Multistation Access Unit

(MAU)

 For practical purpose, individual automatic switches   
 are combined into hub called a Multistation Access

Unit (MAU)

 One MAU can support up to eight stations

FIBER DISTRIBUTED DATA   
 INTERFACE (FDDI)

Conclusion - Performance

 Deterministic : possible for continuous   
 media (voice, video and etc)

 Low loads: marginally poor   
 Heavy load: appreciably better

Click to add Text

Fiber Distributed Data

Interface (FDDI)

• FDDI uses a ring topology of multimode or   
 single mode optical fiber transmission links

operating at 100 Mbps to span up to 200 kms and permits up to 500 stations.

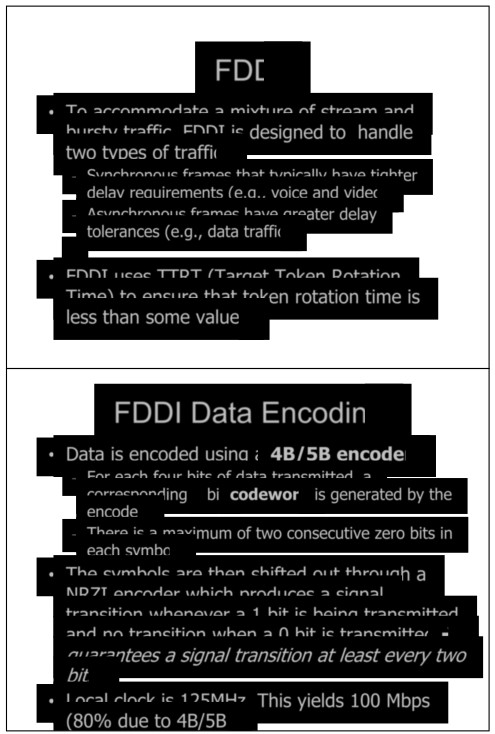
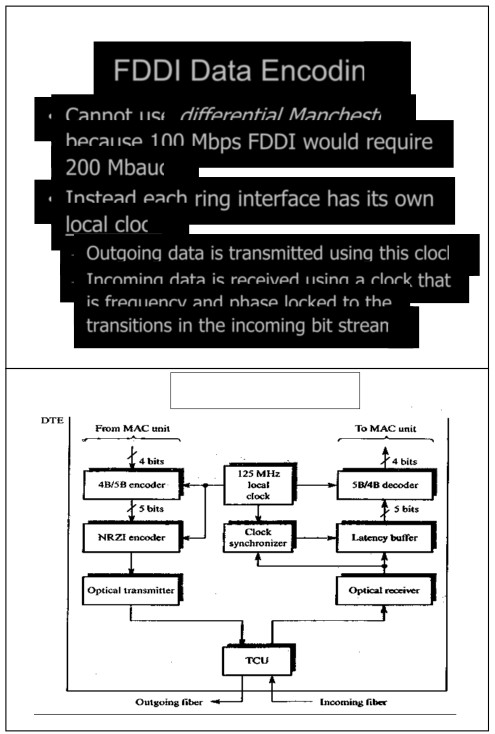
• Employs dual counter-rotating rings.

• 16 and 48-bit addresses are allowed.

• In FDDI, token is absorbed by station and

released as soon as it completes the frame   
transmission {release after transmission}.

25



FDDI

• To accommodate a mixture of stream and   
 bursty traffic, FDDI is designed to handle

two types of traffic:

- Synchronous frames that typically have tighter   
 delay requirements (e.g., voice and video)

- Asynchronous frames have greater delay

tolerances (e.g., data traffic)

• FDDI uses TTRT (Target Token Rotation   
 Time) to ensure that token rotation time is

less than some value.

26

FDDI Data Encoding

• Data is encoded using a 4B/5B encoder.

- For each four bits of data transmitted, a   
 corresponding 5-bit codeword is generated by the

encoder.

- There is a maximum of two consecutive zero bits in   
 each symbol.

• The symbols are then shifted out through a   
 NRZI encoder which produces a signal

transition whenever a 1 bit is being transmitted   
and no transition when a 0 bit is transmitted    
guarantees a signal transition at least every two

bits.

• Local clock is 125MHz. This yields 100 Mbps   
 (80% due to 4B/5B).

FDDI Data Encoding

• Cannot use differential Manchester   
 because 100 Mbps FDDI would require

200 Mbaud!

• Instead each ring interface has its own   
 local clock.

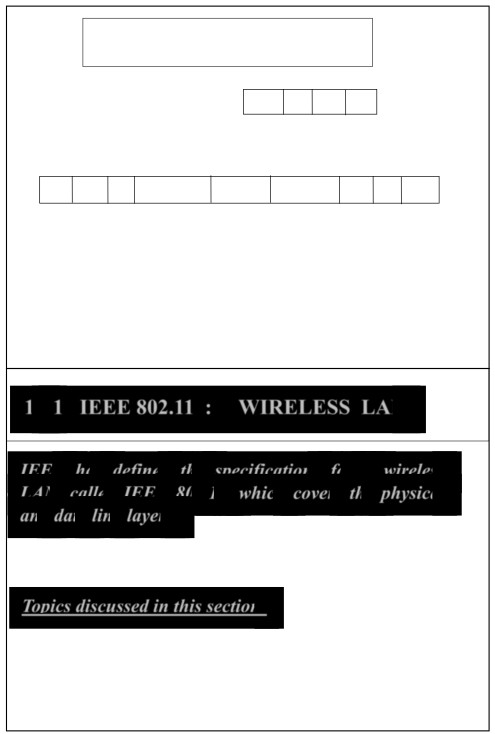
- Outgoing data is transmitted using this clock.

- Incoming data is received using a clock that

is frequency and phase locked to the   
transitions in the incoming bit stream.

27

FDDI



FDDI frame structure

Token Frame Format PRE SD

Data Frame Format

8 1 1 2 or 6 2 or 6

FC ED

•

•

4 1 1

Differences between 802.5 and   
 FDDI

Token Ring FDDI

Shielded twisted pair Optical Fiber

4, 16 Mbps 100 Mbps

PRE SD FC   
Preamble

Destination Source

Address Address

Information FCS ED FS

• No reliability specified

• Differential Mancheste

• Centralized clock

Reliability specified (dual

ring)

4B/5B encoding

Frame CLFF C = Synch/Asynch

Control L = Address length (16 or 48 bits)

FF = LLC/MAC control/reserved frame type

30

• Priority and Reservatio

bits

• New token after receiv

Distributed clocking

Timed Token Rotation Time New token after transmit

31

14-1 IEEE 802.11 : WIRELESS LAN

*IEEE has defined the specifications for a wireless*

*LAN, called IEEE 802.11, which covers the physical* *Note*

*and data link layers.*

A BSS without an AP is called an ad hoc   
 network;

a BSS with an AP is called an

*Topics discussed in this section:* infrastructure network.

MAC Sublayer

Physical Layer

14.1

14.2

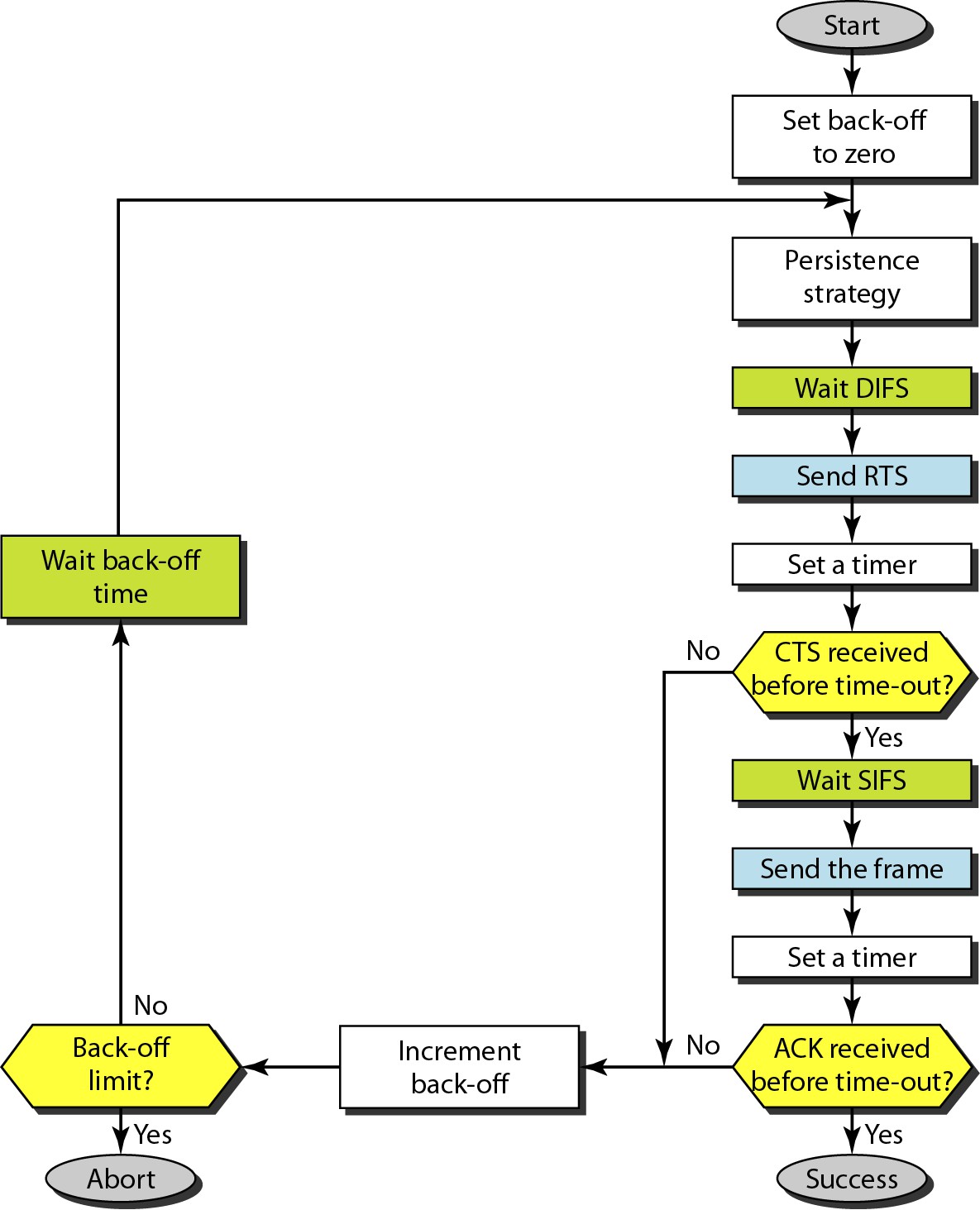
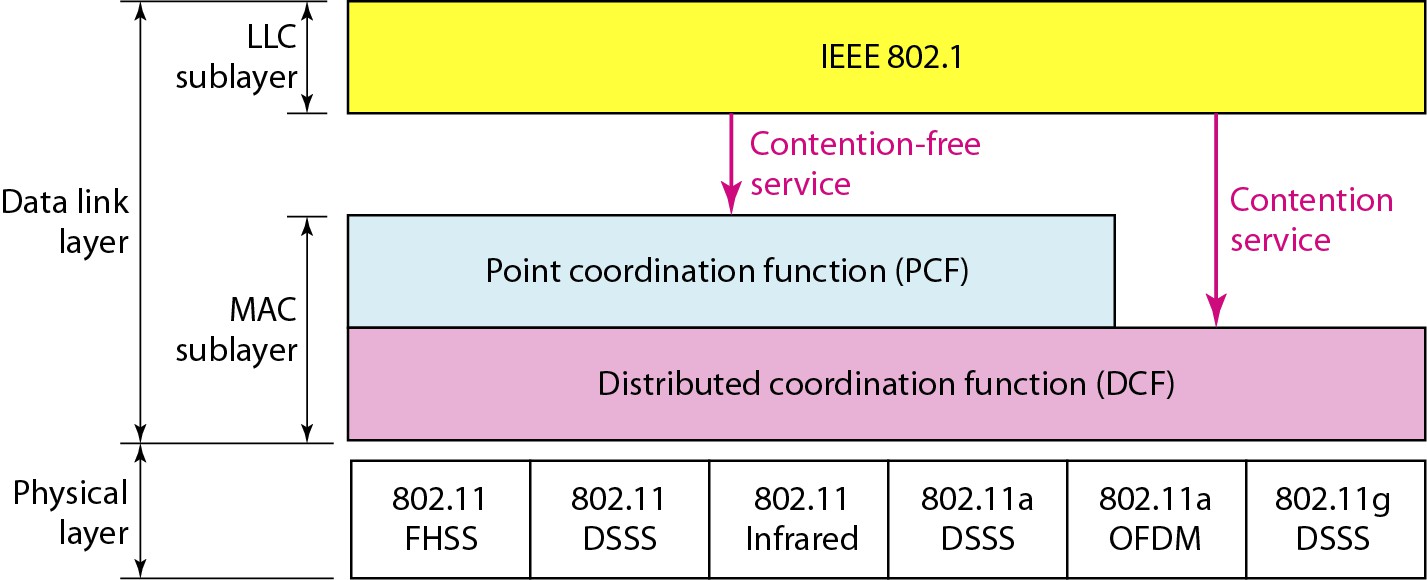
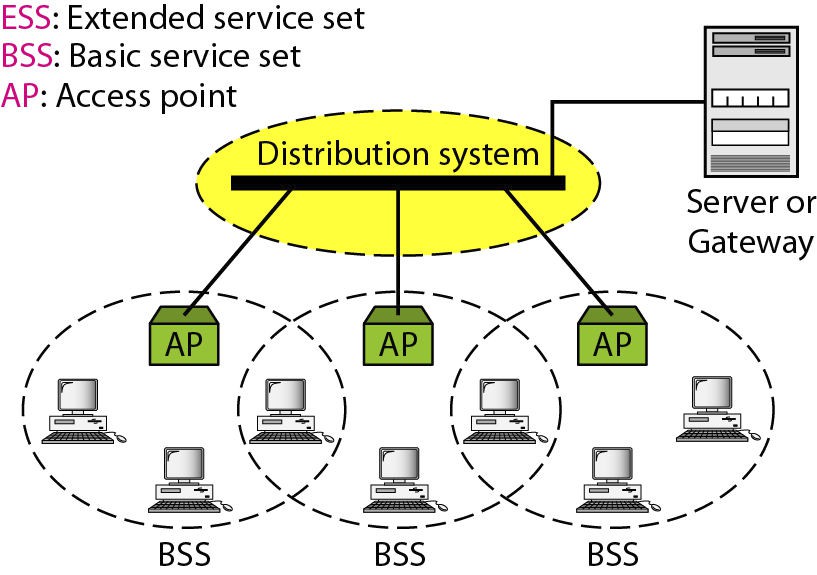
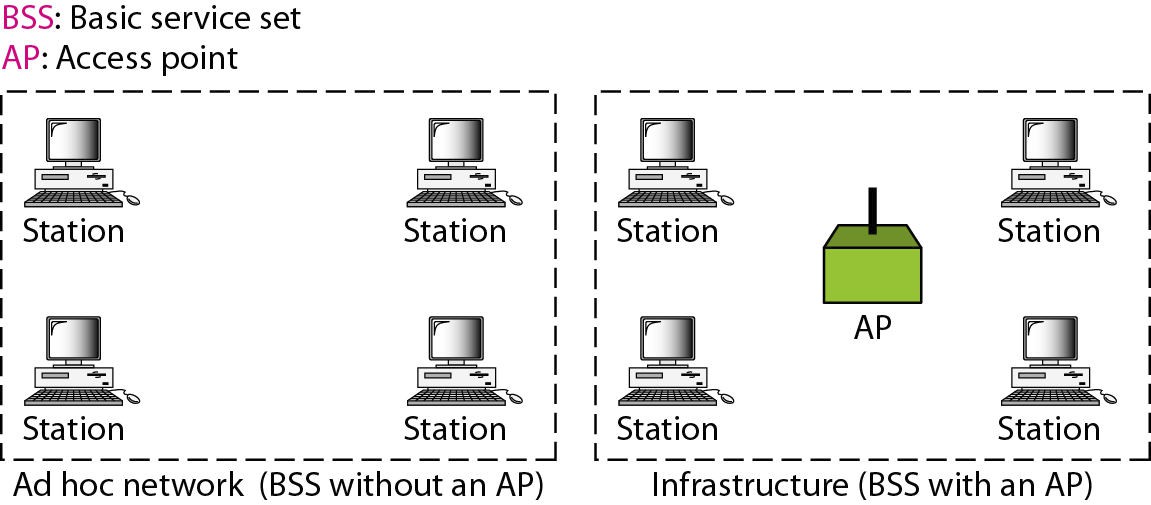


