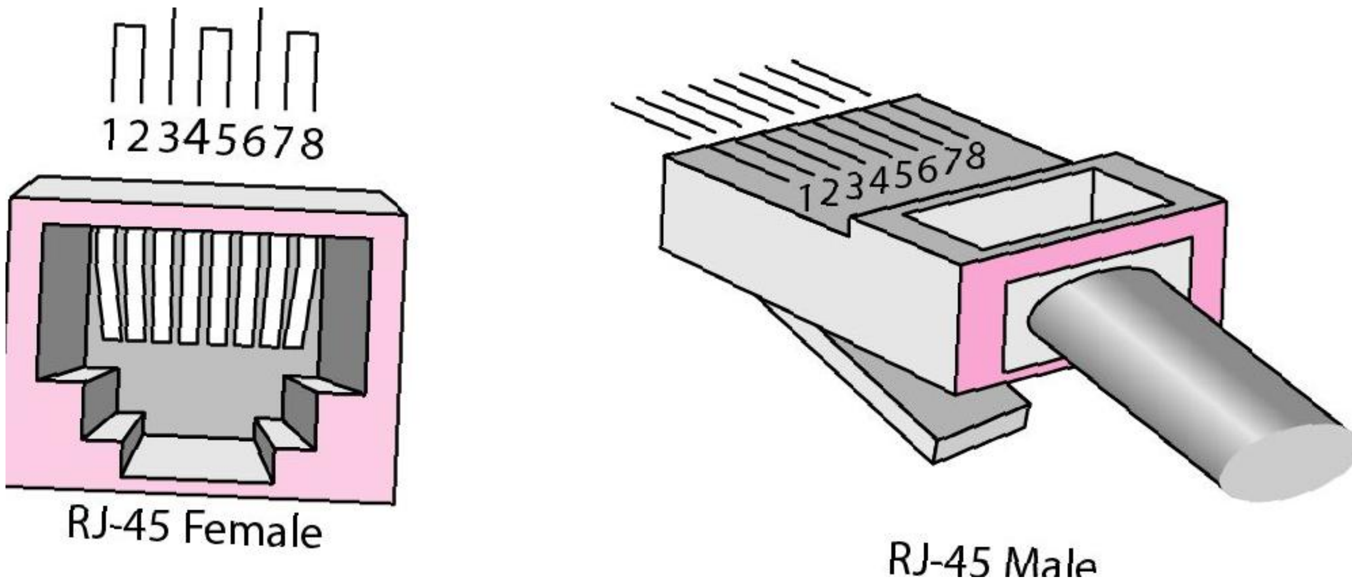
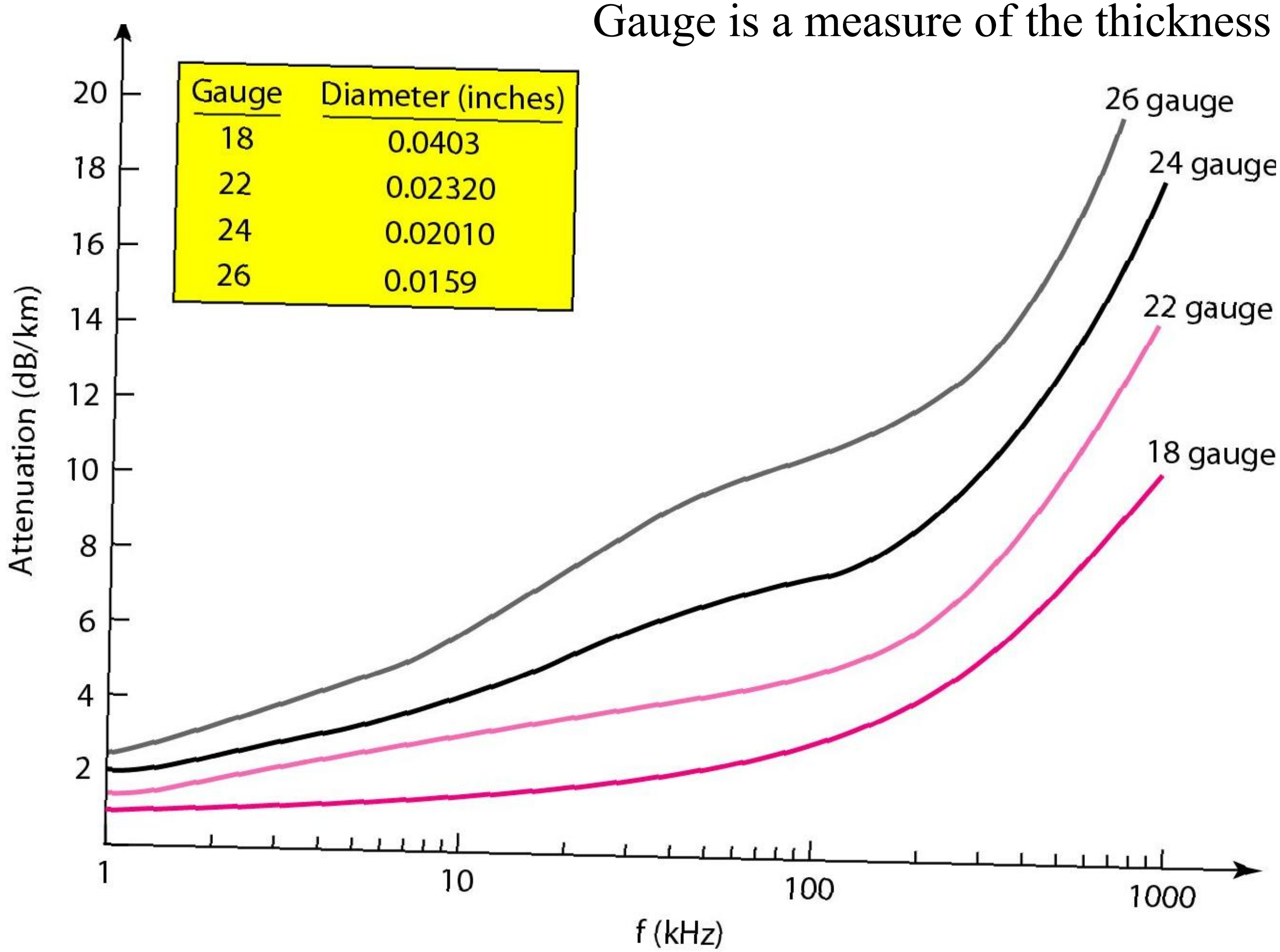


Figure 1.6 *UTP performance*

Gauge is a measure of the thickness of the wire



Twisted Pair

Applications:

1. Telephone lines
2. LAN

Coaxial Cable

Figure 1.1 *Coaxial cable*

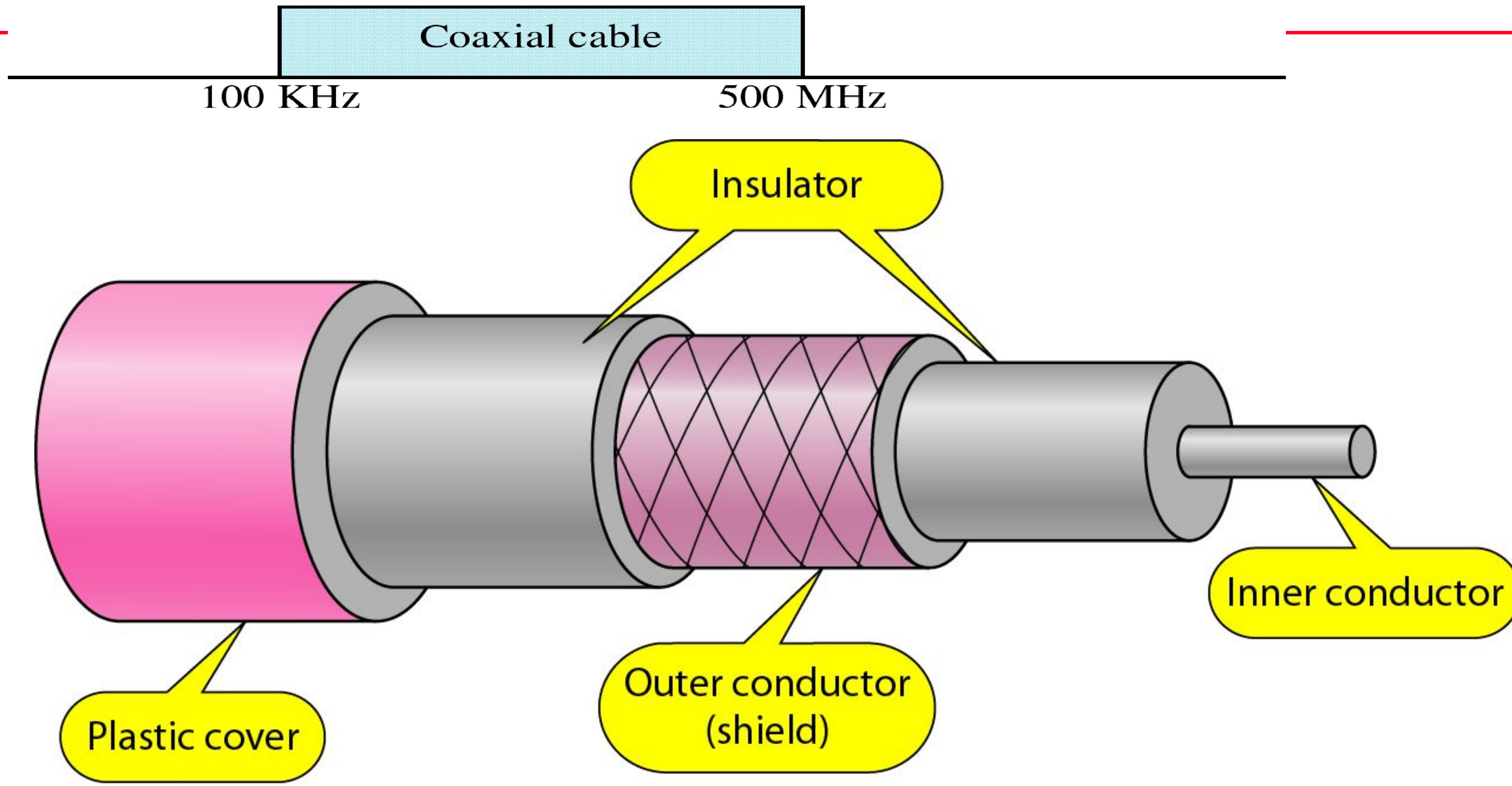
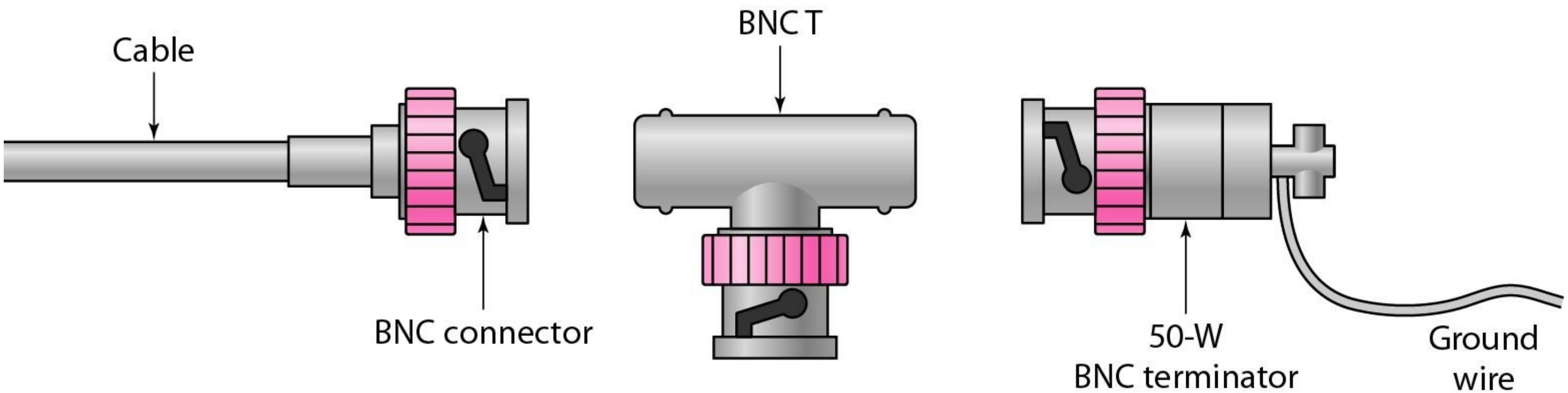


Table 1.2 *Categories of coaxial cables*

Category	*Impedance*	*Use*
RG-59	75 Ω	Cable TV
RG-58	50 Ω	Thin Ethernet
RG-11	50 Ω	Thick Ethernet

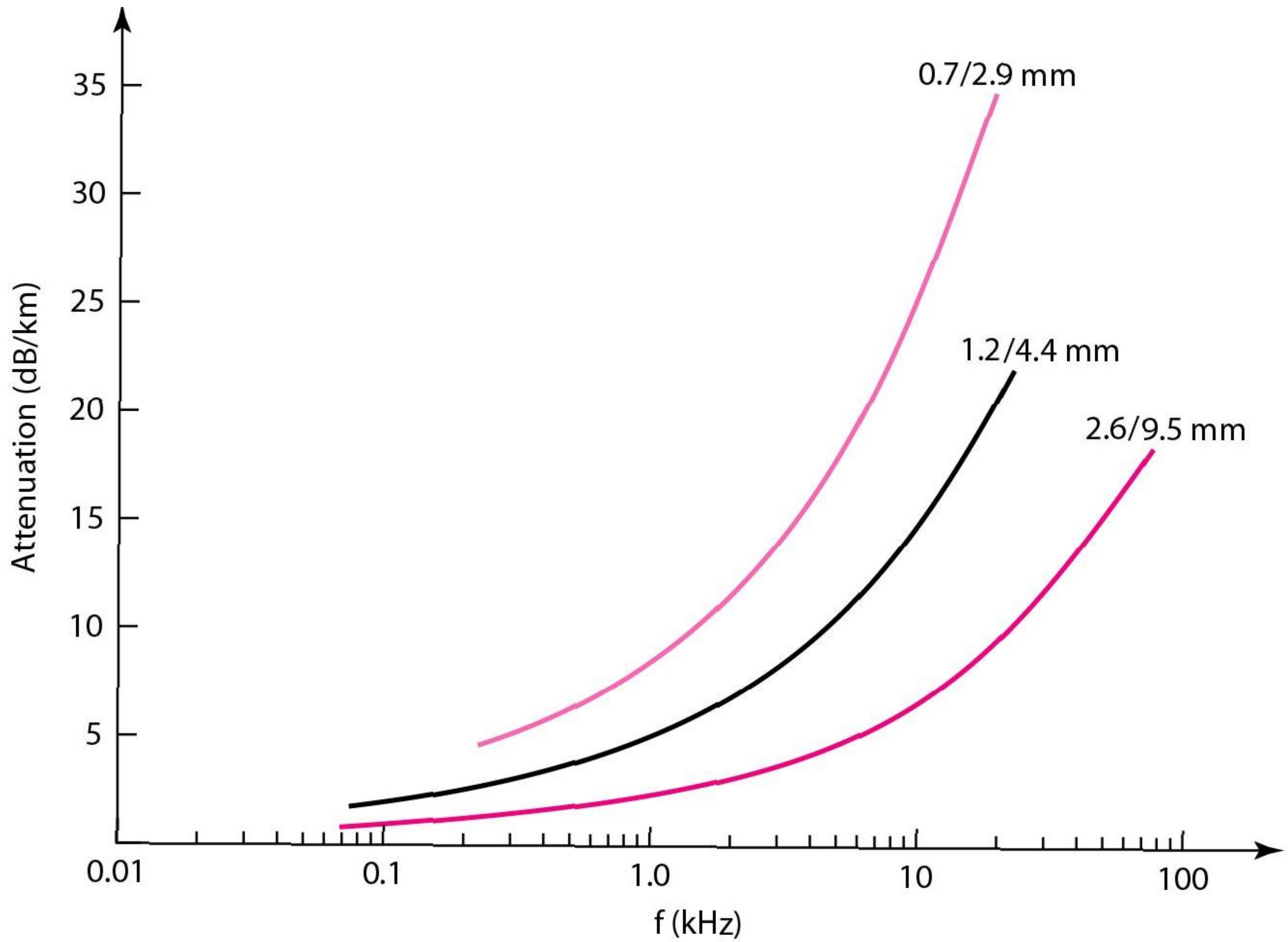
Figure 1.8 *BNC connectors*

BNC connectors are used to connect end of the cable to a device such as TV Set.



BNC: Bayonet Neil-Concelman

Figure 1.9 *Coaxial cable performance*



Has higher attenuation than coaxial cable.

Figure 1.10 **Fiber optics**: *Bending of light ray*

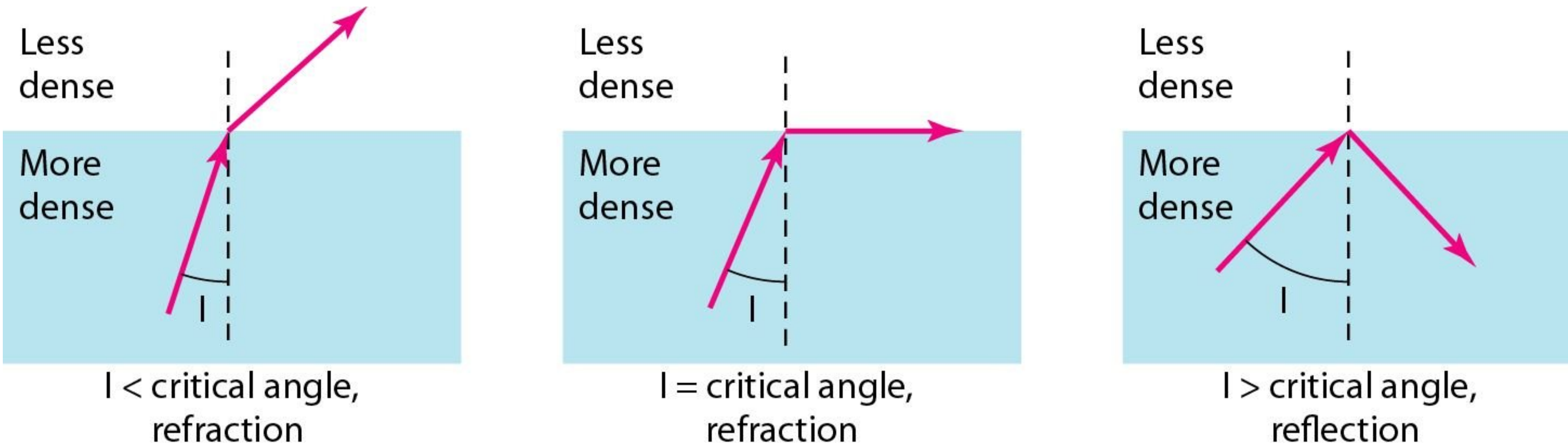


Figure 1.11 *Optical fiber*

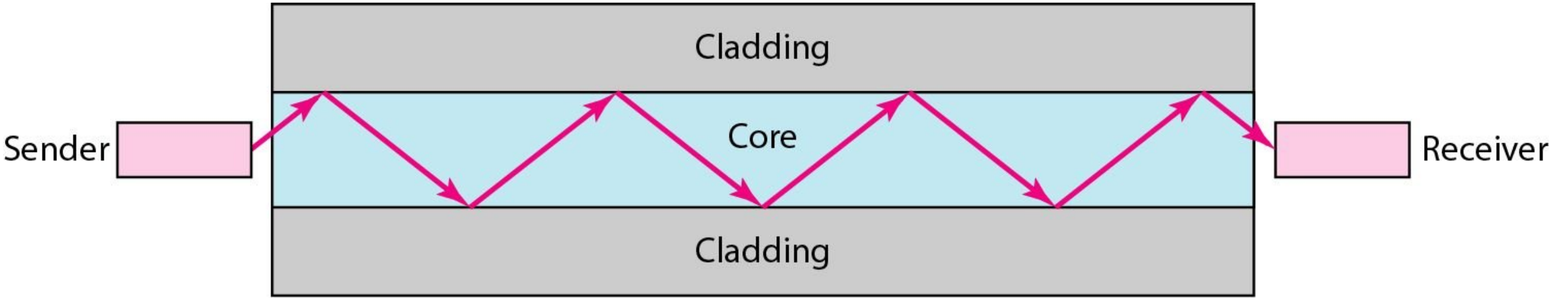
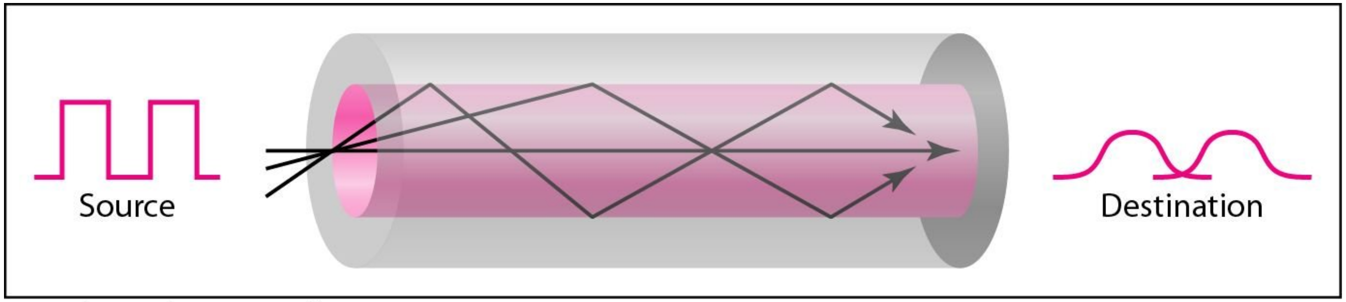
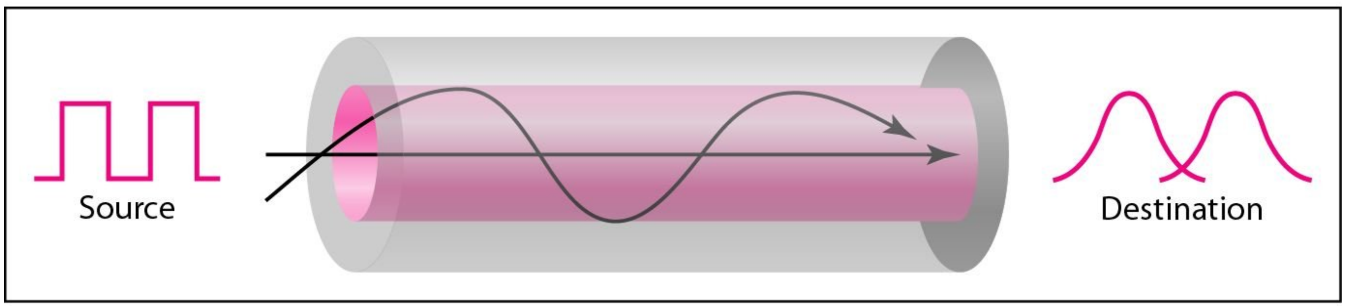


