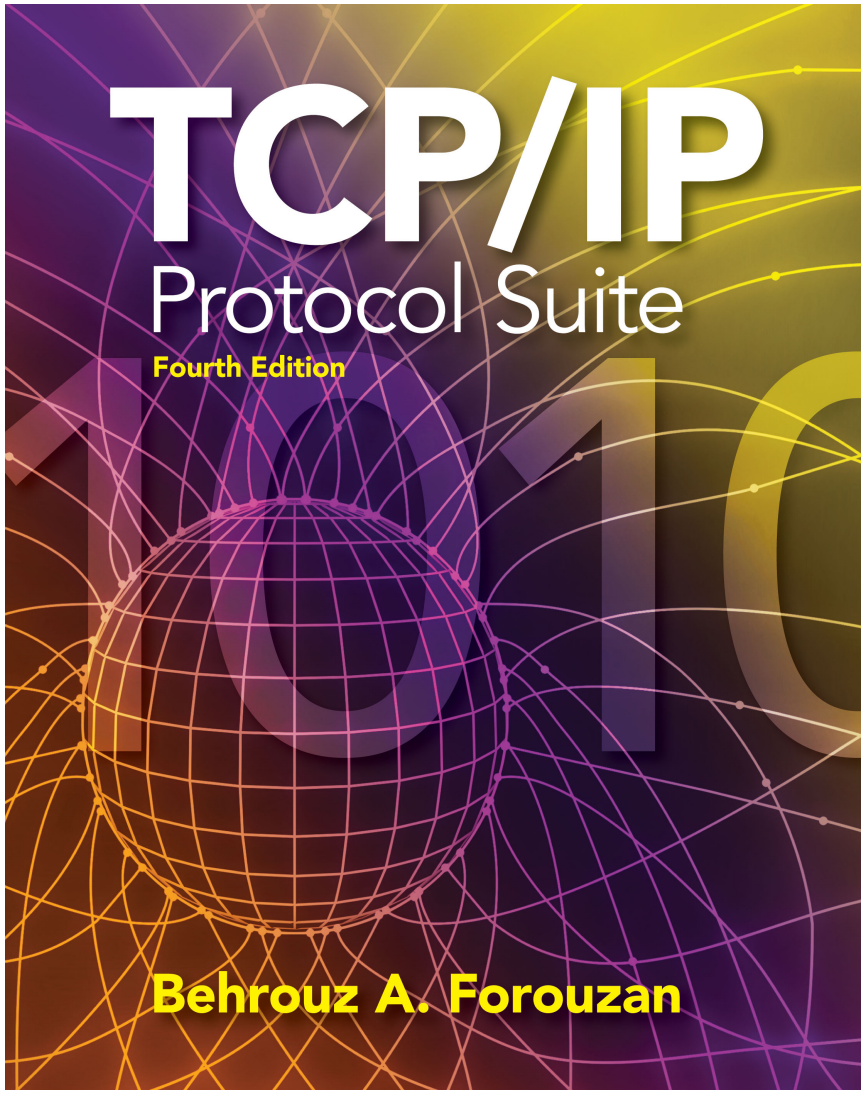
Chapter 3

Underlying Technology



OBJECTIVES:

- To briefly discuss the technology of dominant wired LANs, Ethernet, including traditional, fast, gigabit, and ten-gigabit Ethernet.
- To briefly discuss the technology of wireless WANs, including IEEE 802.11 LANs, and Bluetooth.
- To briefly discuss the technology of point-to-point WANs including 56K modems, DSL, cable modem, T-lines, and SONET.
- To briefly discuss the technology of switched WANs including X.25, Frame Relay, and ATM.
- To discuss the need and use of connecting devices such as repeaters (hubs), bridges (two-layer switches), and routers (three-layer switches).

Chapter Outline

3.1 Wired Local Area Network

3.2 Wireless LANs

3.3 Point-to-Point WANs

3.4 Switched WANs

3.5 Connecting Devices

3-1 WIRED LOCAL AREA NETWORKS

- A local area network (LAN) is a computer network that is designed for a limited geographic area such as a building or a campus.
- Although a LAN can be used as an isolated network to connect computers in an organization for the sole purpose of sharing resources, most LANs today are also linked to a wide area network (WAN) or the Internet.
- The LAN market has seen several technologies such as Ethernet, token ring, token bus, FDDI, and ATM LAN, but Ethernet is by far the dominant technology.

Topics Discussed in the Section

- ✓ IEEE Standards
- ✓ Frame Format
- ✓ Addressing
- ✓ Ethernet Evolution
- ✓ Standard Ethernet
- ✓ Fast Ethernet
- ✓ Gigabit Ethernet
- ✓ Ten-Gigabit Ethernet

Figure 3.1 *IEEE standard for LANs*

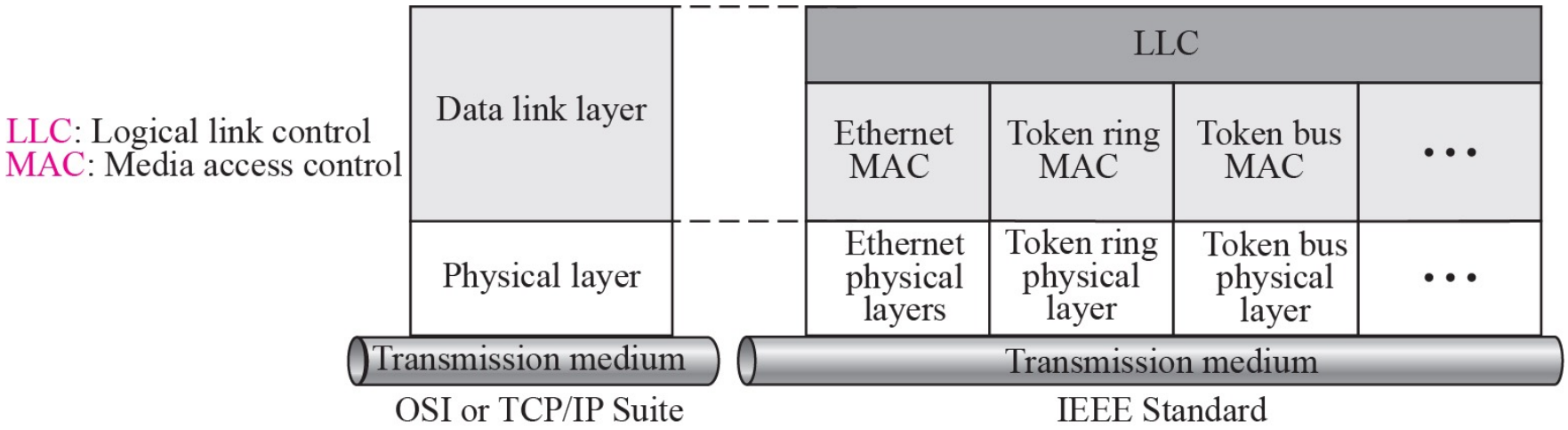


Figure 3.2 *Ethernet Frame*

Preamble: 56 bits of alternating 1s and 0s.

SFD: Start frame delimiter, flag (10101011)

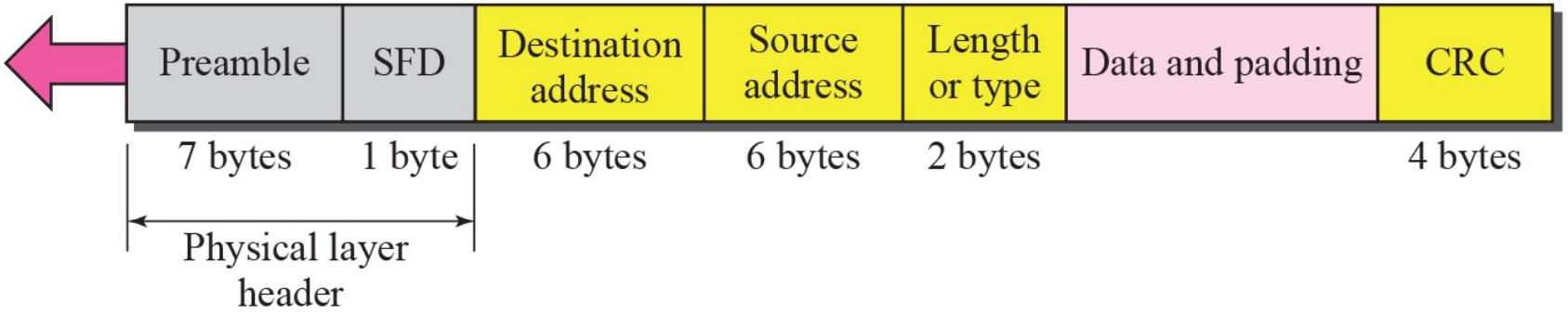
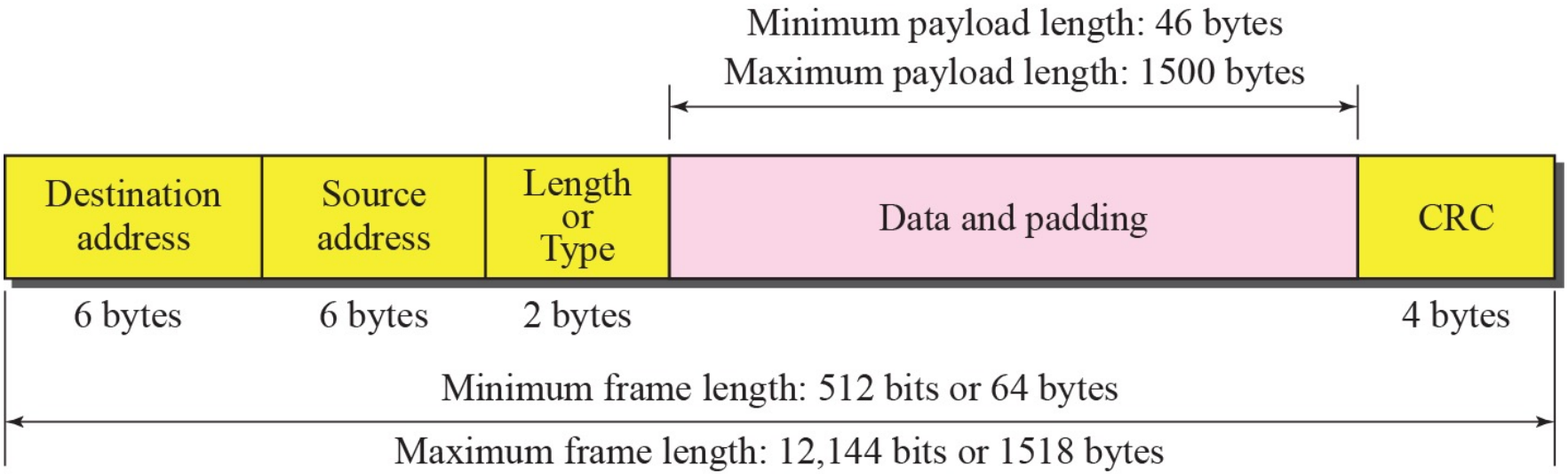


Figure 3.3 *Maximum and minimum lengths*



Note

Minimum length: 64 bytes (512 bits)

Maximum length: 1518 bytes (12,144 bits)

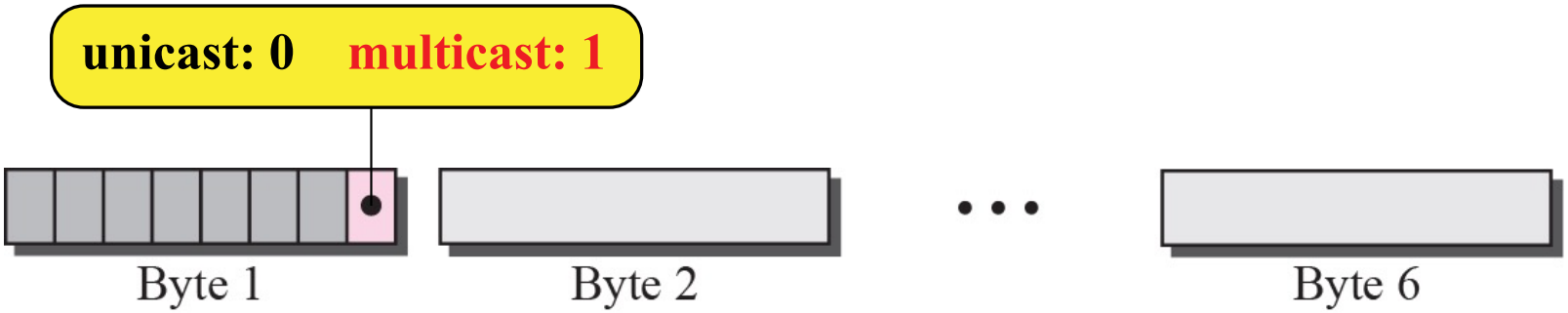
Figure 3.4 *Ethernet address in hexadecimal notation*

d: Hexadecimal digit

$$d_1d_2 : d_3d_4 : d_5d_6 : d_7d_8 : d_9d_{10} : d_{11}d_{12}$$

6 bytes = 12 hexadecimal digits = 48 bits

Figure 3.5 *Unicast and multicast addresses*



Note

The broadcast destination address is a special case of the multicast address in which all bits are 1s.

Note

The least significant bit of the first byte defines the type of address. If the bit is 0, the address is unicast; otherwise, it is multicast.

Example 3.1

Define the type of the following destination addresses:

a. 4A:30:10:21:10:1A
b. 47:20:1B:2E:08:EE
c. FF:FF:FF:FF:FF:FF

Solution

To find the type of the address, we need to look at the second hexadecimal digit from the left. If it is even, the address is unicast. If it is odd, the address is multicast. If all digits are F's, the address is broadcast. Therefore, we have the following:

a. This is a unicast address because A in binary is 1010 (even).
b. This is a multicast address because 7 in binary is 0111 (odd).
c. This is a broadcast address because all digits are F's.

Example 3.2

Show how the address 47:20:1B:2E:08:EE is sent out on line.