Figure 14.1 *Basic service sets (BSSs)* Figure 14.2 *Extended service sets (ESSs)*

14.3 14.4

Figure 14.4 *CSMA/CA flowchart*

Figure 14.3 *MAC layers in IEEE 802.11 standard*

14.5

14.6

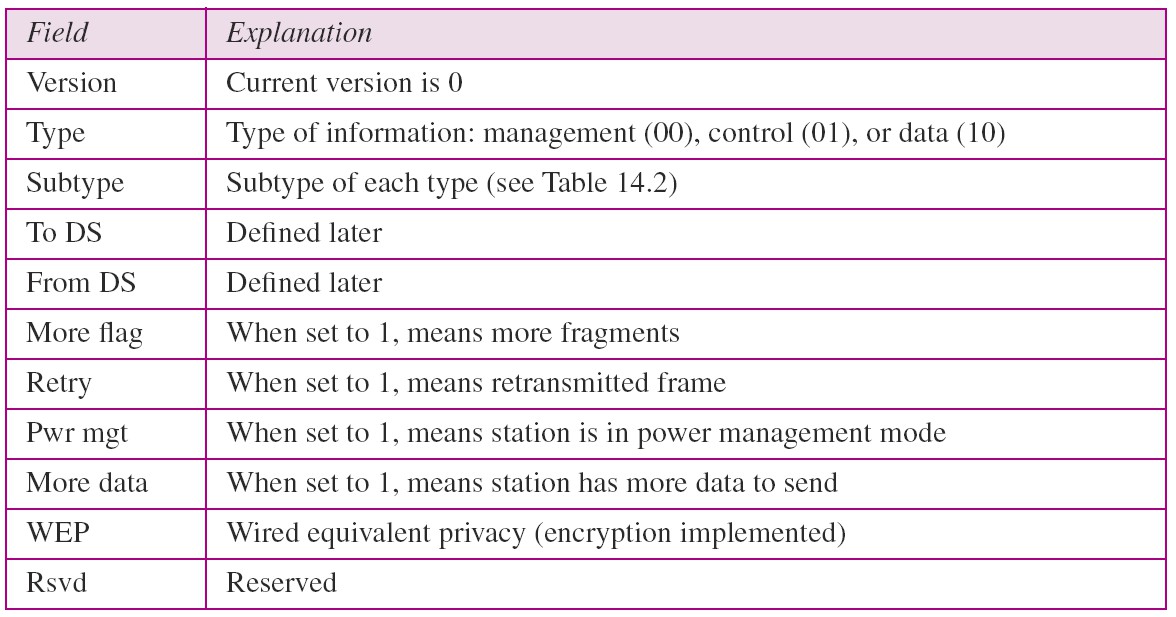
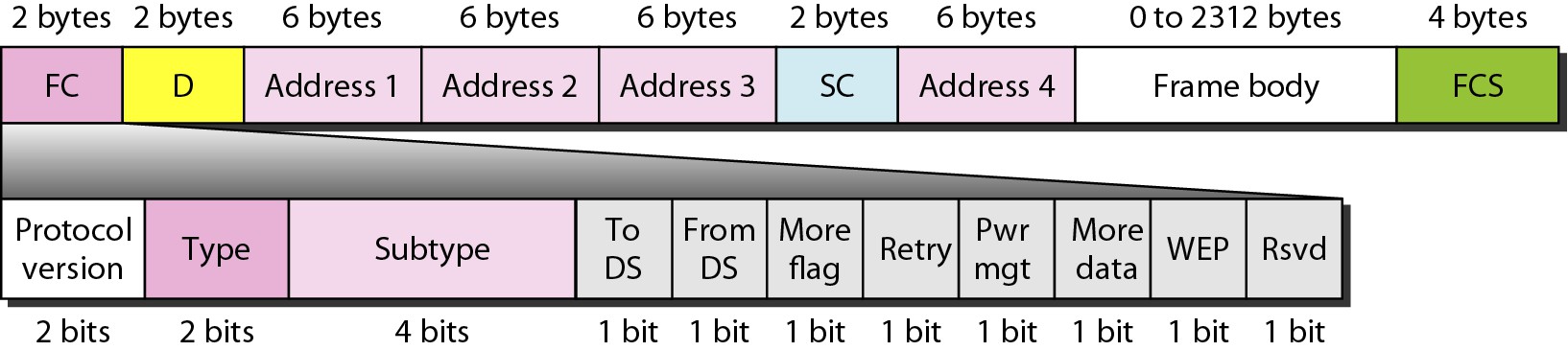
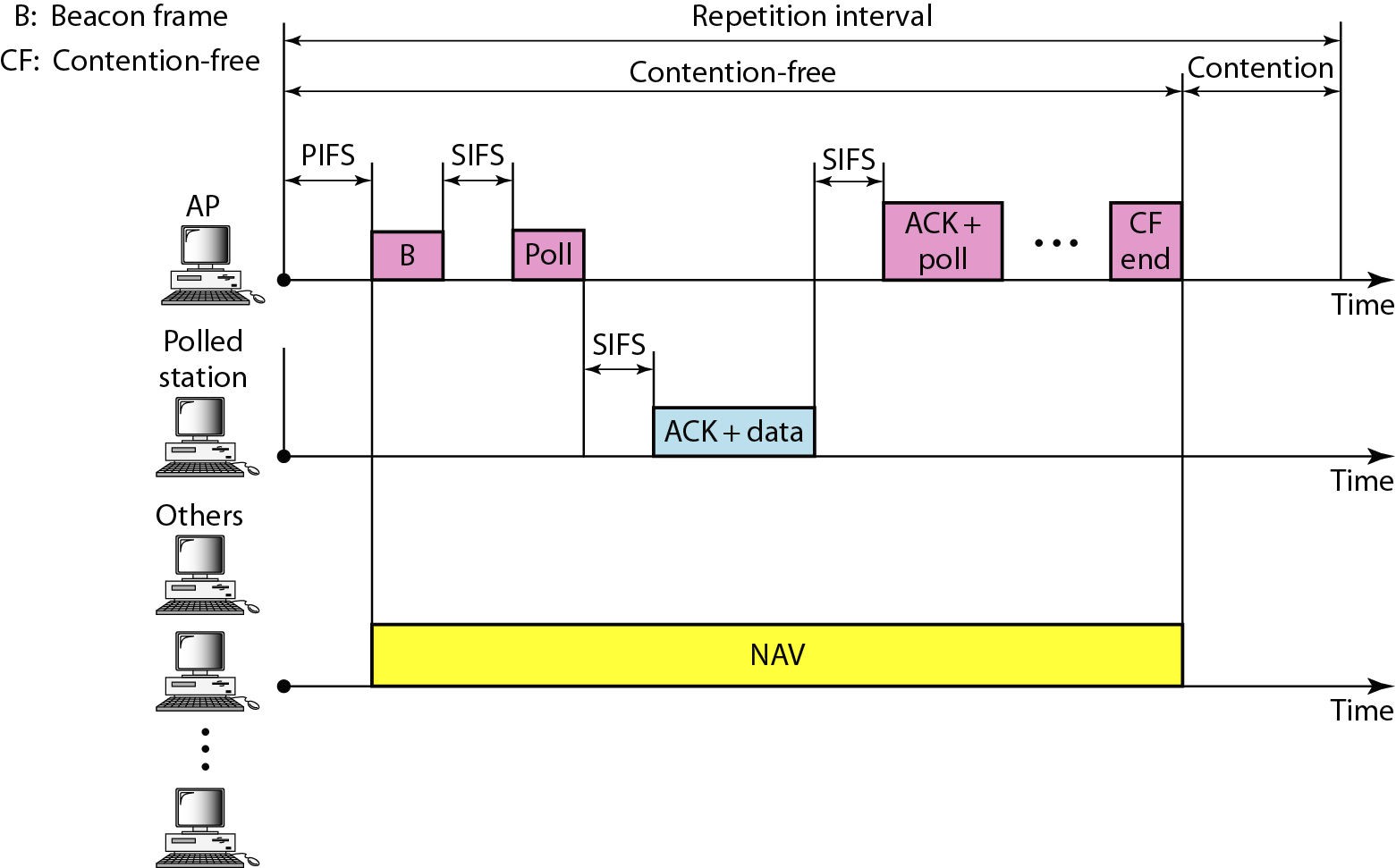
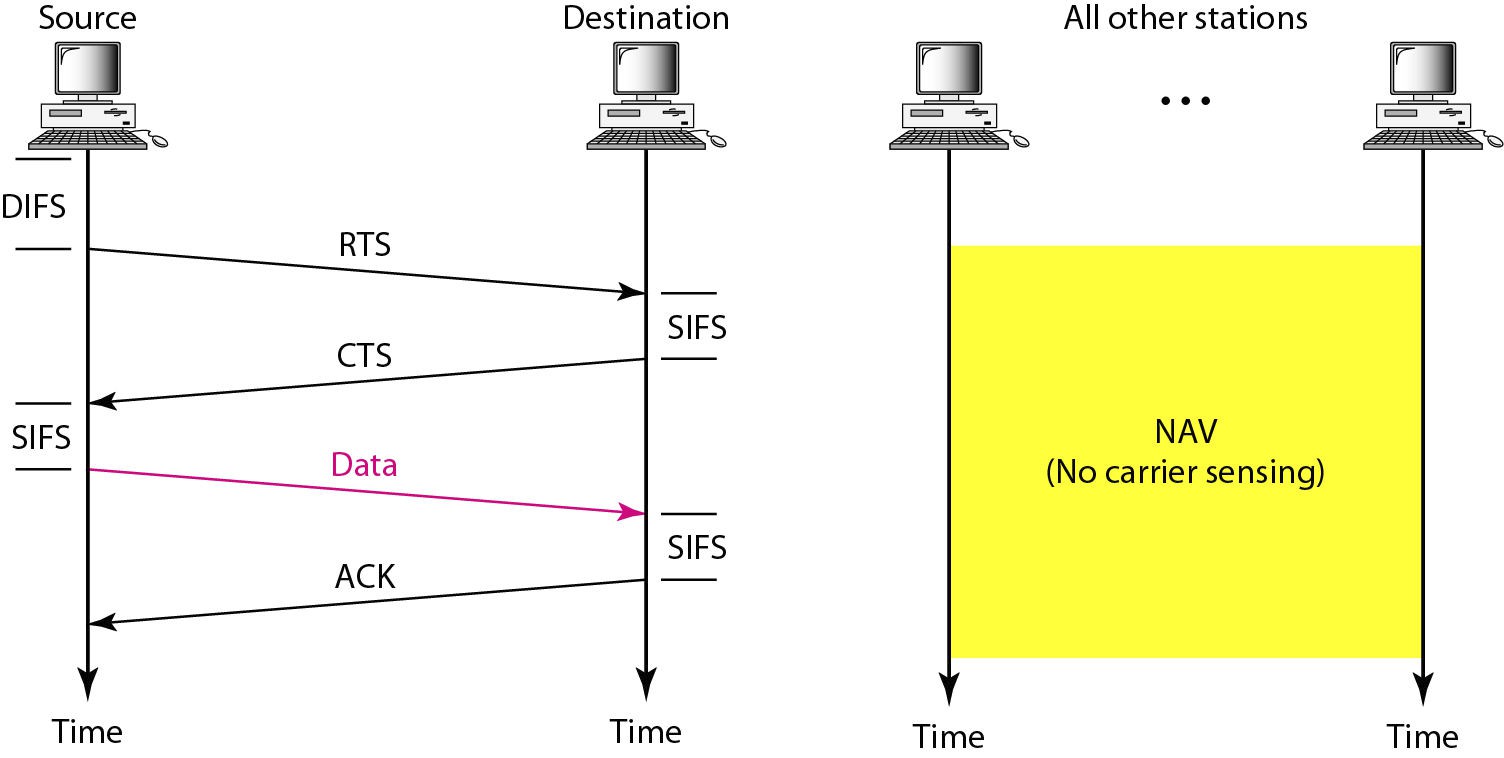