Figure 1.13 *Modes*

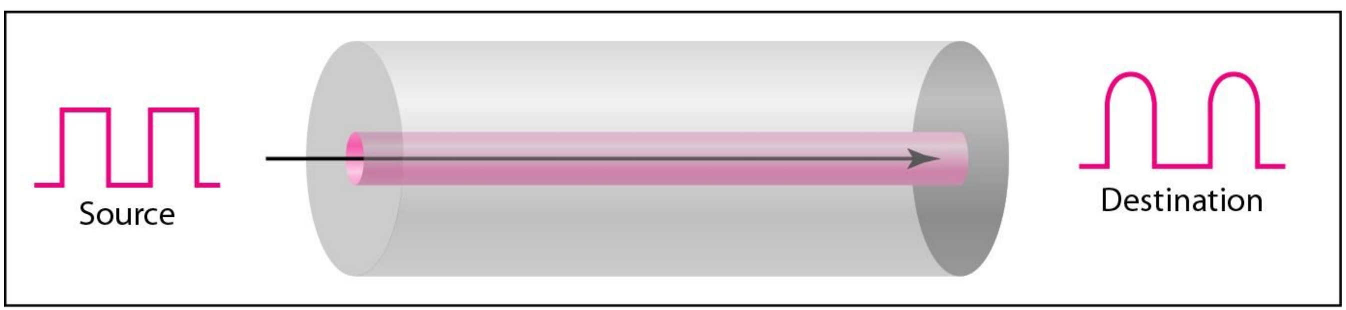
Index refers to refraction and is related to density



a. Multimode, step index



b. Multimode, graded index



c. Single mode

Table 1.3 *Fiber types*

Type	*Core (µm)*	*Cladding (µm)*	*Mode*
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

Figure 1.14 *Fiber construction*

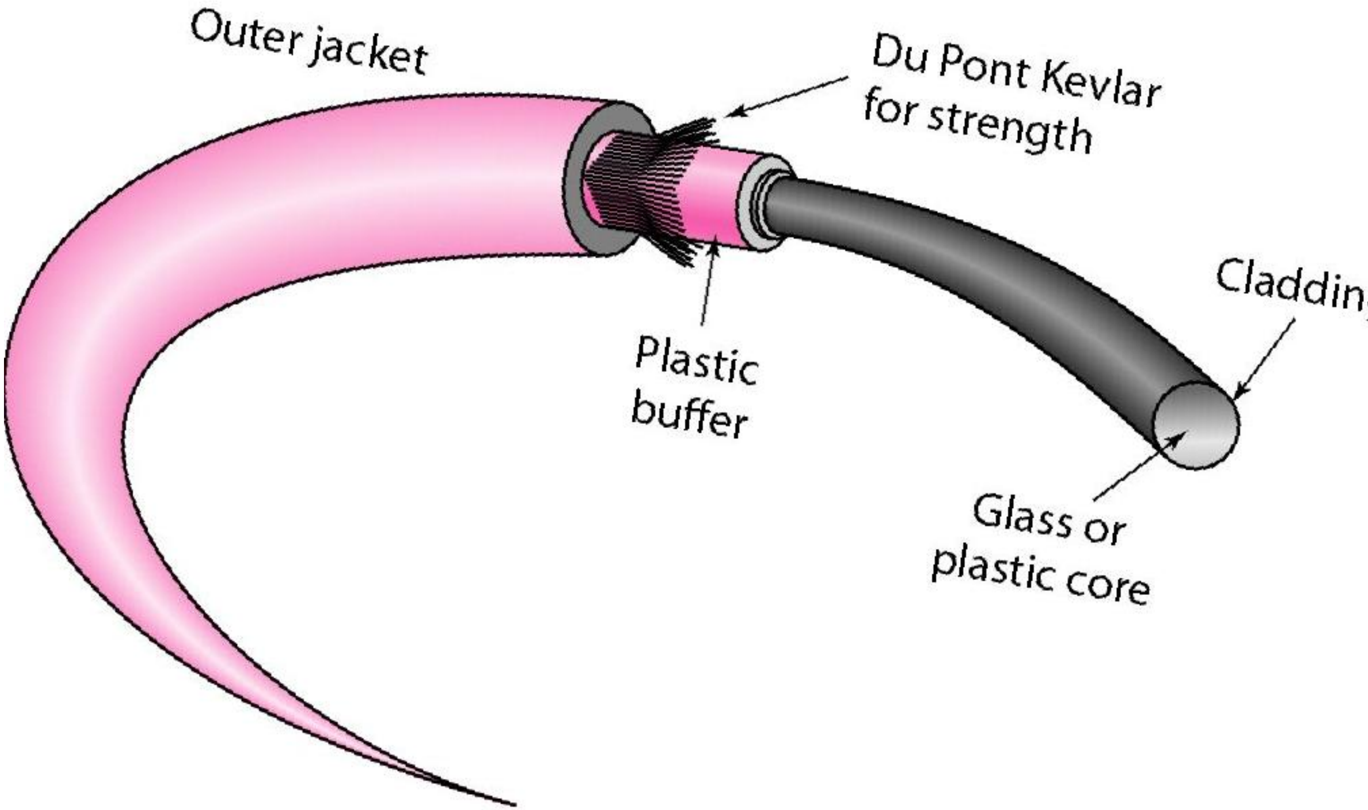
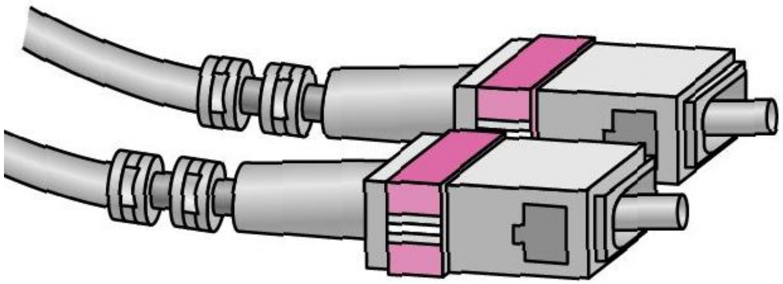


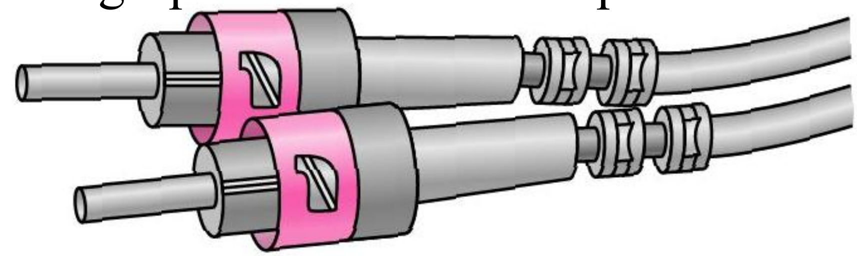
Figure 1.15 *Fiber-optic cable connectors*



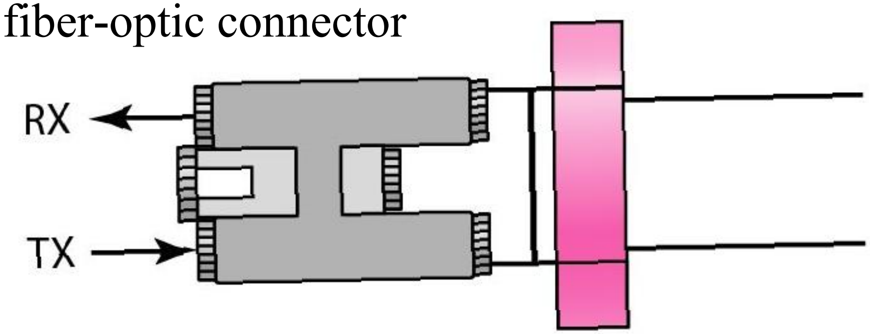
SC connector

SC: subscriber connector
standard-duplex fiber-optic connector

ST: straight tip
high-performance fiber-optic connector



ST connector

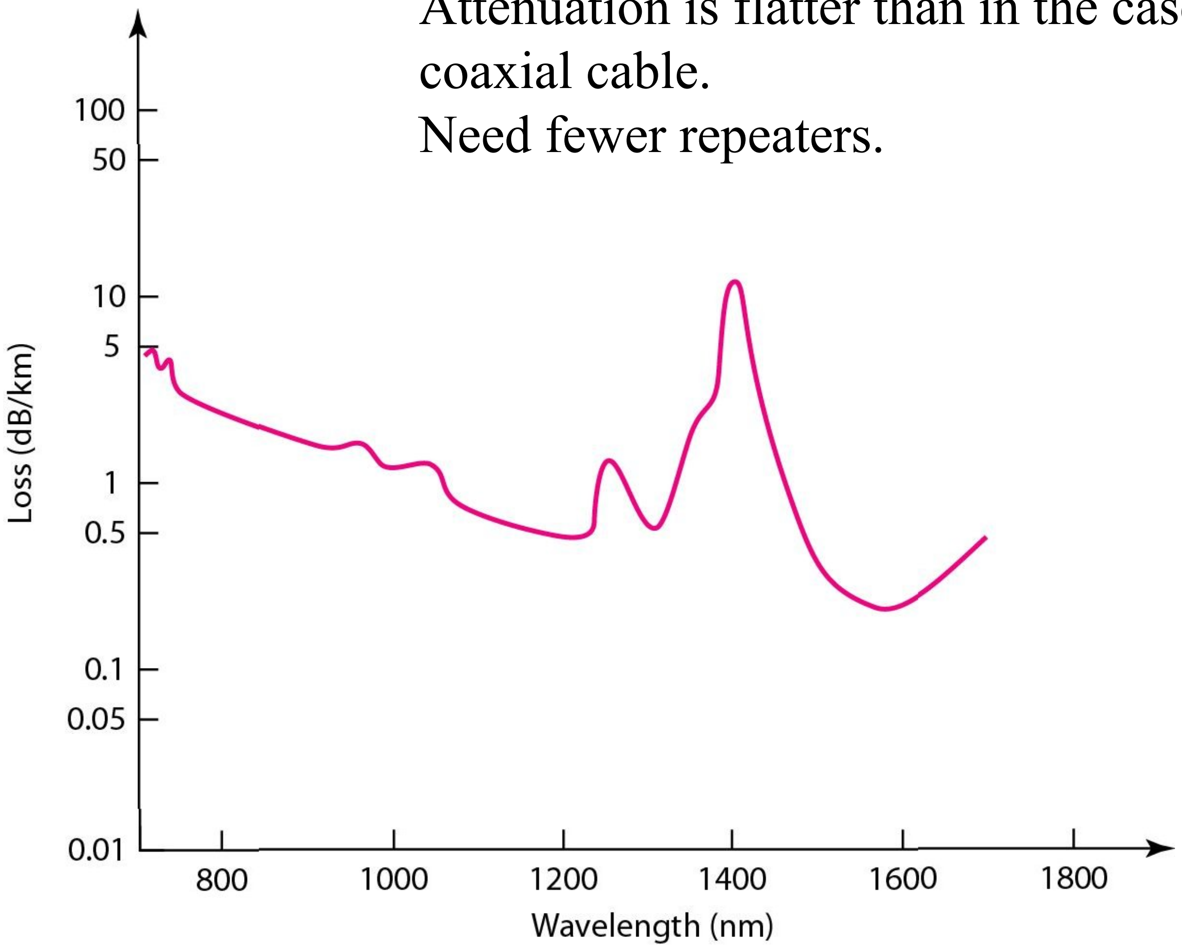


MT-RJ connector

Mechanical Transfer Registered Jack. popular for small form factor devices due to its small size

Figure 1.16 *Optical fiber performance*

Attenuation is flatter than in the case of twisted and coaxial cable.
Need fewer repeaters.



1-2 UNGUIDED MEDIA: WIRELESS

Unguided media transport electromagnetic waves without using a physical conductor.

This type of communication is often referred to as wireless communication.

Topics discussed in this section:

Radio Waves
Microwaves
Infrared

Figure 1.11 *Electromagnetic spectrum for wireless communication*

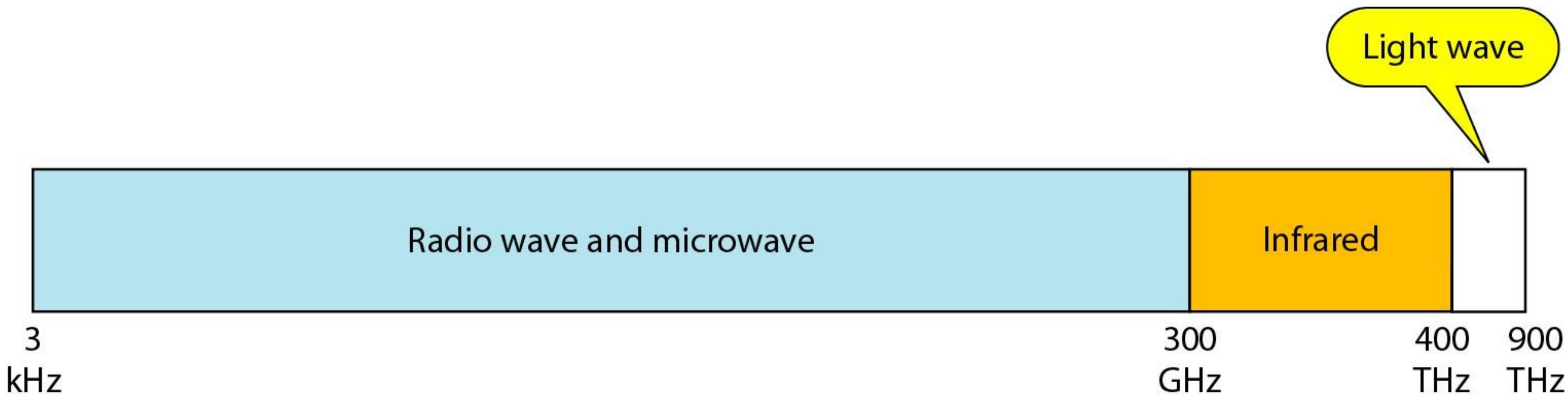


Figure 1.18 *Propagation methods*

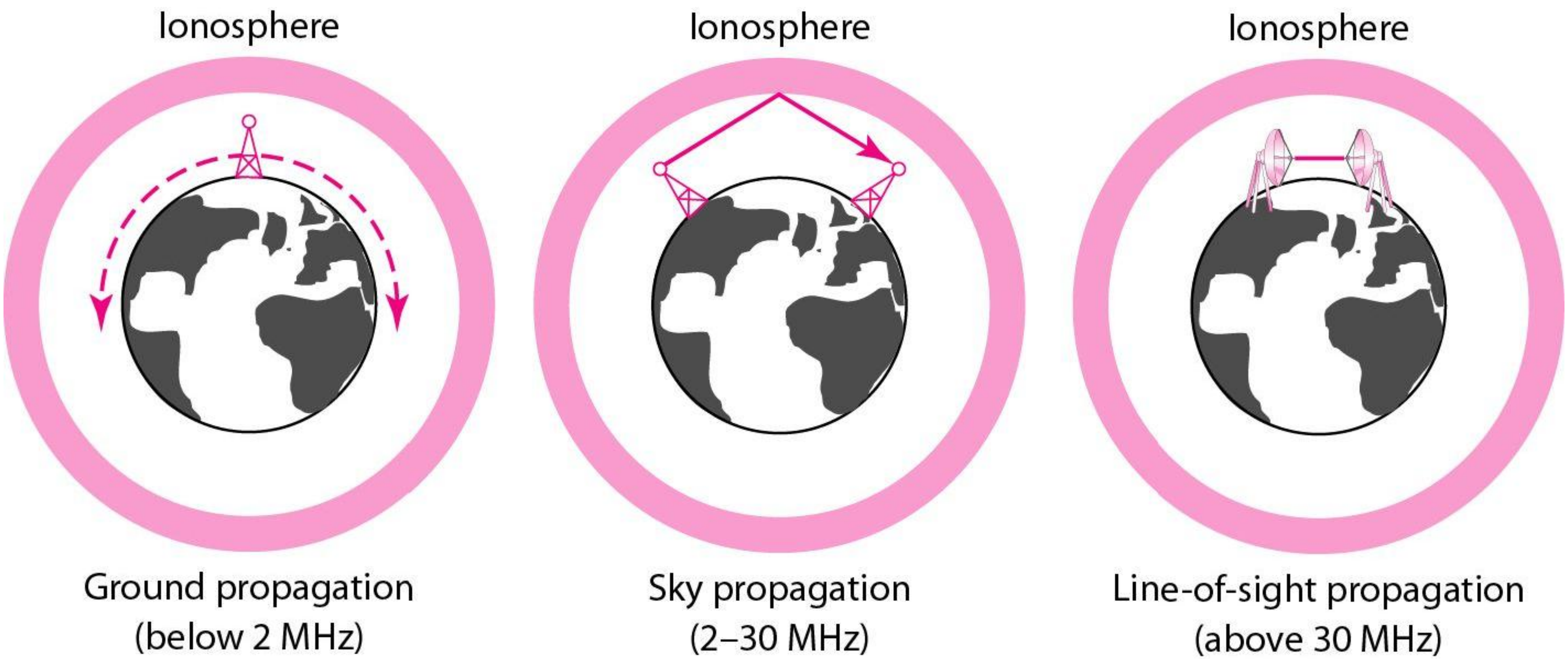
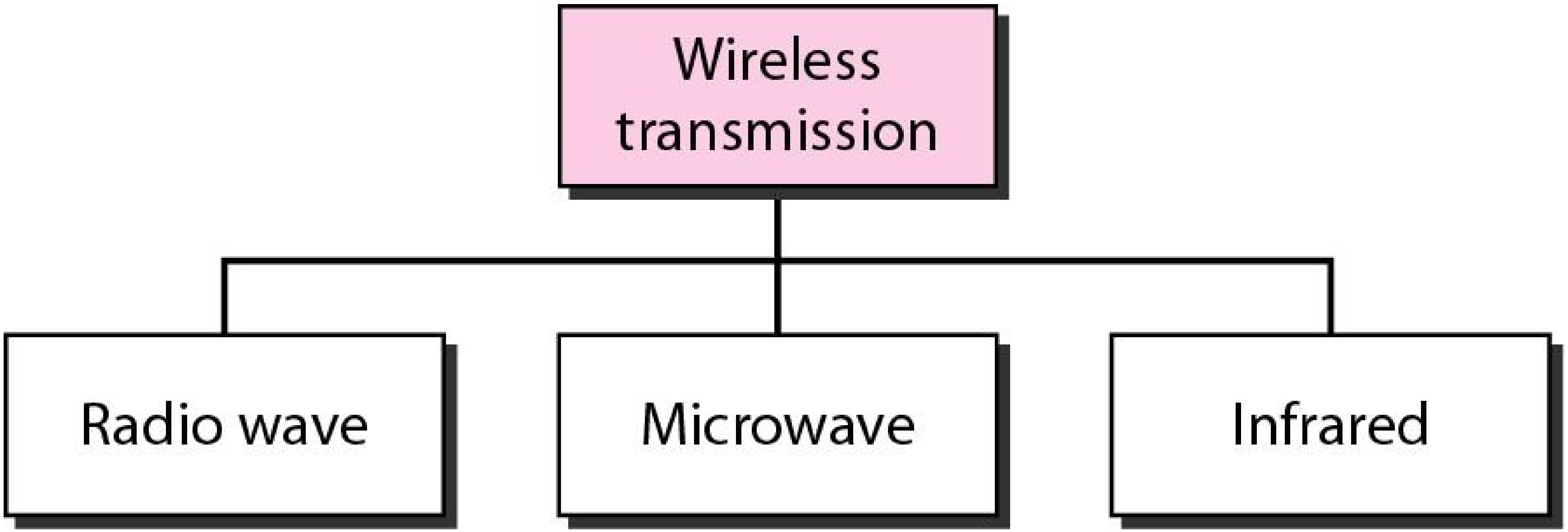


Table 1.4 *Bands*

Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3–30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30–300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz–3 MHz	Sky	AM radio
HF (high frequency)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3–30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30–300 GHz	Line-of-sight	Radar, satellite

Figure 1.19 *Wireless transmission waves*



Radio waves

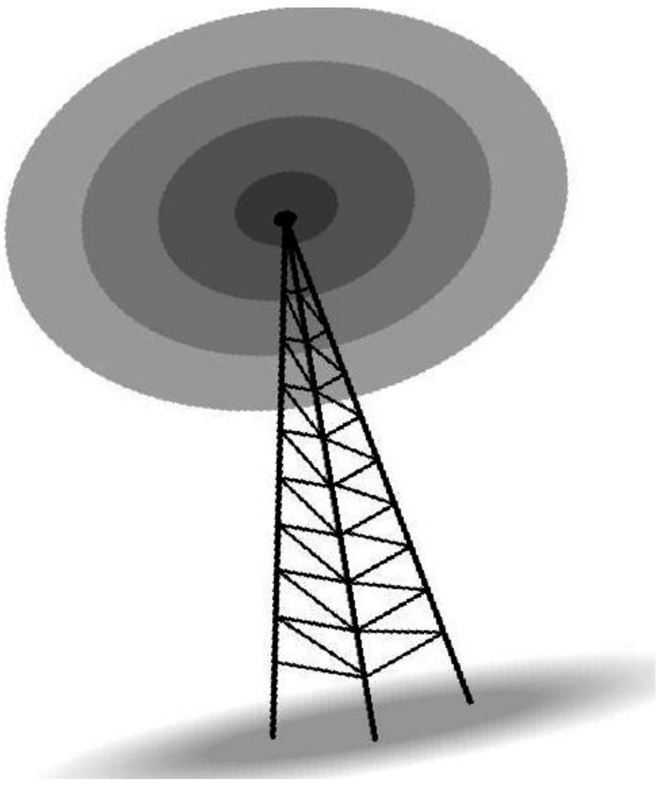
Note

Radio waves are used for multicast communications, such as radio and television, and paging systems.