Solution

The address is sent left-to-right, byte by byte; for each byte, it is sent right-to-left, bit by bit, as shown below:

← 11100010 00000100 11011000 01110100 00010000 01110111

Figure 3.6 *Ethernet evolution through four generations*

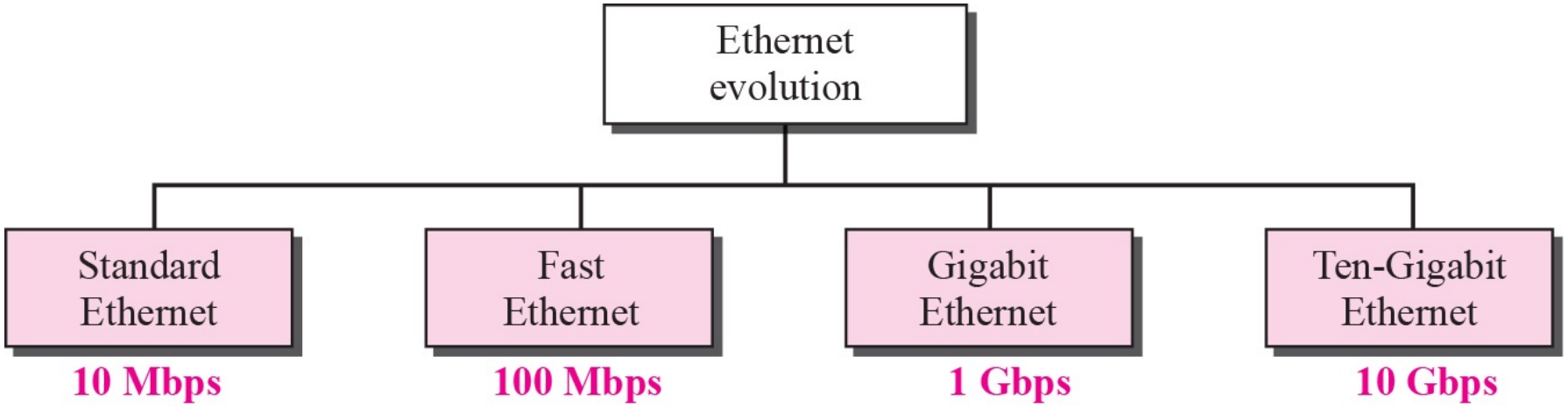


Figure 3.7 *Space/time model of a collision in CSMA*

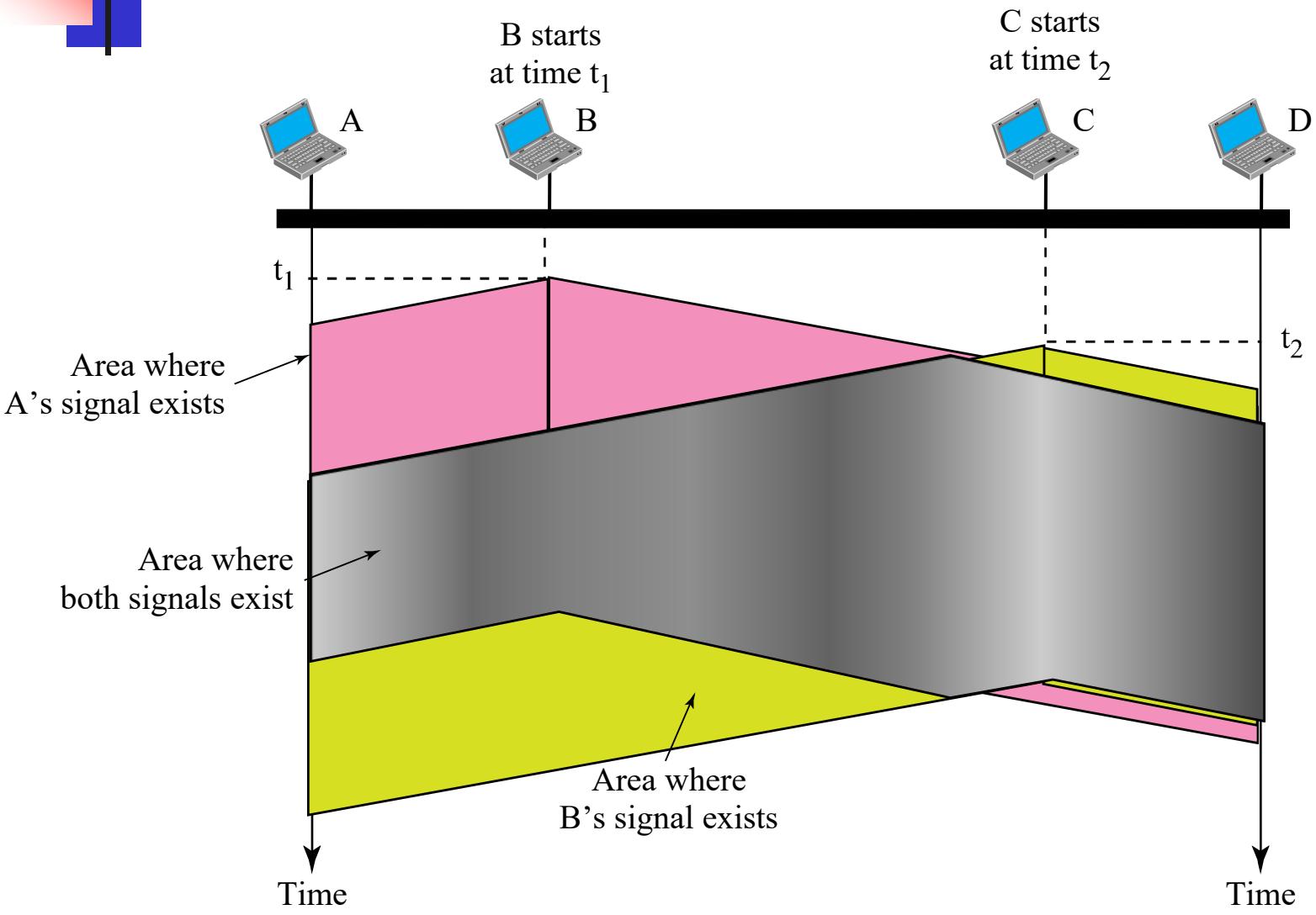
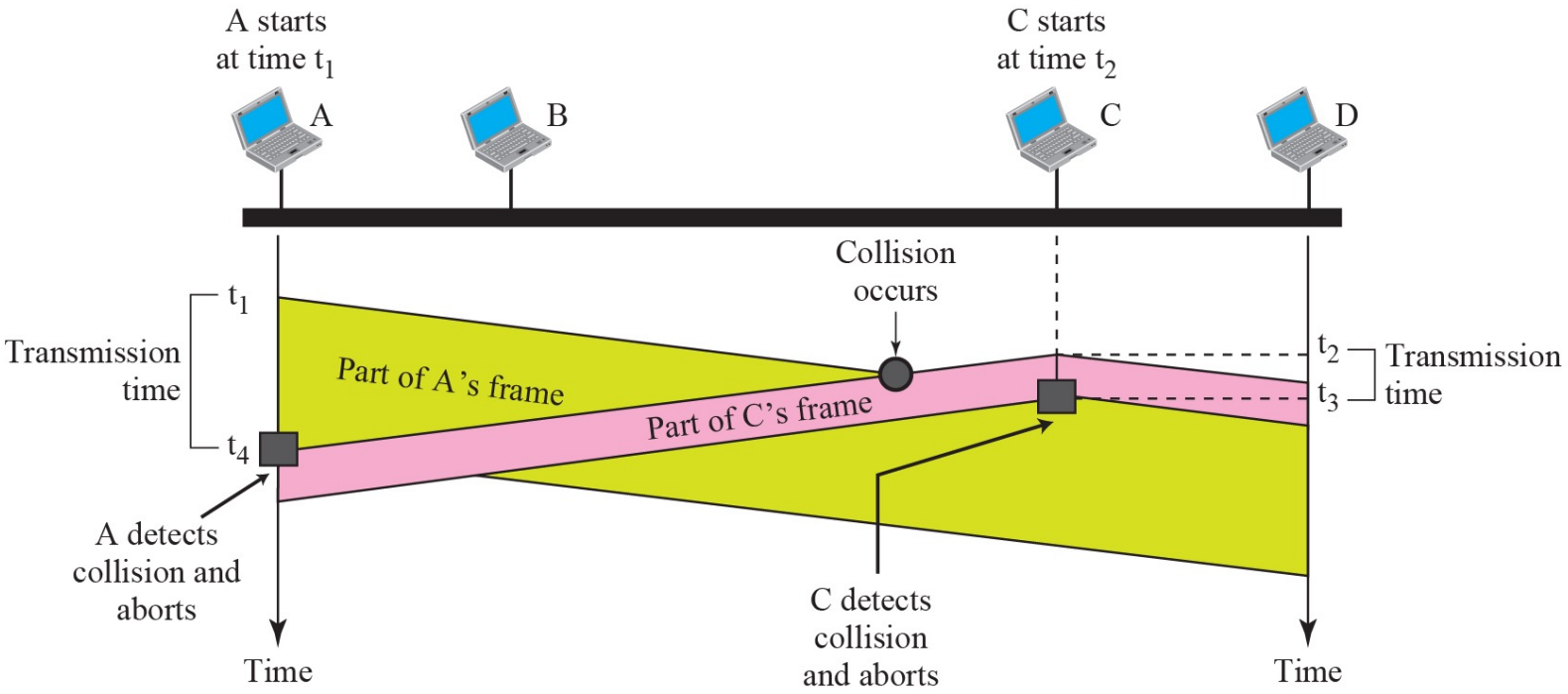


Figure 3.8 *Collision of the first bit in CSMA/CD*



Example 3.3

In the standard Ethernet, if the maximum propagation time is 25.6 μs, what is the minimum size of the frame?

Solution

The frame transmission time is $T_{fr} = 2 \times T_p = 51.2$ μs. This means, in the worst case, a station needs to transmit for a period of 51.2 μs to detect the collision. The minimum size of the frame is 10 Mbps × 51.2 μs = 512 bits or 64 bytes. This is actually the minimum size of the frame for Standard Ethernet, as we discussed before.

Figure 3.9 *CSMA/CD flow diagram*

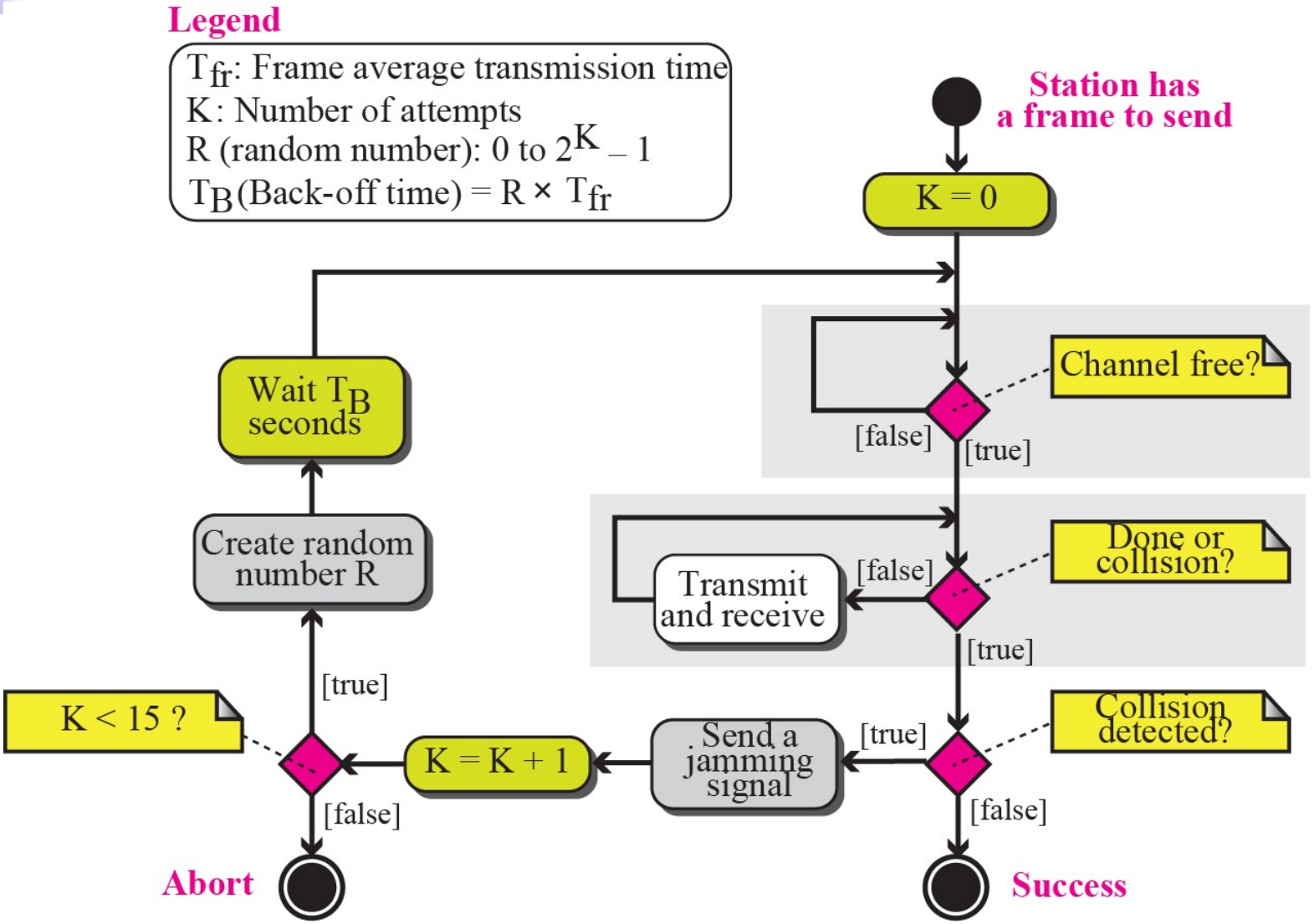
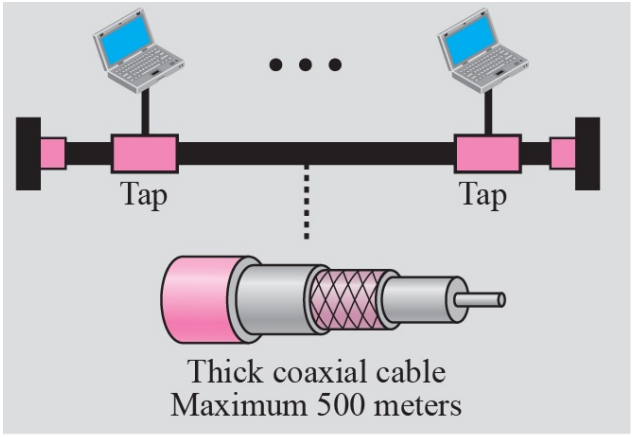


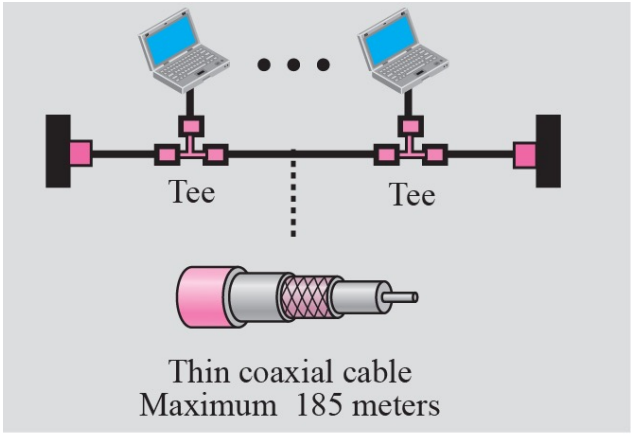
Table 3.1 *Summary of Standard Ethernet implementations*

Characteristics	*10Base5*	*10Base2*	*10Base-T*	*10Base-F*
Medium	Thick coax	Thin coax	2 UTP	2 Fiber
Maximum length	500 m	185 m	100 m	2000 m

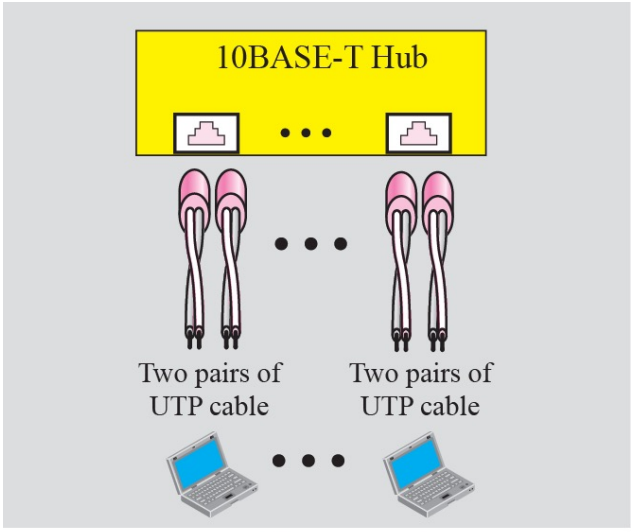
Figure 3.10 *Standard Ethernet implementation*