Figure 14.5 *CSMA/CA and NAV* Figure 14.6 *Example of repetition interval*

14.7 14.8

Table 14.1 *Subfields in FC field*

Figure 14.7 *Frame format*

14.9

14.10

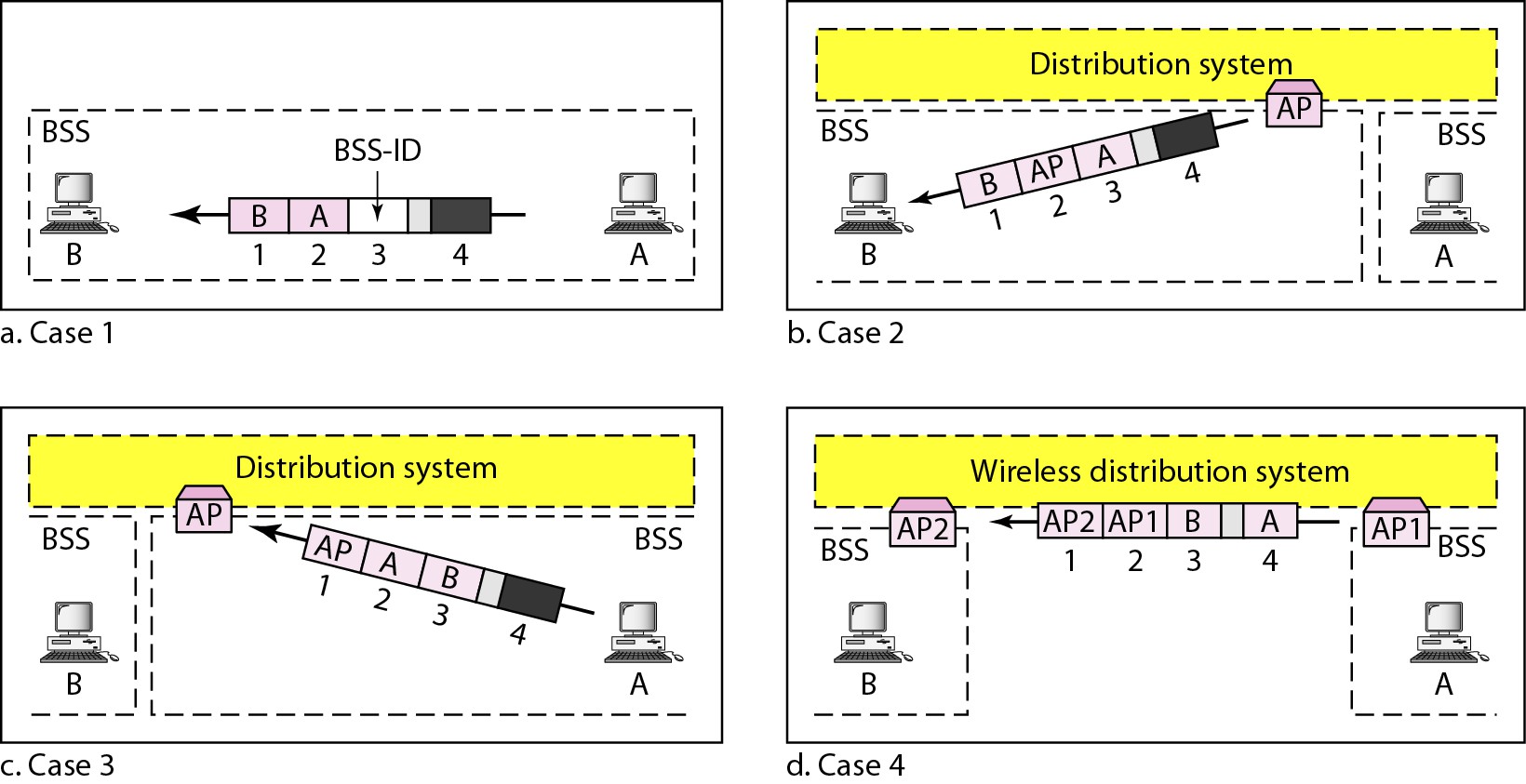
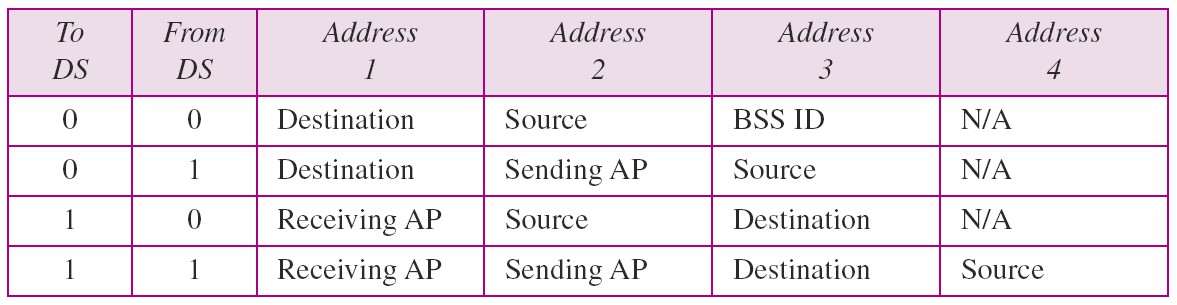
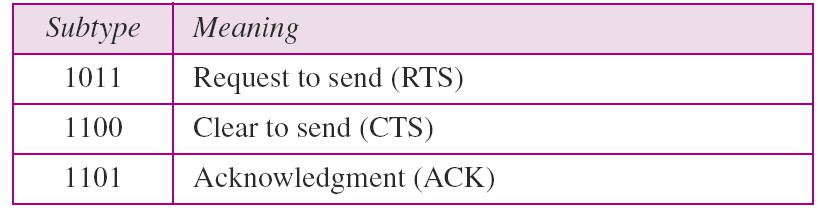
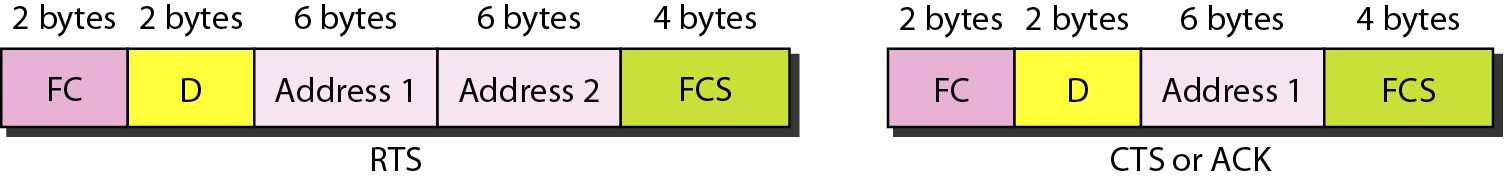


Figure 14.8 *Control frames*

Table 14.2 *Values of subfields in control frames*

14.11 14.12

Figure 14.9 *Addressing mechanisms*

Table 14.3 *Addresses*

14.13

14.14

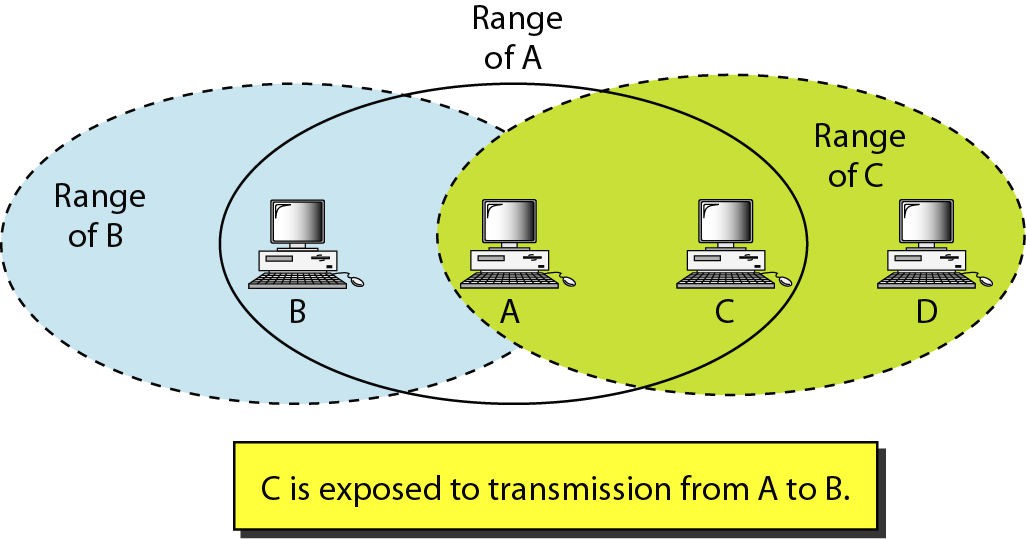
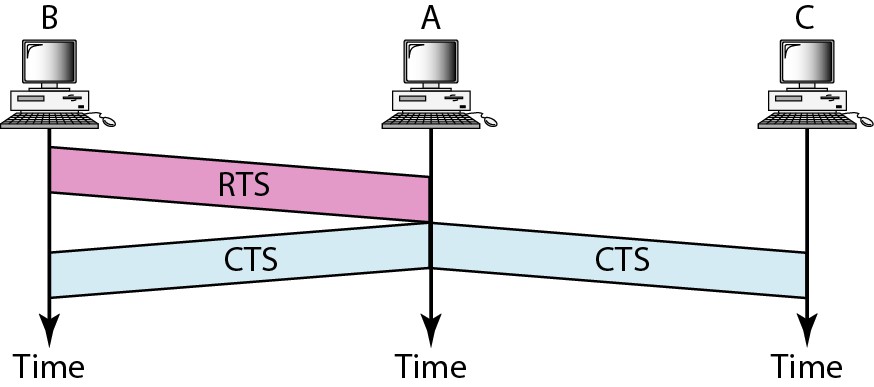
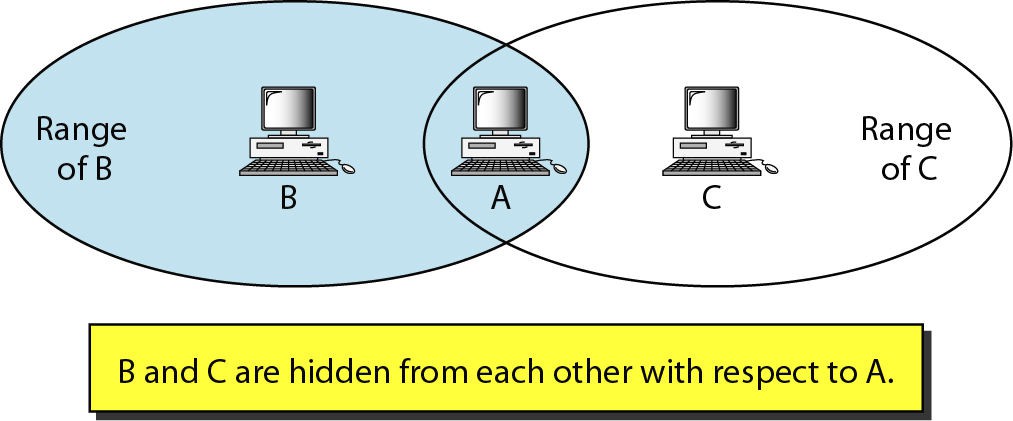


Figure 14.10 *Hidden station problem*

*Note*

The CTS frame in CSMA/CA handshake   
 can prevent collision from

a hidden station.

14.15 14.16

Figure 14.11 *Use of handshaking to prevent hidden station problem* Figure 14.12 *Exposed station problem*

14.17

14.18

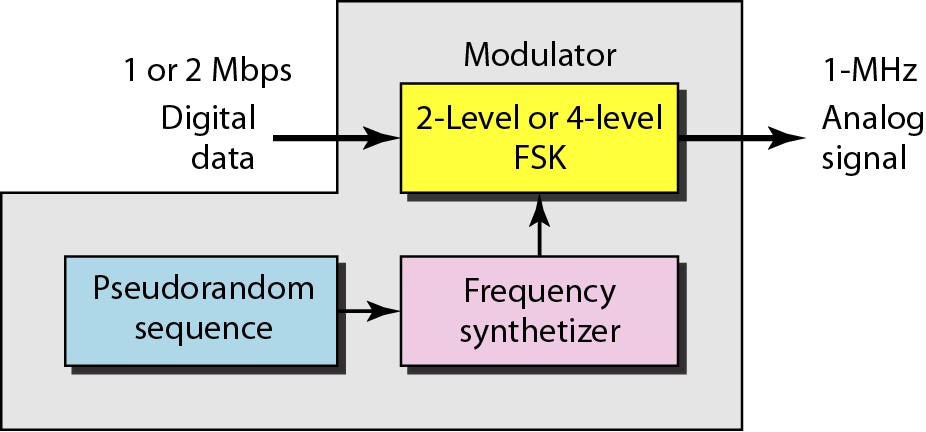
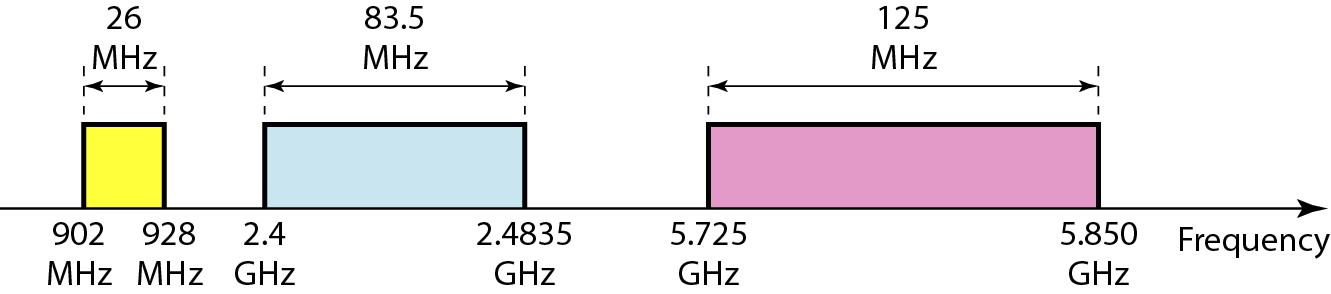
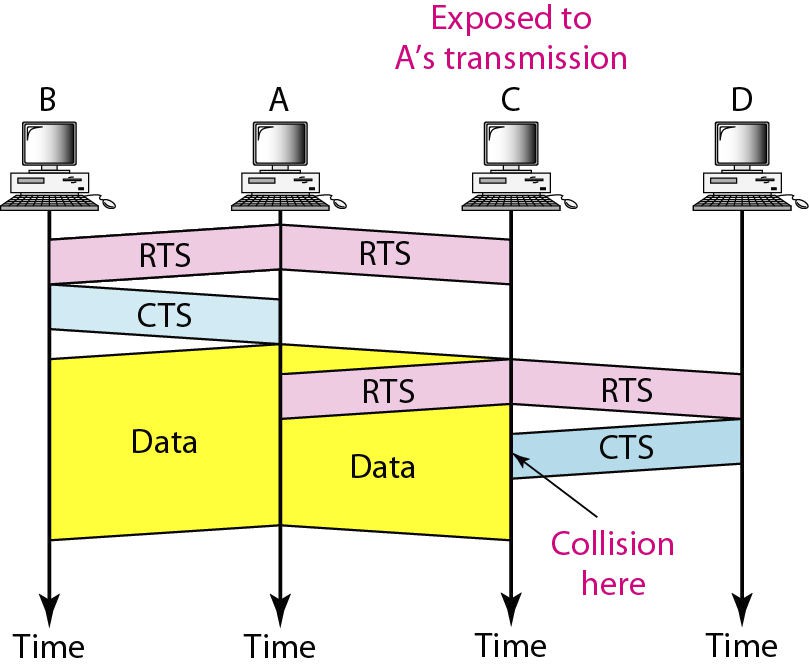


Figure 14.13 *Use of handshaking in exposed station problem*

Table 14.4 *Physical layers*

14.19 14.20

Figure 14.14 *Industrial, scientific, and medical (ISM) band* Figure 14.15 *Physical layer of IEEE 802.11 FHSS*

14.21

14.22

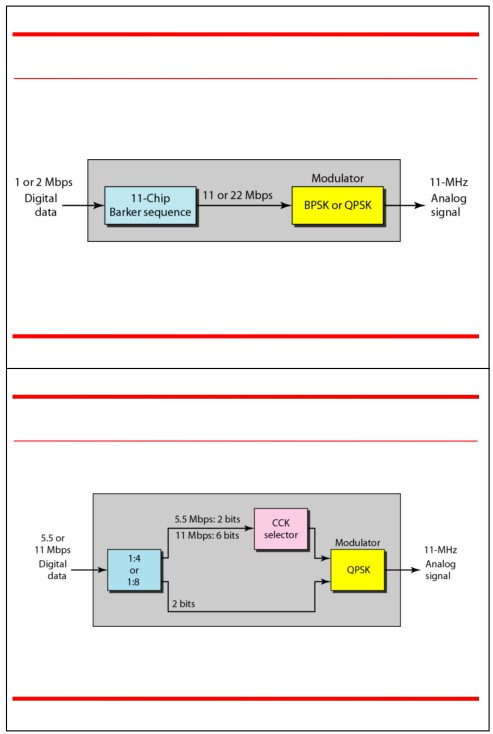
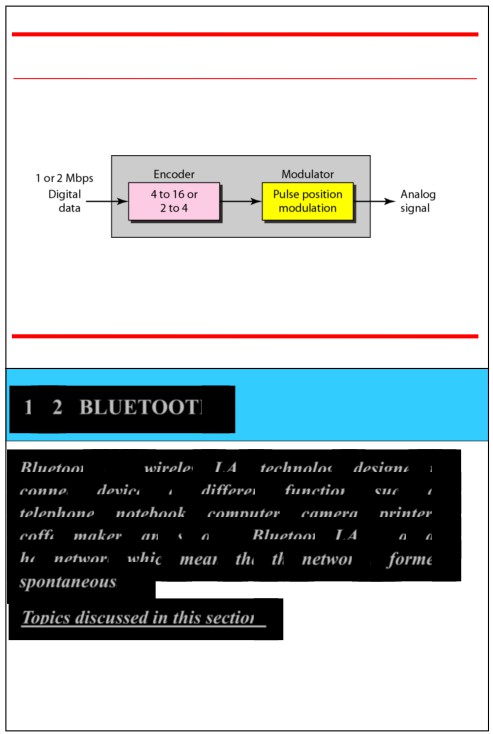


Figure 14.16 *Physical layer of IEEE 802.11 DSSS* Figure 14.17 *Physical layer of IEEE 802.11 infrared*

14.23 14.24

14-2 BLUETOOTH

Figure 14.18 *Physical layer of IEEE 802.11b*

*Bluetooth is a wireless LAN technology designed to*   
*connect devices of different functions such as*   
*telephones, notebooks, computers, cameras, printers,*