They can penetrate through walls.
Highly regulated.

Use omni directional antennas

Figure 1.20 *Omnidirectional antenna*



Microwaves

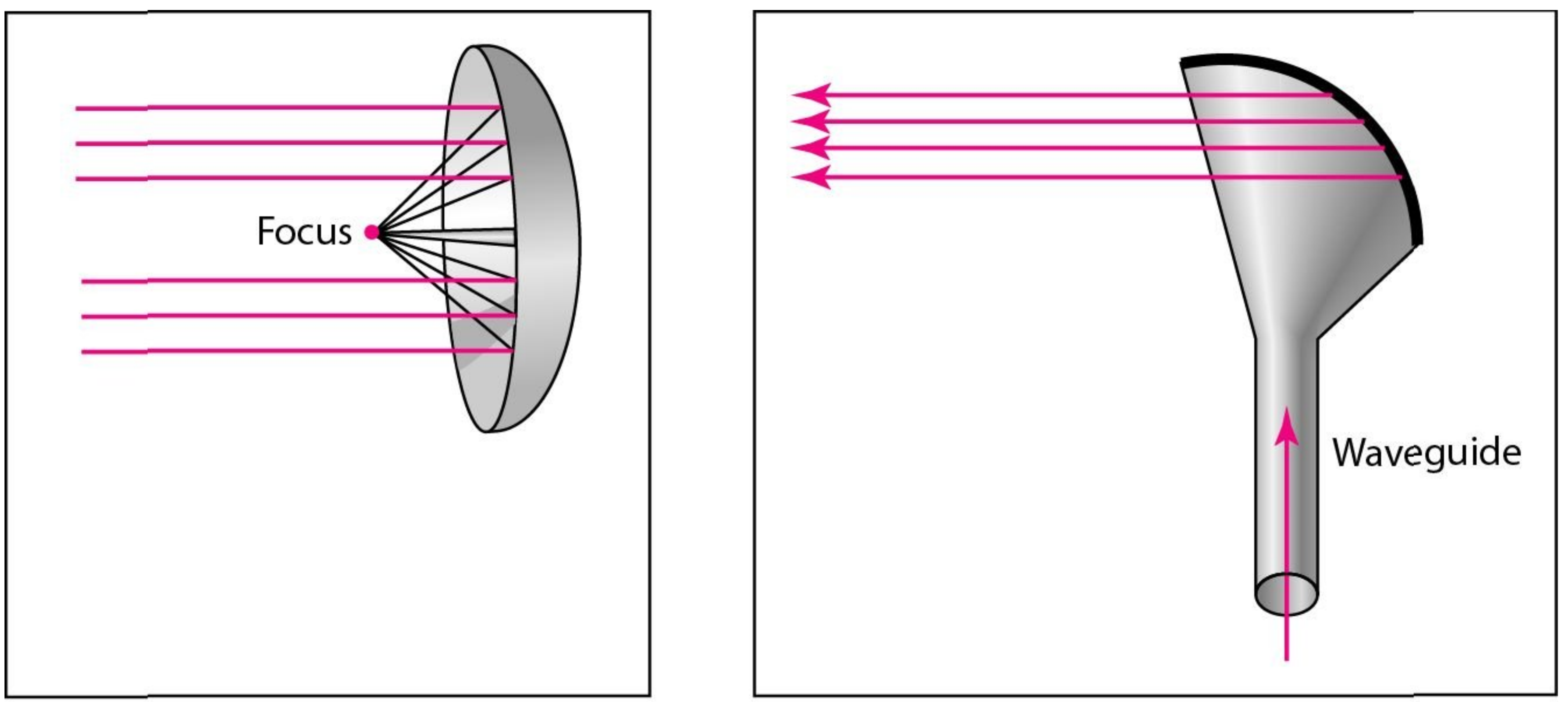
Note

Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs.

Higher frequency ranges cannot penetrate walls.

Use directional antennas - point to point line of sight communications.

Figure 1.21 *Unidirectional antennas*



a. Dish antenna b. Horn antenna

Infrared

Note

Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

Wireless Channels

- Are subject to a lot more errors than guided media channels.
- Interference is one cause for errors, can be circumvented with high SNR.
- The higher the SNR the less capacity is available for transmission due to the broadcast nature of the channel.
- Channel also subject to fading and no coverage holes.

IEEE 802 Standards

Institute of Electrical and Electronics Engineers

STANDARDS	PURPOSE
802.1	Bridging and Management
802.2	Logical Link Control
802.3	Ethernet Lan (CSMA/CD)
802.4	Token-Bus Lan
802.5	Token-Ring Lan
802.7	Broadband LAN
802.9	Isochronous LAN
802.10	Network Security
802.11	Wireless Networks
802.12	Demand Priority Access Lan (100 VG - Any LAN)
802.15	Wireless PAN
802.16	Broadband and Wireless MAN

Switching

Figure 8.1 *Switched network*

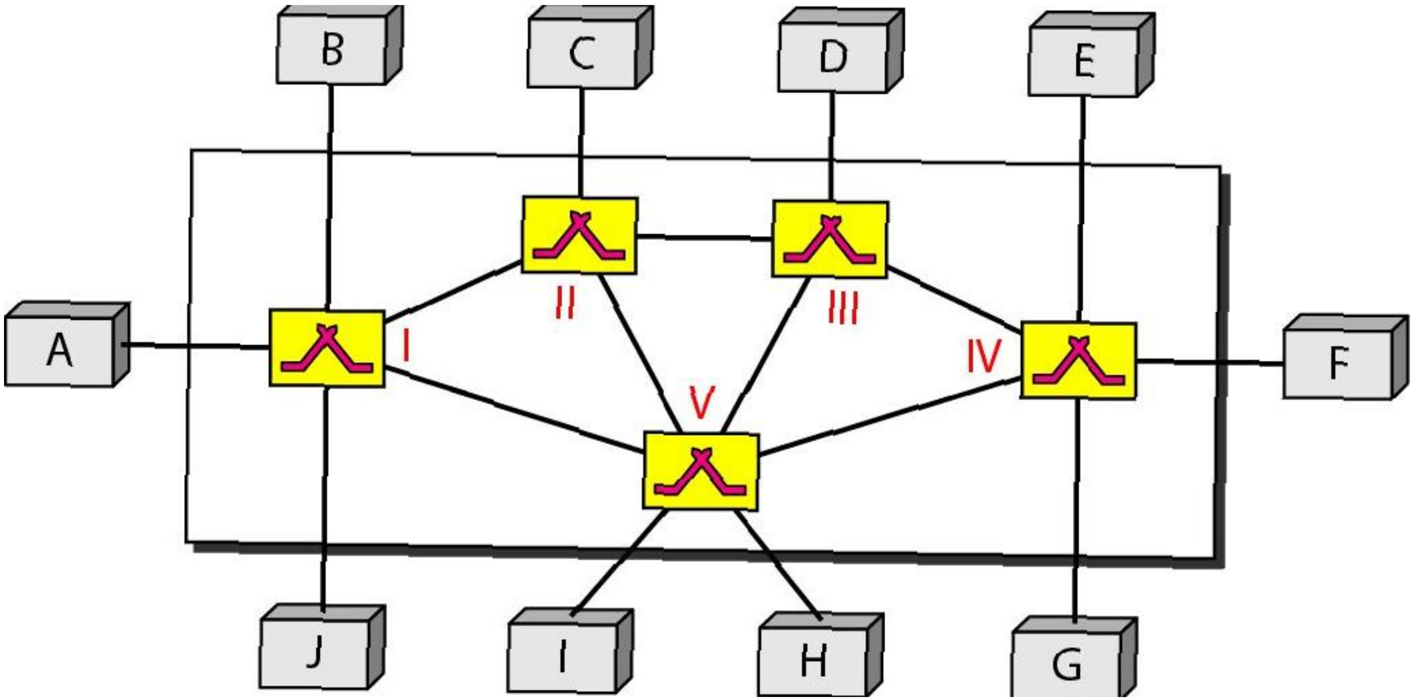
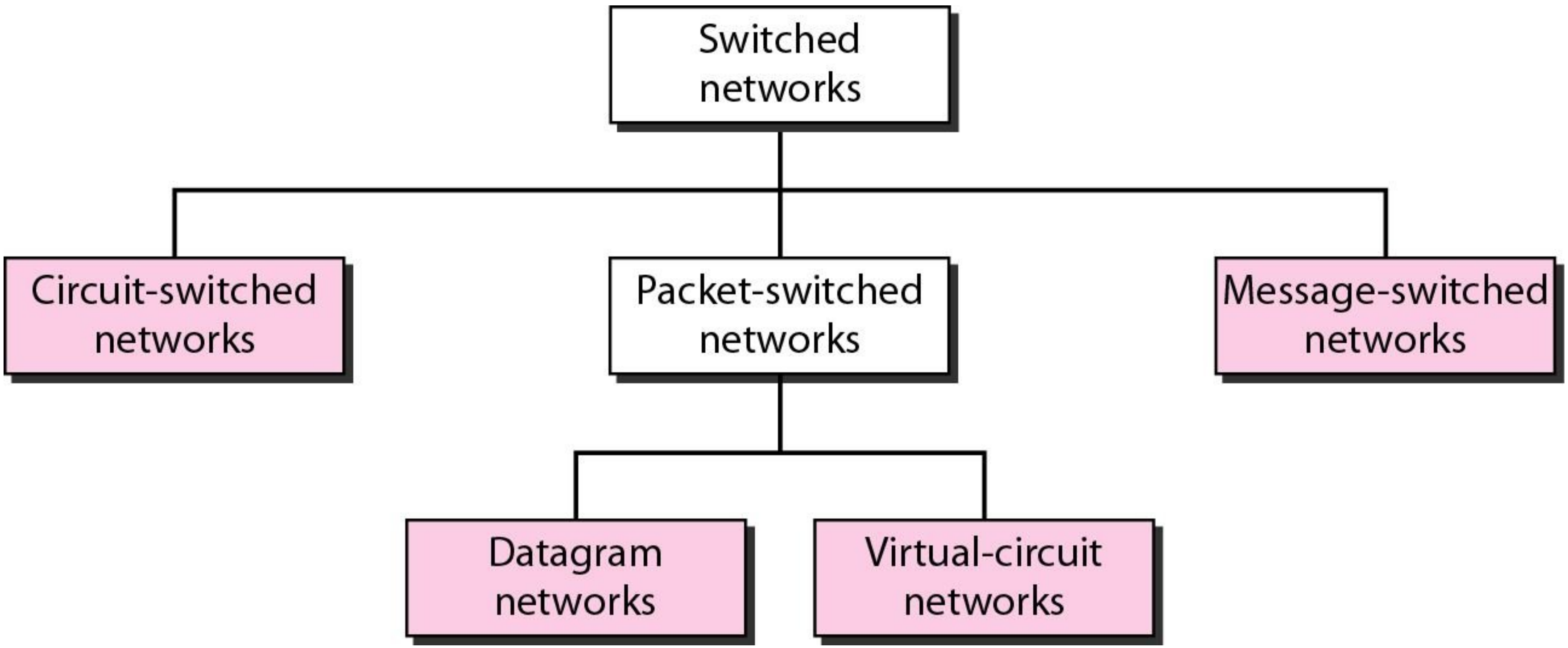


Figure 8.2 *Taxonomy of switched networks*



8-1 CIRCUIT-SWITCHED NETWORKS

- *A circuit-switched network consists of a set of switches connected by physical links.*
- *A connection between two stations is a dedicated path made of one or more links.*
- *However, each connection uses only one dedicated channel on each link.*
- *Each link is normally divided into n channels by using FDM or TDM.*

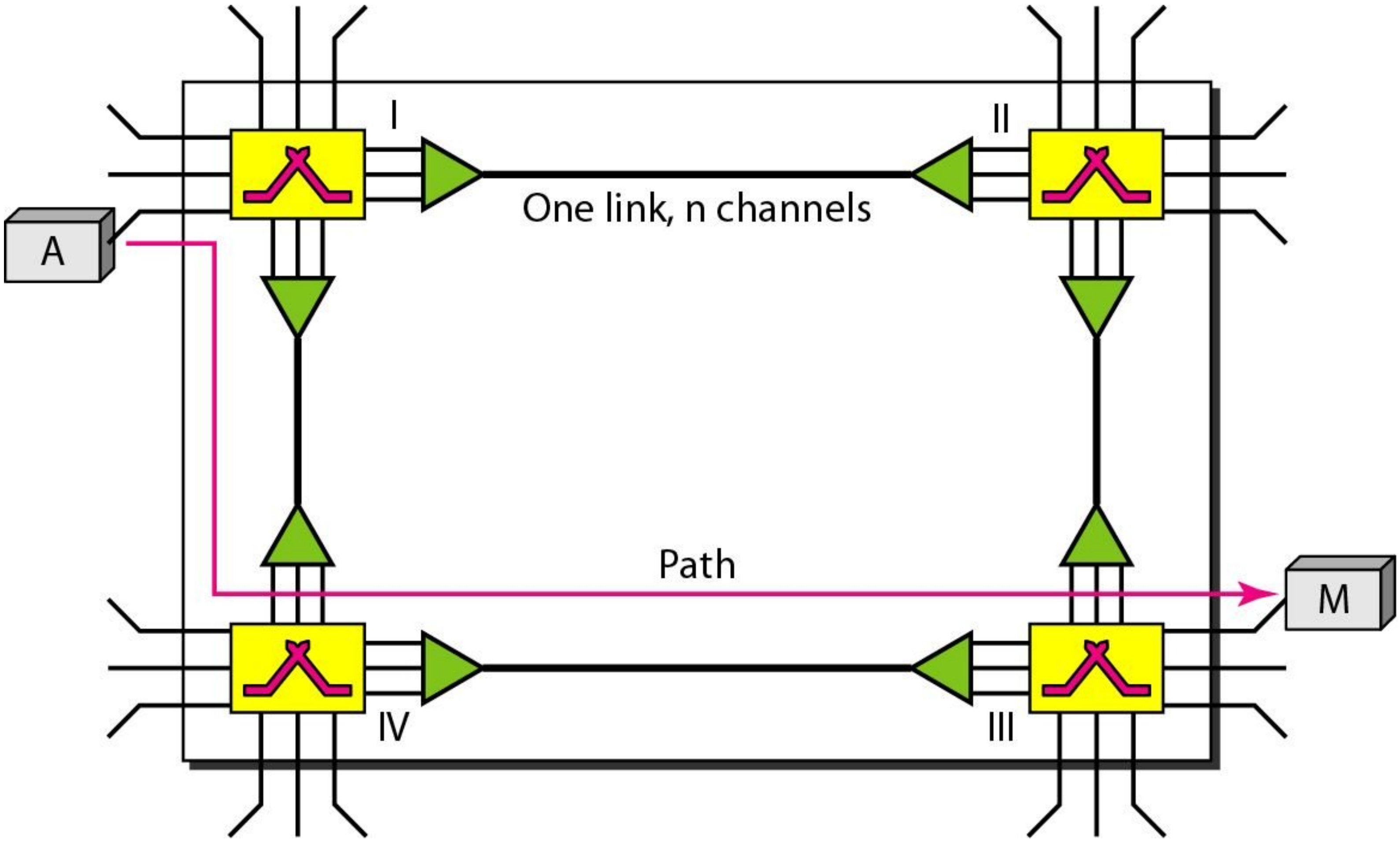
Topics discussed in this section:

Three Phases
Efficiency
Delay
Circuit-Switched Technology in Telephone Networks

Note

A circuit-switched network is made of a set of switches connected by physical links, in which each link is divided into *n* channels.

Figure 8.3 *A trivial circuit-switched network*



Note

In circuit switching, the resources need to be reserved during the setup phase;
the resources remain dedicated for the entire duration of data transfer until the teardown phase.

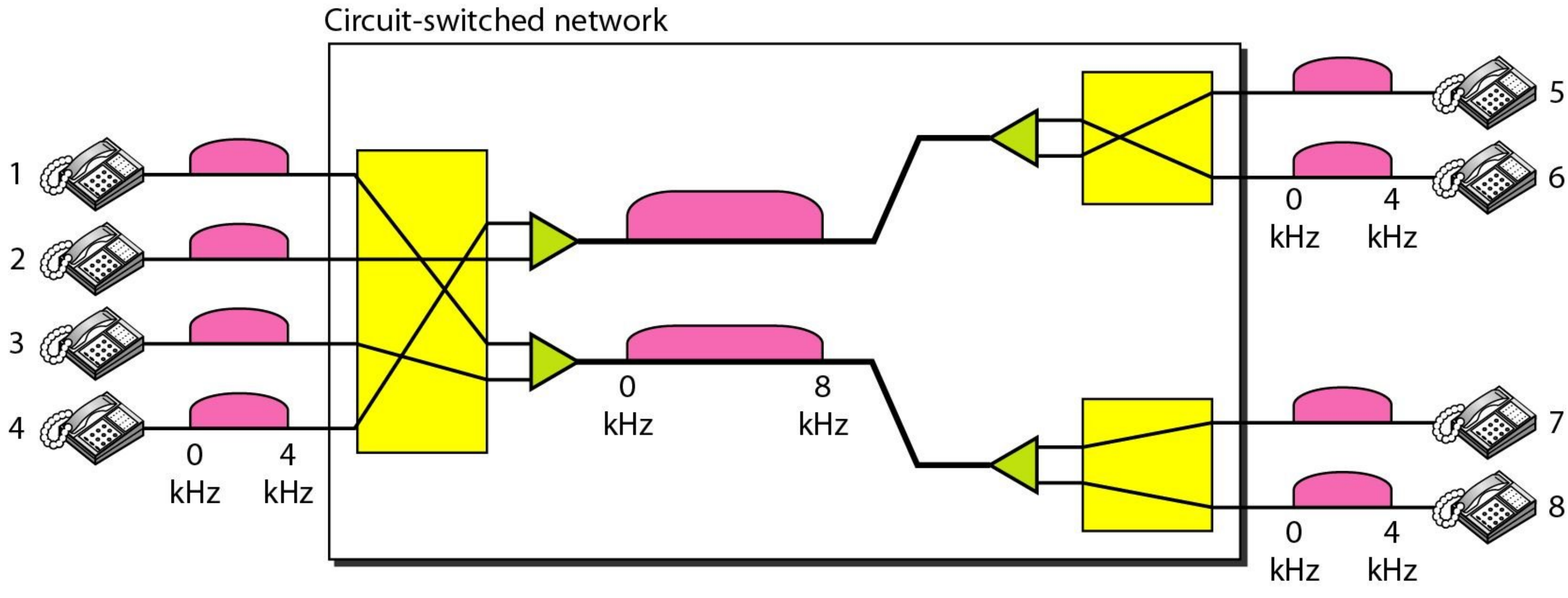
Example 8.1

As a trivial example, let us use a circuit-switched network to connect eight telephones in a small area. Communication is through 4-kHz voice channels.

We assume that each link uses FDM to connect a maximum of two voice channels. The bandwidth of each link is then 8 kHz.

Figure 8.4 shows the situation. Telephone 1 is connected to telephone 1; 2 to 5; 3 to 8; and 4 to 6. Of course the situation may change when new connections are made. The switch controls the connections.

Figure 8.4 *Circuit-switched network used in Example 8.1*



Example 8.2

As another example, consider a circuit-switched network that connects computers in two remote offices of a private company. The offices are connected using a T-1 line leased from a communication service provider. There are two 4 × 8 (4 inputs and 8 outputs) switches in this network. For each switch, four output ports are folded into the input ports to allow communication between computers in the same office. Four other output ports allow communication between the two offices. Figure 8.5 shows the situation.