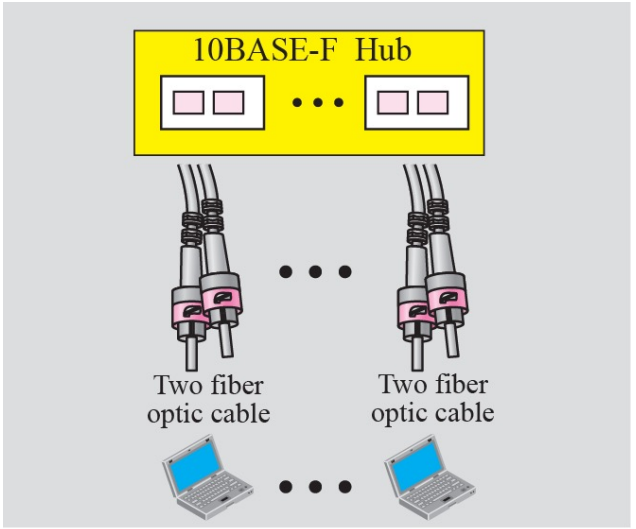
a. 10BASE5



b. 10BASE2



c. 10BASE-T

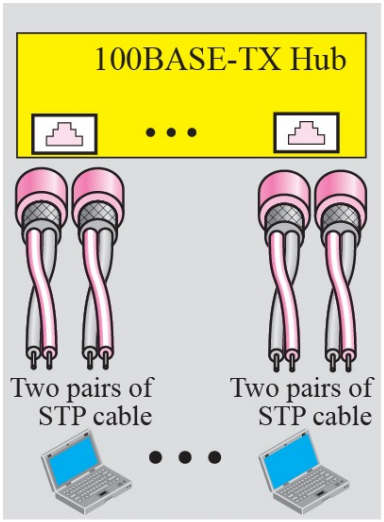


d. 10BASE-F

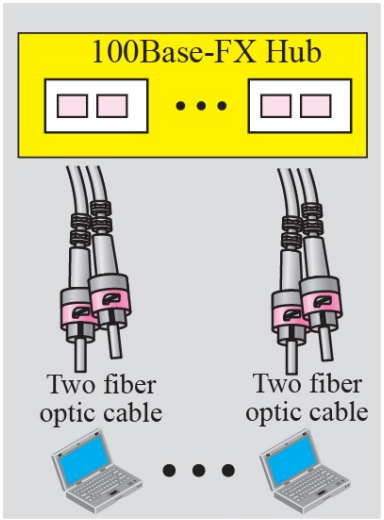
Table 3.2 *Summary of Fast Ethernet implementations*

Characteristics	*100Base-TX*	*100Base-FX*	*100Base-T4*
Media	STP	Fiber	UTP
Number of wires	2	2	4
Maximum length	100 m	100 m	100 m

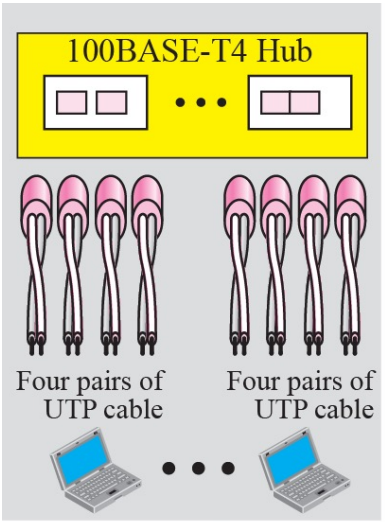
Figure 3.11 *Fast Ethernet implementation*



a. 100BASE-TX



b. 100BASE-FX



c. 100BASE-T4

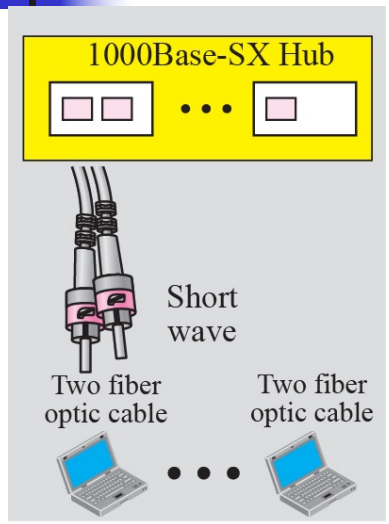
Table 3.3 *Summary of Gigabit Ethernet implementations*

Characteristics	*1000Base-SX*	*1000Base-LX*	*1000Base-CX*	*1000Base-T4*
Media	Fiber short-wave	Fiber long-wave	STP	Cat 5 UTP
Number of wires	2	2	2	4
Maximum length	550 m	5000 m	25 m	100 m

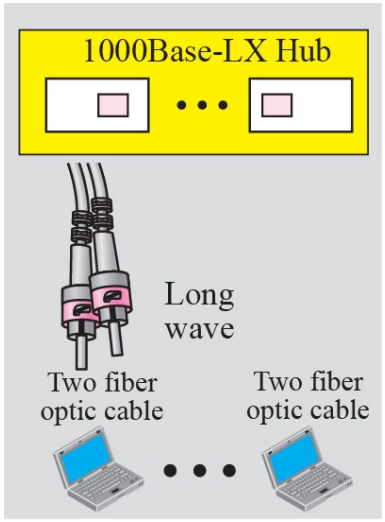
Note

In the full-duplex mode of Gigabit Ethernet, there is no collision; the maximum length of the cable is determined by the signal attenuation in the cable.

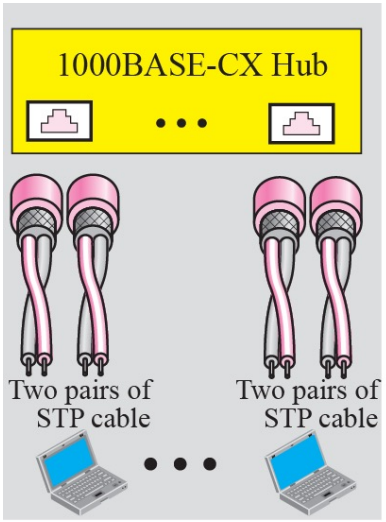
Figure 3.12 *Gigabit Ethernet implementation*



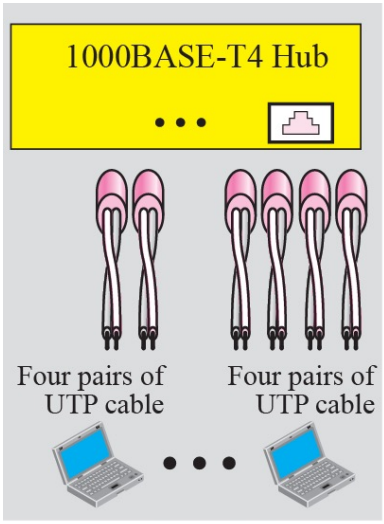
a. 1000BASE-SX



b. 100BASE-LX



c. 1000BASE-CX



d. 1000BASE-T4

Table 3.4 *Ten-Gigabit Ethernet Implementation*

Characteristics	*10GBase-S*	*10GBase-L*	*10GBase-E*
Media	multi-mode fiber	single-mode fiber	single-mode fiber
Number of wires	2	2	2
Maximum length	300 m	10,000 m	40,000 m

3-2 WIRELESS LANS

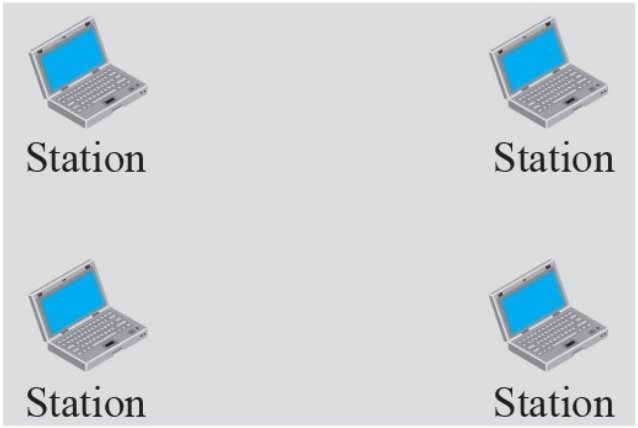
Wireless communication is one of the fastest growing technologies. The demand for connecting devices without the use of cables is increasing everywhere. Wireless LANs can be found on college campuses, in office buildings, and in many public areas. In this section, we concentrate on two wireless technologies for LANs: IEEE 802.11 wireless LANs, sometimes called wireless Ethernet, and Bluetooth, a technology for small wireless LANs.

Topics Discussed in the Section

- ✓ **IEEE 802.1**
- ✓ **MAC Sublayer**
- ✓ **Addressing Mechanism**
- ✓ **Bluetooth**

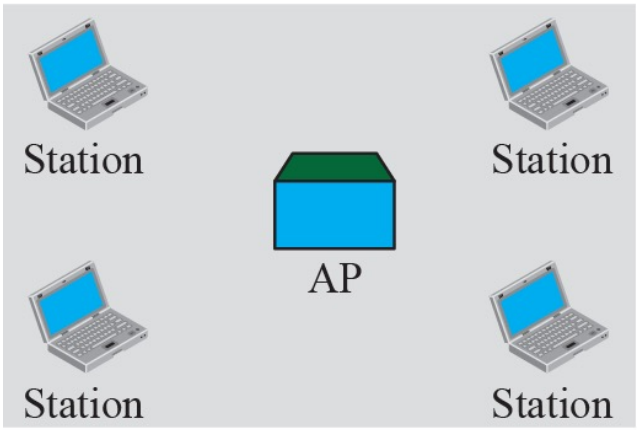
Figure 3.13 *Basic service sets (BSSs)*

BSS: Basic service set



Ad hoc network (BSS without an AP)

AP: Access point



Infrastructure (BSS with an AP)