*coffee makers, and so on. A Bluetooth LAN is an ad*

*hoc network, which means that the network is formed spontaneously.*

*Topics discussed in this section:*

Bluetooth Layers

Baseband Layer   
L2CAP

14.25 14.26

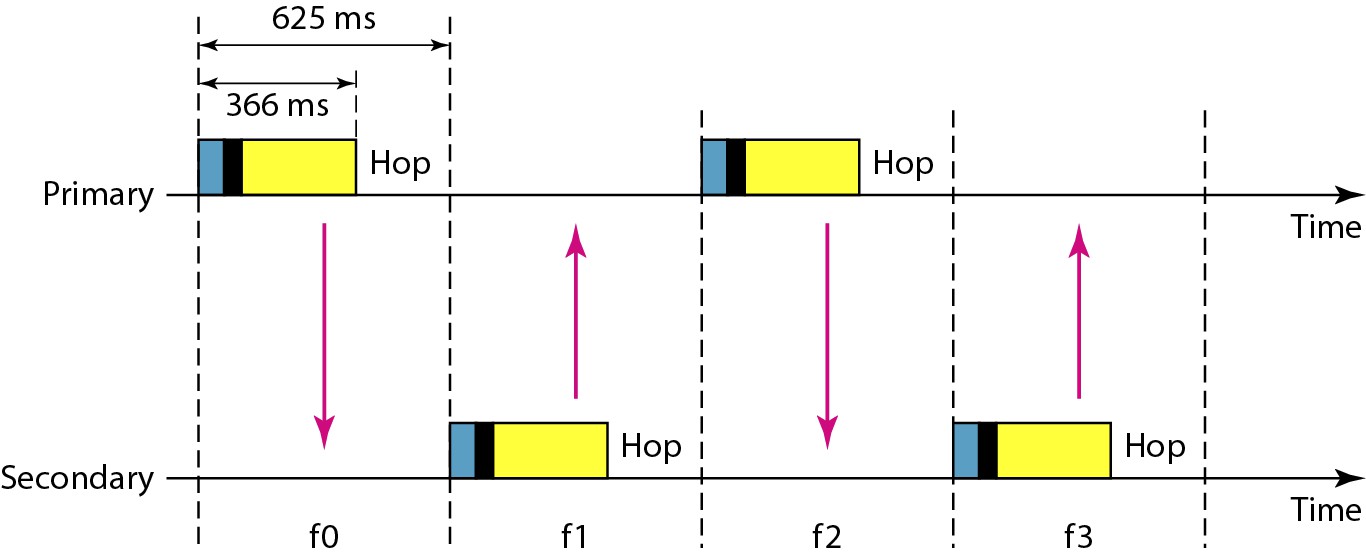
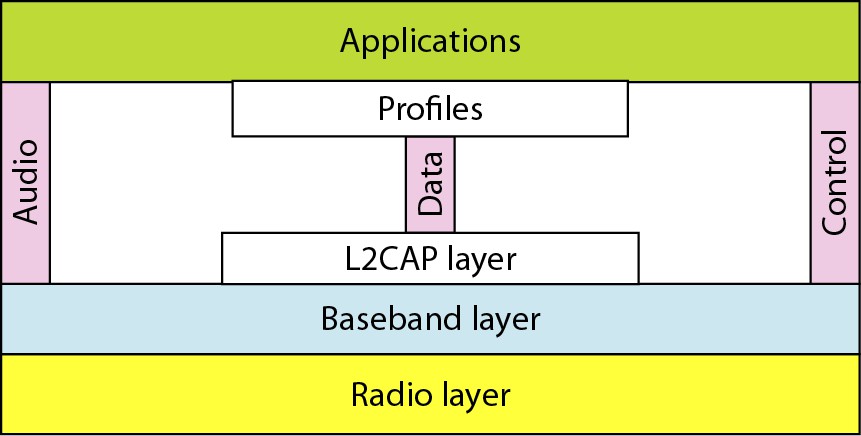
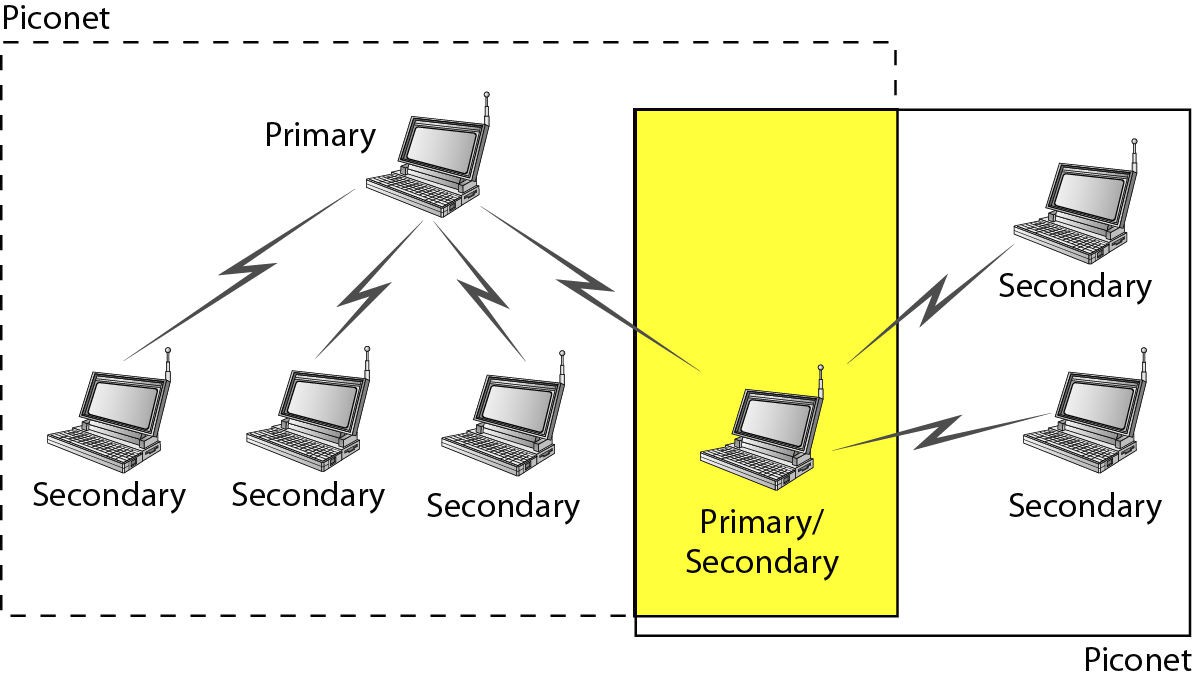
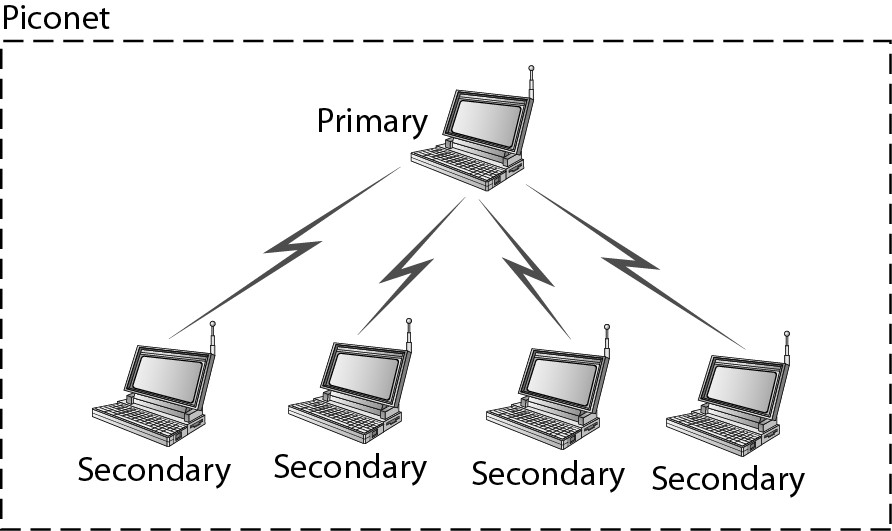


Figure 14.19 *Piconet* Figure 14.20 *Scatternet*

14.27 14.28

Figure 14.21 *Bluetooth layers* Figure 14.22 *Single-secondary communication*

14.29

14.30

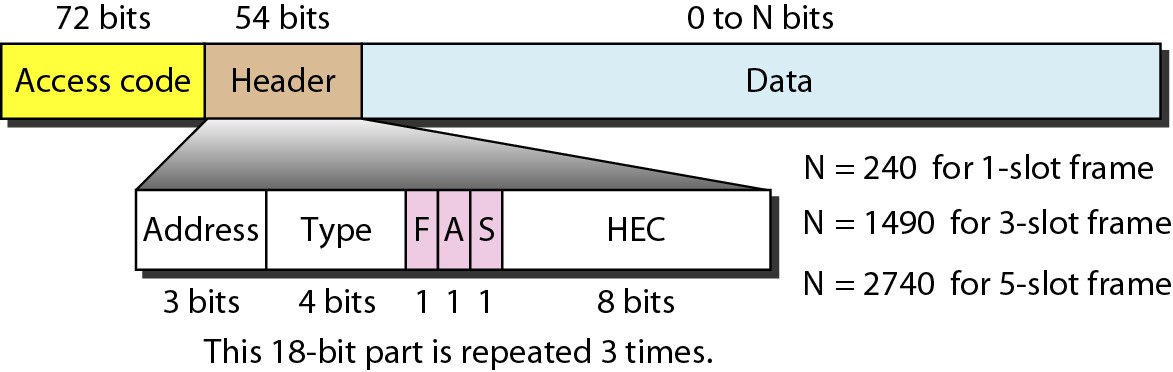
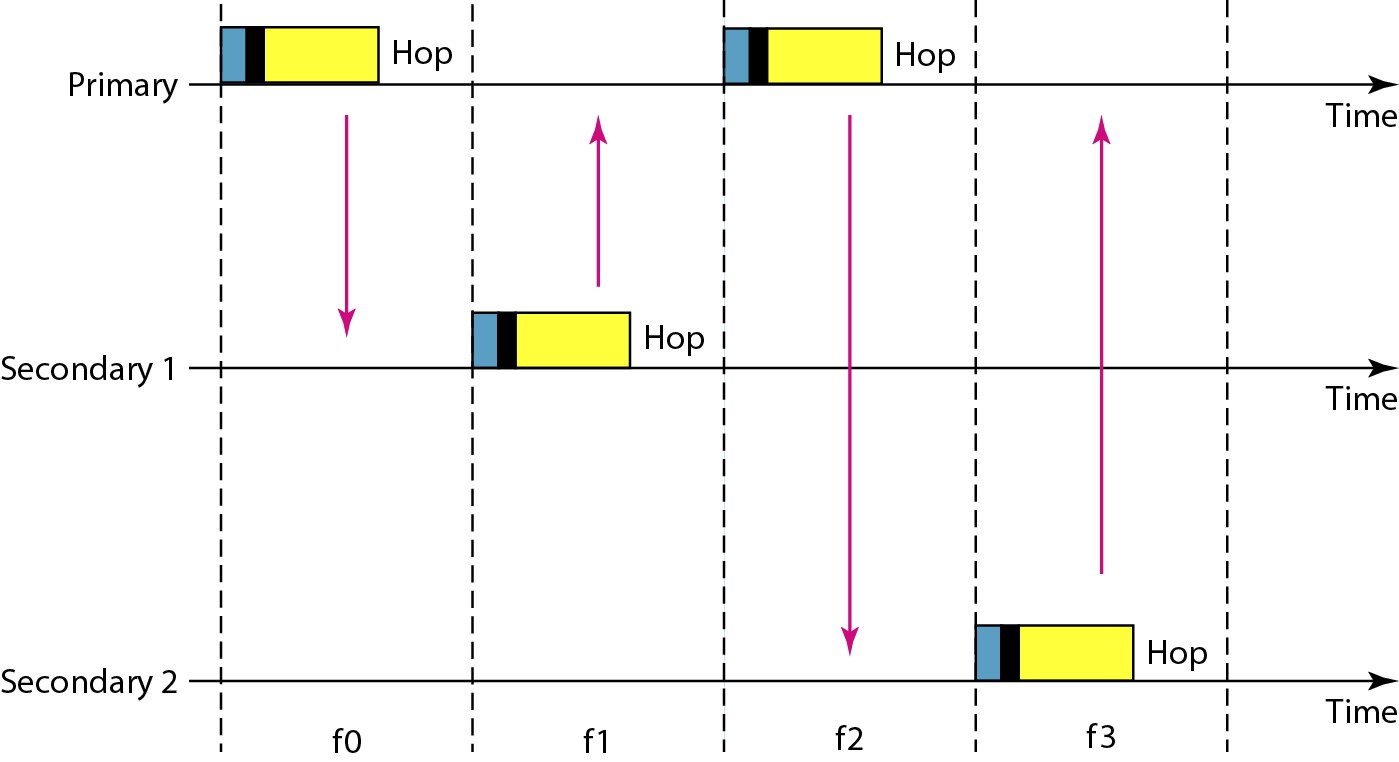