Figure 8.5 *Circuit-switched network used in Example 8.2*

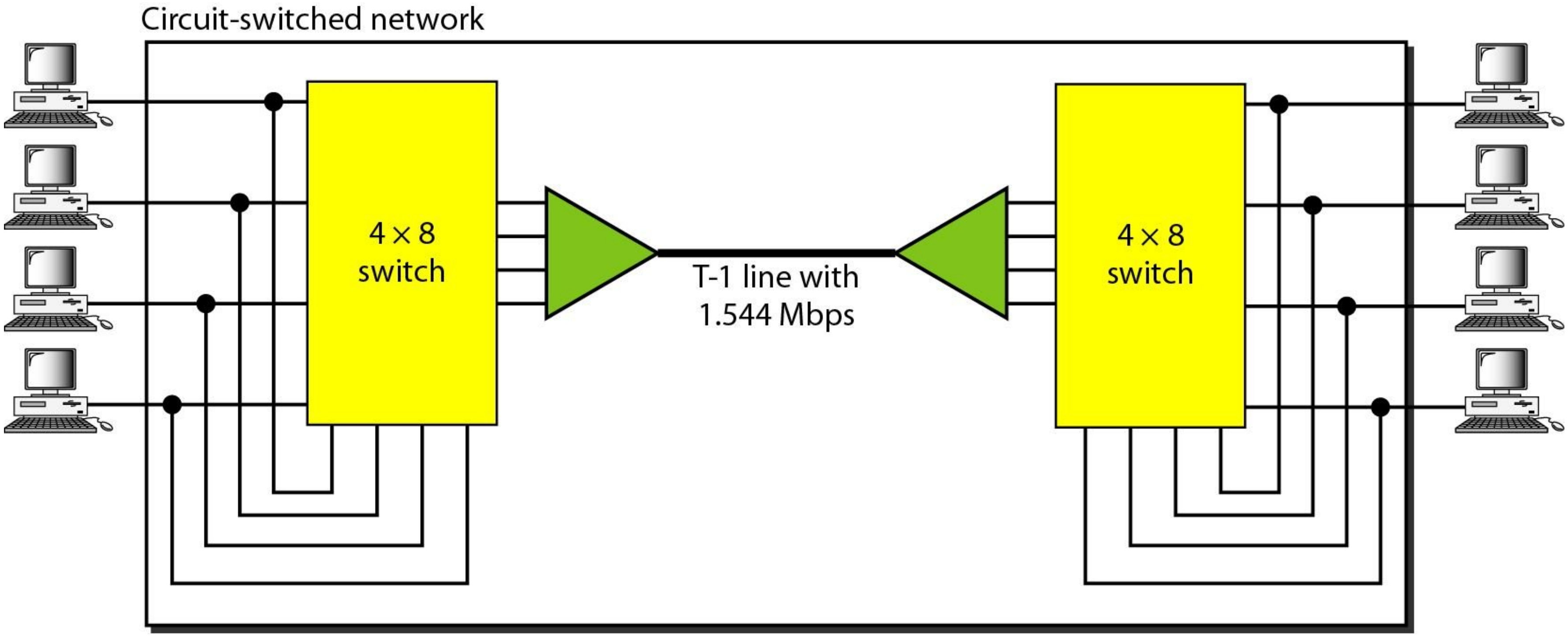
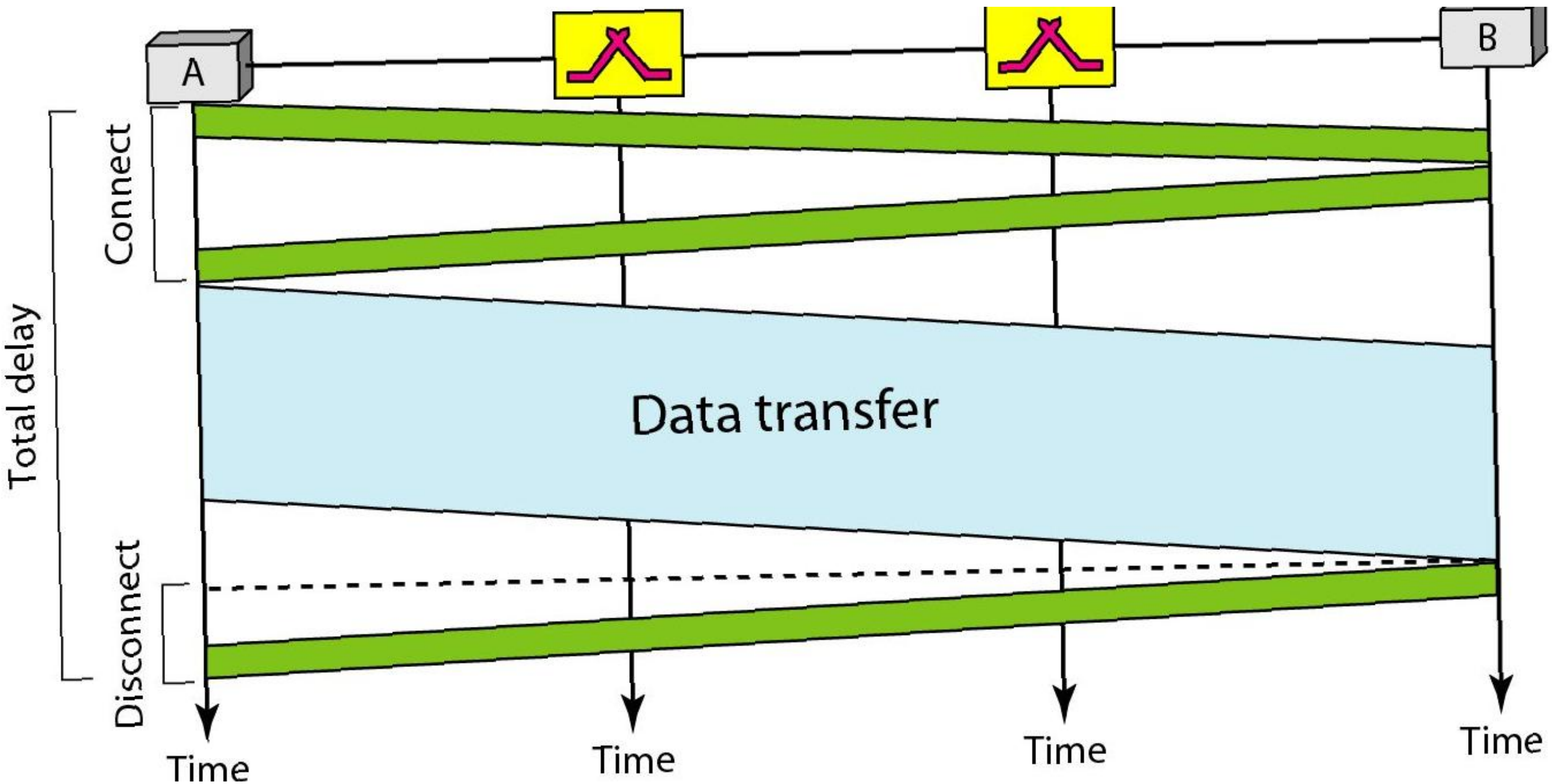


Figure 8.6 *Delay in a circuit-switched network*



Note

Switching at the physical layer in the traditional telephone network uses the circuit-switching approach.

8-2 DATAGRAM NETWORKS

- *In data communications, we need to send messages from one end system to another.*
- *If the message is going to pass through a packet-switched network, it needs to be divided into packets of fixed or variable size.*
- *The size of the packet is determined by the network and the governing protocol.*

Topics discussed in this section:

Routing Table
Efficiency
Delay
Datagram Networks in the Internet

Note

In a packet-switched network, there is no resource reservation; resources are allocated on demand.

Figure 8.1 *A datagram network with four Nodes*

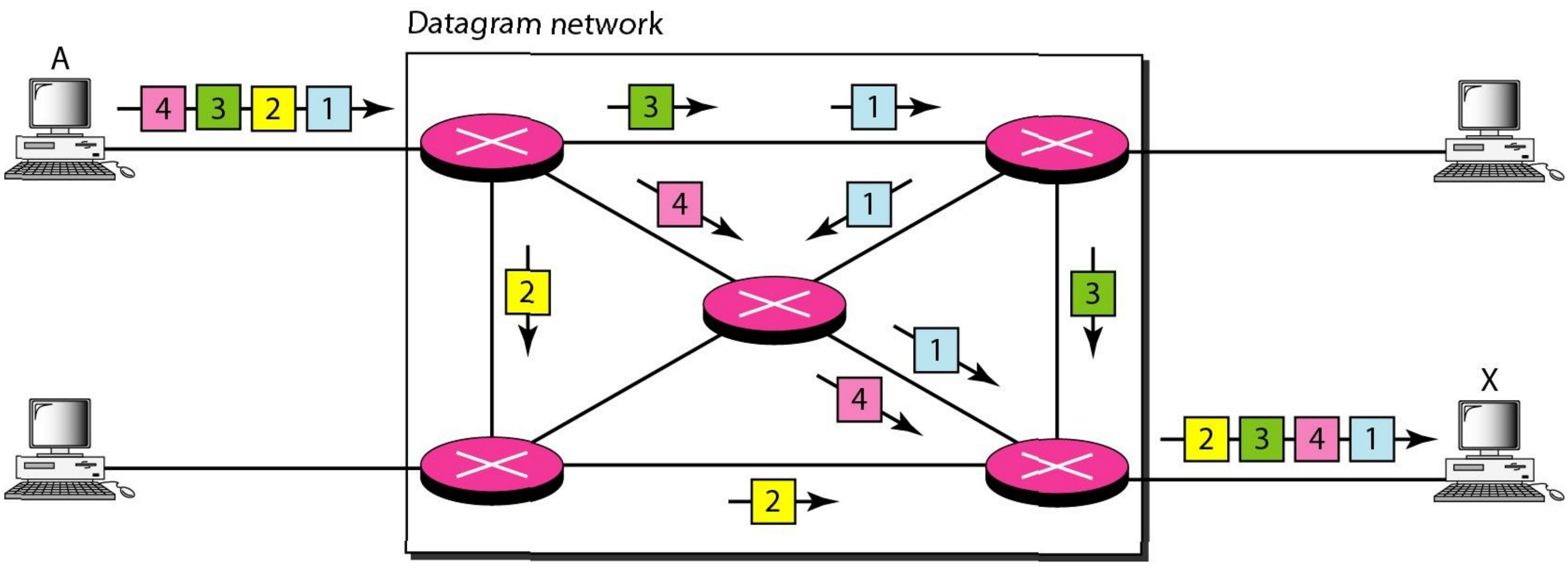
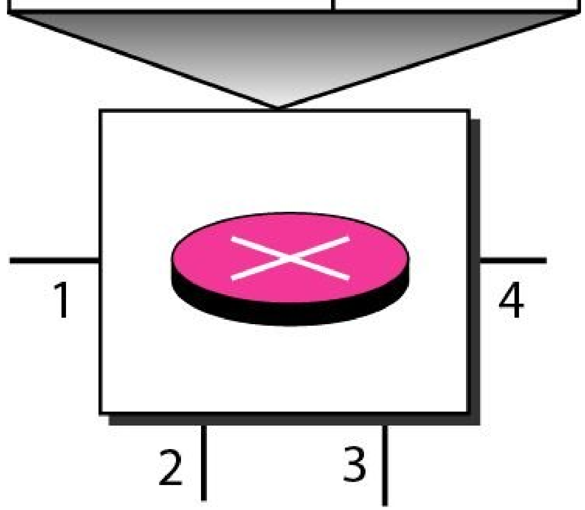


Figure 8.8 *Routing table in a datagram network*

Destination address	Output port
1232	1
4150	2
⋮	⋮
9130	3



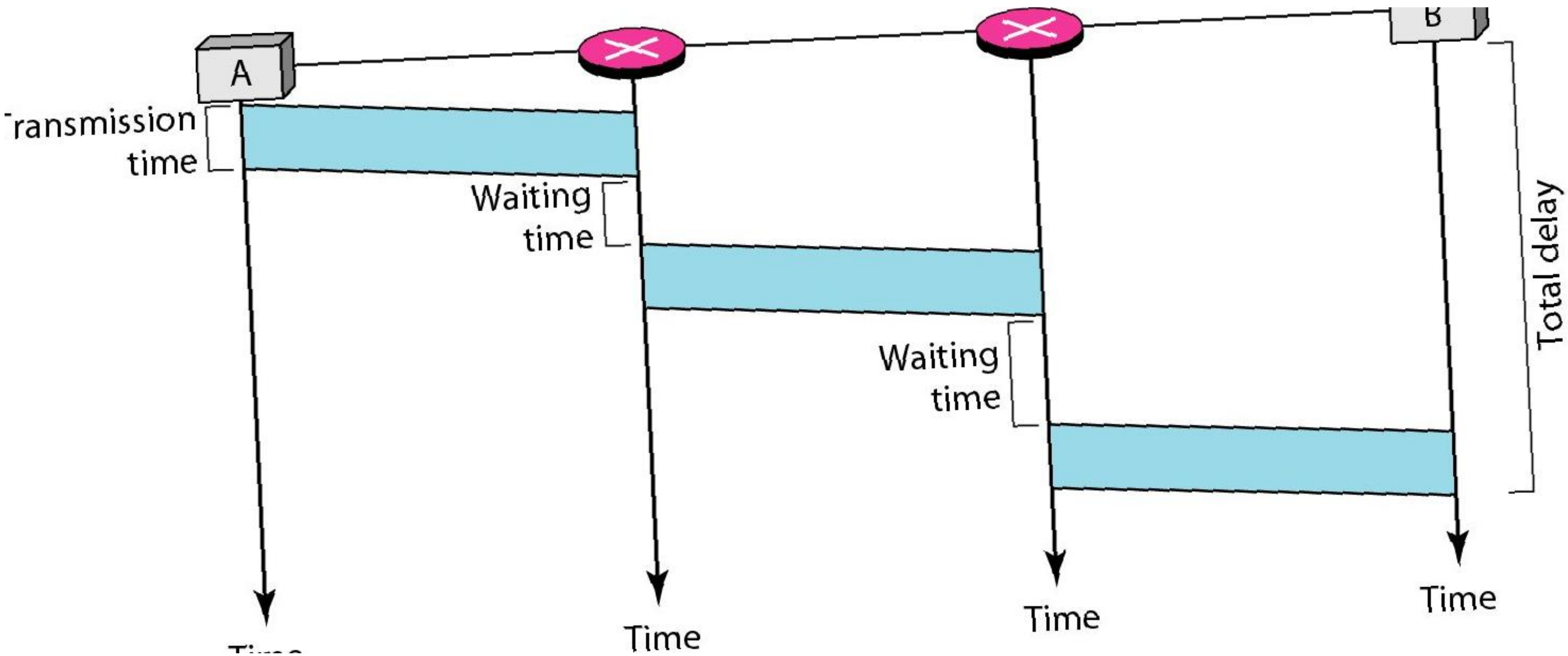
Note

A switch in a datagram network uses a routing table that is based on the destination address.

Note

The destination address in the header of a packet in a datagram network remains the same during the entire journey of the packet.

Figure 8.9 *Delay in a datagram network*



Note

Switching in the Internet is done by using the datagram approach
to packet switching at
the network layer.

8-3 VIRTUAL-CIRCUIT NETWORKS

- *A virtual-circuit network is a cross between a circuit-switched network and a datagram network.*
- *It has some characteristics of both.*

Topics discussed in this section:

Addressing
Three Phases
Efficiency
Delay
Circuit-Switched Technology in WANs

Figure 8.10 *Virtual-circuit network*

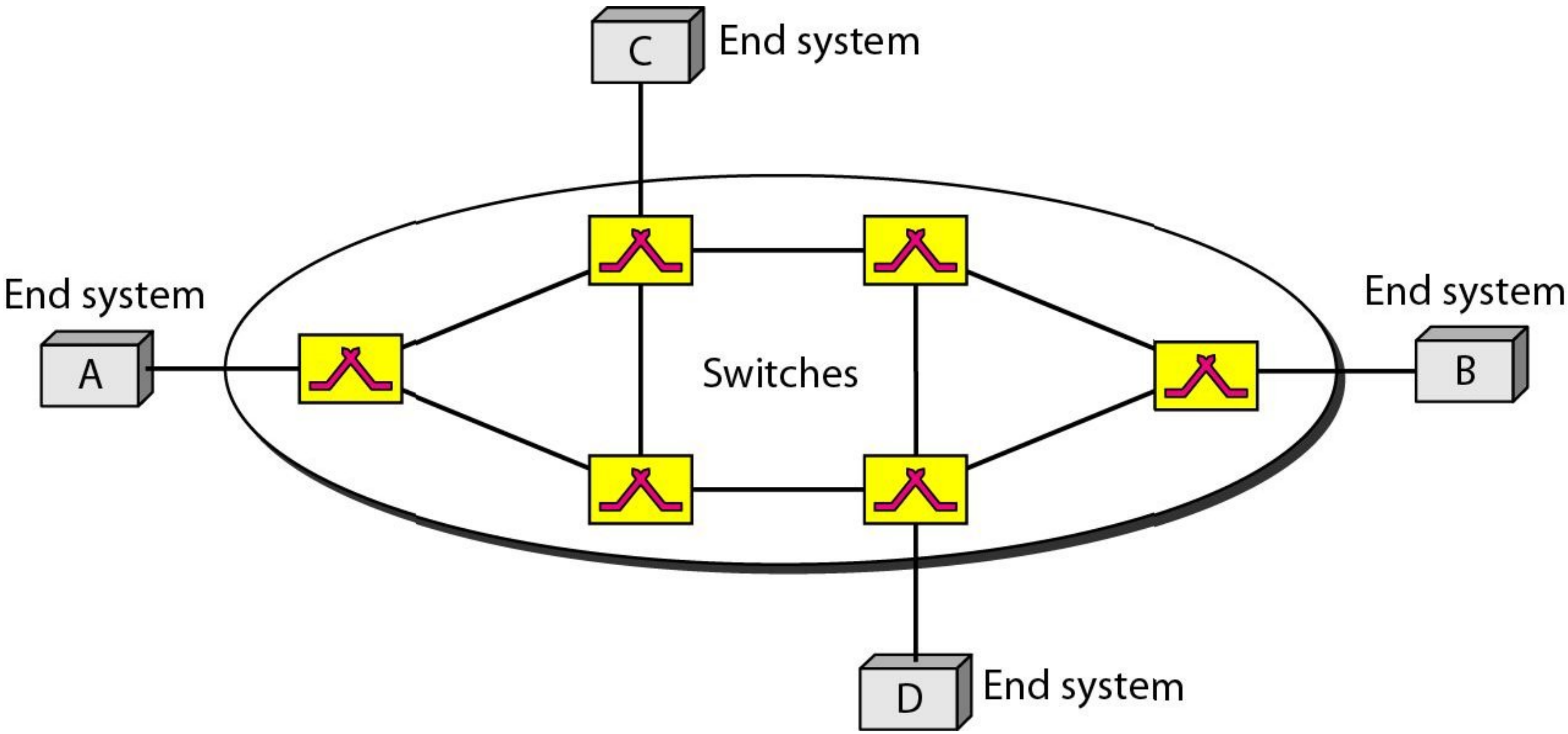


Figure 8.11 *Virtual-circuit identifier*

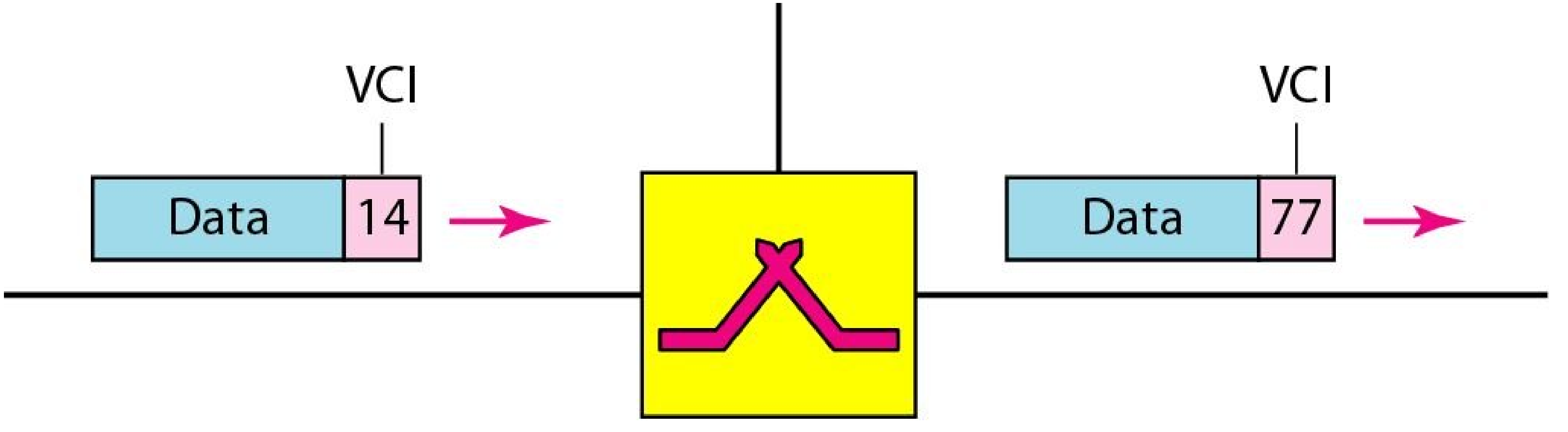


Figure 8.12 *Switch and tables in a virtual-circuit network*

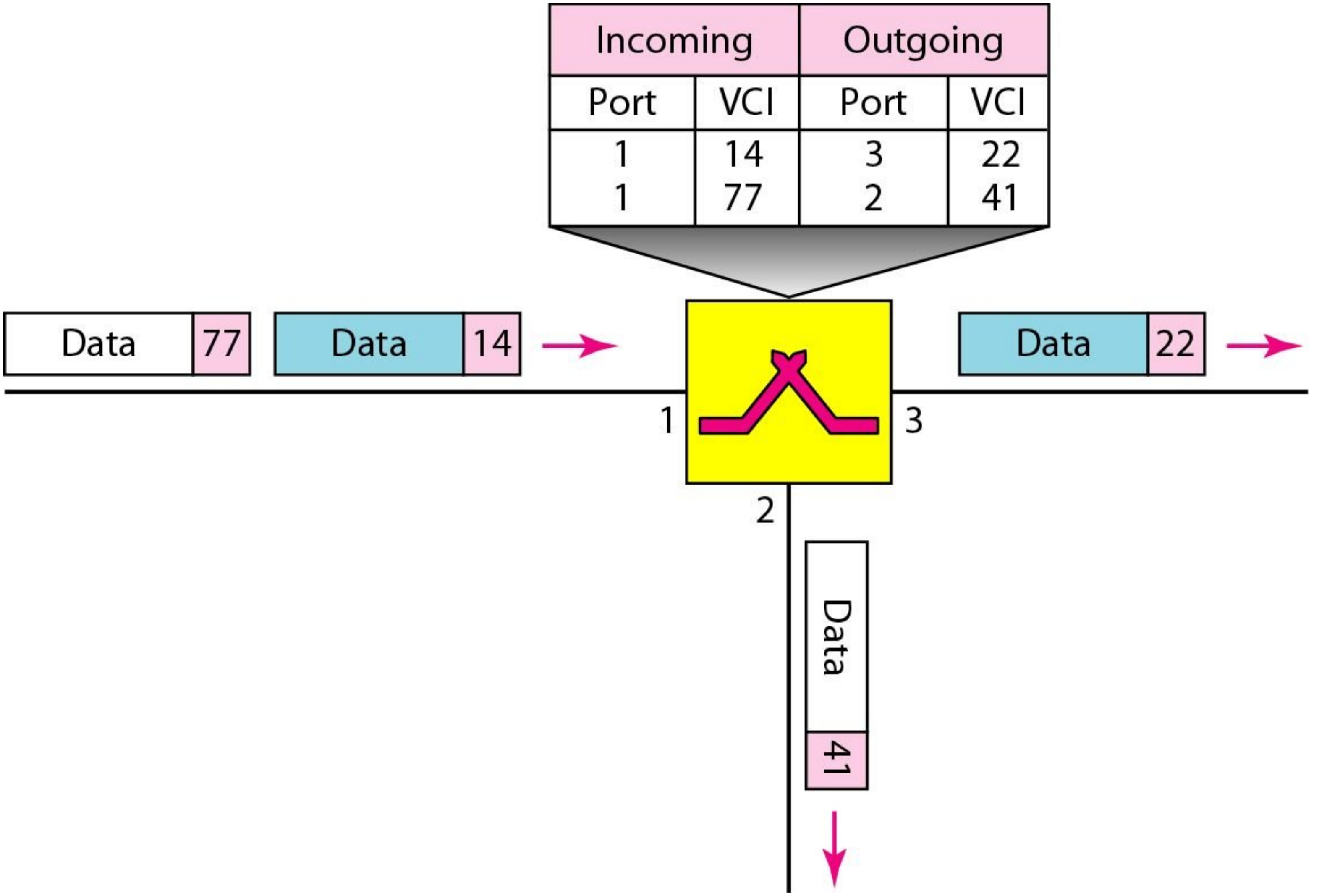


Figure 8.13 *Source-to-destination data transfer in a virtual-circuit network*

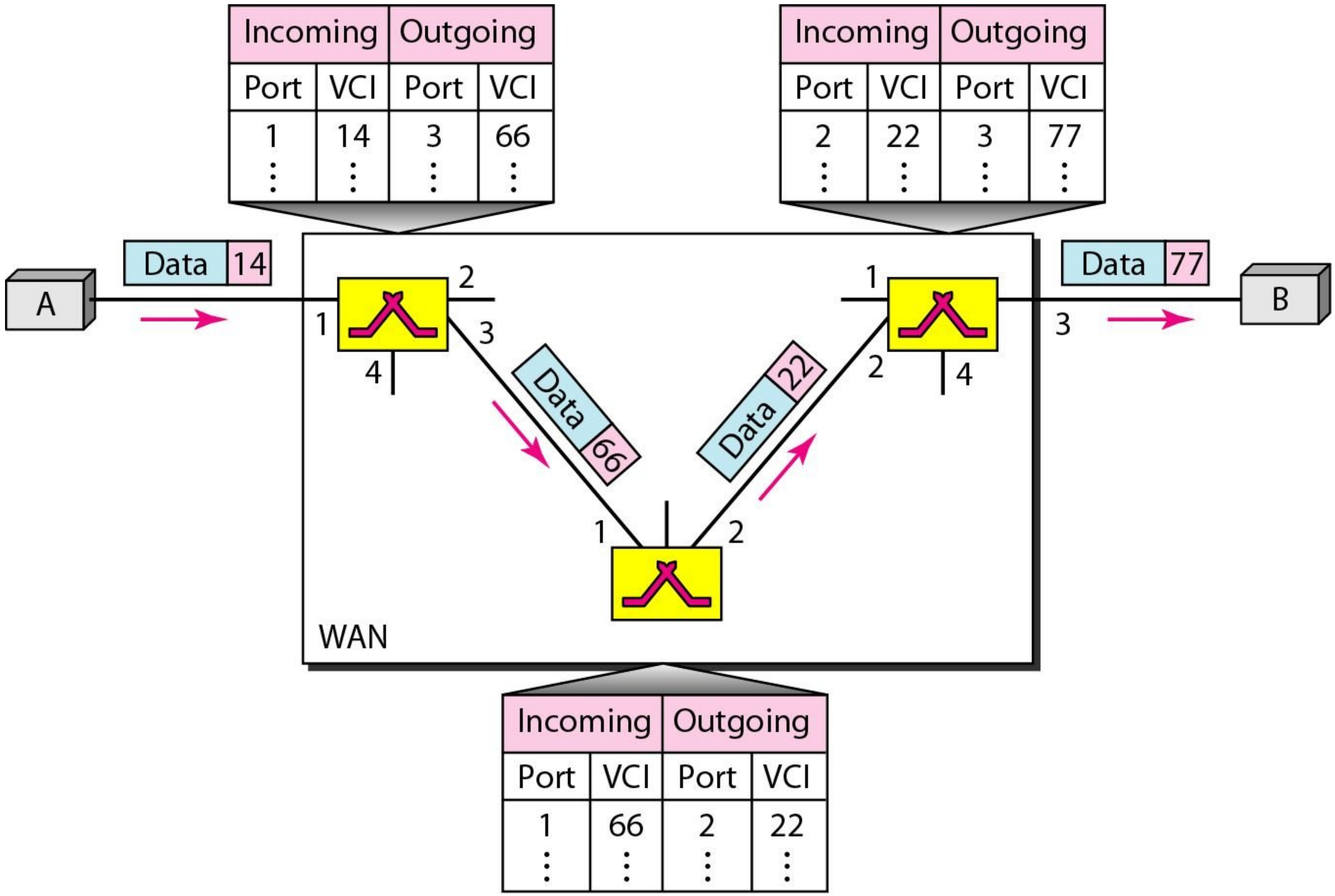


Figure 8.14 *Setup request in a virtual-circuit network*

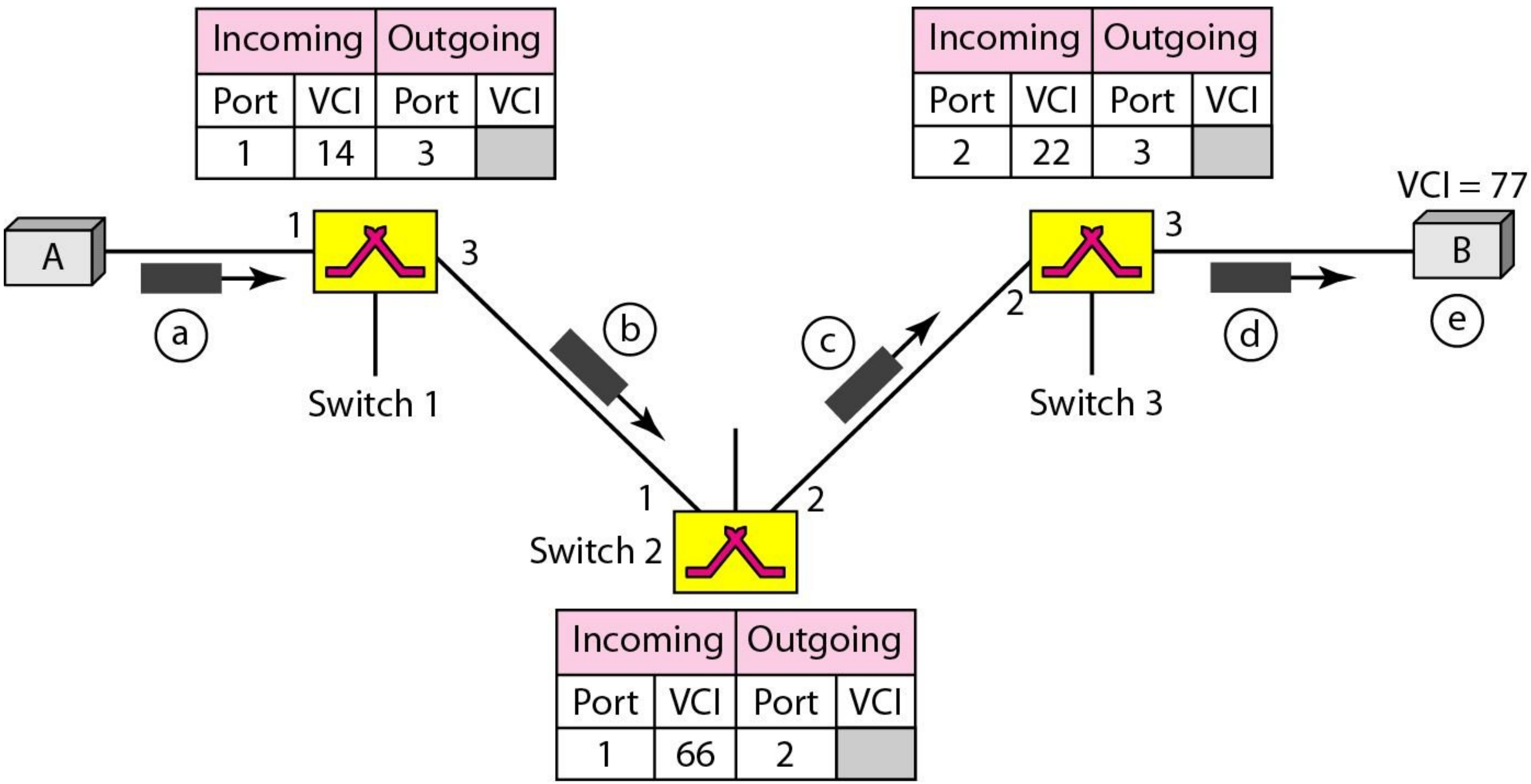
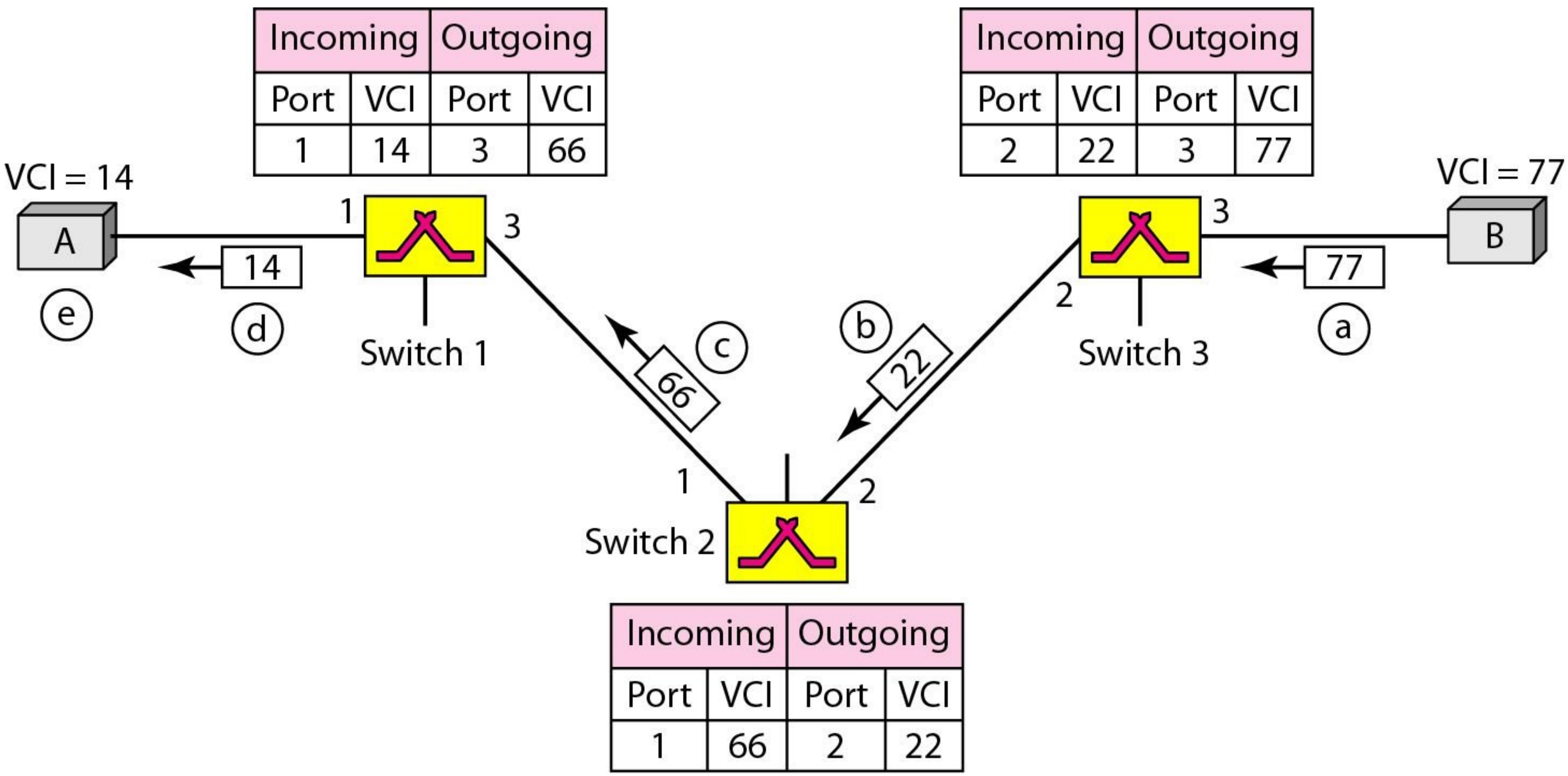


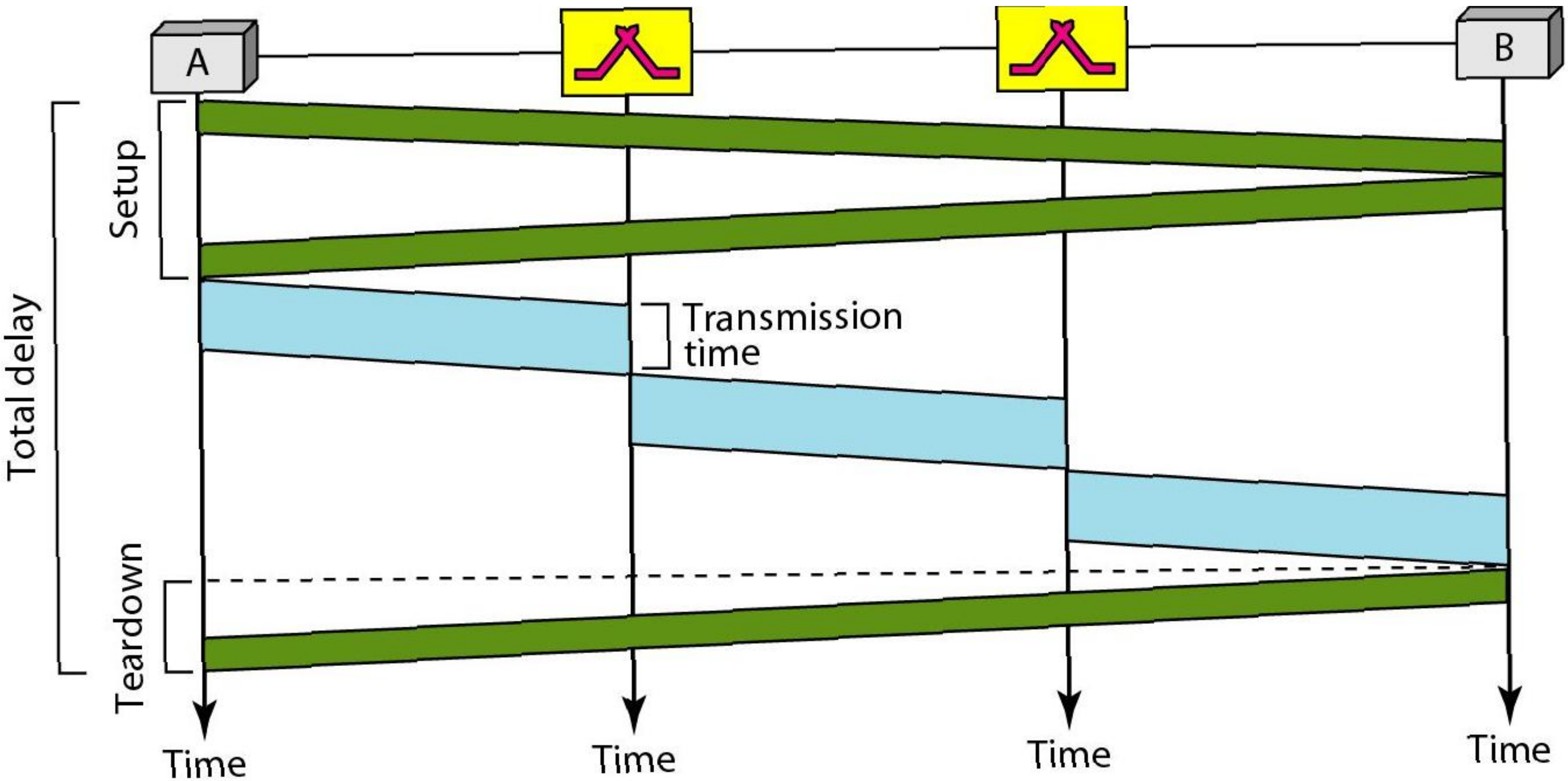
Figure 8.15 *Setup acknowledgment in a virtual-circuit network*

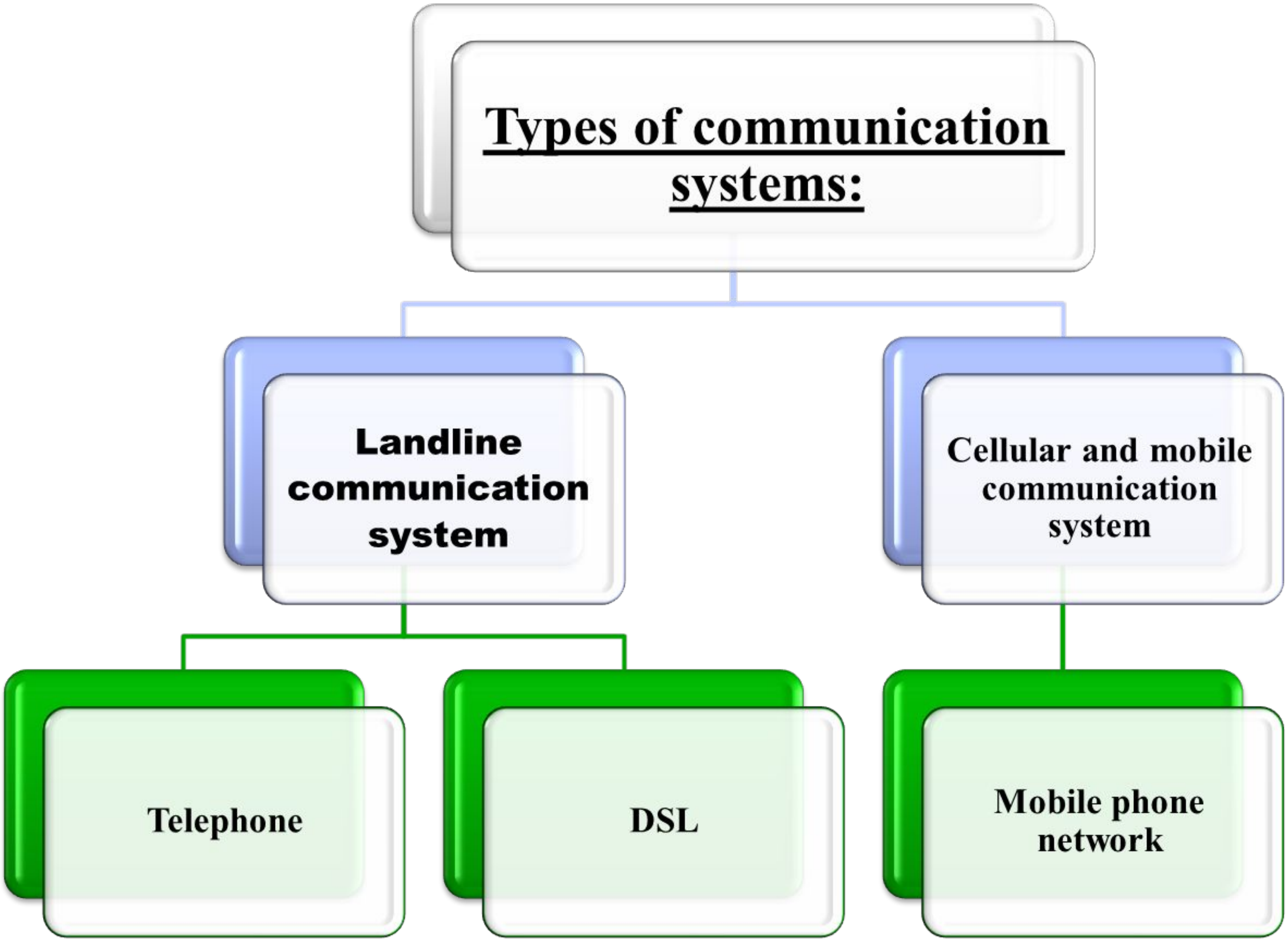


Note

In virtual-circuit switching, all packets belonging to the same source and
destination travel the same path;
but the packets may arrive at the destination with different delays
if resource allocation is on demand.

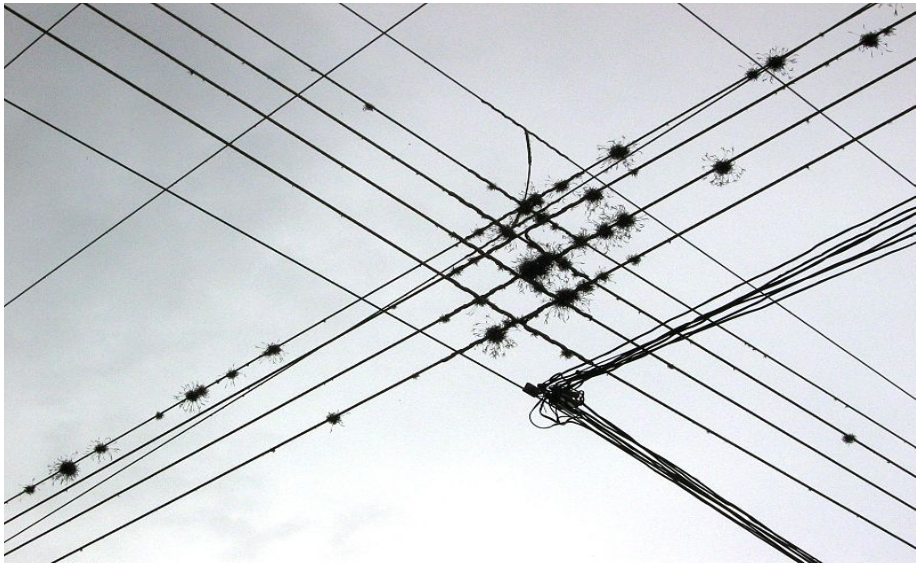
Figure 8.16 *Delay in a virtual-circuit network*

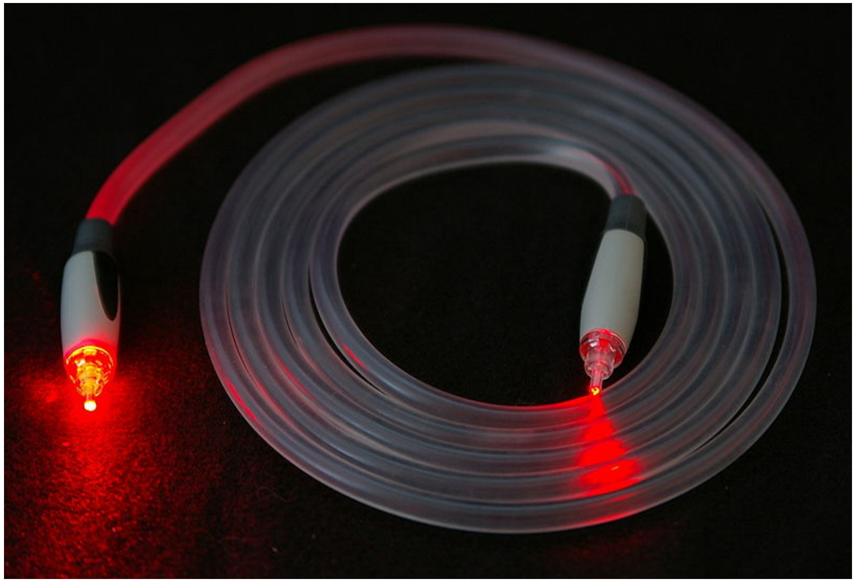



Types of communication systems:
Landline communication system
Cellular and mobile communication system
Telephone
DSL
Mobile phone network

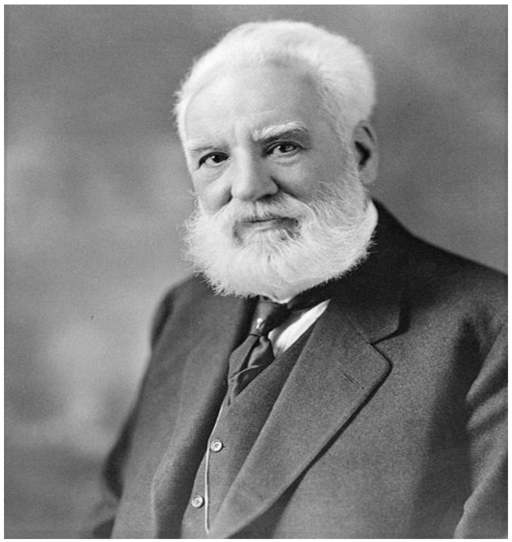
What is a Landline?