Figure 3.14 *Extended service sets (ESSs)*

ESS: Extended service set
BSS: Basic service set
AP: Access point

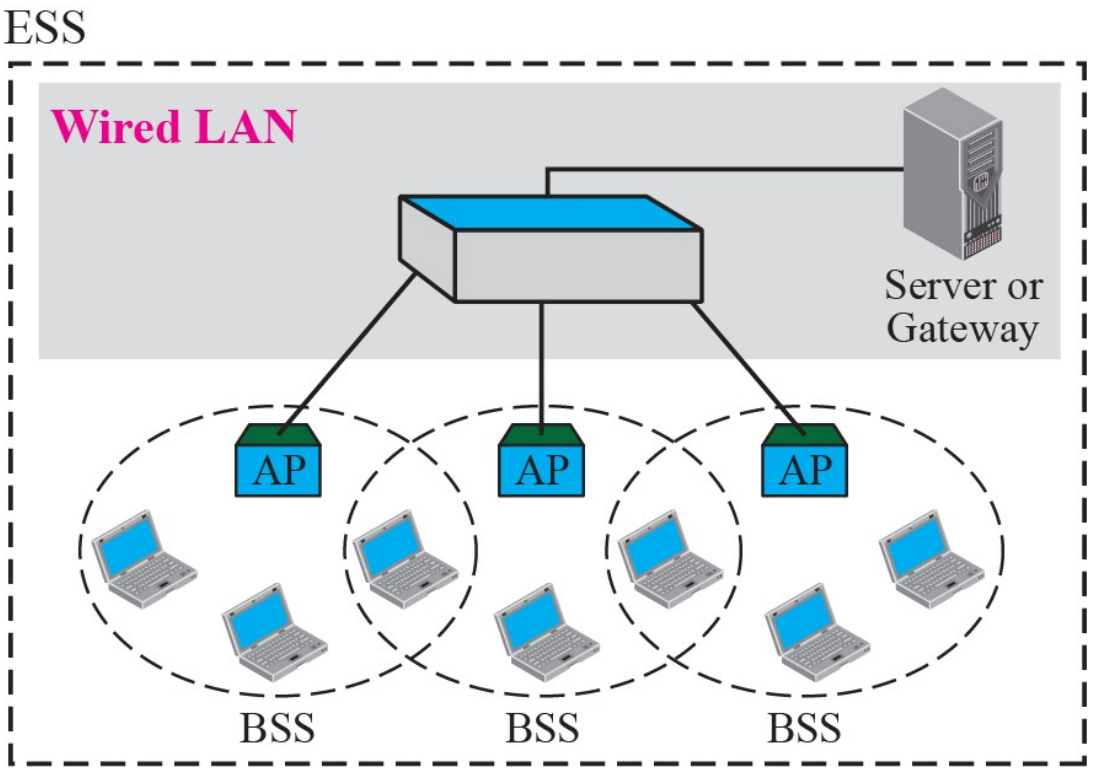


Figure 3.15 *CSMA/CA flow diagram*

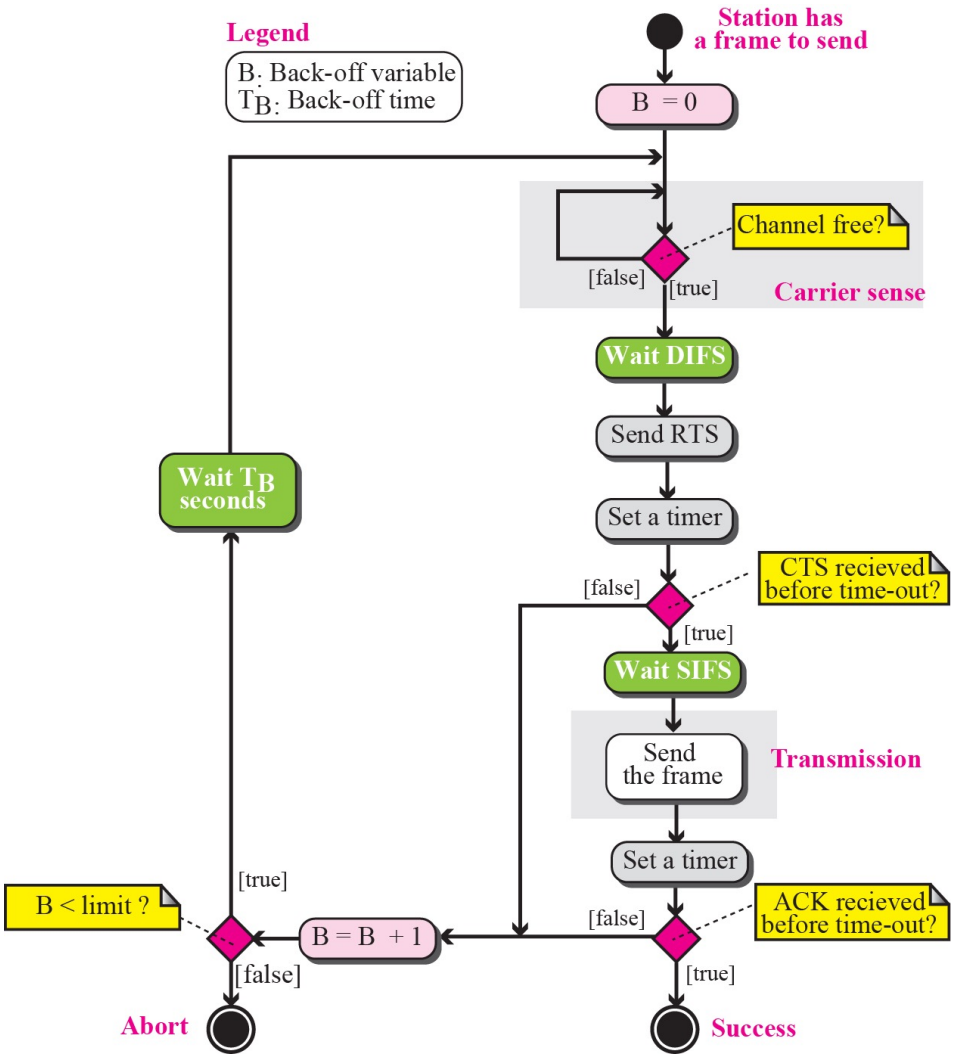


Figure 3.16 *CSMA/CA and NAV*

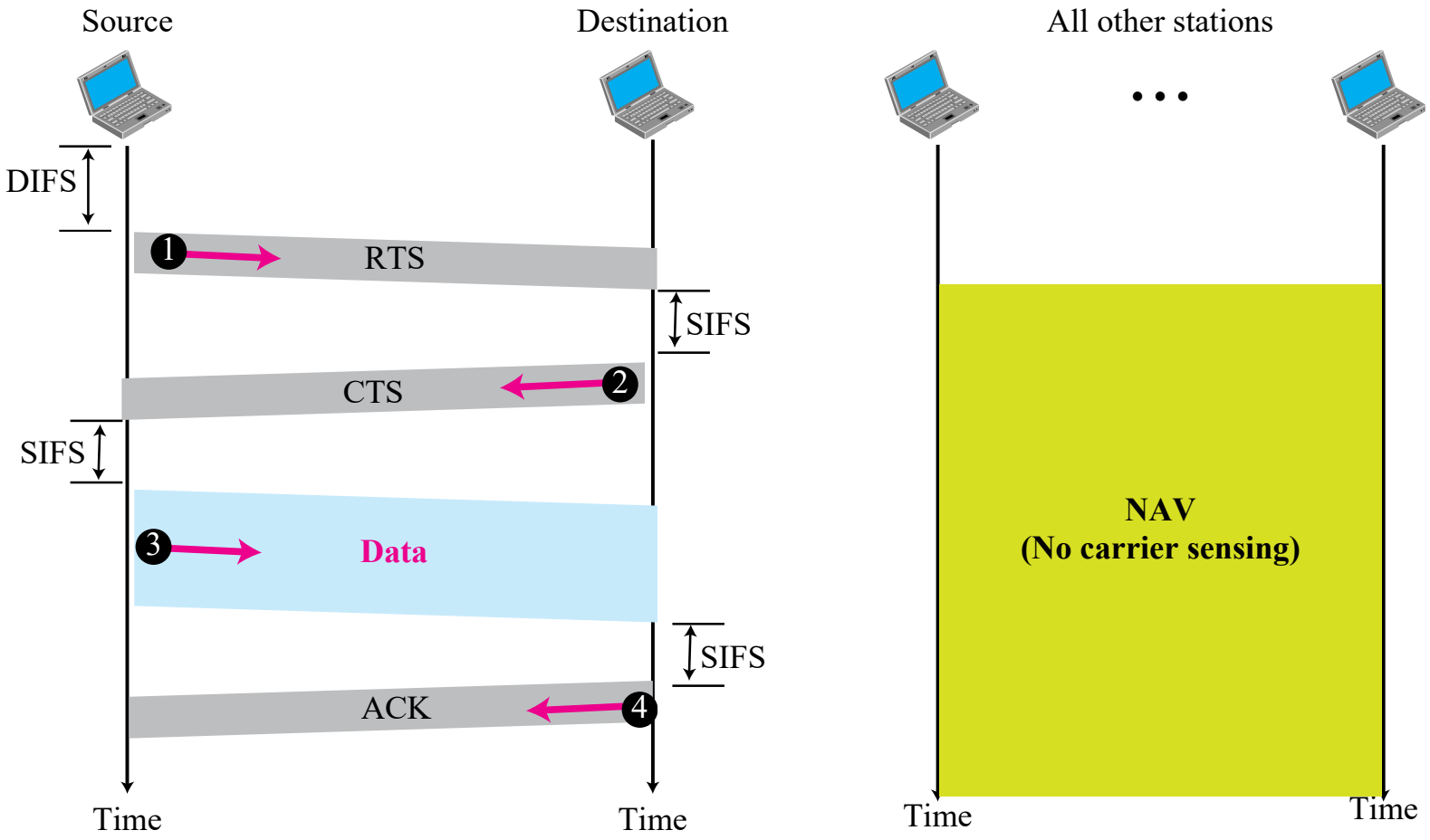


Figure 3.17 *Frame format*

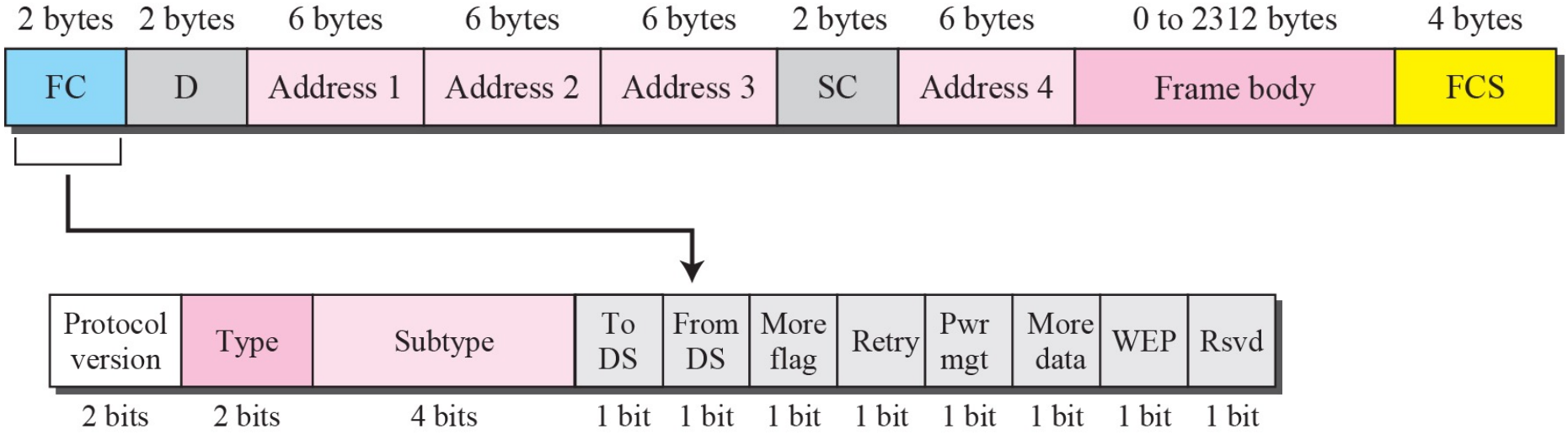


Table 3.5 *Subfields in FC field*

Field	*Explanation*
Version	Current version is 0
Type	Type of information: management (00), control (01), or data (10)
Subtype	Subtype of each type (see Table 3.6)
To DS	Defined later
From DS	Defined later
More flag	When set to 1, means more fragments
Retry	When set to 1, means retransmitted frame
Pwr mgt	When set to 1, means station is in power management mode
More data	When set to 1, means station has more data to send
WEP	Wired equivalent privacy (encryption implemented)
Rsvd	Reserved

Figure 3.18 *Control frames*

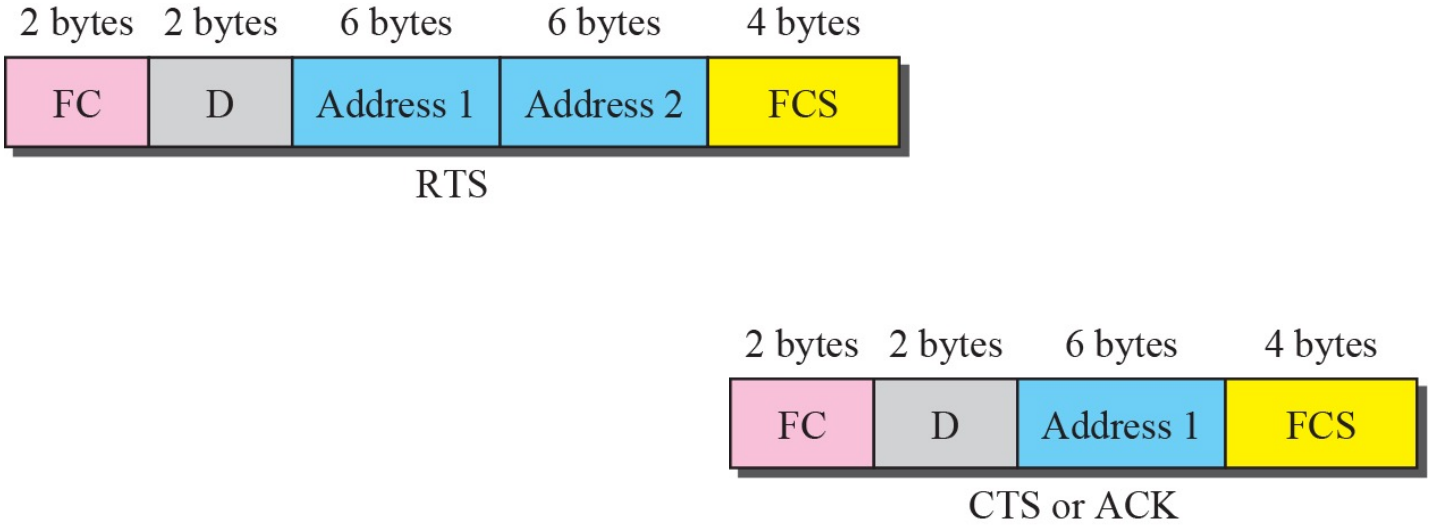


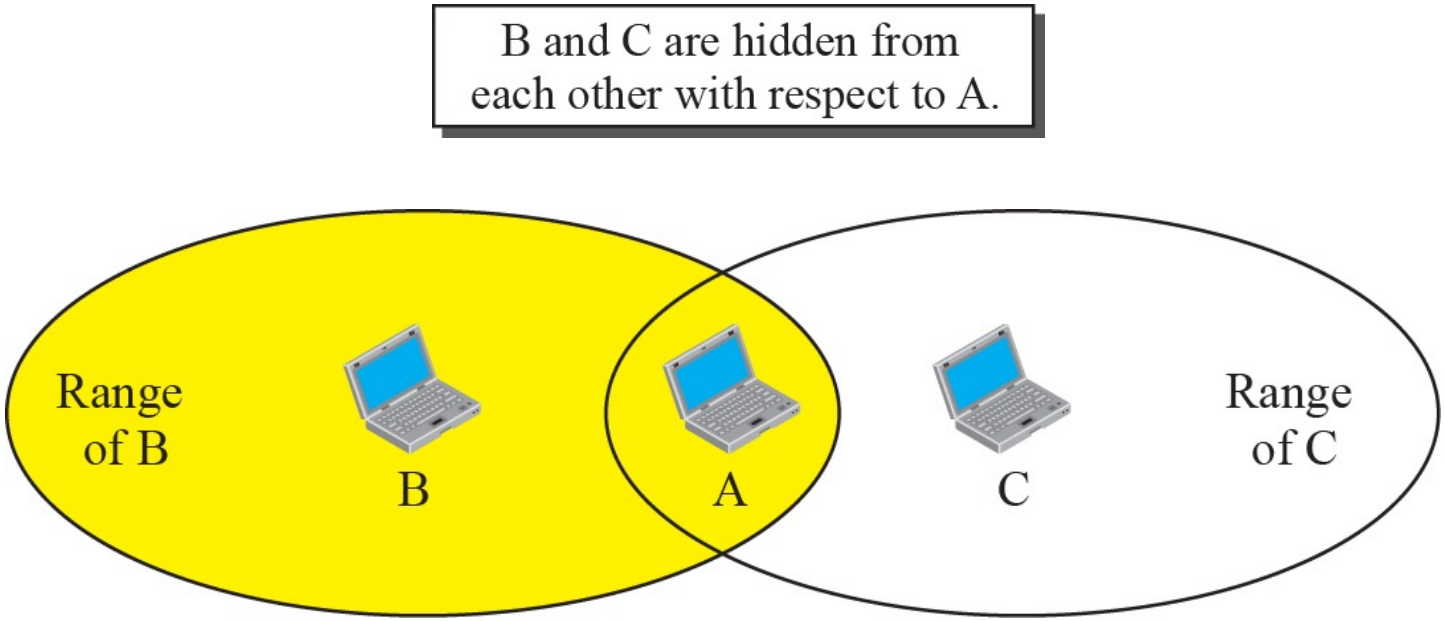
Table 3.6 *Values of subfields in control frames*

Subtype	*Meaning*
1011	Request to send (RTS)
1100	Clear to send (CTS)
1101	Acknowledgment (ACK)

Table 3.7 *Addresses*

To DS	*From DS*	*Address 1*	*Address 2*	*Address 3*	*Address 4*
0	0	Destination	Source	BSS ID	N/A
0	1	Destination	Sending AP	Source	N/A
1	0	Receiving AP	Source	Destination	N/A
1	1	Receiving AP	Sending AP	Destination	Source

Figure 3.19 *Hidden station problem*



Note

The CTS frame in CSMA/CA handshake can prevent collision from a hidden station.