Figure 14.23 *Multiple-secondary communication*

14.31

Figure 14.25 *L2CAP data packet format*

Figure 14.24 *Frame format types*

14.32

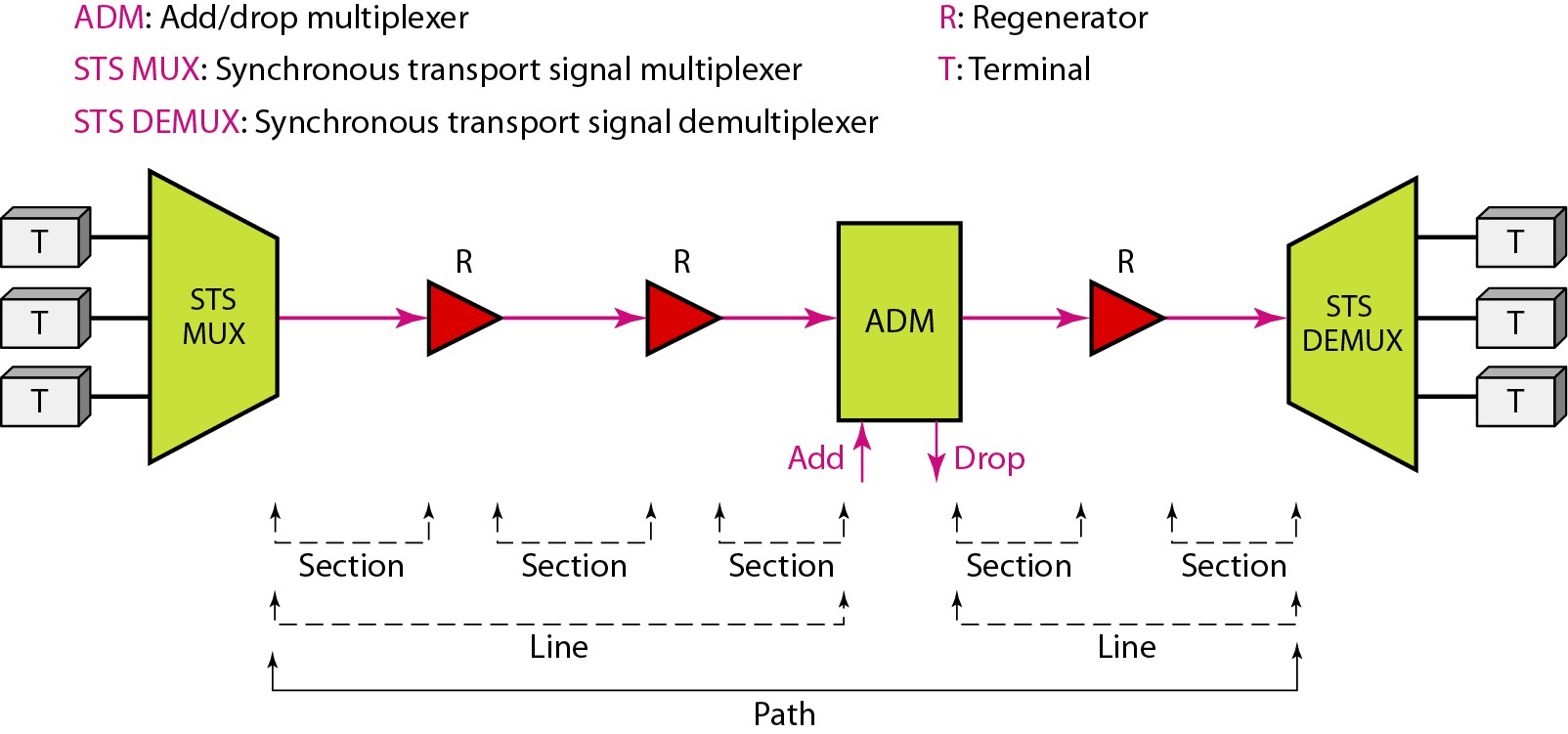
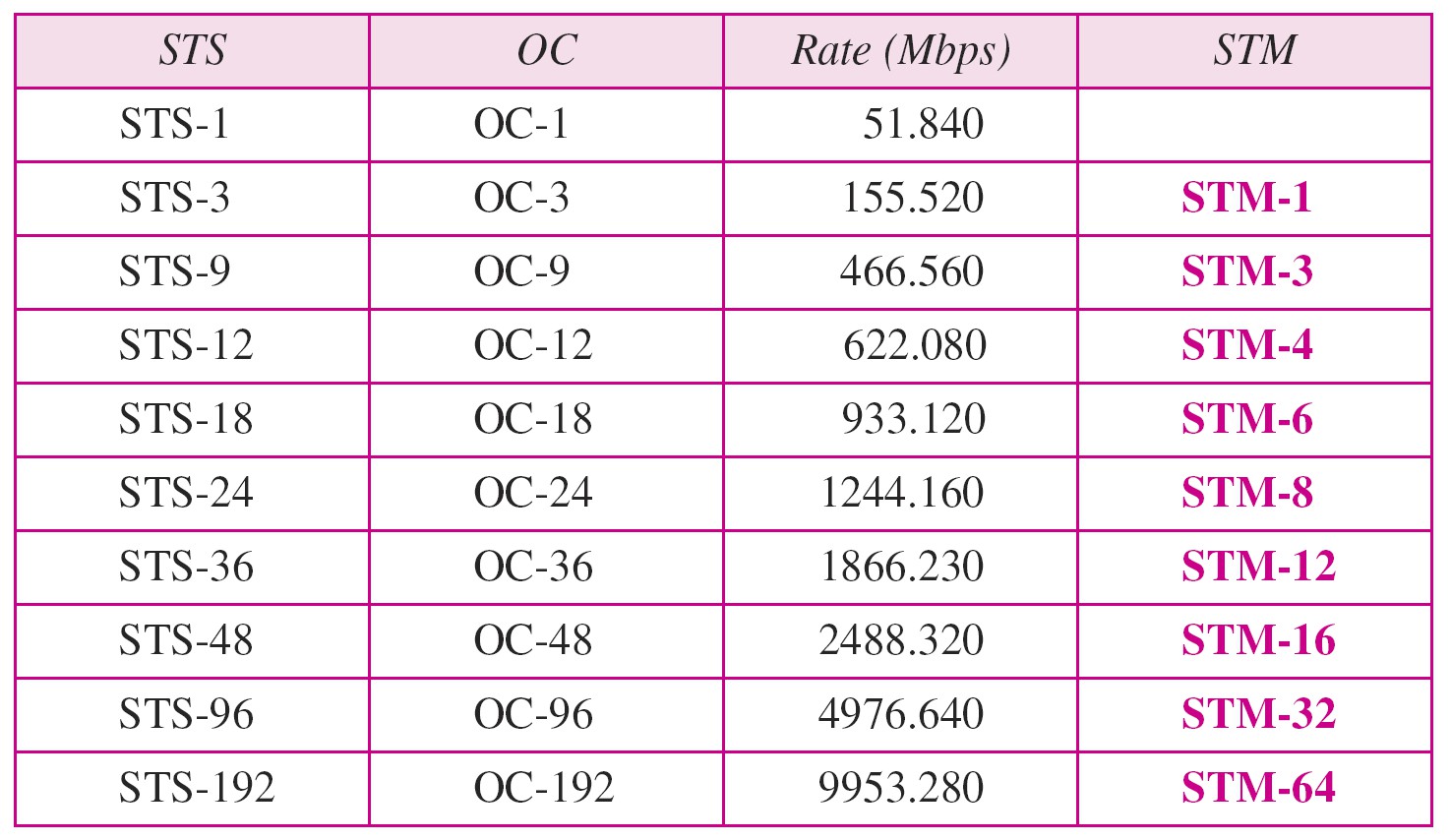
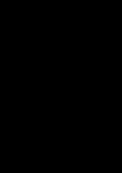
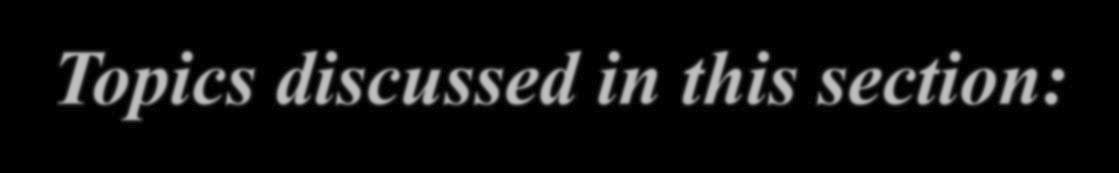
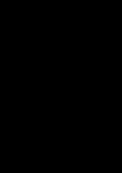
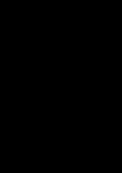
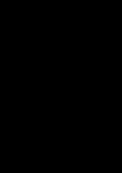
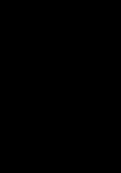
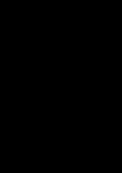
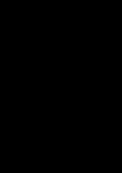
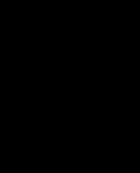
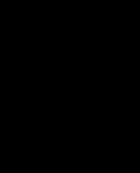
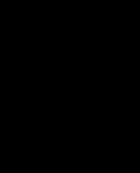
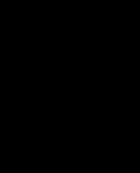
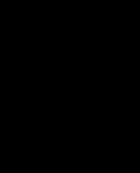
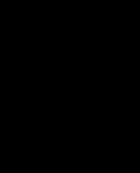
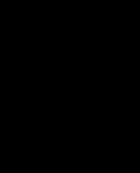
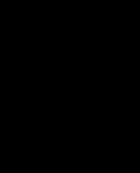
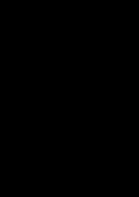
Chapter 17

SONET/SDH

14.33

17.1

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17-1 ARCHITECTURE

*Let us first introduce the architecture of a SONET*

*Note* *system: signals, devices, and connections.*

SONET was developed by ANSI;   
SDH was developed by ITU-T.

*Topics discussed in this section:*

SONET Devices

Connections

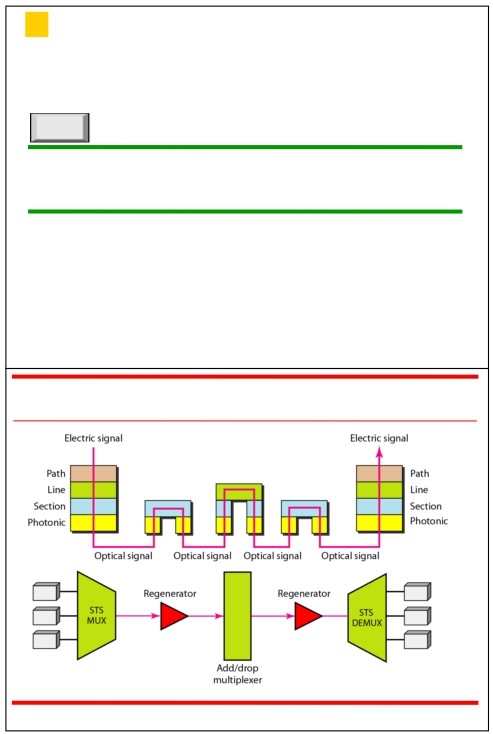
17.2 17.3

Table 17.1 *SONET/SDH rates*

Figure 17.1 *A simple network using SONET equipment*

17.4

17.5



17-2 SONET LAYERS

*The SONET standard includes four functional layers:*

*the photonic, the section, the line, and the path layer.*   
*They correspond to both the physical and the data link*

*layers.*

*Topics discussed in this section:*

Line Layer

Section Layer   
Photonic Layer

Device-Layer Relationships

17.6

Figure 17.2 *SONET layers compared with OSI or the Internet layers*

17.8

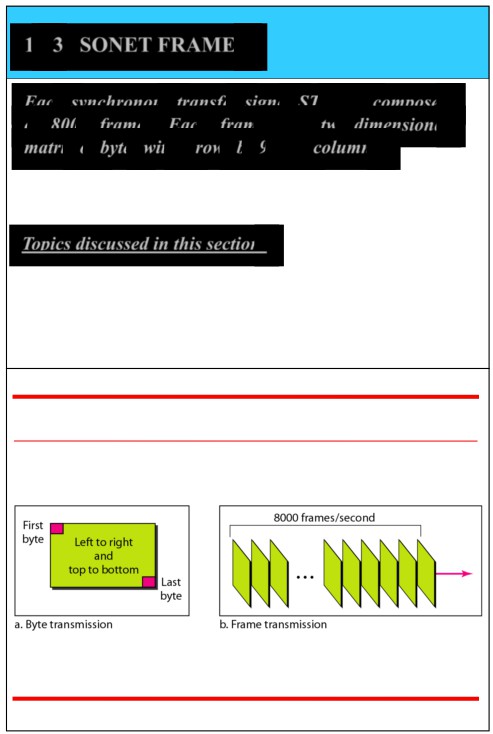
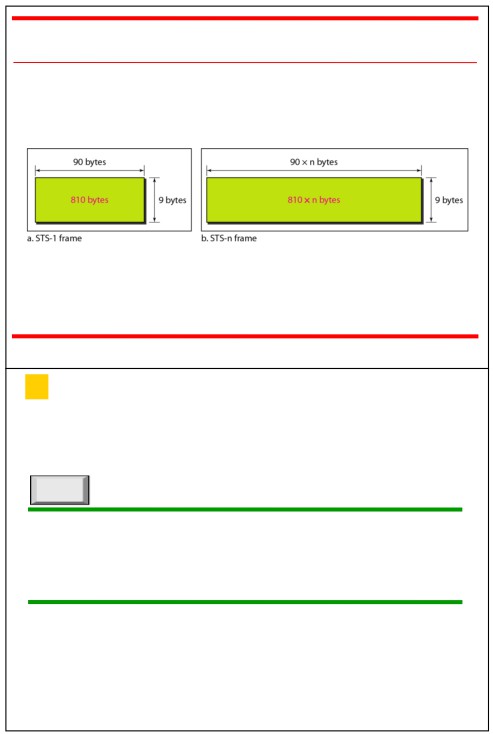
*Note*

SONET defines four layers:   
path, line, section, and photonic.

17.7

Figure 17.3 *Device*-*layer relationship in SONET*

17.9



17-3 SONET FRAMES Figure 17.4 *An STS-1 and an STS-n frame*

*Each synchronous transfer signal STS-n is composed of 8000 frames. Each frame is a two-dimensional matrix of bytes with 9 rows by 90* × *n columns.*

*Topics discussed in this section:*

STS-1 Frame Format

Encapsulation

17.10 17.11

Figure 17.5 *STS-1 frames in transmission*

*Note*

A SONET STS-n

signal is transmitted at

8000 frames per second.

17.12

17.13



*Example 17.1*

*Find the data rate of an STS-1 signal.*

*Note*

Each byte in a SONET frame can carry a   
 digitized voice channel.

17.14

*Example 17.2*

*Find the data rate of an STS-3 signal.*

*Solution*

*STS-3, like other STS signals, sends 8000 frames per second. Each STS-3 frame is made of 9 by (3* × *90) bytes. Each byte is made of 8 bits. The data rate is*

17.16

*Solution*

*STS-1, like other STS signals, sends 8000 frames per second. Each STS-1 frame is made of 9 by (1* × *90) bytes. Each byte is made of 8 bits. The data rate is*

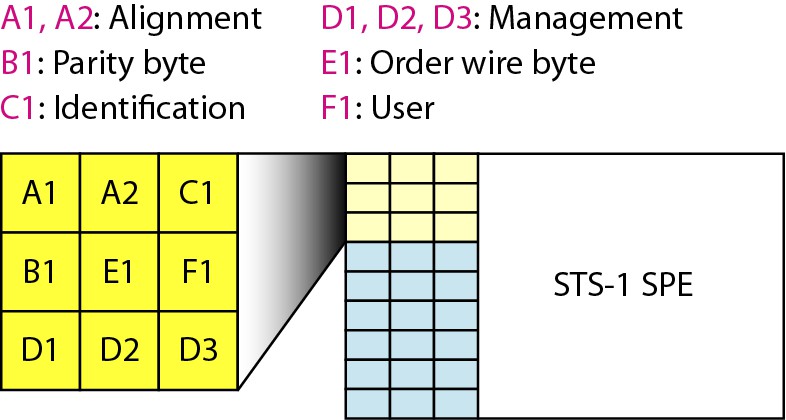
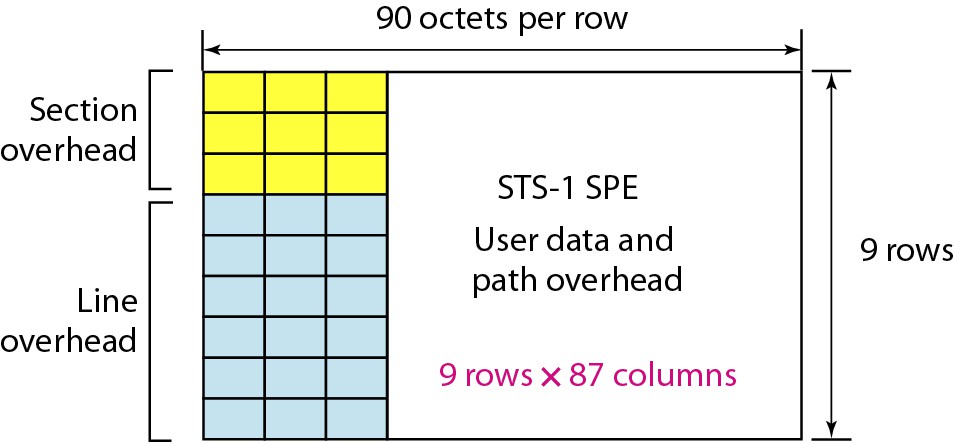
17.15

*Note*

In SONET, the data rate of an STS-n   
 signal is n times the data rate

of an STS-1 signal.

17.17



*Example 17.3*

*What is the duration of an STS-1 frame? STS-3 frame? STS-n frame?*

*Note*

In SONET,

*Solution*

*In SONET, 8000 frames are sent per second. This means*

*that the duration of an STS-1, STS-3, or STS-n frame is the same and equal to 1/8000 s, or 125* μs*.*

17.18

Figure 17.6 *STS-1 frame overheads*

17.20

the duration of any frame is 125 μs.