- **A landline is a physical connection between two devices.**
- Example on a Landline:
- Landline Phone (metal wire or fiber cable)





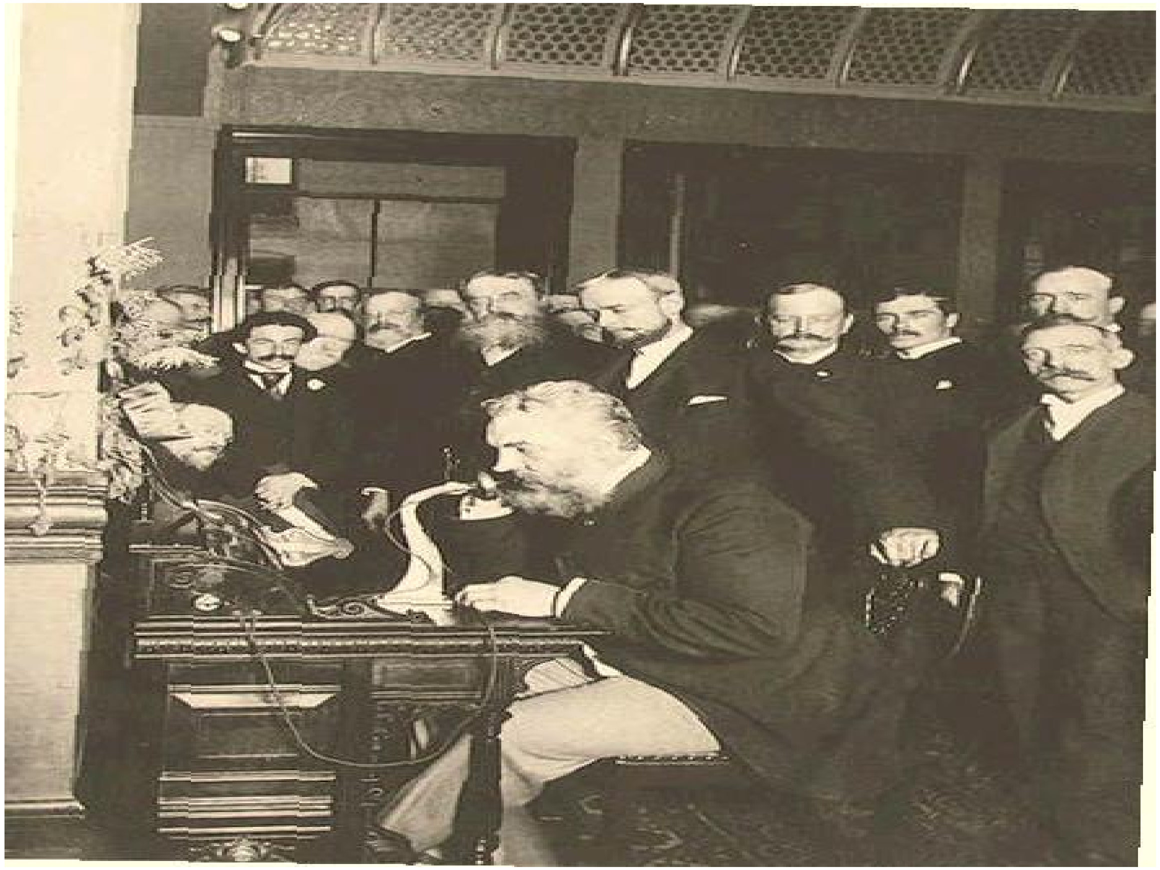
History Of Telephone



Alexander Graham

Alexander Graham inventing the first practical telephone.

Tho **Thomas Edison, invented the** carbon microphone **which produced a strong telephone signal**



Bell on the telephone in New York (calling Chicago) in 1892

Evolution in Telephone

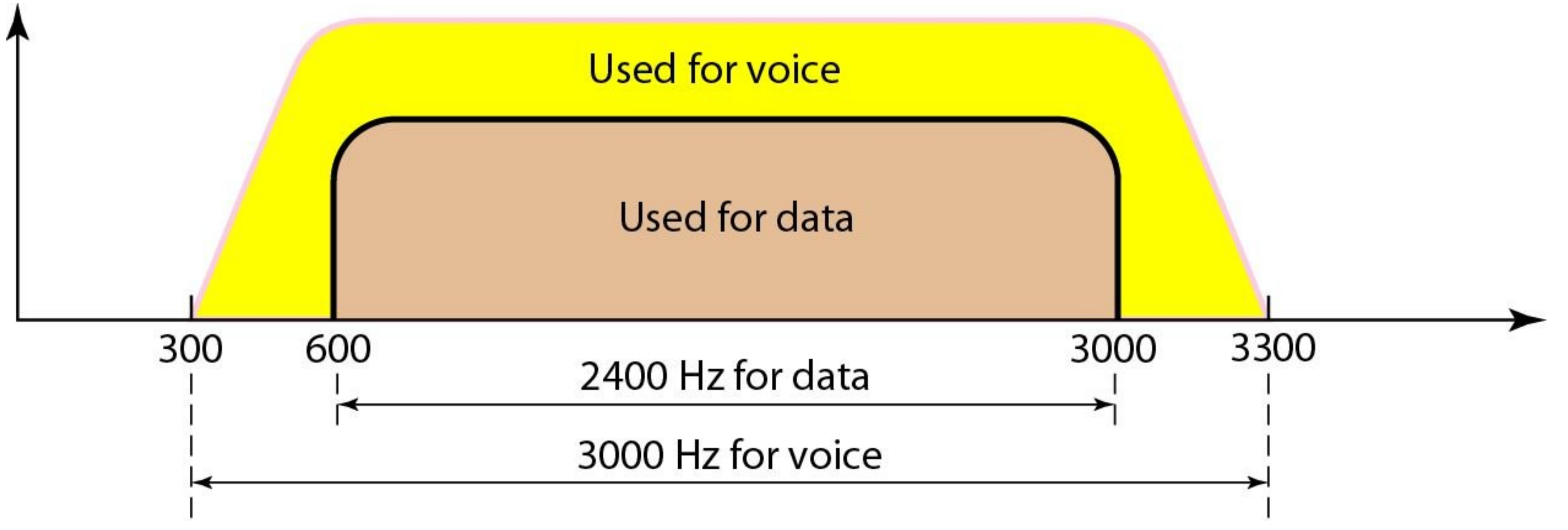
DIAL-UP MODEMS

- *Traditional telephone lines can carry frequencies between 300 and 3300 Hz, giving them a bandwidth of 3000 Hz.*
- *All this range is used for transmitting voice, where a great deal of interference and distortion can be accepted without loss of intelligibility.*

Topics discussed in this section:

Modem Standards

Figure 9.6 *Telephone line bandwidth*



Note

Modem
stands for modulator/demodulator.

Figure 9.1 *Modulation/demodulation*

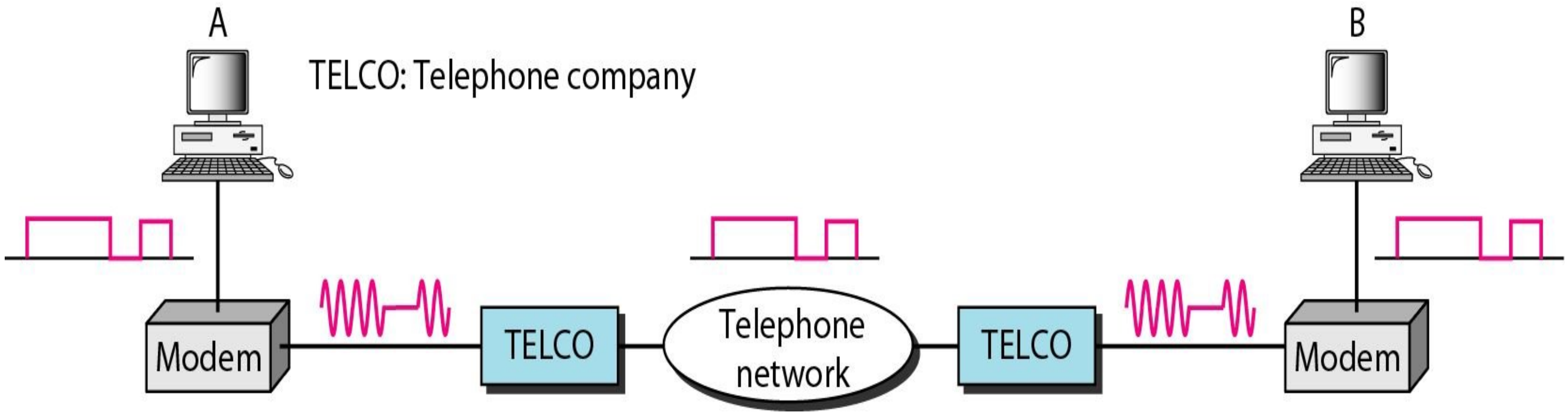
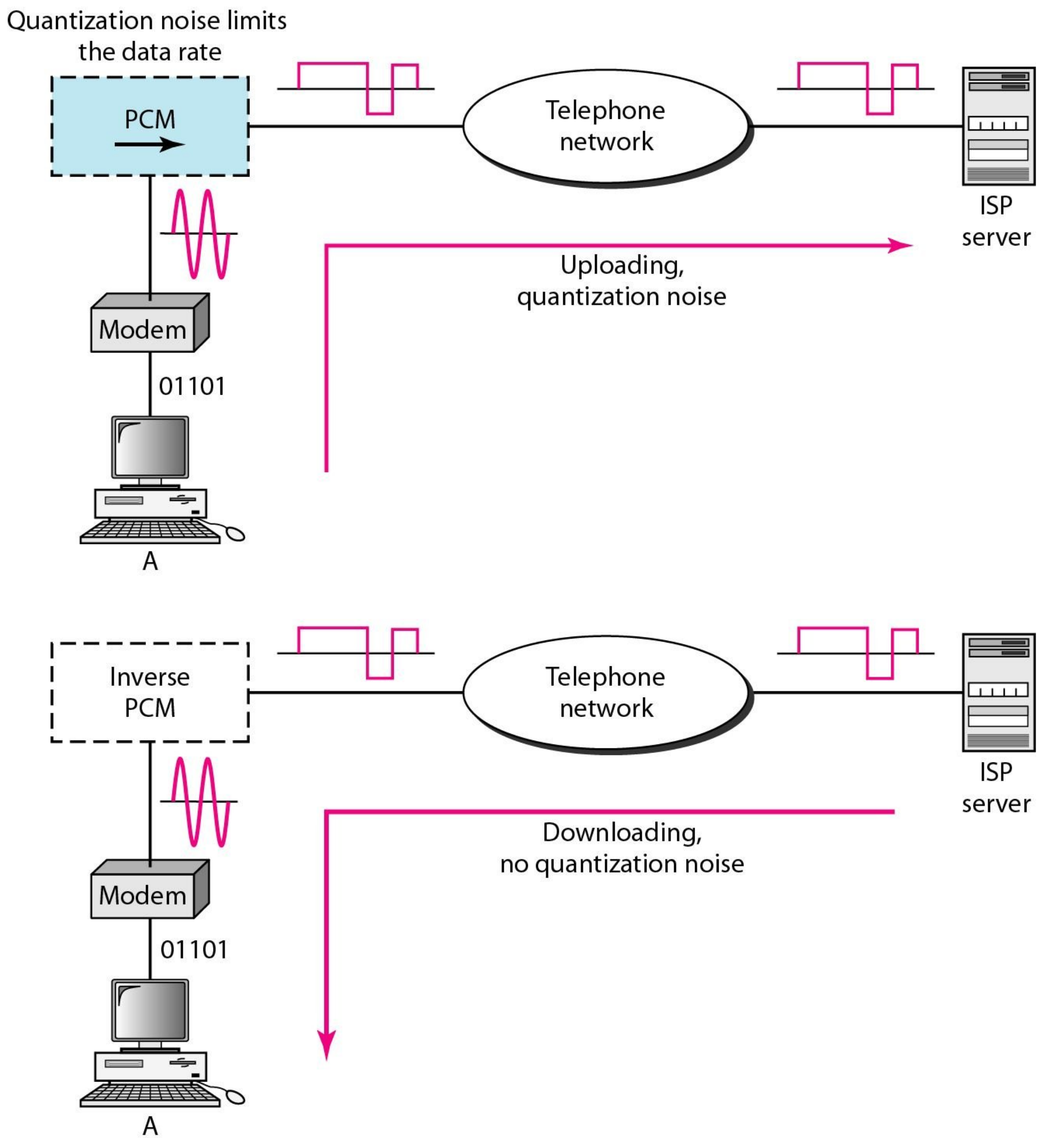


Figure 9.9 *Uploading and downloading in 56K modems*



9-3 DIGITAL SUBSCRIBER LINE

- *After traditional modems reached their peak data rate, telephone companies developed another technology, DSL, to provide higher-speed access to the Internet.*

- *Digital subscriber line (DSL) technology is one of the most promising for supporting high-speed digital communication over the existing local loops.*

- *It is a technology that brings huge data and information to homes and small businesses over ordinary telephone lines.*

- *Different variations of DSL, such as ADSL, HDSL, IDSL, VDSL and RADSL.*

DSL

- Originally designed to carry “Data”.
- 25kHz to 1.1MHz.
- In one wire:
  - Phone call data + Internet data = ?

  <u>BUT IN DIFFERENT FREQUENCIES</u>

The Splitter

The Splitter

- One input and two outs device:
  - Phone output get.
  - DSL output get.

- Phone output gat is a Low-pass filter:
  - It passes DC to 3.4kHz.

Note

ADSL is an asymmetric communication technology designed for residential users; it is not suitable for businesses.

Note

The existing local loops can handle bandwidths up to 1.1 MHz.

Note

ADSL is an adaptive technology.

The system uses a data rate
based on the condition of
the local loop line.

Figure 9.10 *Discrete multitone technique*

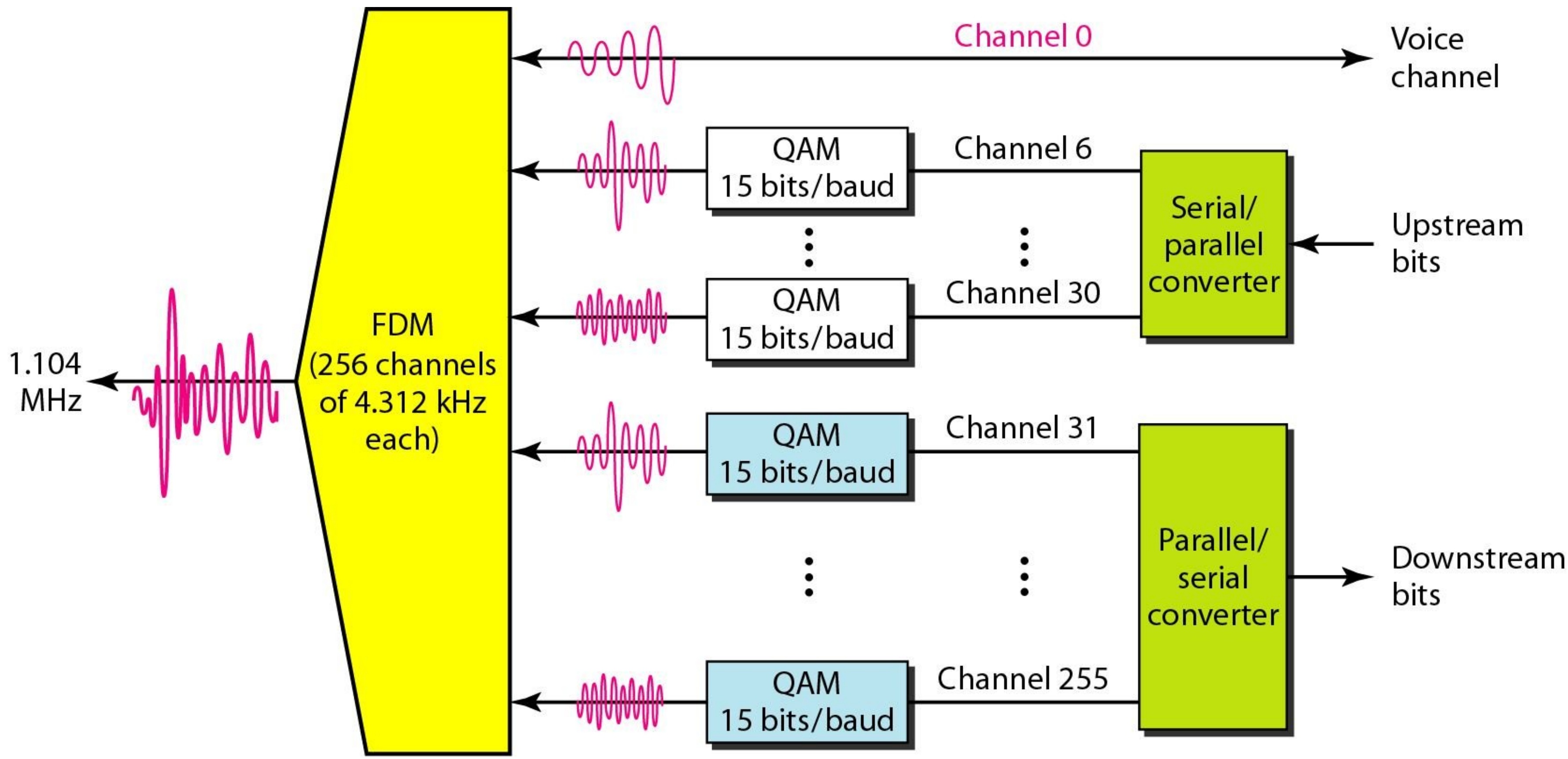
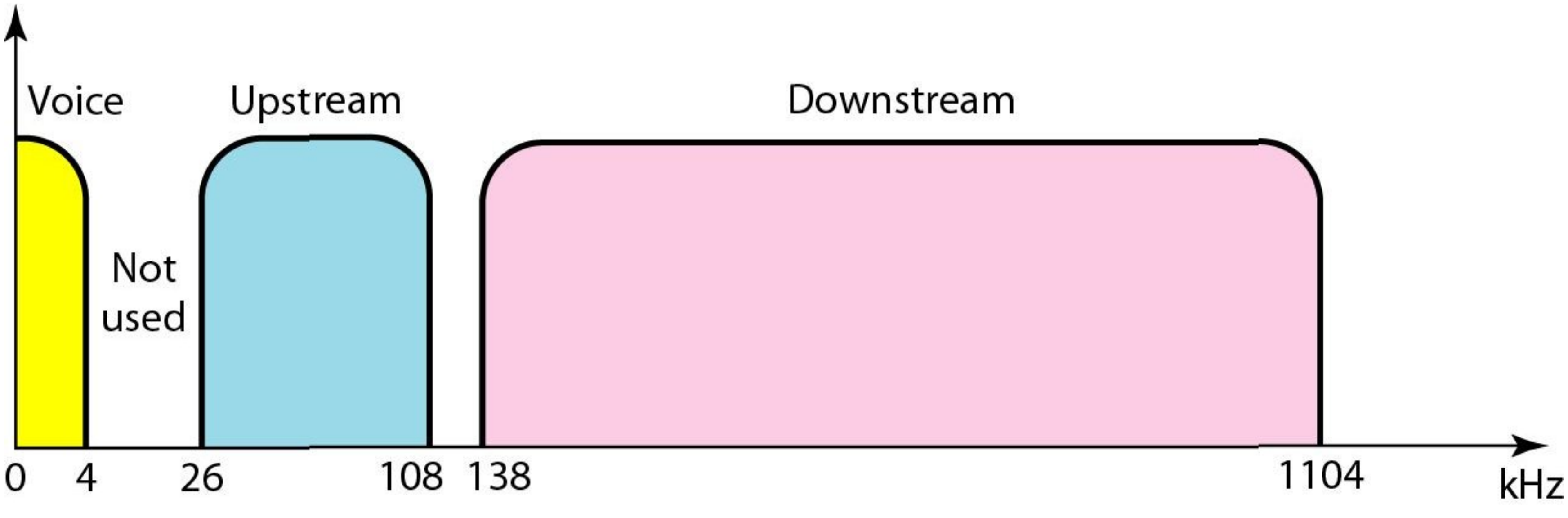