Figure 3.20 *Use of handshaking to prevent hidden station problem*

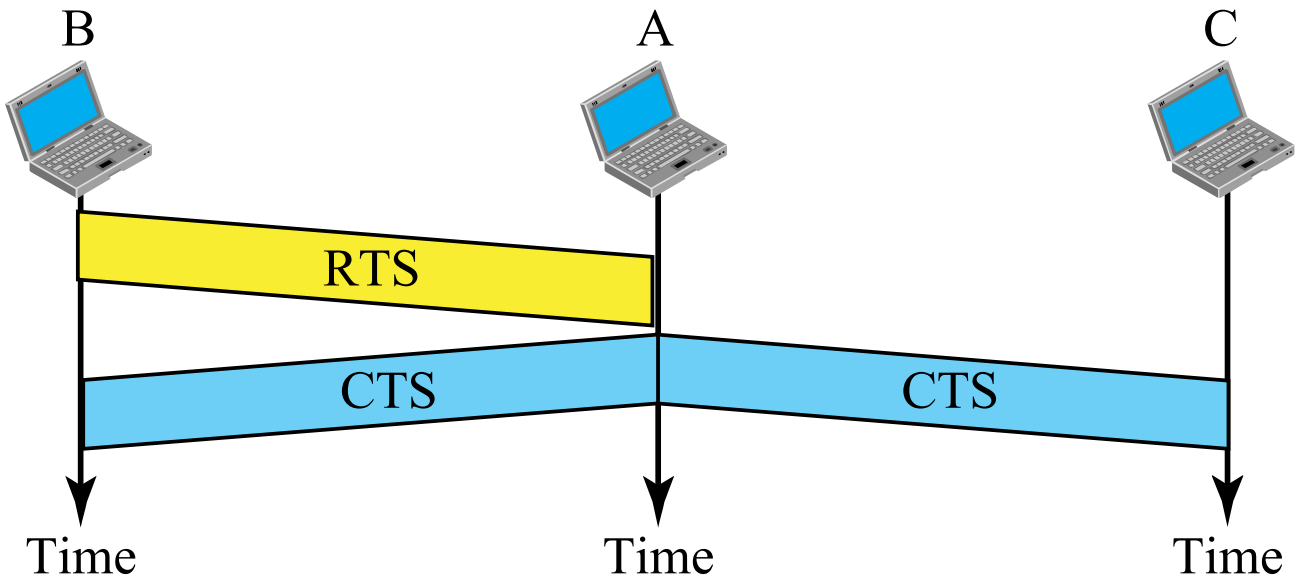


Figure 3.21 *Exposed station problem*

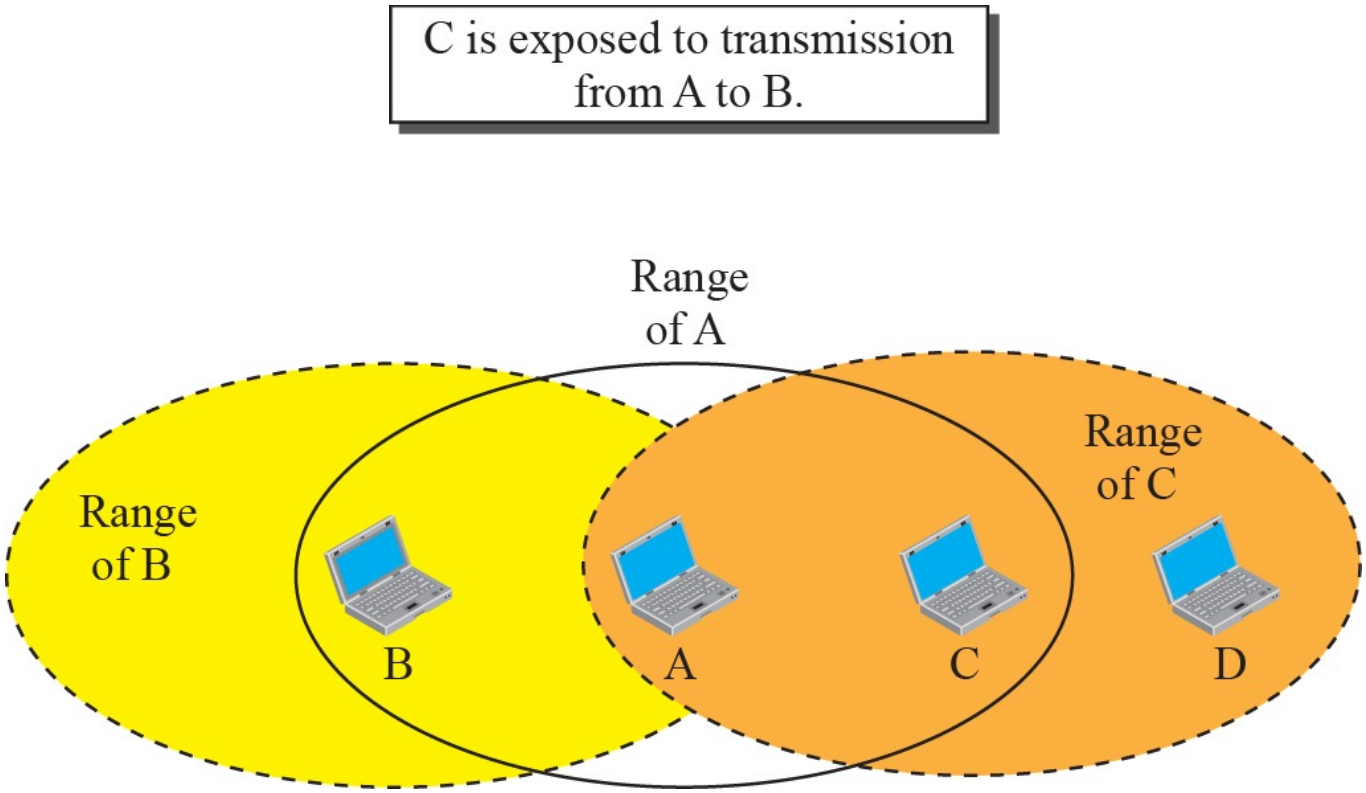


Figure 3.22 *Use of handshaking in exposed station problem*

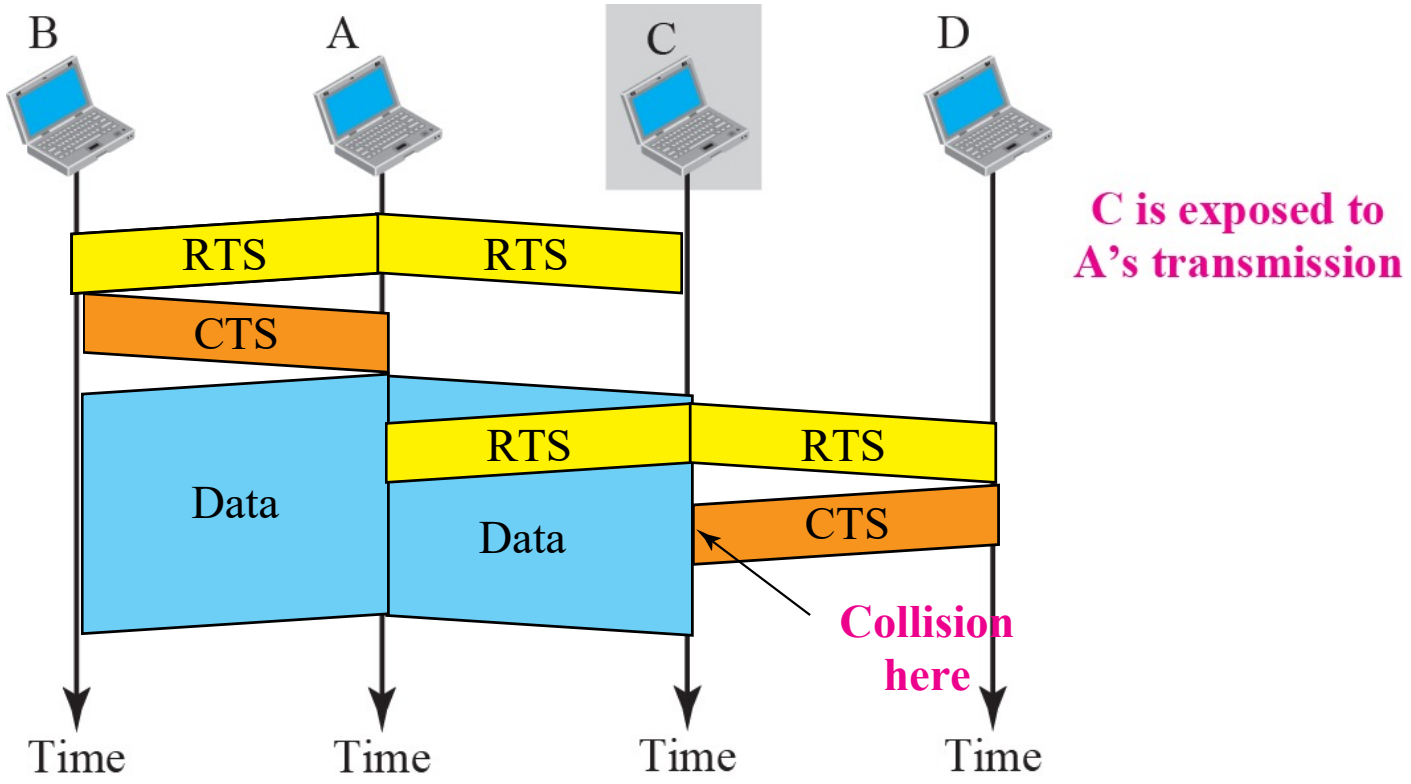


Figure 3.23 *Piconet*

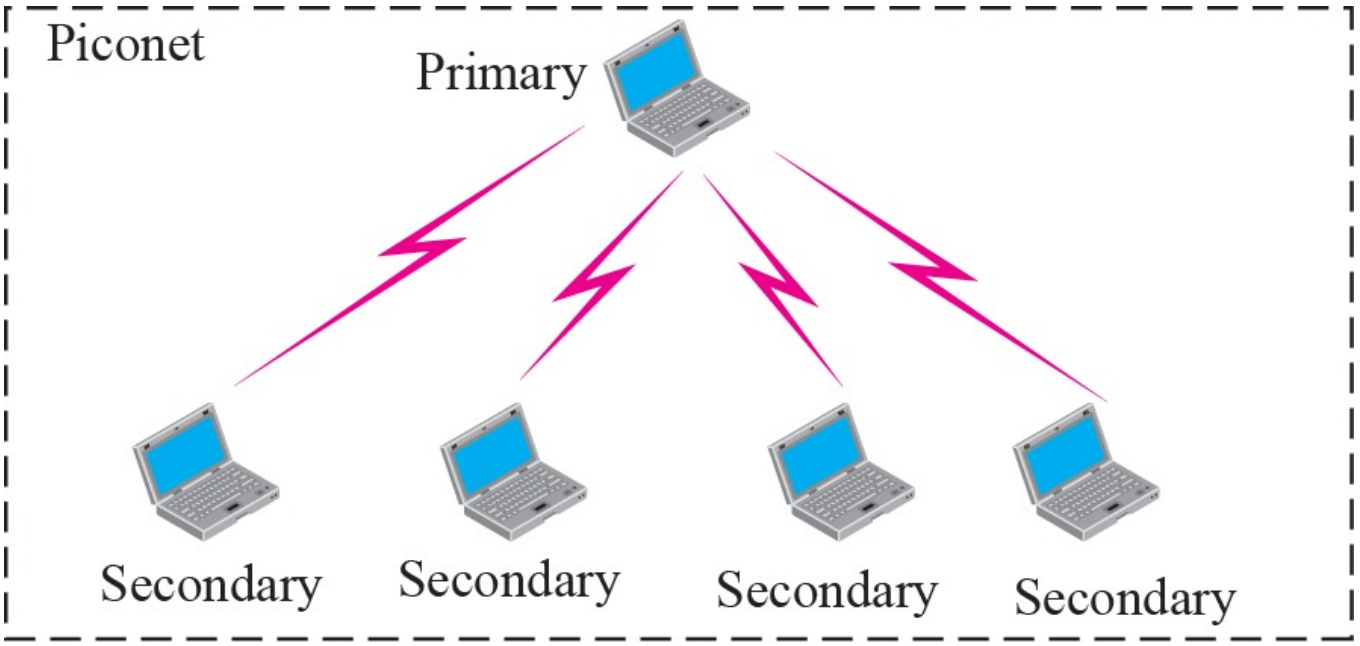


Figure 3.24 *Scatternet*

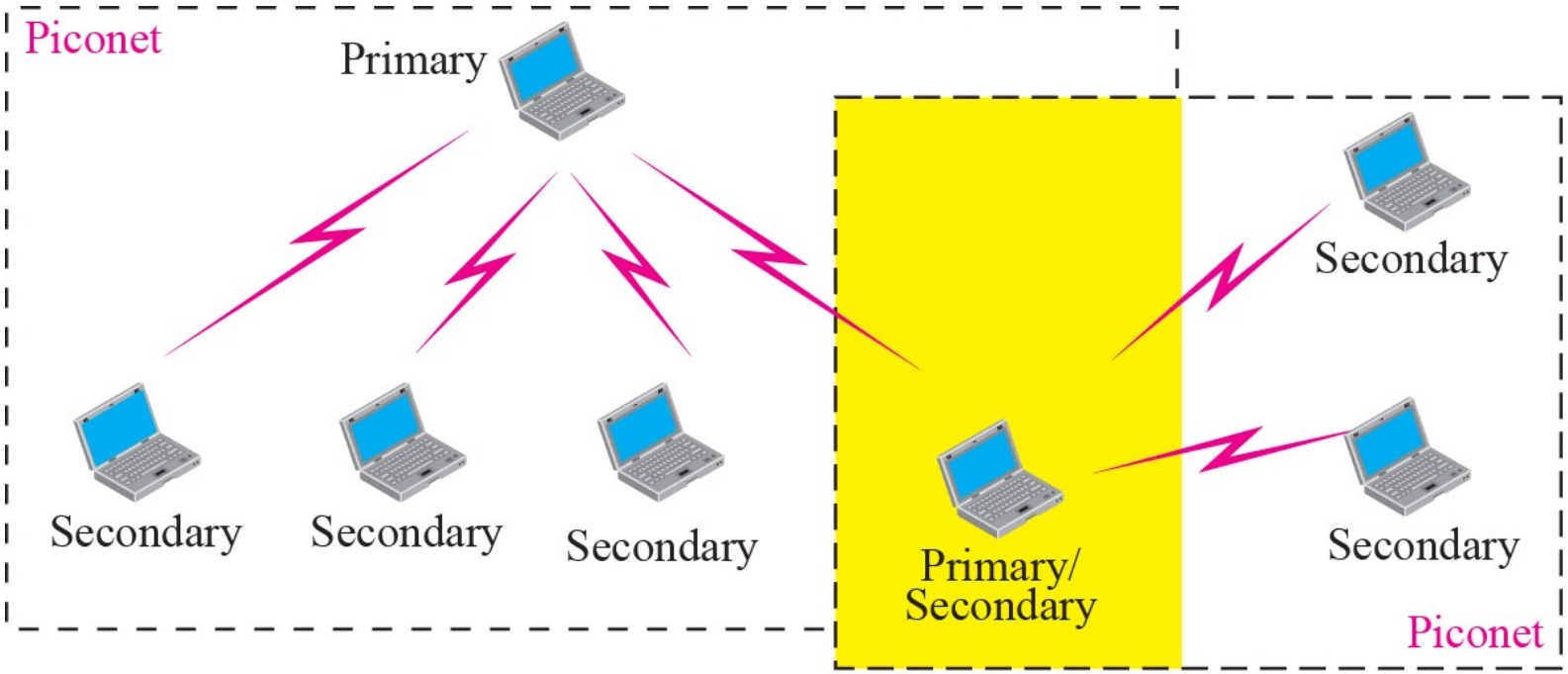
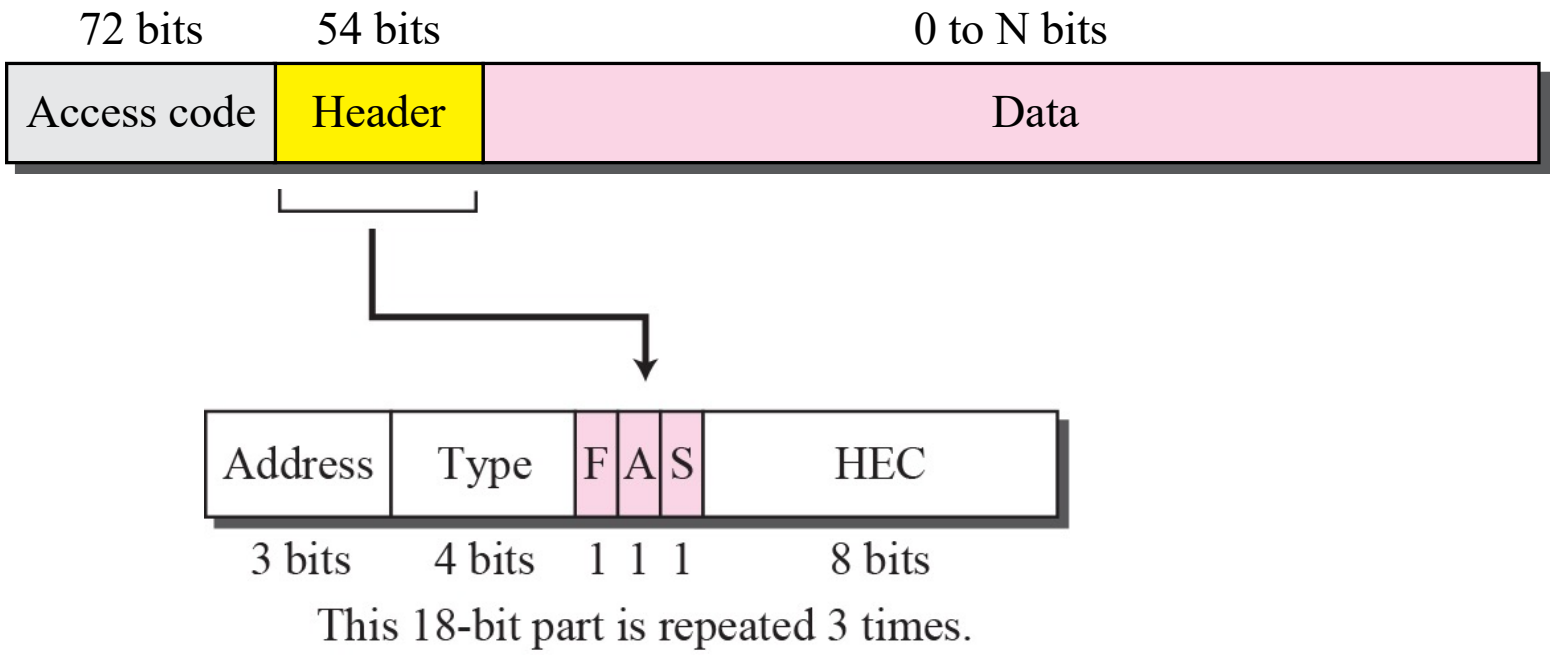


Figure 3.25 *Frame format types*

N = 240 for 1-slot frame
N = 1490 for 3-slot frame
N = 2740 for 5-slot frame



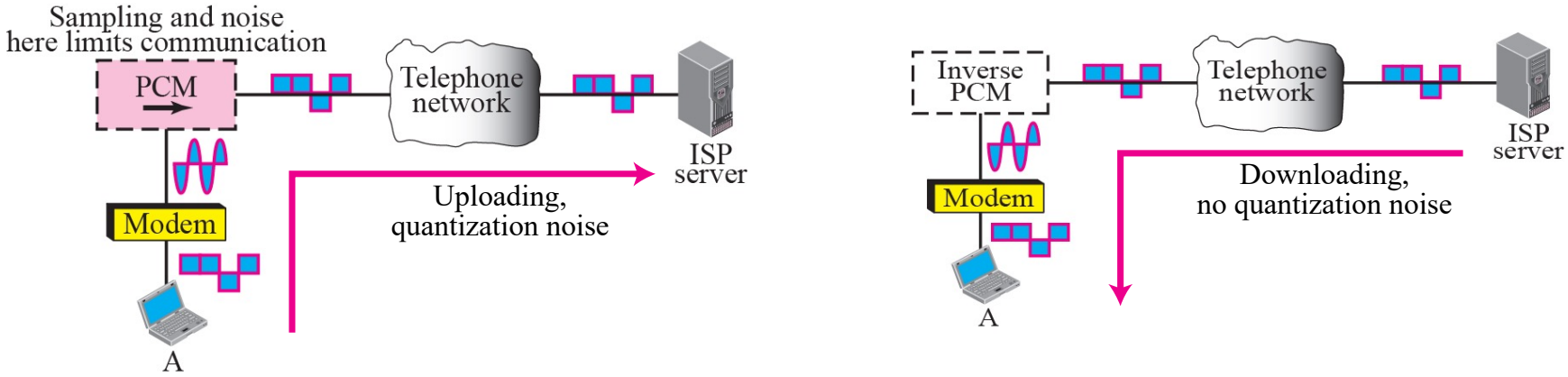
3-3 POINT-TO-POINT WANS

A second type of network we encounter in the Internet is the point-to-point wide area network. A point-to-point WAN connects two remote devices using a line available from a public network such as a telephone network. We discuss traditional modem technology, DSL line, cable modem, T-lines, and SONET.