17.19

Figure 17.7 *STS-1 frame: section overhead*

17.21

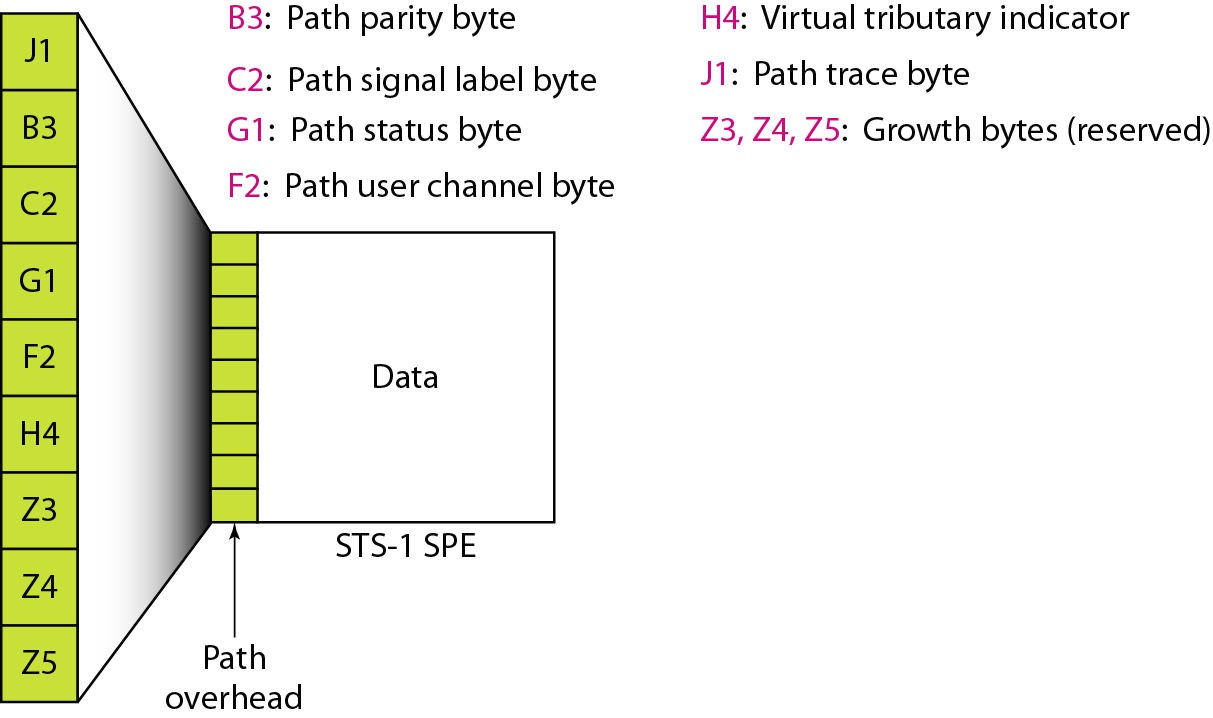
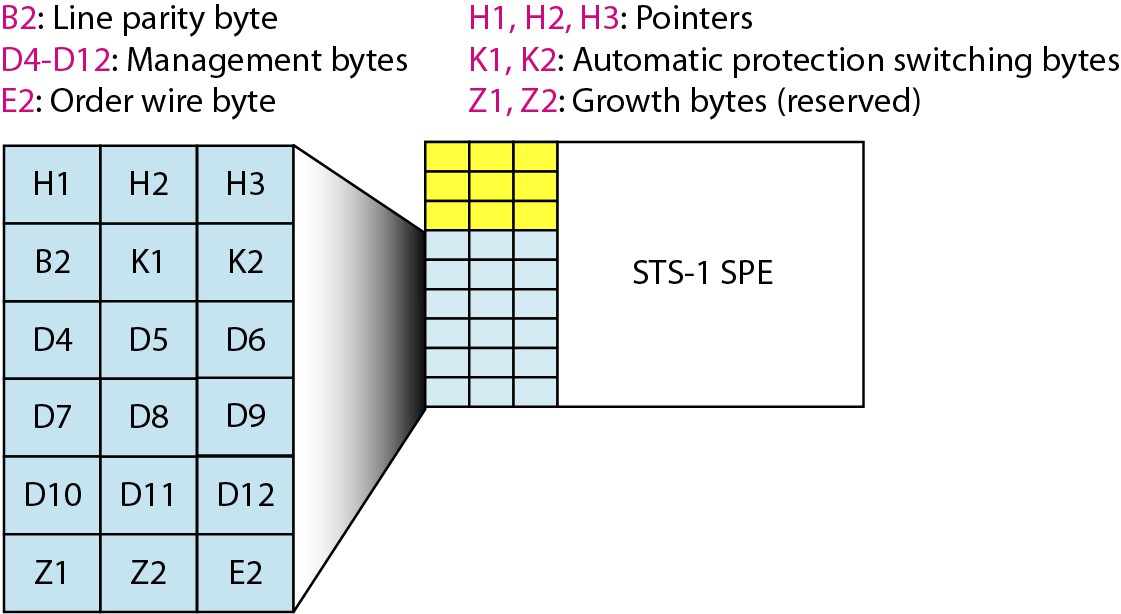


Figure 17.8 *STS-1 frame: line overhead*

*Note*

Section overhead is recalculated for   
 each SONET device

(regenerators and multiplexers).

17.22 17.23

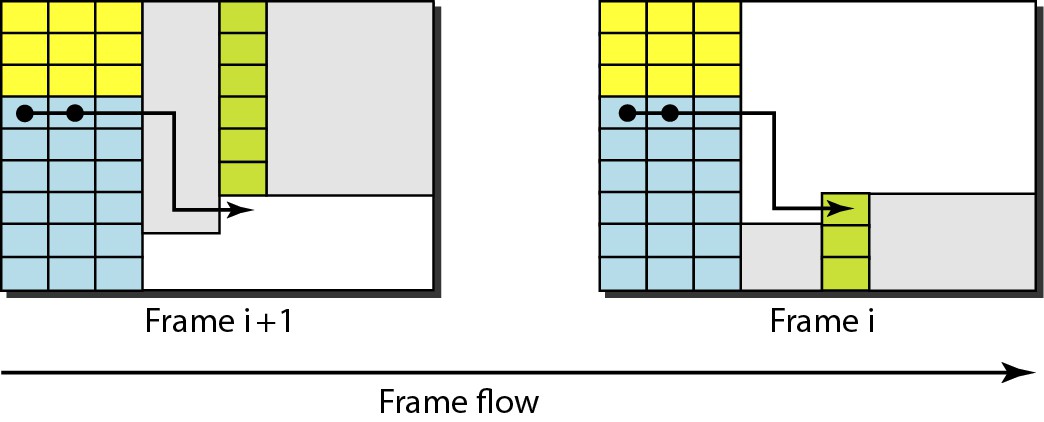
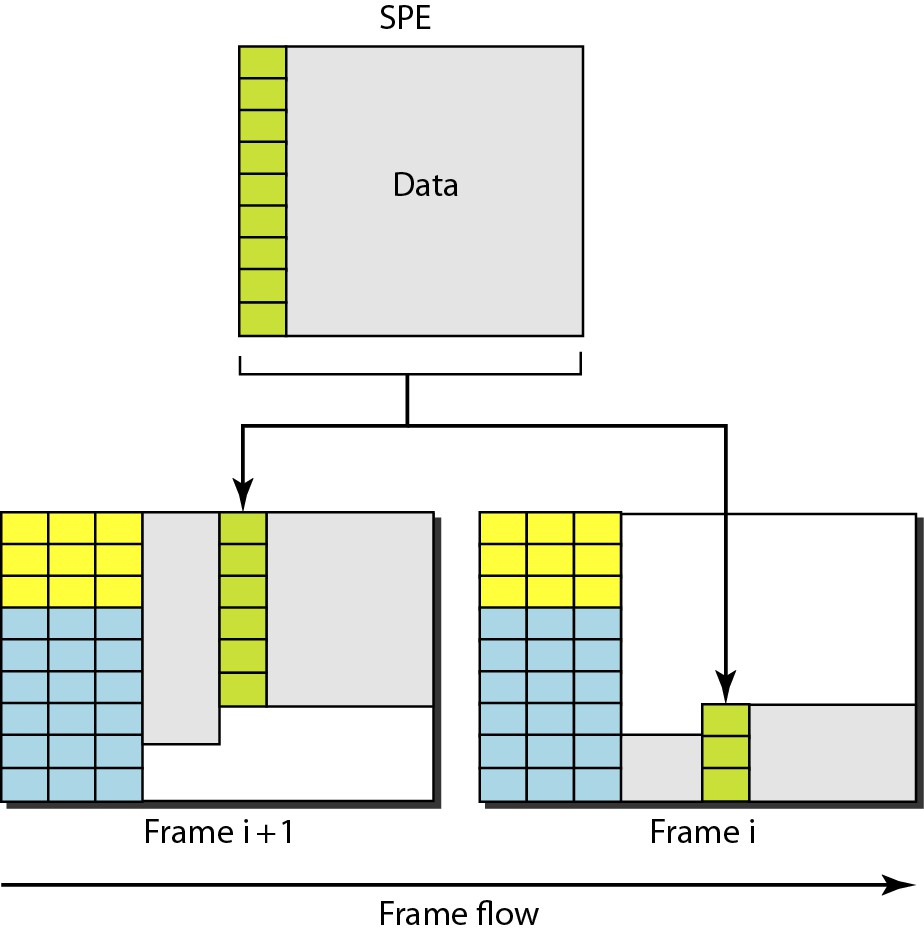
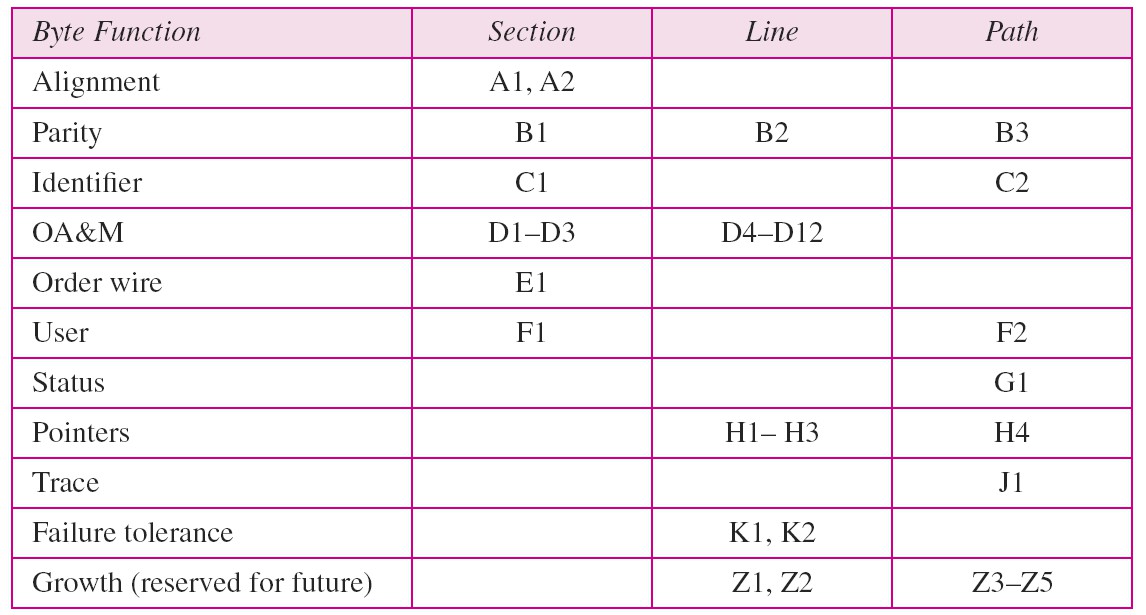
Figure 17.9 *STS-1 frame: path overhead*

*Note*

Path overhead is only calculated for   
end-to-end (at STS multiplexers).

17.24

17.25



*Example 17.4*

Table 17.2 *Overhead bytes*

*What is the user data rate of an STS-1 frame (without considering the overheads)?*

*Solution*

*The user data part in an STS-1 frame is made of 9 rows*

*and 86 columns. So we have*

17.26

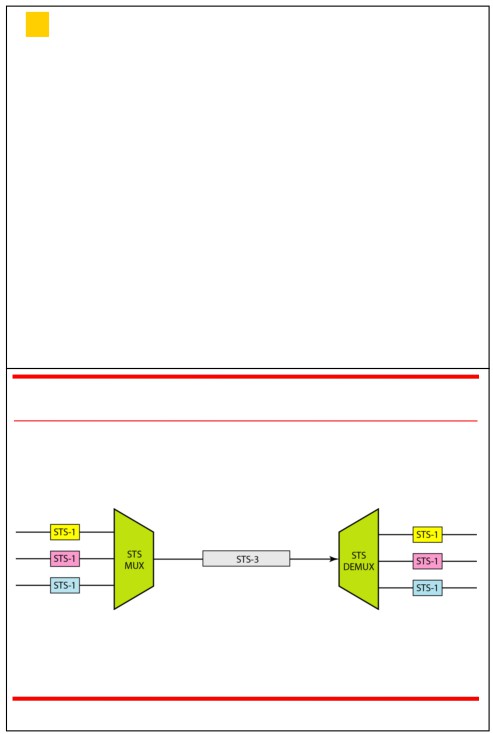
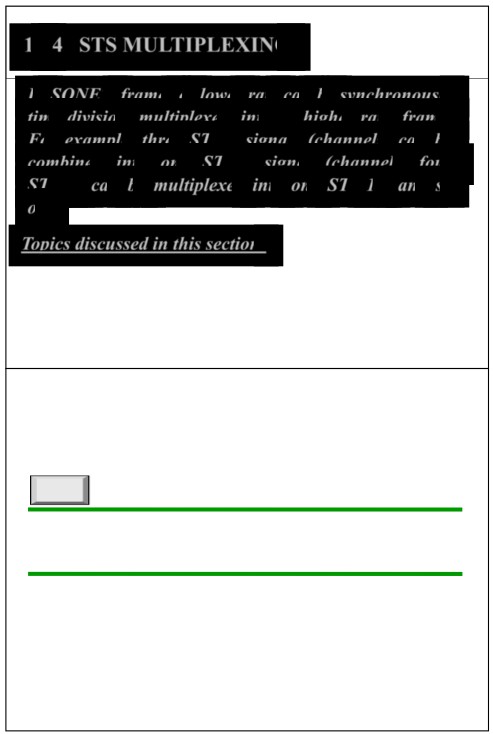
Figure 17.10 *Offsetting of SPE related to frame boundary*

17.28

17.27

Figure 17.11 *The use of H1 and H2 pointers to show the start of*   
 *an SPE in a frame*

17.29



*Example 17.5*

17-4 STS MULTIPLEXING

*What are the values of H1 and H2 if an SPE starts at byte number 650?*

*Solution*

*The number 650 can be expressed in four hexadecimal digits as 0x028A. This means the value of H1 is 0x02 and the value of H2 is 0x8A.*

17.30

Figure 17.12 *STS multiplexing/demultiplexing*

17.32

*In SONET, frames of lower rate can be synchronously*   
*time-division multiplexed into a higher-rate frame.*   
*For example, three STS-1 signals (channels) can be*   
*combined into one STS-3 signal (channel), four*   
*STS-3s can be multiplexed into one STS-12, and so*   
*on.*

*Topics discussed in this section:*

Concatenated Signal   
Add/Drop Multiplexer

17.31

*Note*

In SONET, all clocks in the network are   
 locked to a master clock.