Figure 9.11 *Bandwidth division in ADSL*



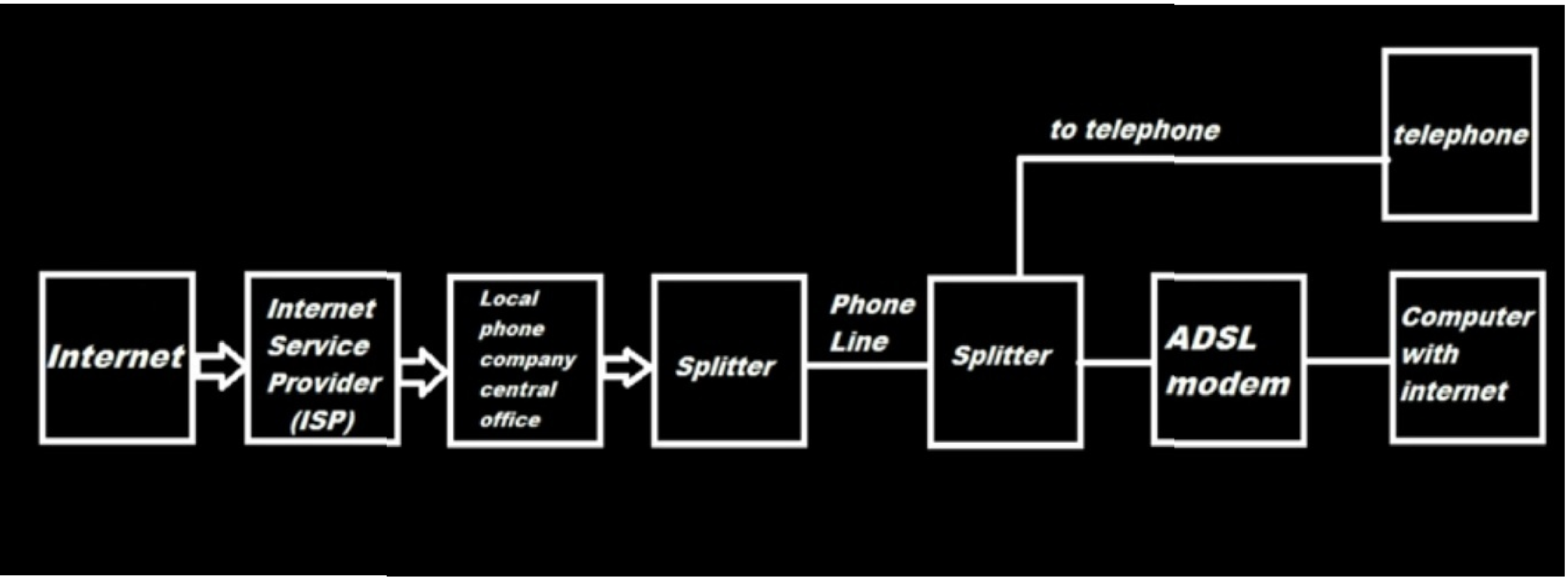

Internet
Internet Service Provider (ISP)
Local phone company central office
Splitter
Phone Line
Splitter
to telephone
telephone
ADSL modem
Computer with internet

Figure 9.12 *ADSL modem*

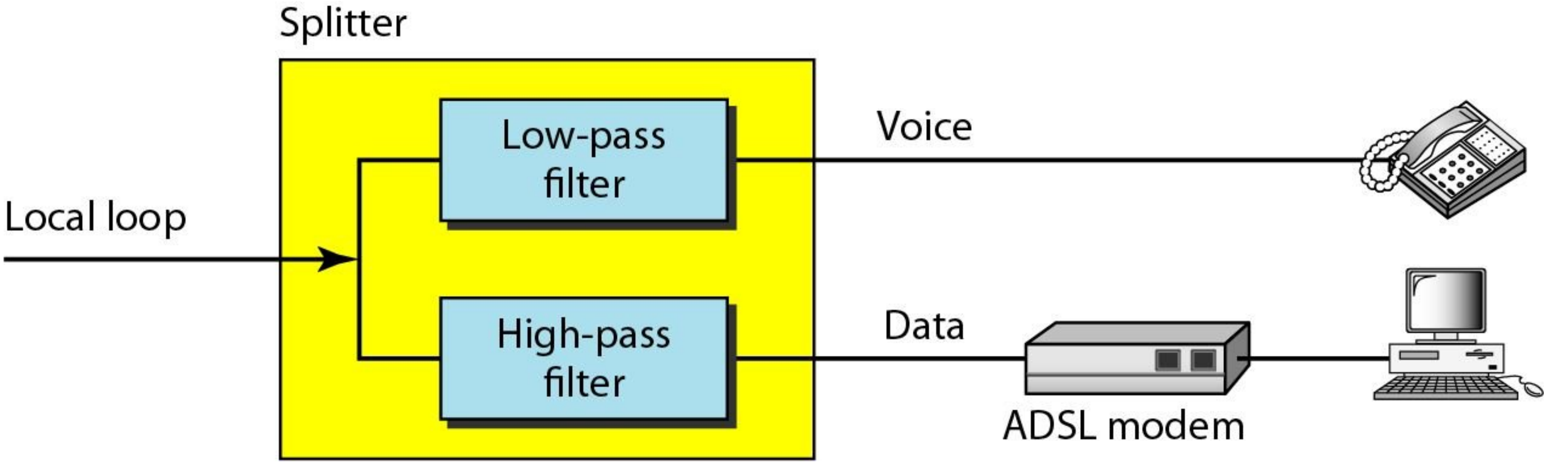
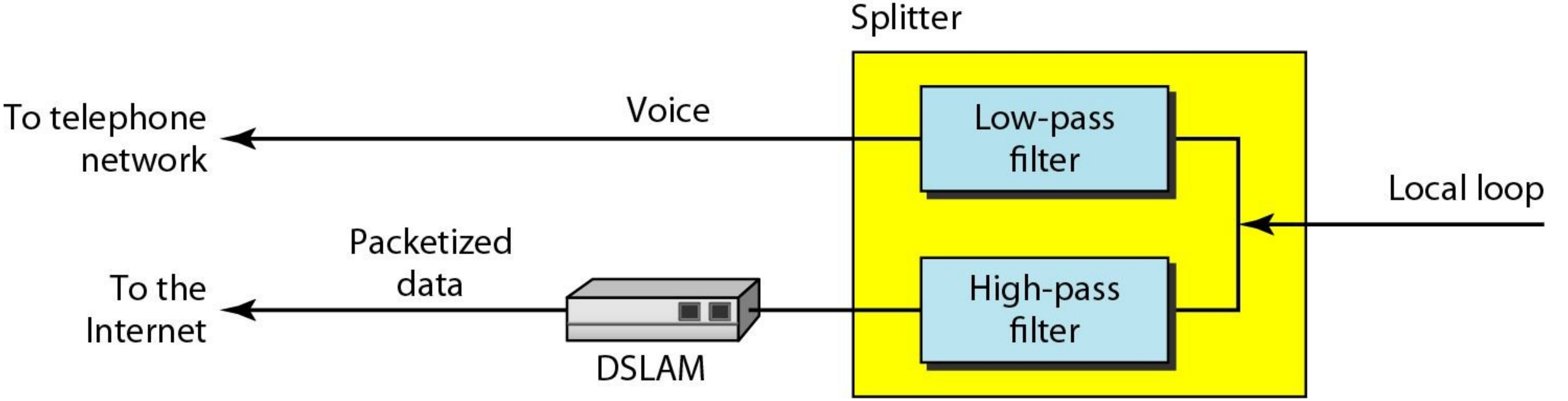


Figure 9.13 *DSLAM* (Digital Subscriber Line Access Multiplexer)



A symmetric digital subscriber line **(SDSL)** is a digital subscriber line that transmits digital data over the copper wires of the telephone network, where the bandwidth in the downstream direction, from the network to the subscriber, is identical to the bandwidth in the upstream direction, from the subscriber to the network.

High-bit-rate digital subscriber line **(HDSL)** is a telecommunications protocol standardized in 1994. It was the first digital subscriber line (DSL) technology to use a higher frequency spectrum over copper, twisted pair cables.

Very-high-bit-rate digital subscriber line **(VDSL)** and very-high-bit-rate digital subscriber line 2 (VDSL2) are digital subscriber line (DSL) technologies providing data transmission faster than asymmetric digital subscriber line (ADSL).

Table 9.2 *Summary of DSL technologies*

Technology	*Downstream Rate*	*Upstream Rate*	*Distance (ft)*	*Twisted Pairs*	*Line Code*
ADSL	1.5–6.1 Mbps	16–640 kbps	12,000	1	DMT
ADSL Lite	1.5 Mbps	500 kbps	18,000	1	DMT
HDSL	1.5–2.0 Mbps	1.5–2.0 Mbps	12,000	2	2B1Q
SDSL	768 kbps	768 kbps	12,000	1	2B1Q
VDSL	25–55 Mbps	3.2 Mbps	3000–10,000	1	DMT

DSL Advantages

- DSL does not tie up the phone line.
- Higher speed.
- DSL doesn't necessarily require new wiring.
- Some companies that offers DSL will usually provide the modem as part of the installation.

DSL Disadvantages

- The farther you are from the central office, the slower your connection is. As you move away from the central office, more distortion enters the line and the signal deteriorates.

- The connection is faster for receiving data than it is for sending data over the Internet.

- The service is not available everywhere.

8-4 STRUCTURE OF A SWITCH

- *We use switches in circuit-switched and packet-switched networks.*
- *In this section, we discuss the structures of the switches used in each type of network.*

Topics discussed in this section:

Structure of Circuit Switches
Structure of Packet Switches

Figure 8.11 *Crossbar switch with three inputs and four outputs*

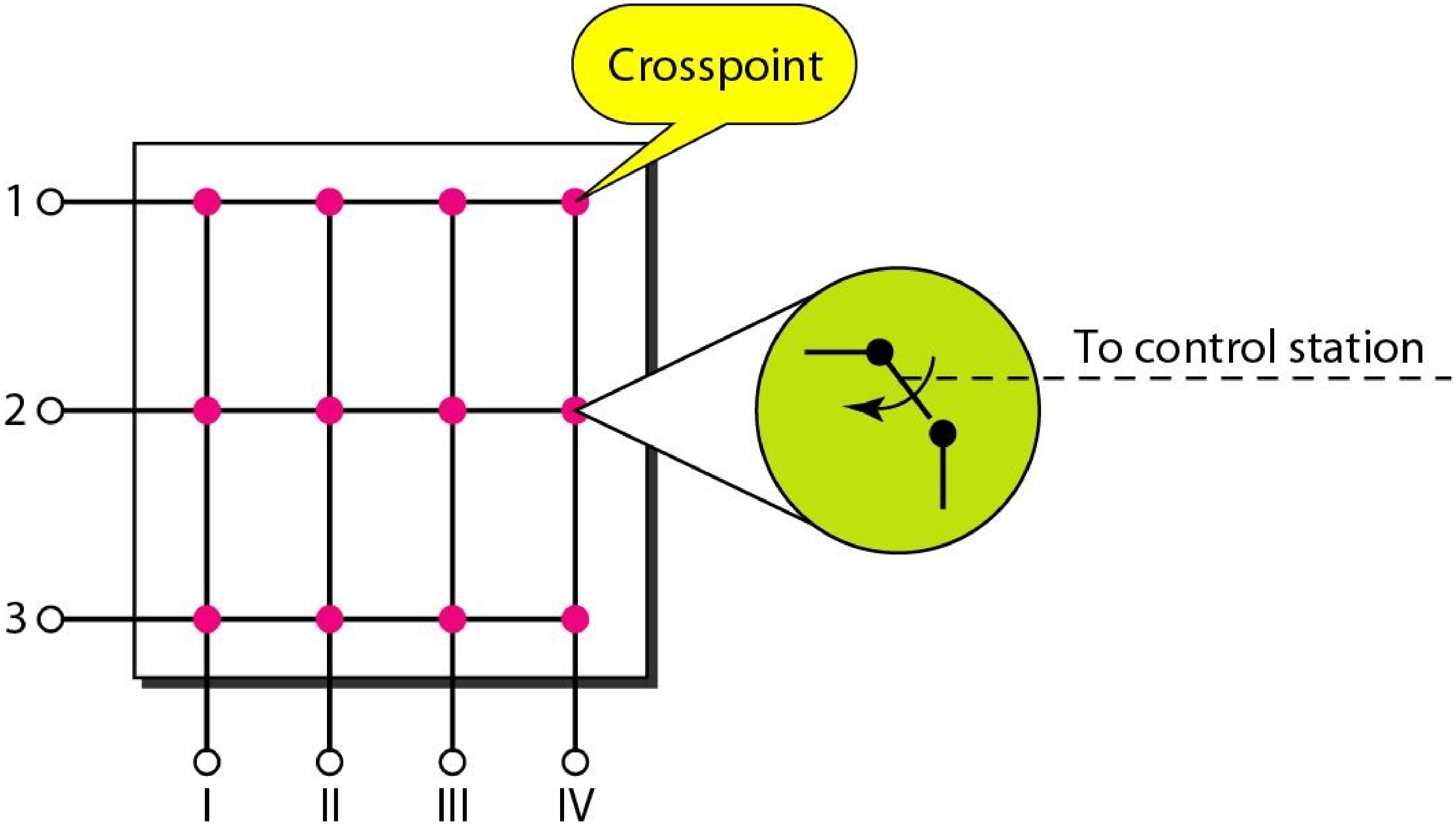
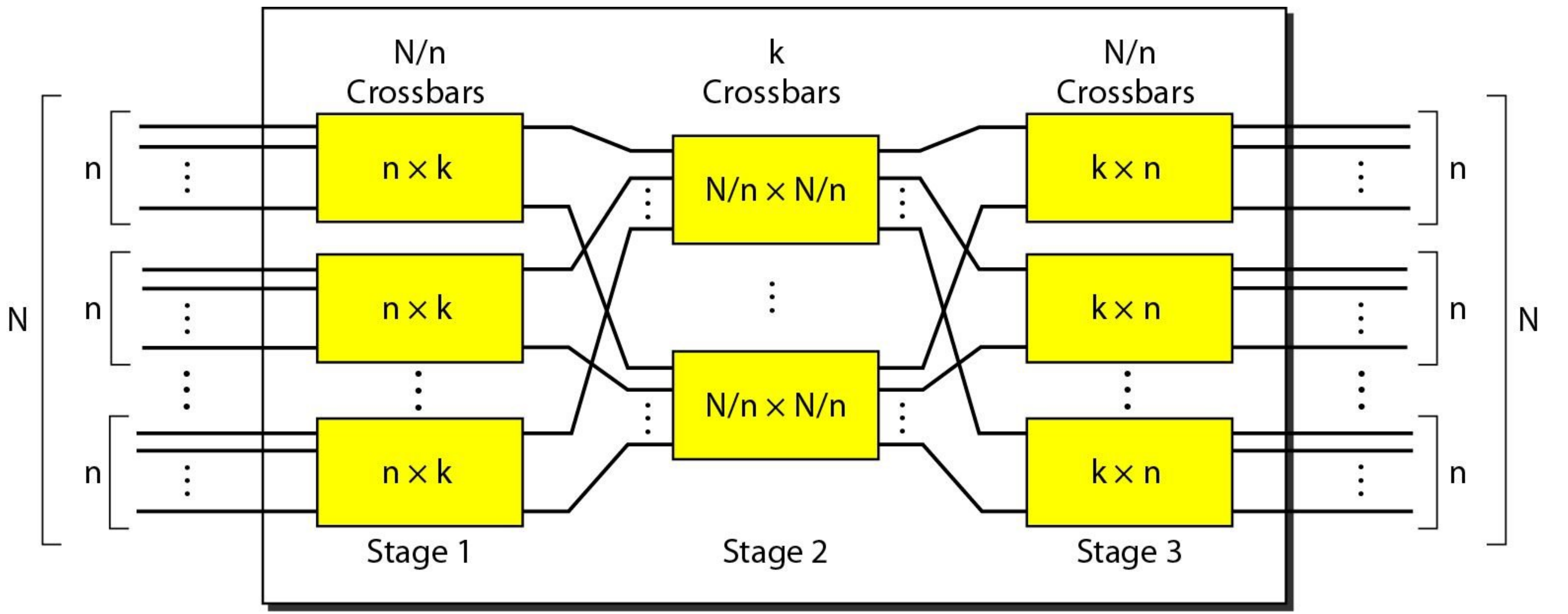


Figure 8.18 *Multistage switch*



Note

In a three-stage switch, the total number of crosspoints is

$$2kN + k(N/n)^2$$

which is much smaller than the number of crosspoints in a single-stage switch (N^2).

Example 8.3

Design a three-stage, 200 × 200 switch (N = 200) with k = 4 and n = 20.

Solution

In the first stage we have N/n or 10 crossbars, each of size 20 × 4. In the second stage, we have 4 crossbars, each of size 10 × 10. In the third stage, we have 10 crossbars, each of size 4 × 20. The total number of crosspoints is $2kN + k(N/n)^2$, *or 2000 crosspoints. This is 5 percent of the number of crosspoints in a single-stage switch (200 × 200 = 40,000).*

Note

According to the Clos criterion:

$n = (N/2)^{1/2}$

$k > 2n - 1$

Crosspoints $\geq 4N\,[(2N)^{1/2} - 1]$

Example 8.4

Redesign the previous three-stage, 200×200 switch, using the Clos criteria with a minimum number of crosspoints.

Solution

We let $n = (200/2)^{1/2}$, or $n = 10$. We calculate $k = 2n - 1 = 19$. In the first stage, we have 200/10, or 20, crossbars, each with 10×19 crosspoints. In the second stage, we have 19 crossbars, each with 10×10 crosspoints. In the third stage, we have 20 crossbars each with 19×10 crosspoints. The total number of crosspoints is $20(10 \times 19) + 19(10 \times 10) + 20(19 \times 10) = 9500$.