Topics Discussed in the Section

- ✓ 65K Modems
- ✓ DSL Technology
- ✓ Cable Modem
- ✓ T Lines
- ✓ SONET
- ✓ PPP

Figure 3.26 *56K modem*



Note

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

Figure 3.27 *Bandwidth division*

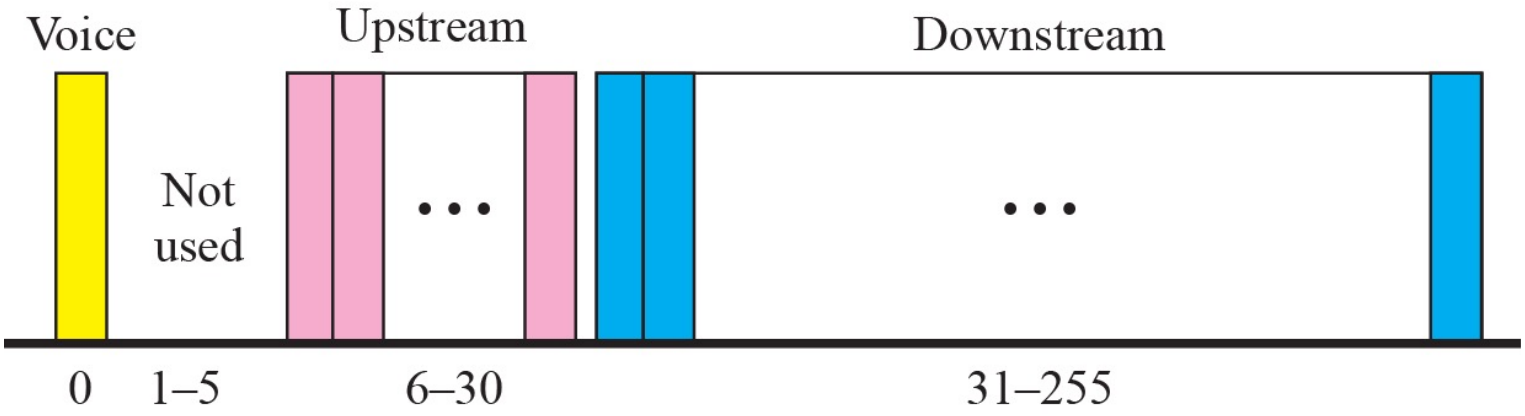


Figure 3.28 *ADSL and DSLAM*

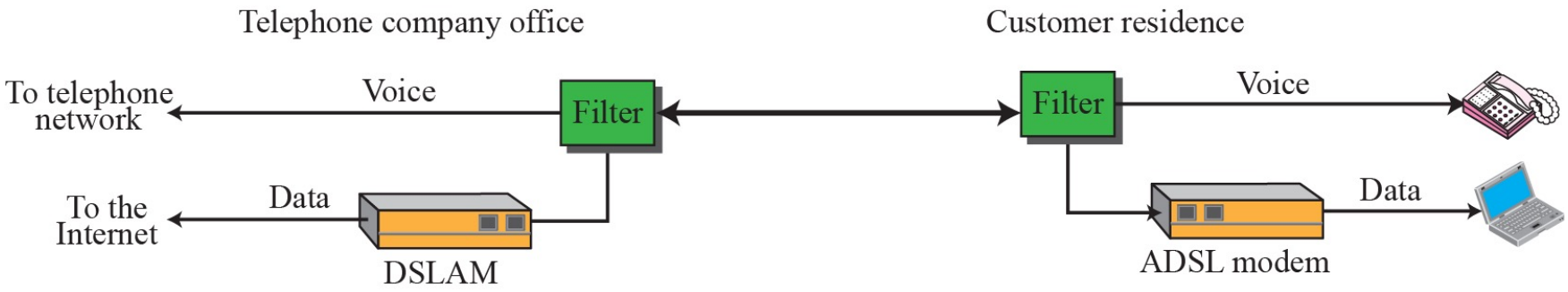


Figure 3.29 *Cable bandwidth*

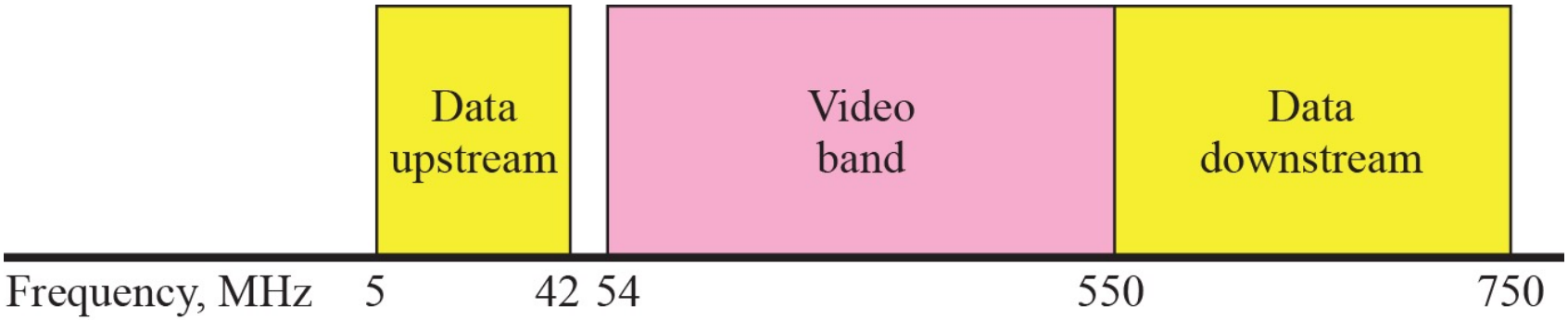


Figure 3.30 *Cable modem configuration*

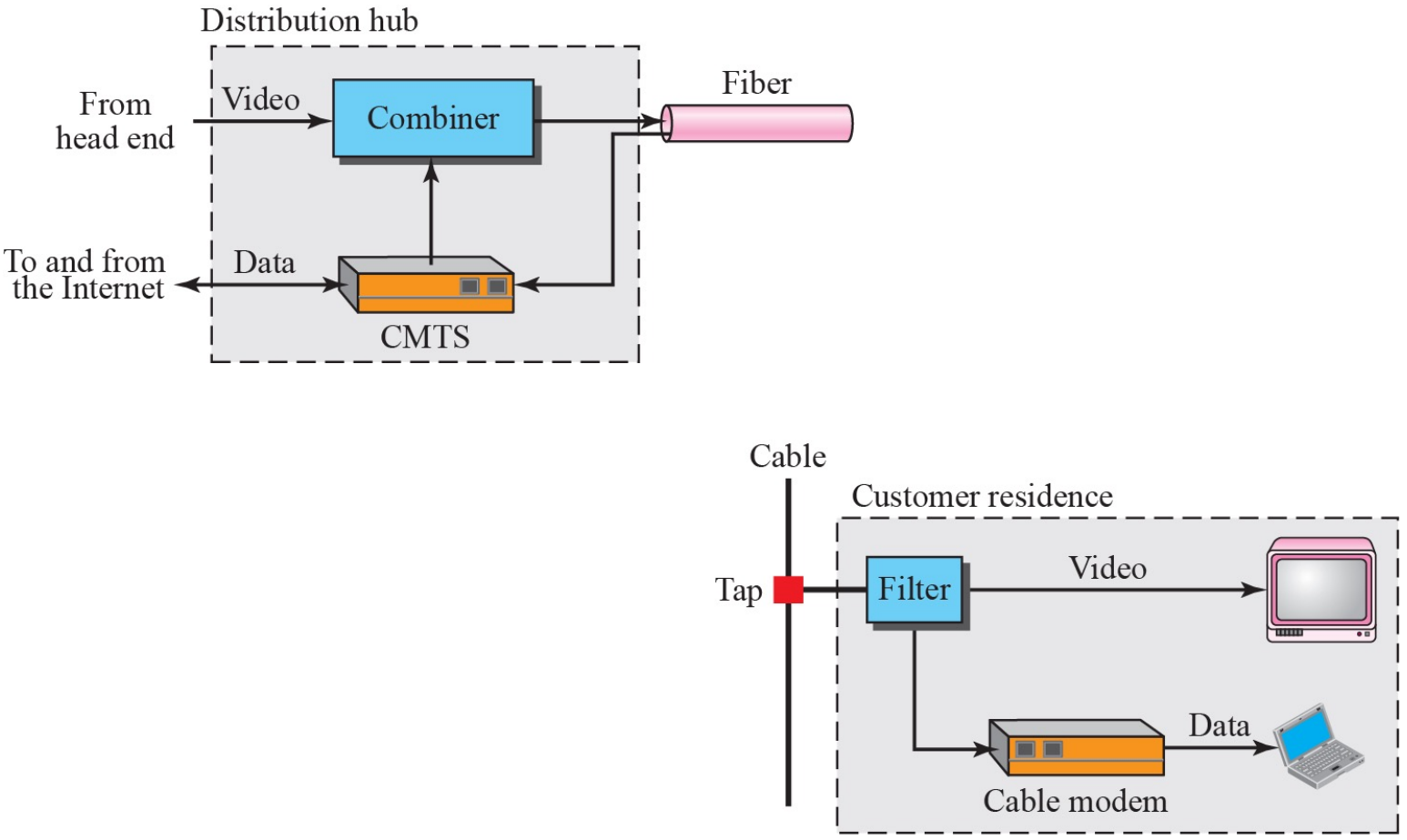


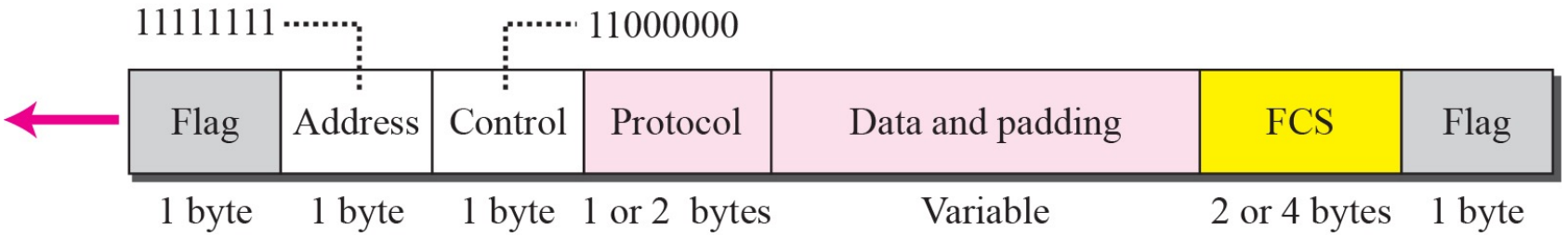
Table 3.8 *T line rates*

Line	*Rate (Mbps)*
T-1	1.544
T-3	44.736

Table 3.9 *SONET rates*

STS	*OC*	*Rate (Mbps)*	*STS*	*OC*	*Rate (Mbps)*
STS-1	OC-1	51.840	STS-24	OC-24	1244.160
STS-3	OC-3	155.520	STS-36	OC-36	1866.230
STS-9	OC-9	466.560	STS-48	OC-48	2488.320
STS-12	OC-12	622.080	STS-96	OC-96	4976.640
STS-18	OC-18	933.120	STS-192	OC-192	9953.280

Figure 3.31 *PPP frame*



3-4 SWITCHED WANS

The backbone networks in the Internet can be switched WANs. A switched WAN is a wide area network that covers a large area (a state or a country) and provides access at several points to the users. Inside the network, there is a mesh of point-to-point networks that connects switches. The switches, multiple port connectors, allow the connection of several inputs and outputs.

Switched WAN technology differs from LAN technology in many ways.

Topics Discussed in the Section

- ✓ X.25
- ✓ Frame Relay
- ✓ ATM

Note

A cell network uses the cell as the basic unit of data exchange.
A cell is defined as a small, fixed-size block of information.