17.33

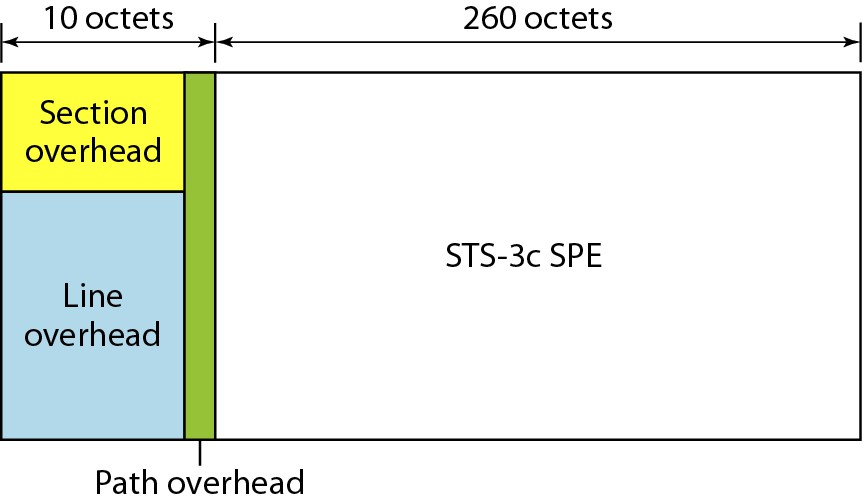
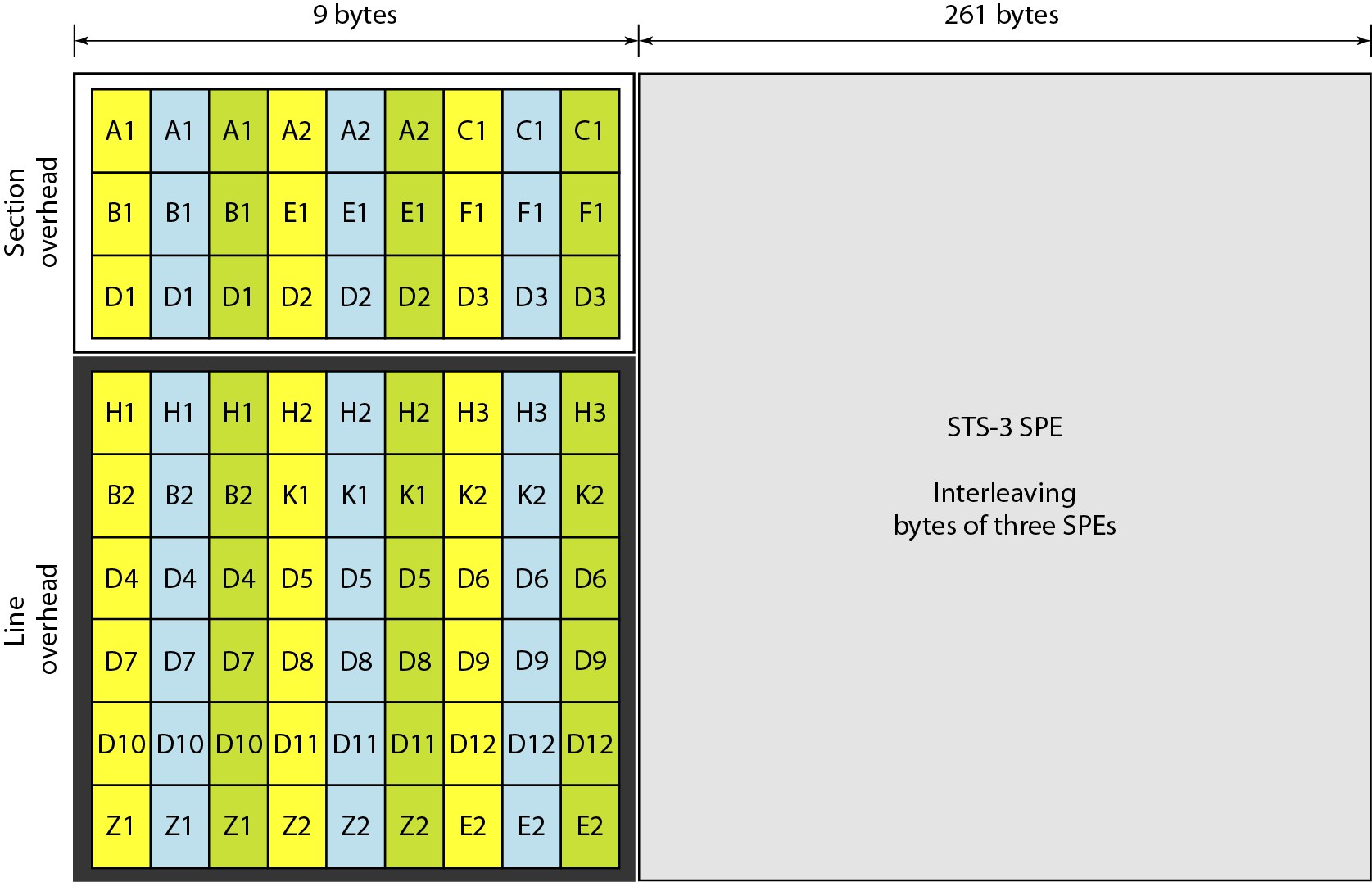
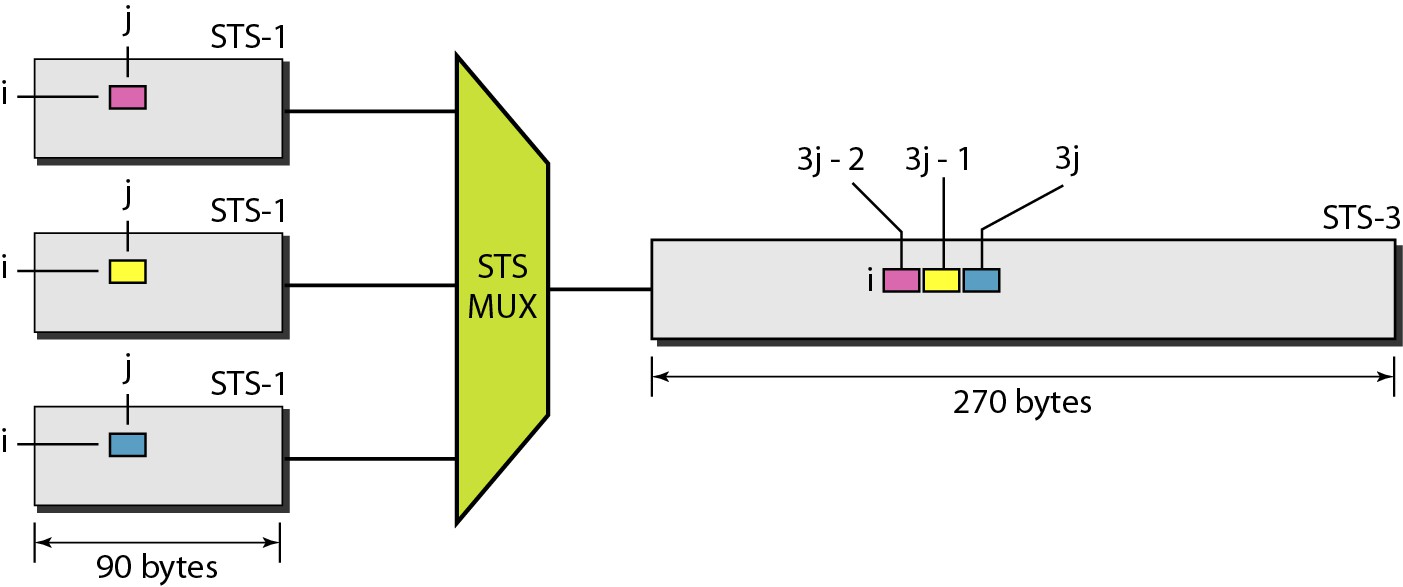


Figure 17.13 *Byte interleaving* Figure 17.14 *An STS-3 frame*

17.34 17.35

Figure 17.15 *A concatenated STS-3c signal*

*Note*

An STS-3c signal can carry

44 ATM cells as its SPE.

17.36

17.37

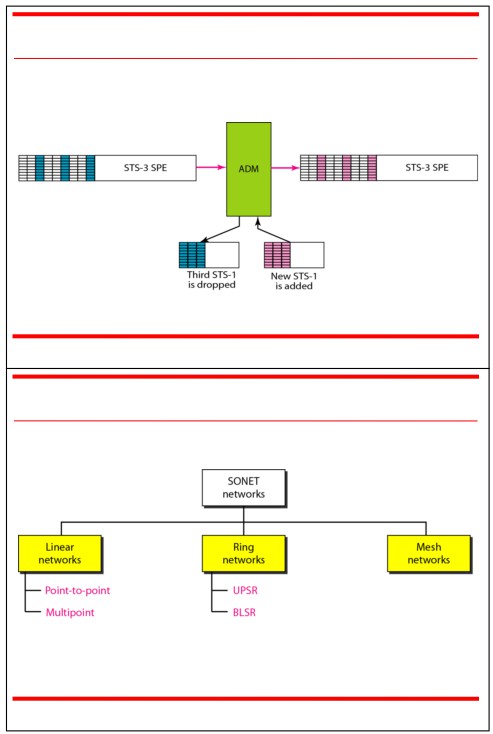
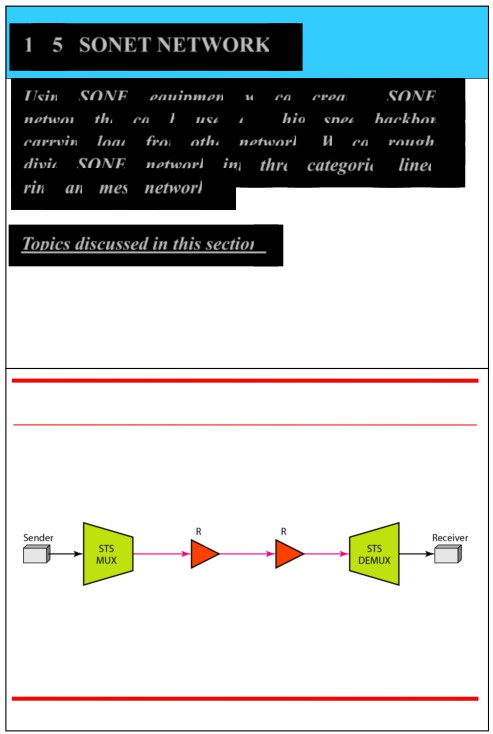


Figure 17.16 *Dropping and adding STS-1 frames in an add/drop multiplexer*

17-5 SONET NETWORKS

*Using SONET equipment, we can create a SONET*

*network that can be used as a high-speed backbone carrying loads from other networks. We can roughly divide SONET networks into three categories: linear, ring, and mesh networks.*