Figure 8.19 *Time-slot interchange*

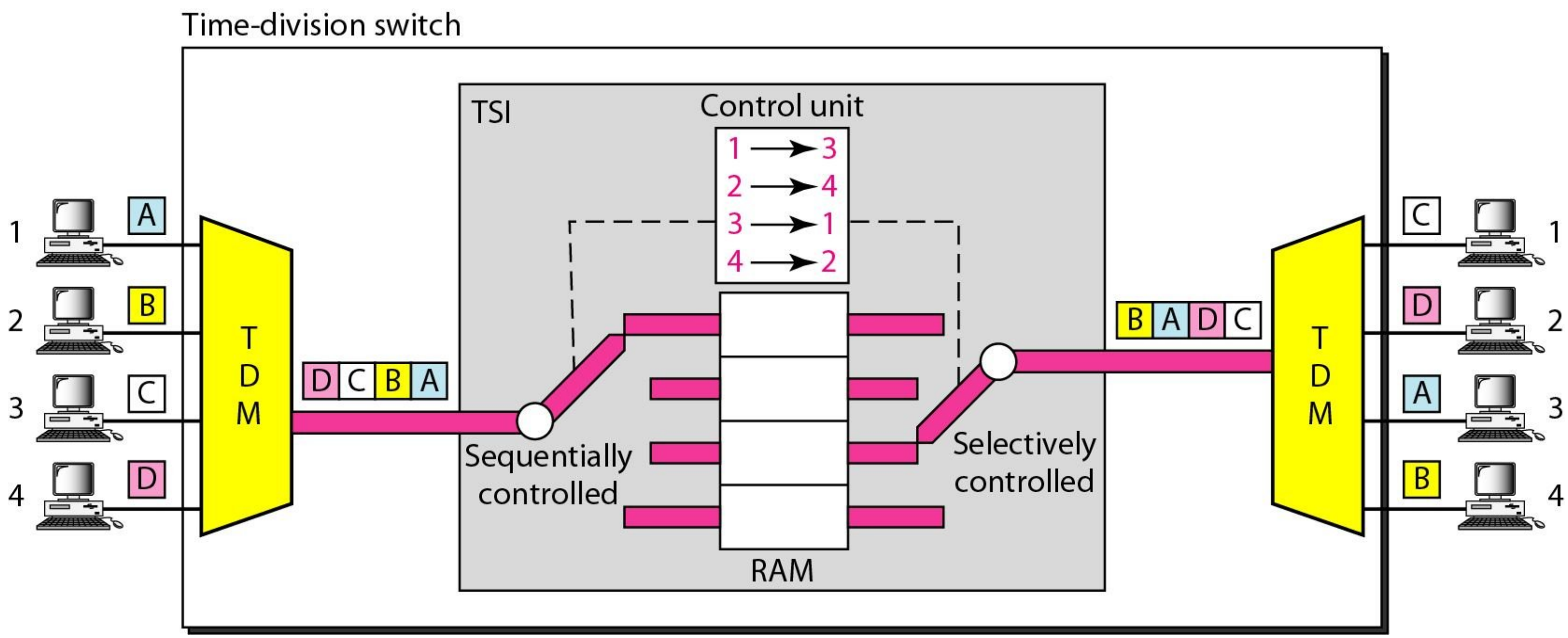


Figure 8.20 *Time-space-time switch*

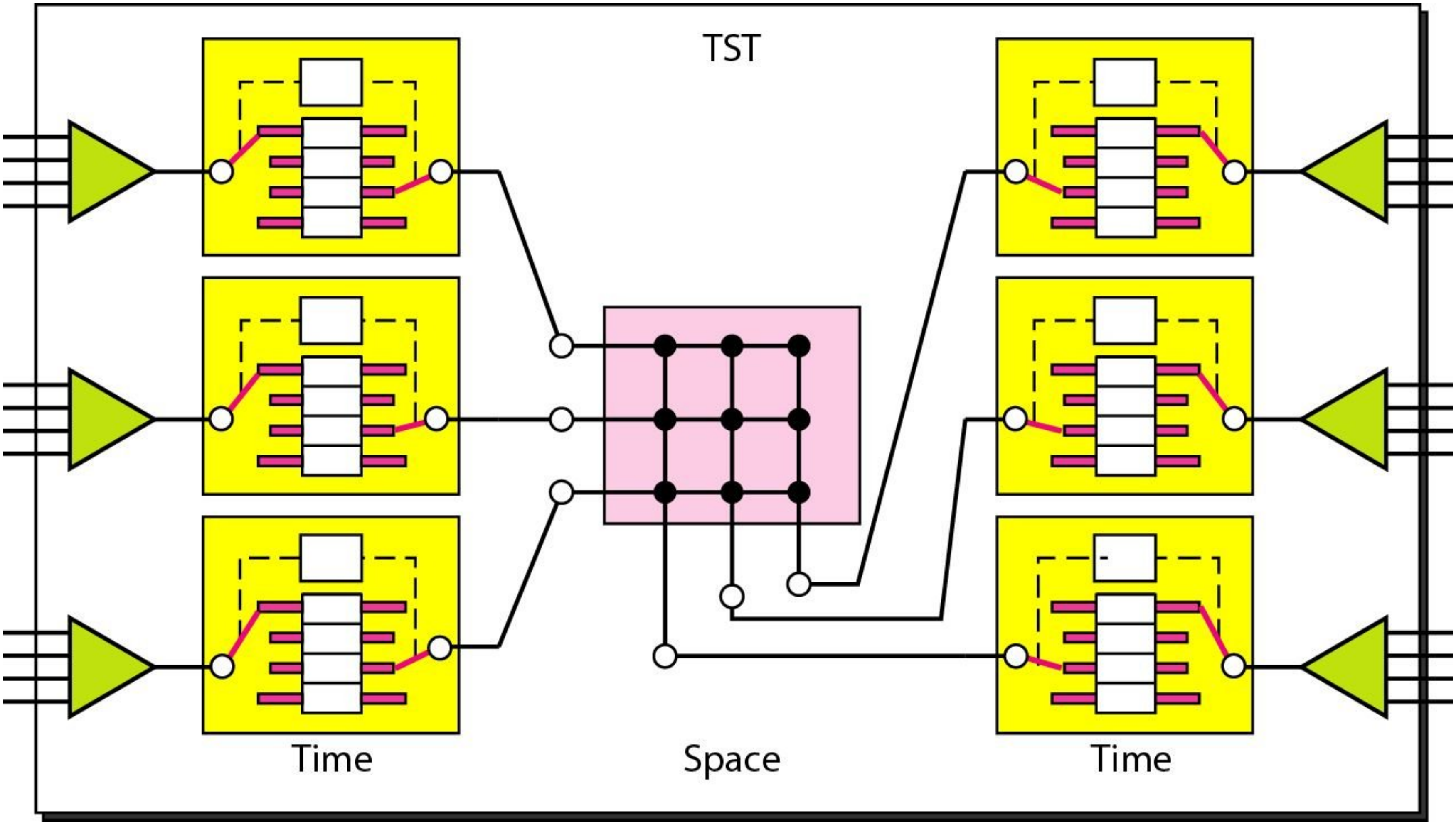


Figure 8.21 *Packet switch components*

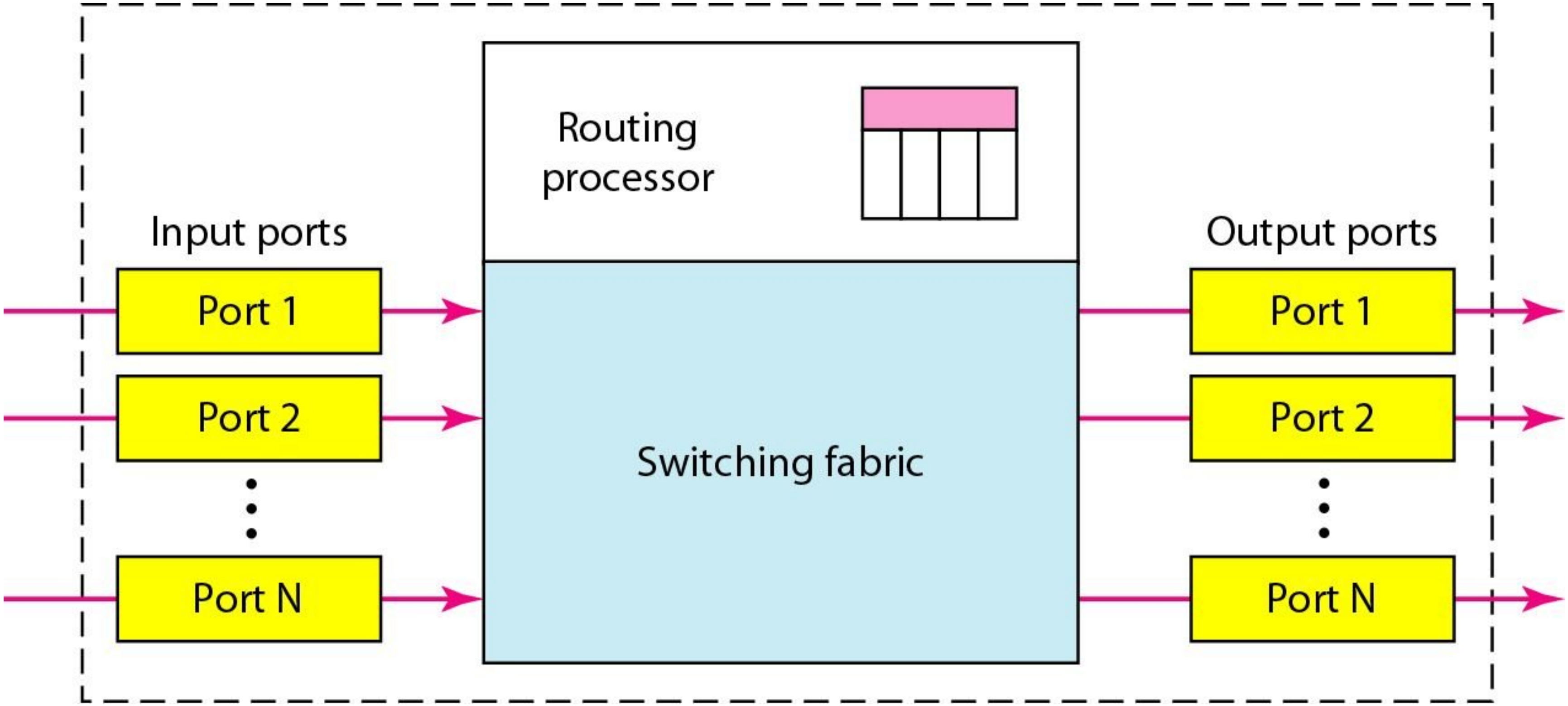


Figure 8.22 *Input port*

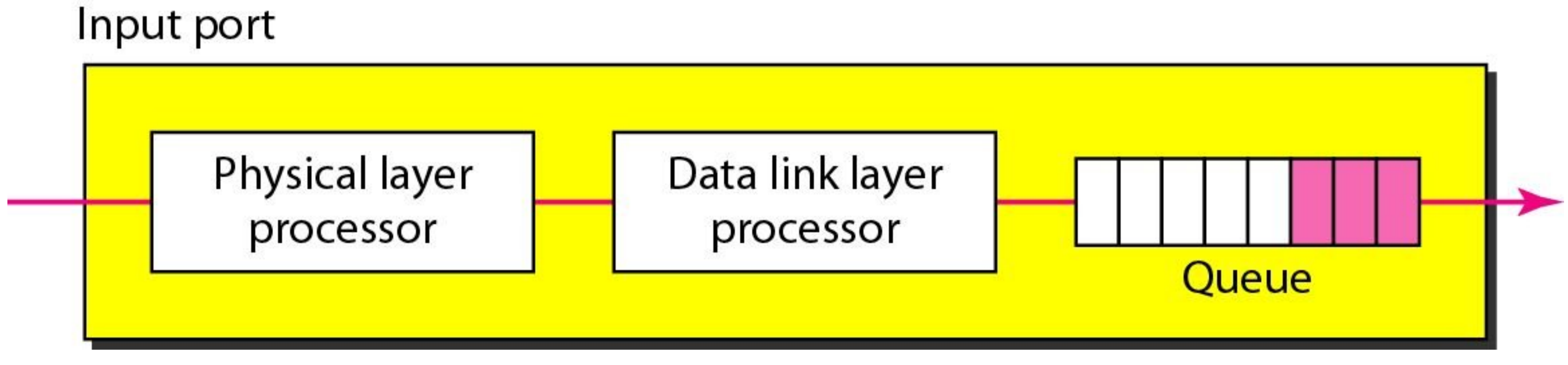


Figure 8.23 *Output port*

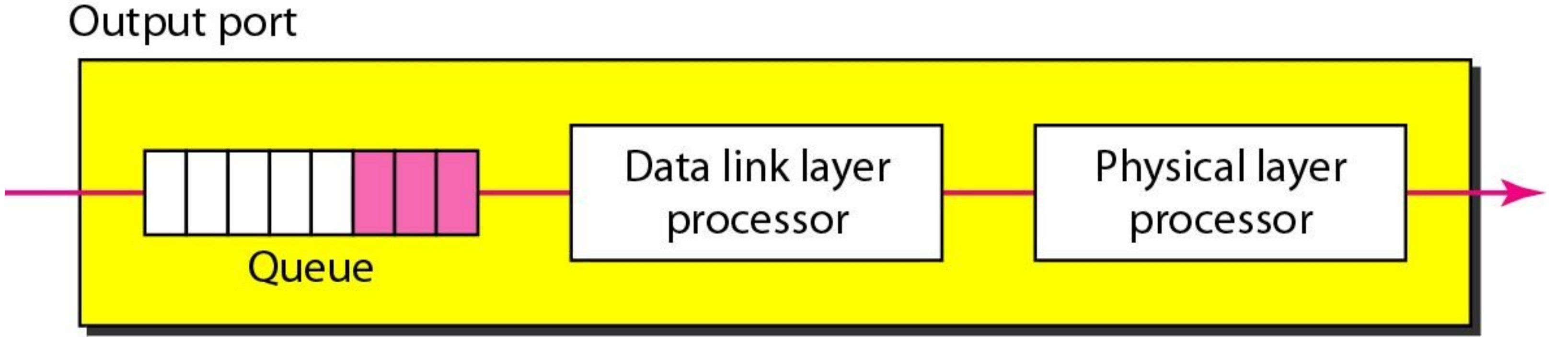


Figure 8.24 *A banyan switch*

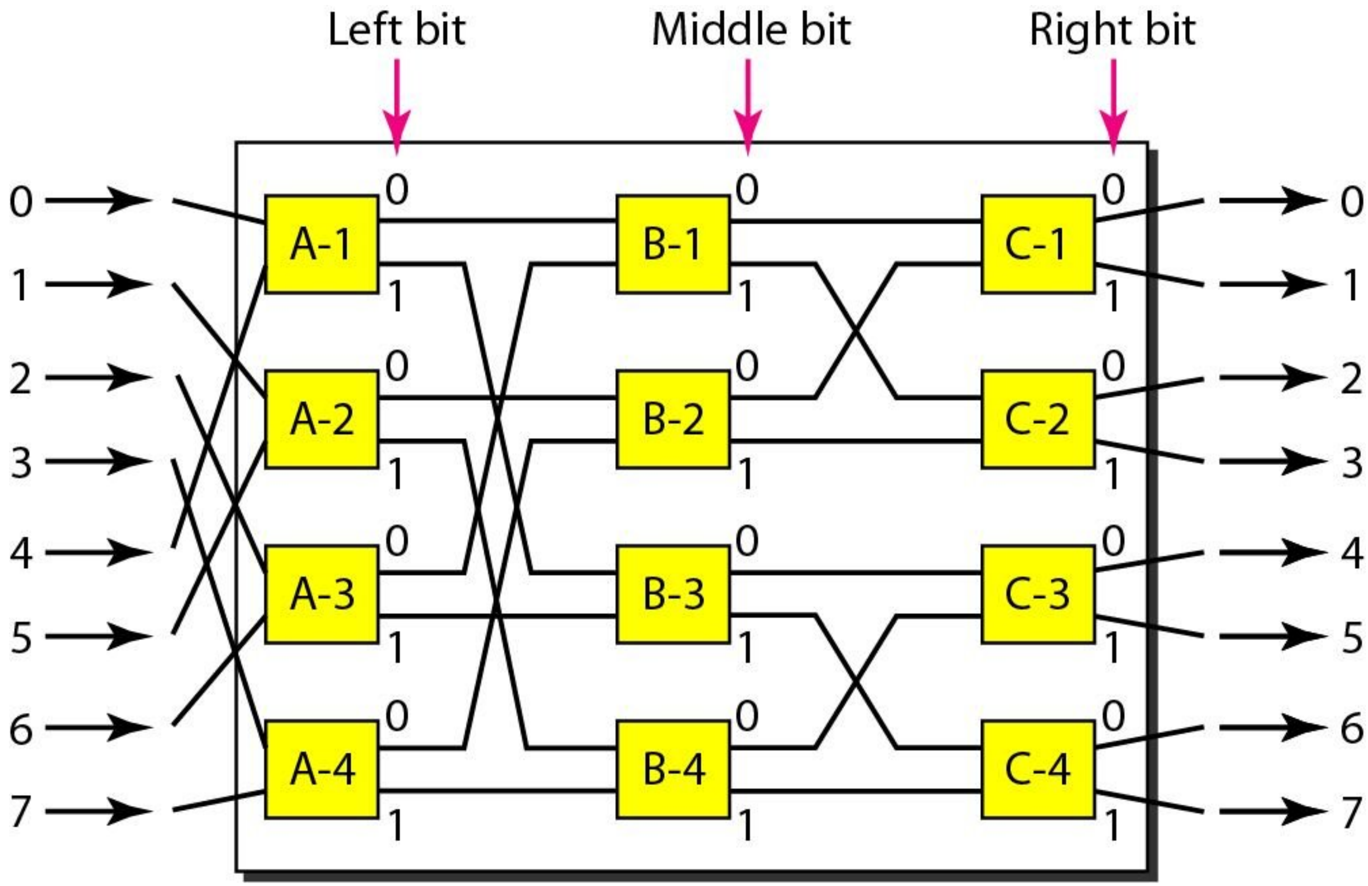
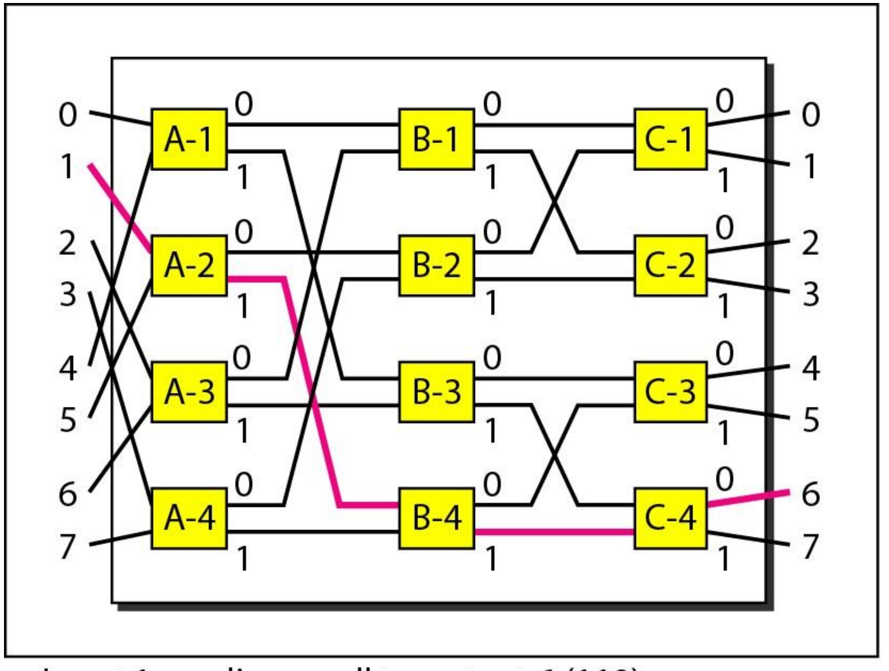
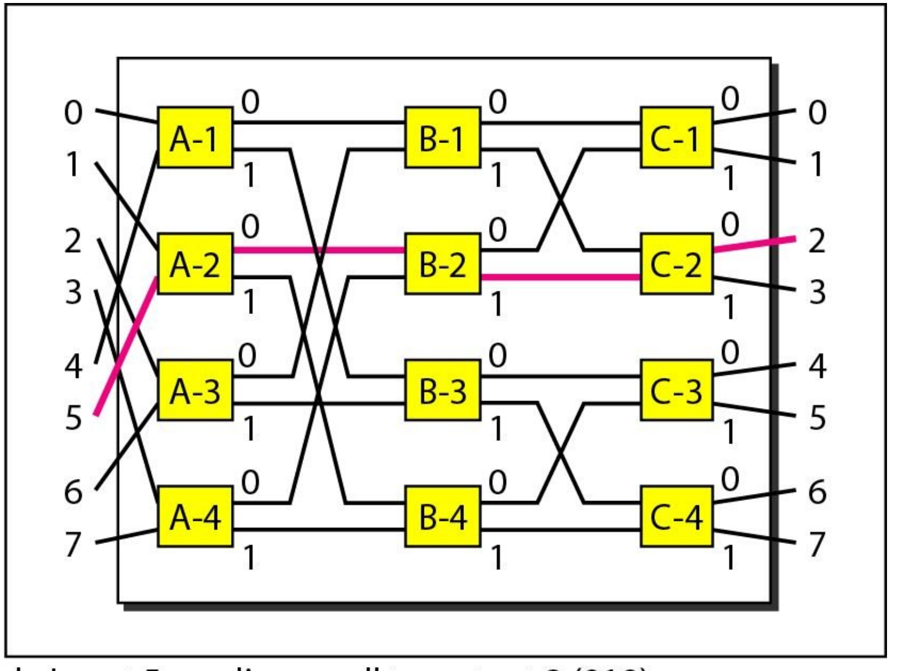


Figure 8.25 *Examples of routing in a banyan switch*

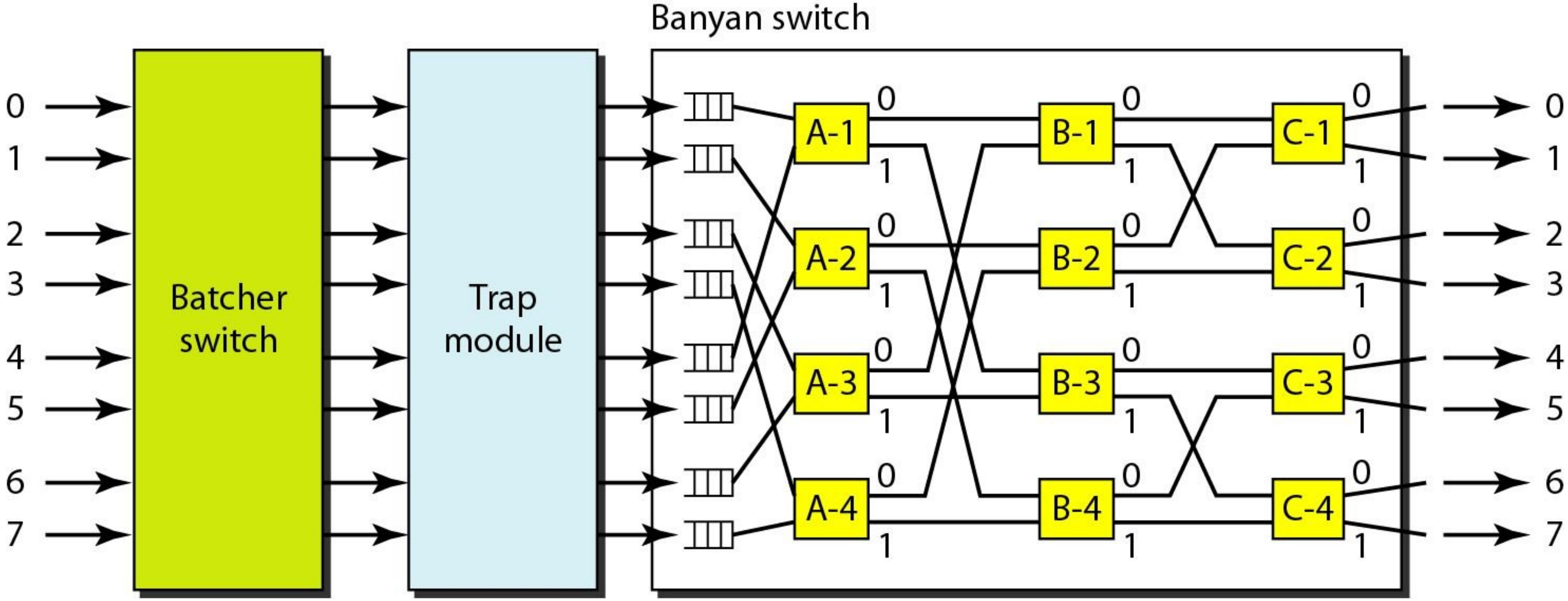


a. Input 1 sending a cell to output 6 (110)

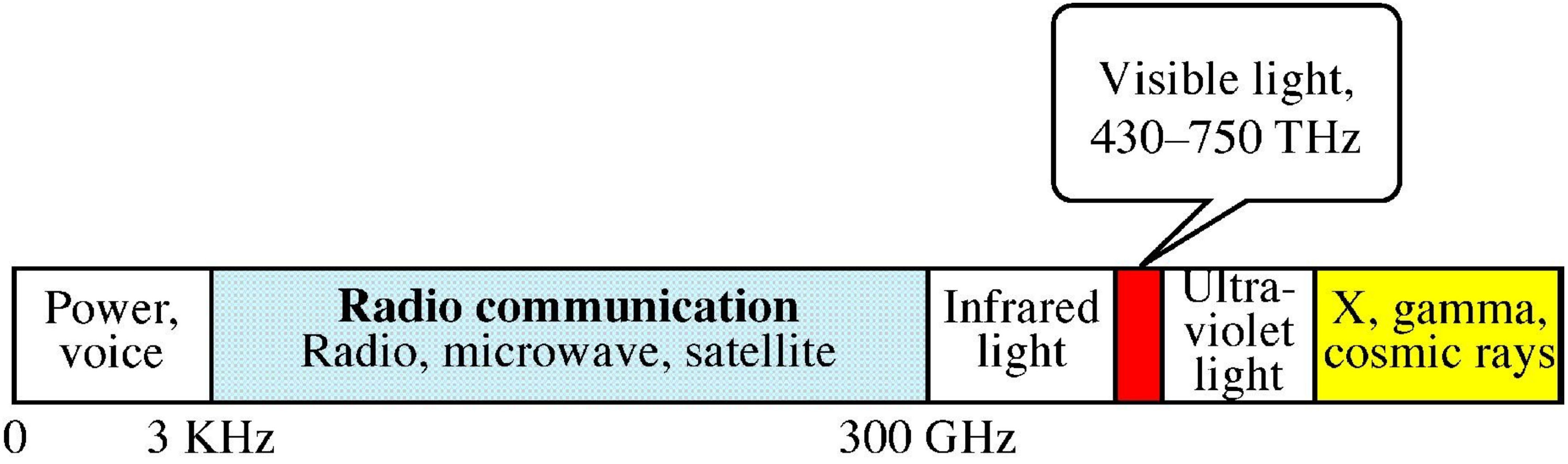


b. Input 5 sending a cell to output 2 (010)

Figure 8.26 *Batcher-banyan switch*



Electromagnetic Spectrum



REFERENCEs

1. Fourauzan B., "Data Communications and Networking", 5th edition, McGraw-Hill Publications
2. Stallings William., "Data and Computer Communications", Sixth Edition, Prentice Hall of India