Figure 3.32 *ATM multiplexing*

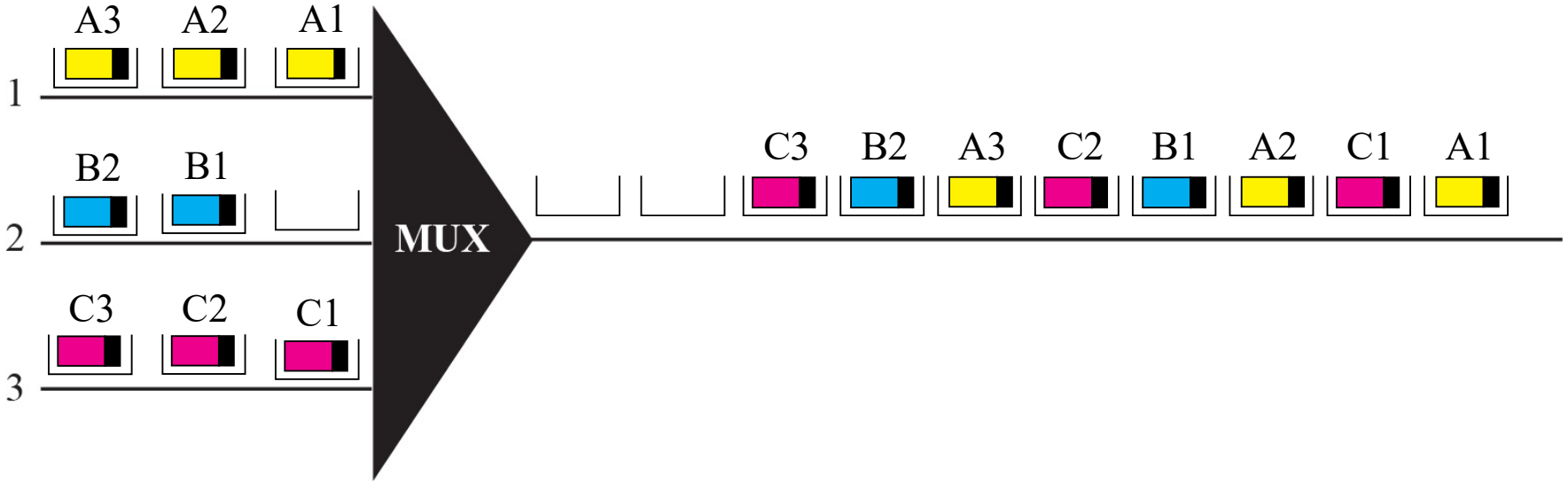


Figure 3.33 *Architecture of an ATM network*

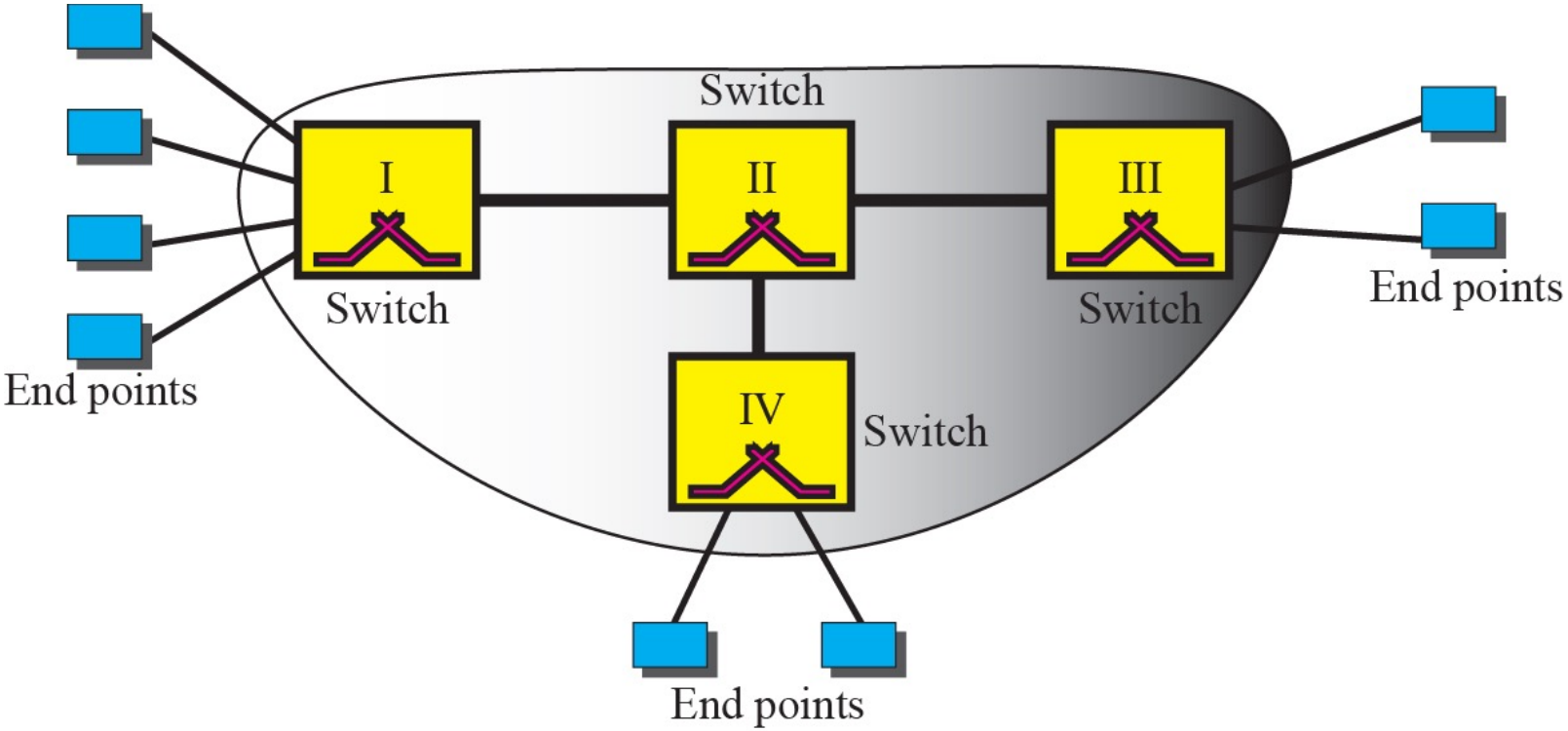
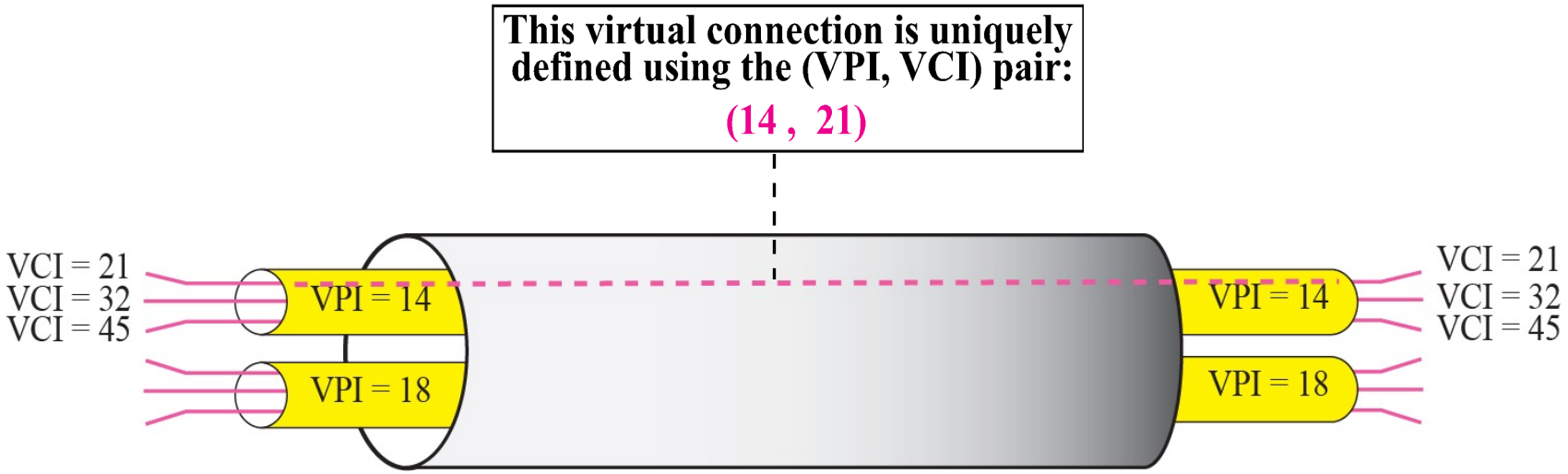


Figure 3.34 *Virtual circuit*



Note

A virtual connection is defined by a pair of numbers: the VPI and the VCI.

Figure 3.35 *ATM layers*

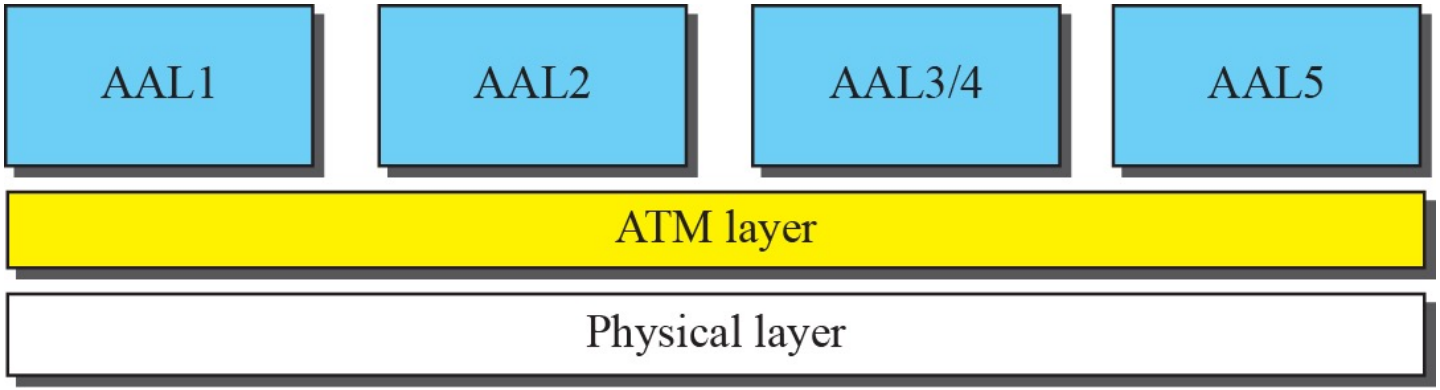
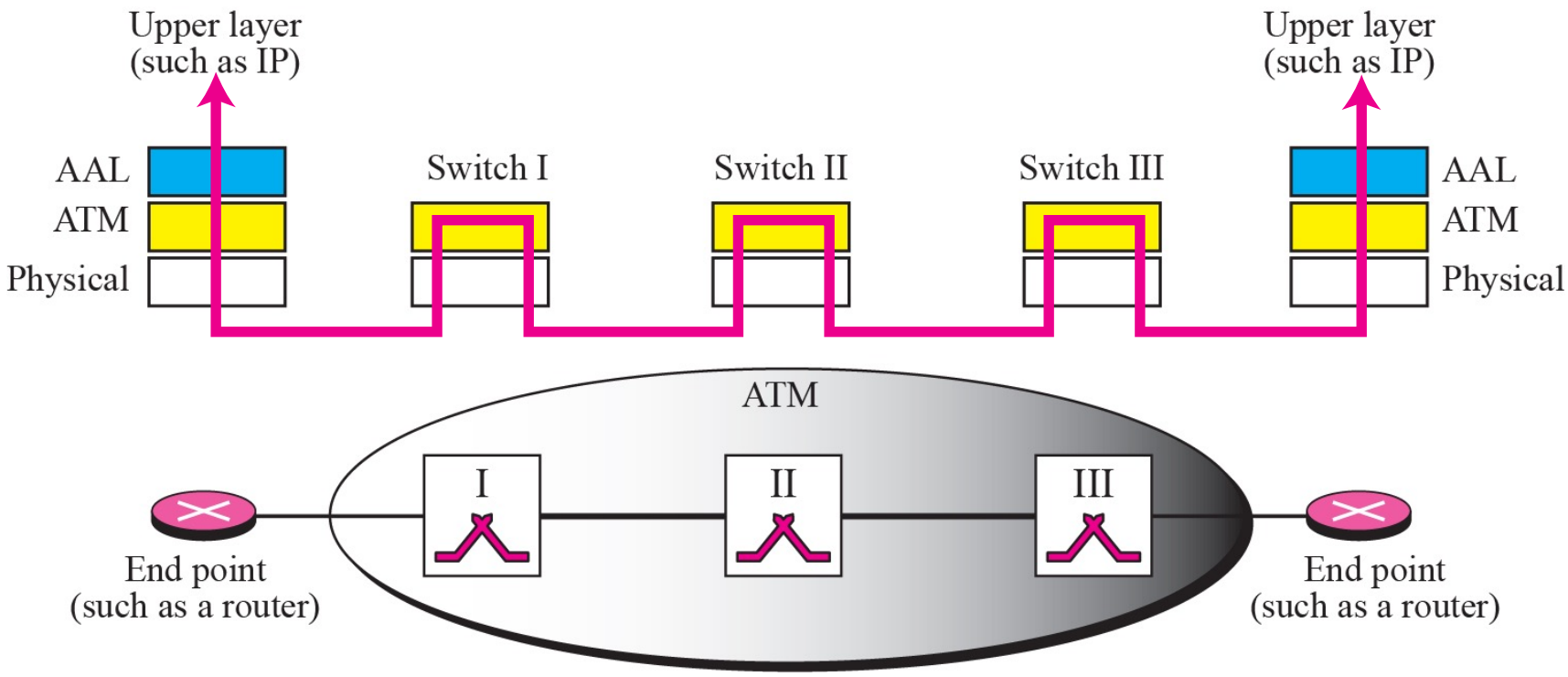


Figure 3.36 *Use of the layers*



Note

The IP protocol uses the AAL5 sublayer.

Figure 3.37 *AAL5*

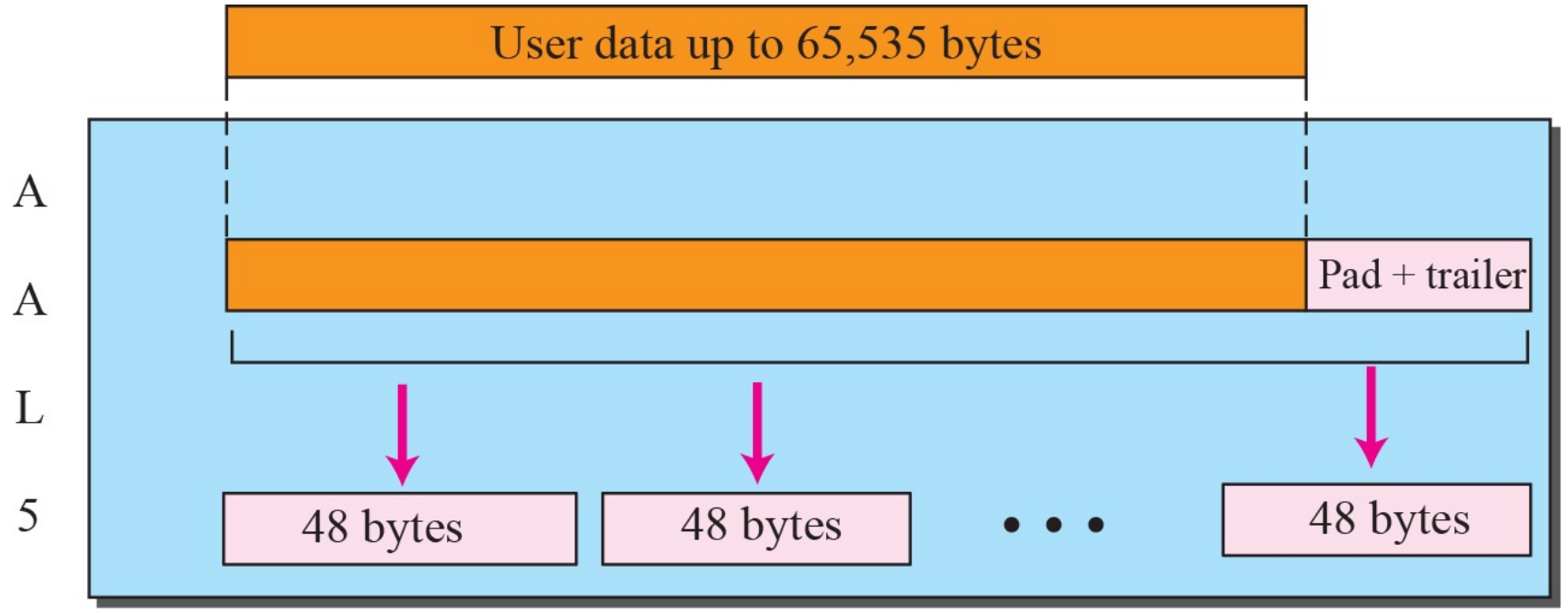


Figure 3.38 *ATM layer*

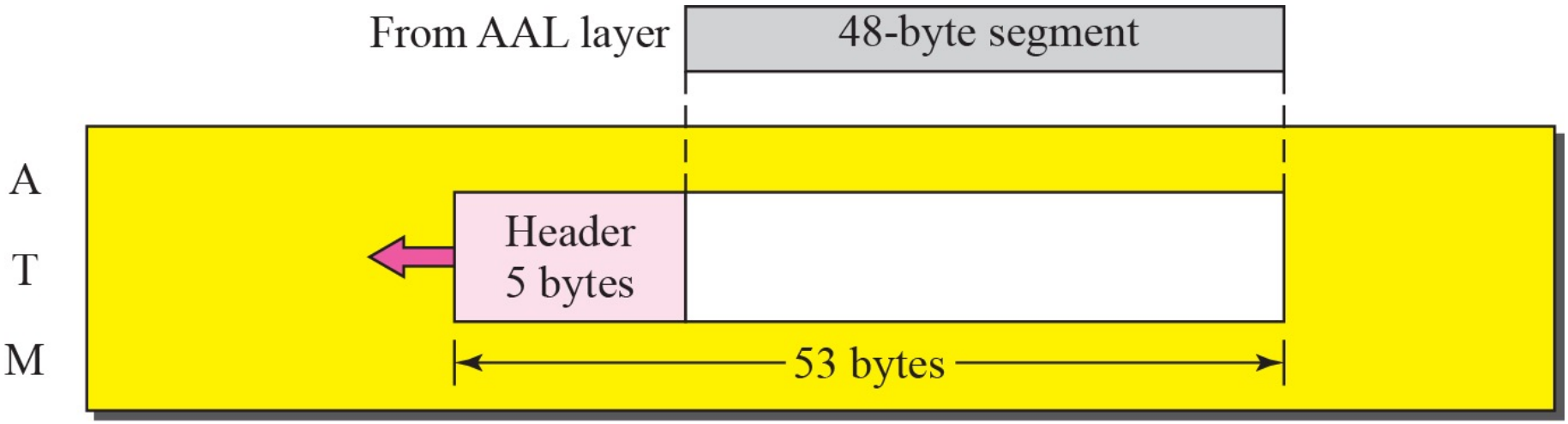
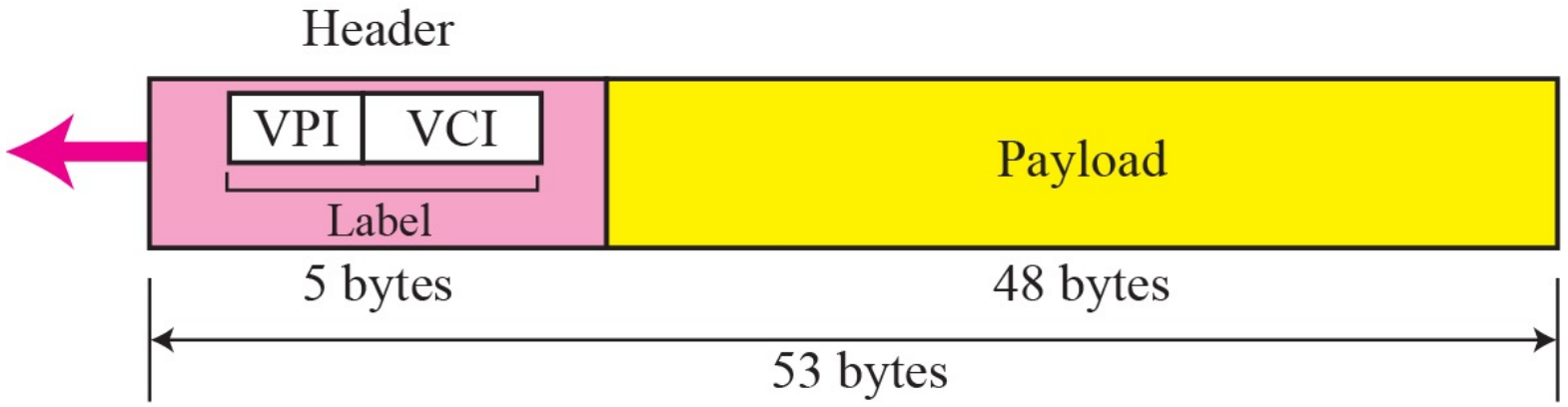


Figure 3.39 *An ATM cell*



3-5 CONNECTING DEVICES

LANs or WANs do not normally operate in isolation. They are connected to one another or to the Internet. To connect LANs and WANs together we use connecting devices. Connecting devices can operate in different layers of the Internet model. We discuss three kinds of connecting devices: repeaters (or hubs), bridges (or two-layer switches), and routers (or three-layer switches).

Topics Discussed in the Section

- ✓ **Repeaters**
- ✓ **Bridges**
- ✓ **Routers**

Figure 3.40 *Connecting devices*

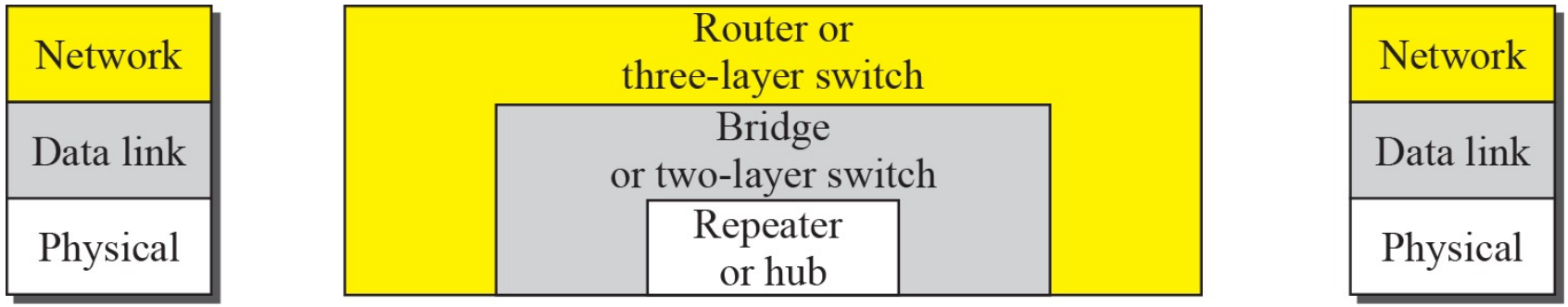
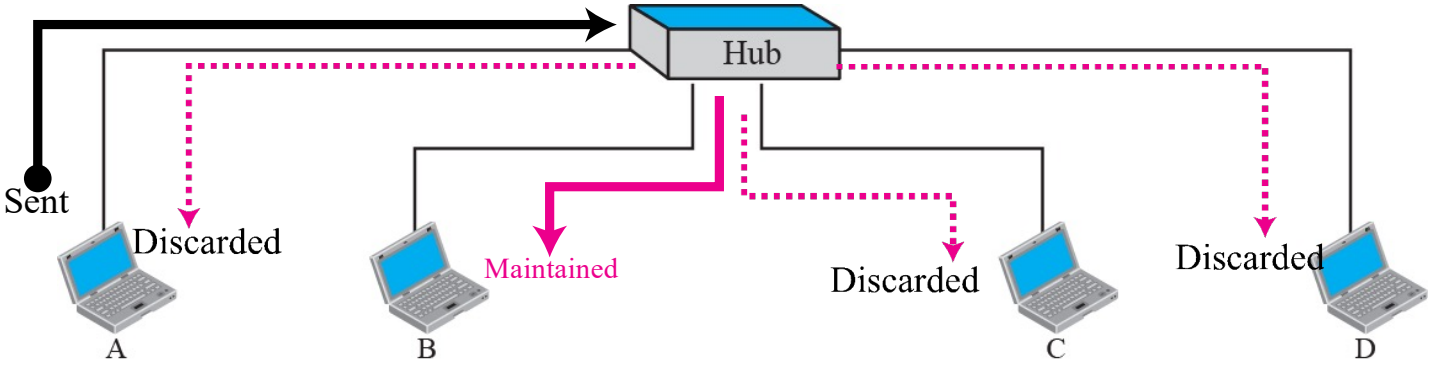


Figure 3.41 *Repeater or hub*



Note

A repeater forwards every bit; it has no filtering capability.

Note

A bridge has a table used in filtering decisions.

Note

A bridge does not change the physical (MAC) addresses in a frame.

Figure 3.42 *Bridge*

Bridge table

Address	Port
71:2B:13:45:61:41	1
71:2B:13:45:61:42	2
64:2B:13:45:61:12	3
64:2B:13:45:61:13	4

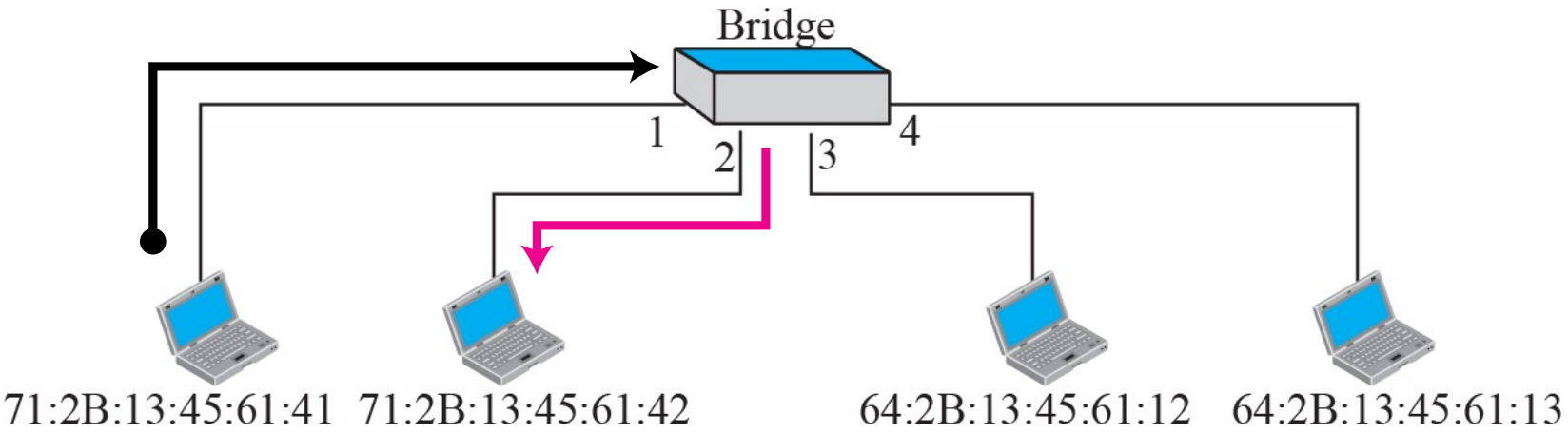


Figure 3.43 *Learning bridge*

Gradual building of Table

Address	Port

a. Original

Address	Port
71:2B:13:45:61:41	1

b. After A sends a frame to D

Address	Port
71:2B:13:45:61:41	1
64:2B:13:45:61:13	4

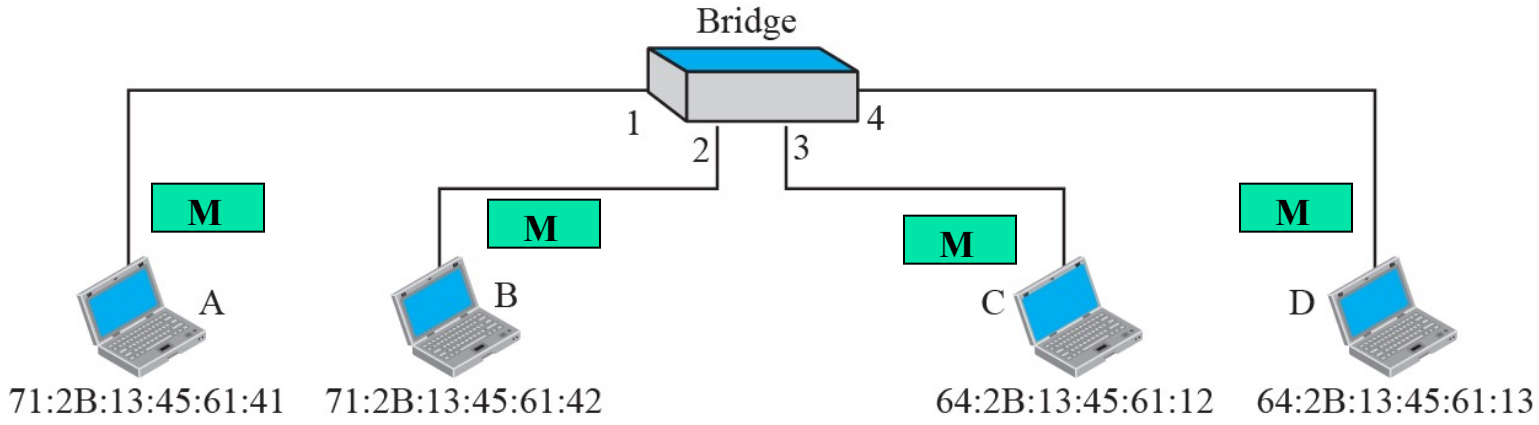
c. After D sends a frame to B

Address	Port
71:2B:13:45:61:41	1
64:2B:13:45:61:13	4
71:2B:13:45:61:42	2

d. After B sends a frame to A

Address	Port
71:2B:13:45:61:41	1
64:2B:13:45:61:13	4
71:2B:13:45:61:42	2
64:2B:13:45:61:12	3

e. After C sends a frame to D



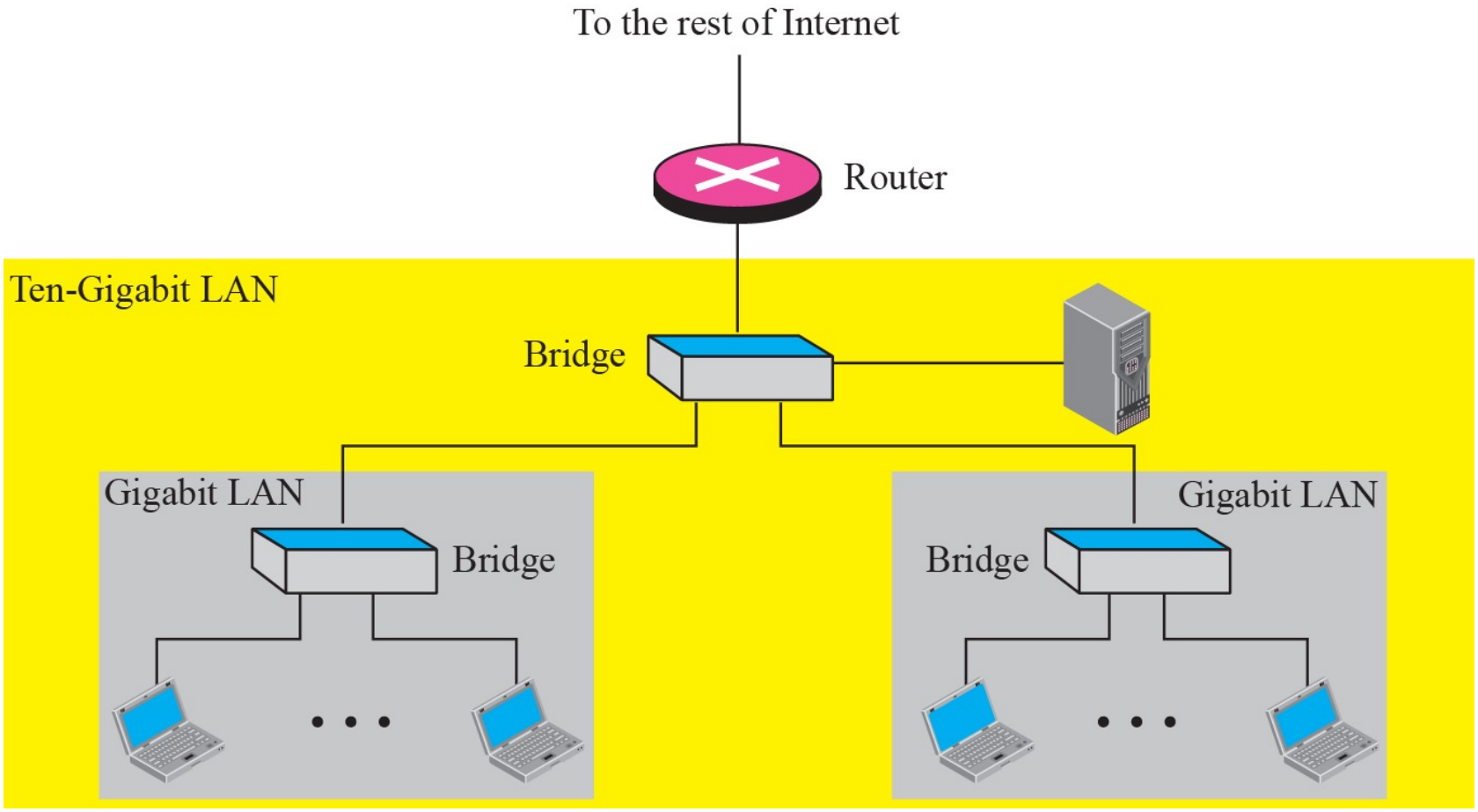
Note

A router is a three-layer (physical, data link, and network) device.

Note

A repeater or a bridge connects segments of a LAN.
A router connects independent LANs or WANs to create an internetwork (internet).

Figure 3.44 *Routing example*



Note

A router changes the physical addresses in a packet.