*Topics discussed in this section:*

Ring Networks

Mesh Networks

17.38

Figure 17.17 *Taxonomy of SONET networks*

17.40

17.39

Figure 17.18 *A point-to-point SONET network*

17.41

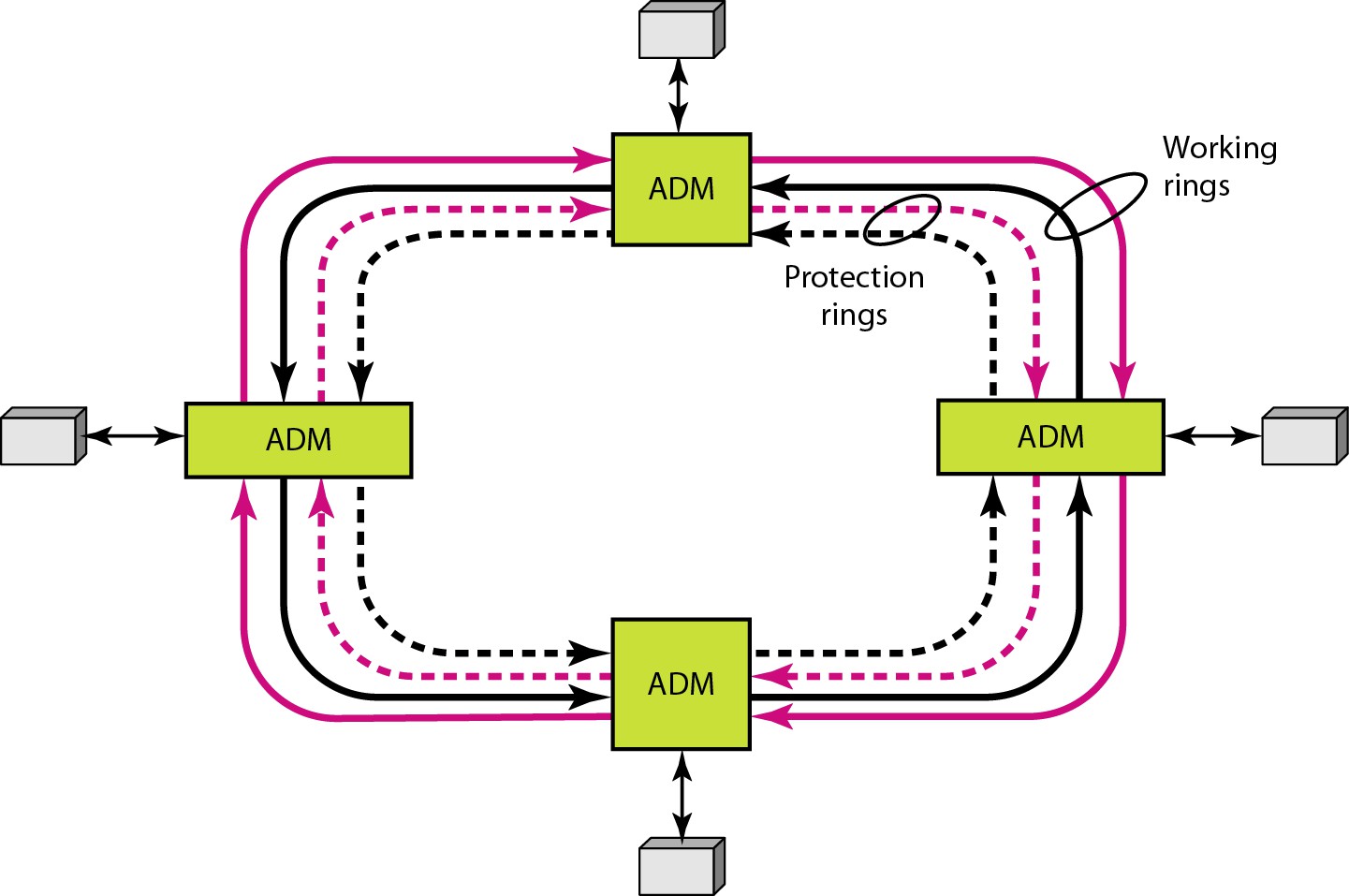
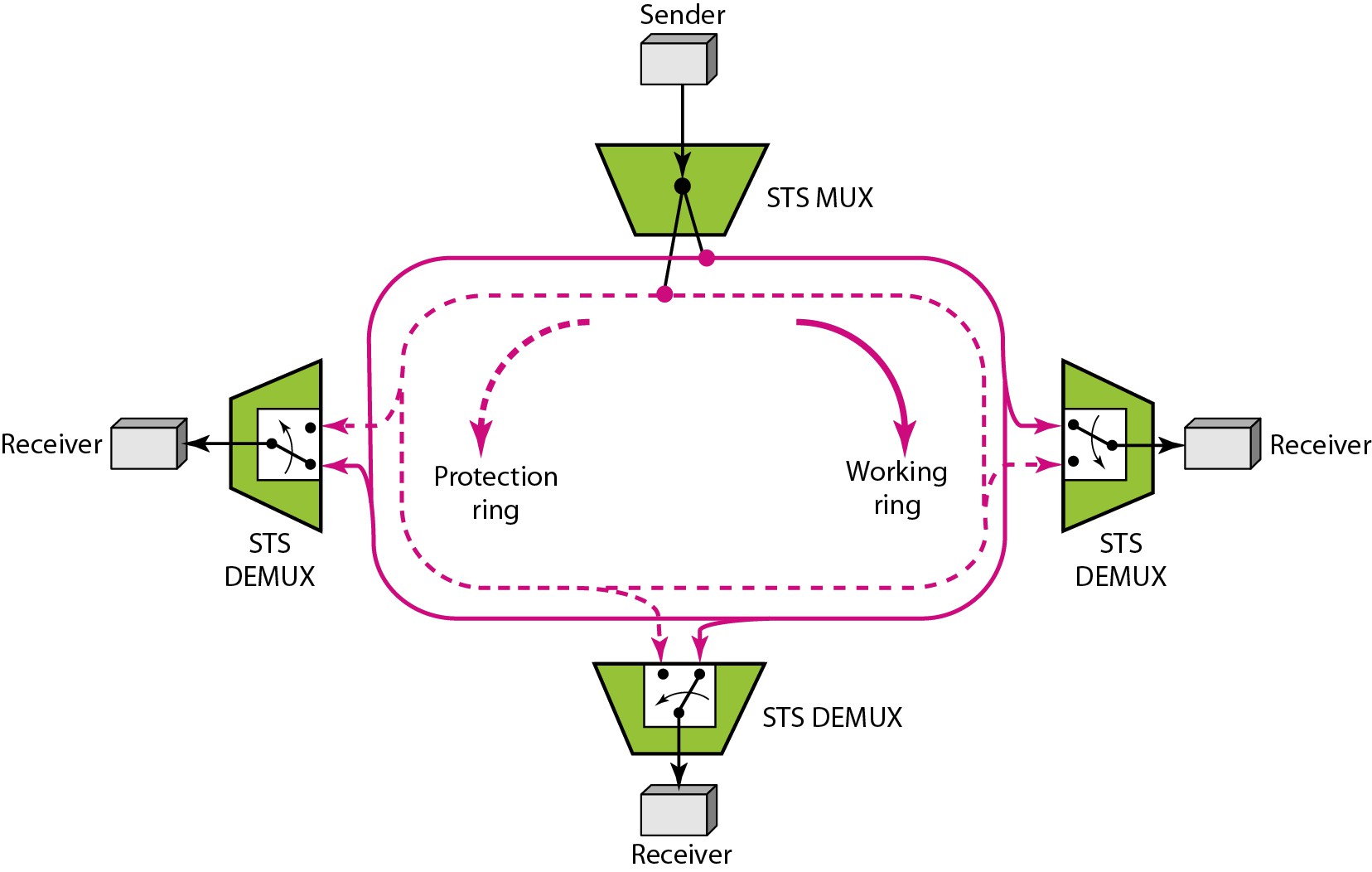
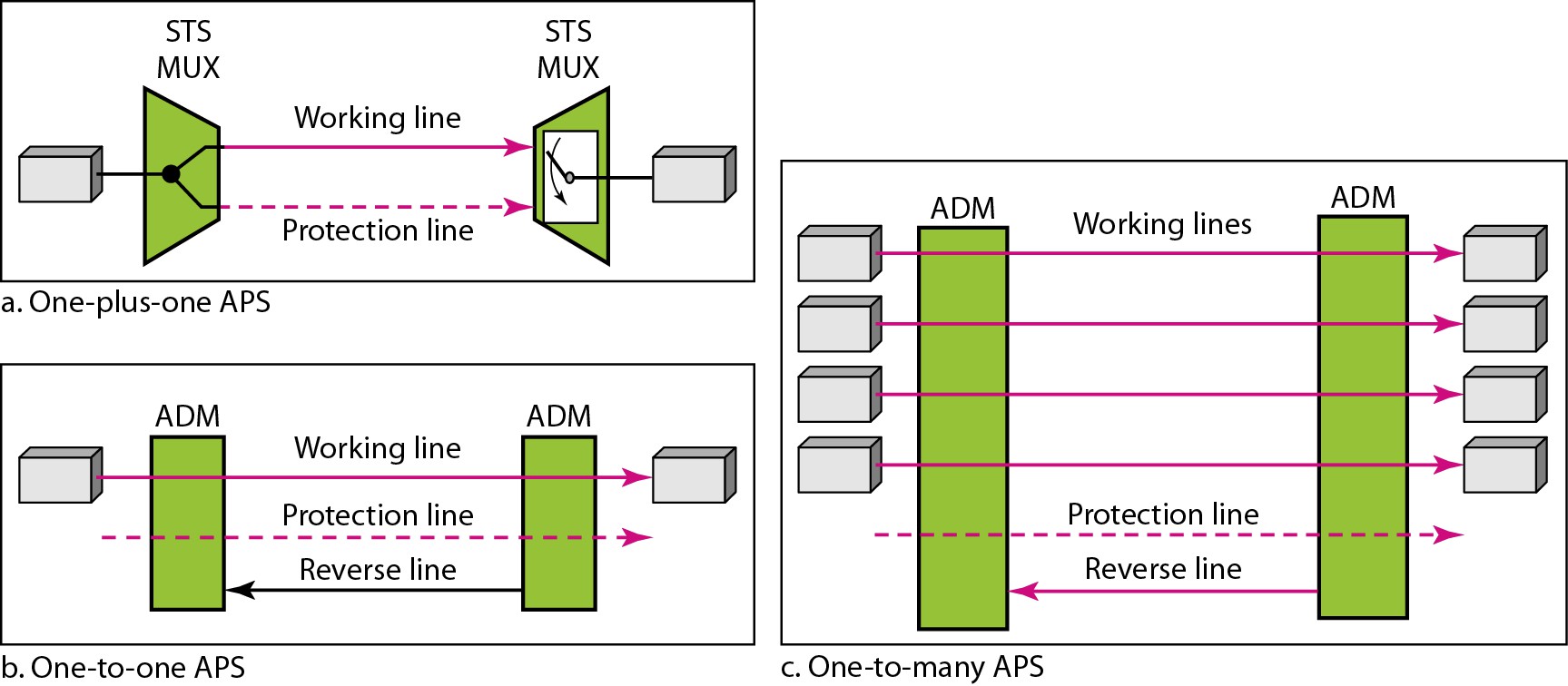
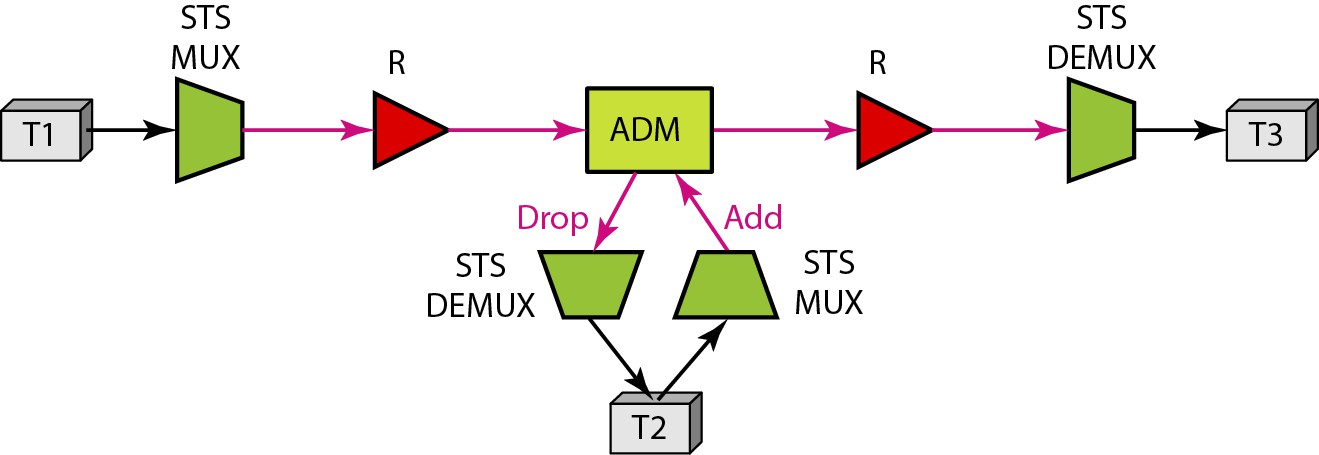


Figure 17.19 *A multipoint SONET network* Figure 17.20 *Automatic protection switching in linear networks*

17.42 17.43

Figure 17.21 *A unidirectional path switching ring* Figure 17.22 *A bidirectional line switching ring*

17.44

17.45

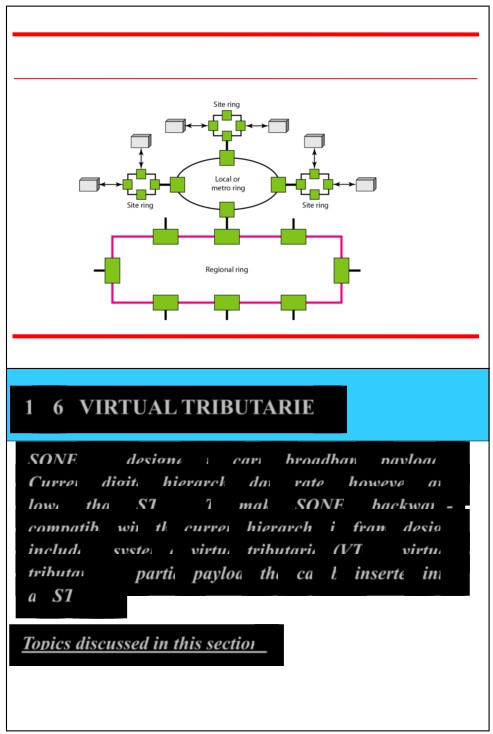
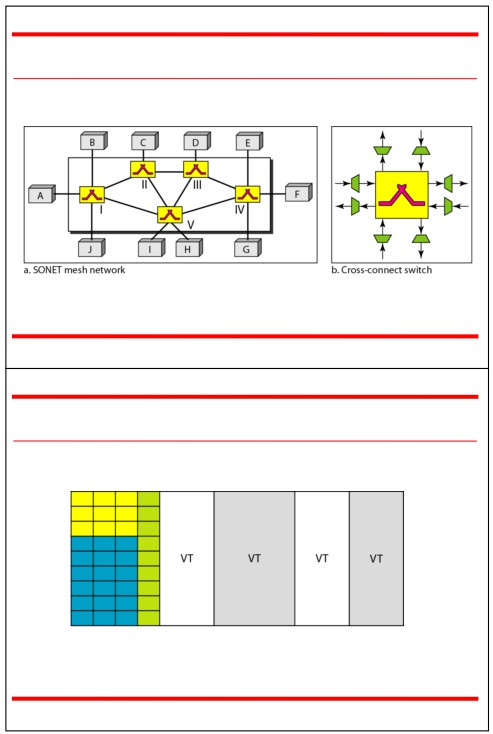


Figure 17.23 *A combination of rings in a SONET network*

17.46

17-6 VIRTUAL TRIBUTARIES

*SONET is designed to carry broadband payloads.*   
*Current digital hierarchy data rates, however, are*   
*lower than STS-1. To make SONET backward-*  
*compatible with the current hierarchy, its frame design*

*includes a system of virtual tributaries (VTs). A virtual*

*tributary is a partial payload that can be inserted into an STS-1.*

*Topics discussed in this section:*

17.48

Figure 17.24 *A mesh SONET network*

17.47

Figure 17.25 *Virtual tributaries*

17.49

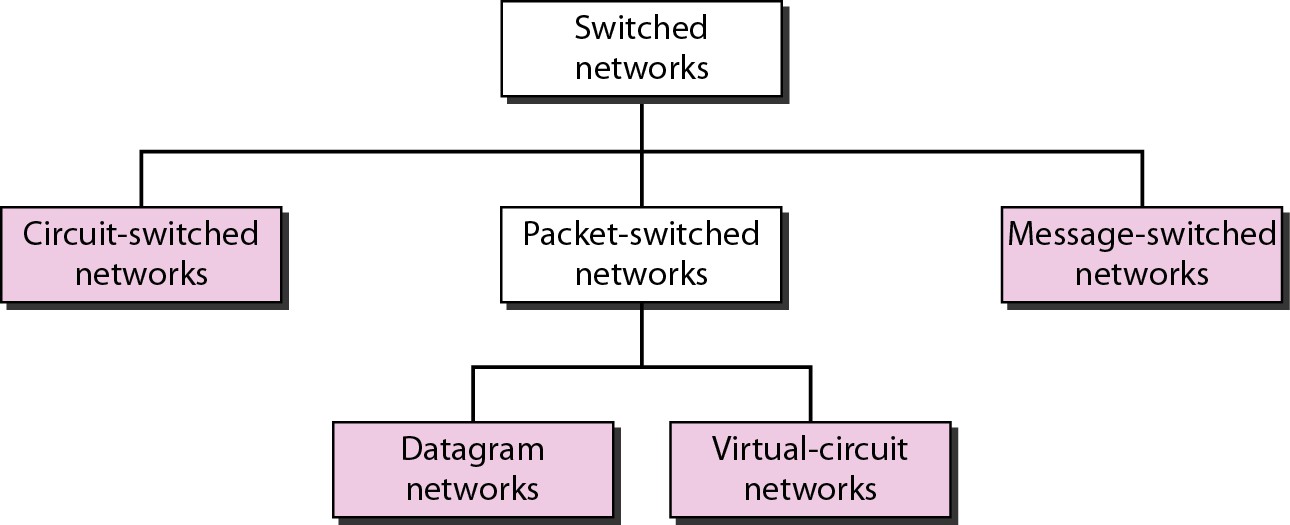
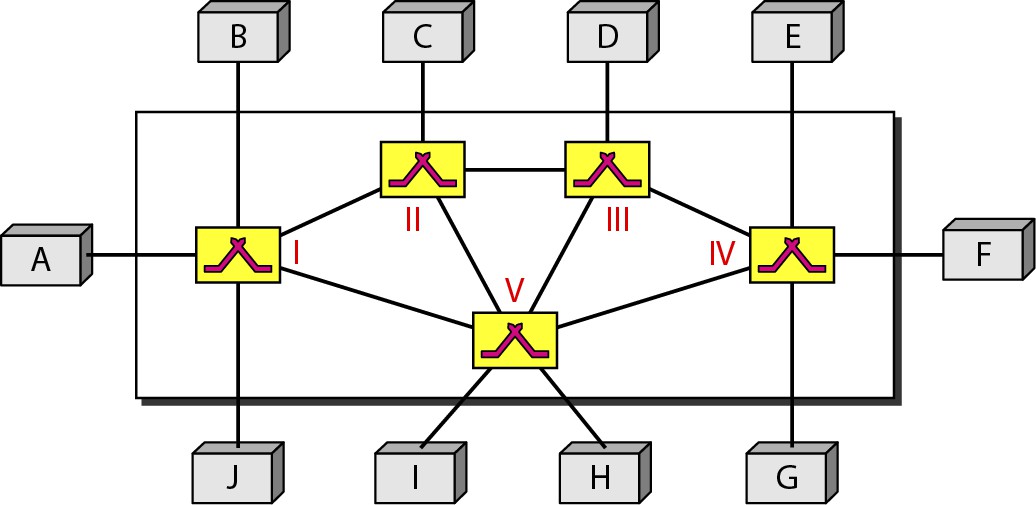
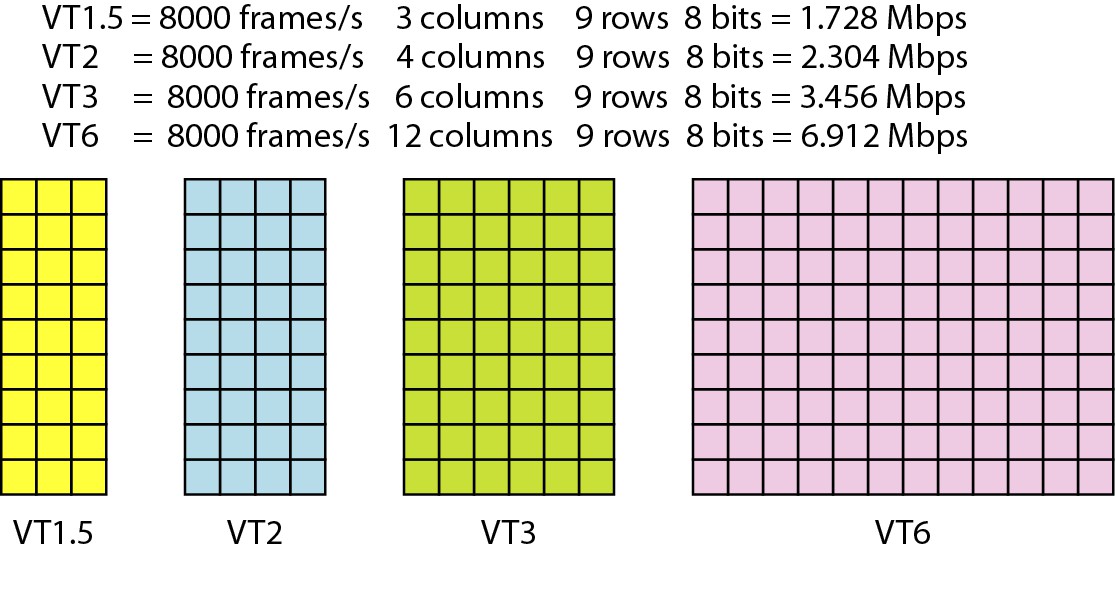


Figure 17.26 *Virtual tributary types*

Chapter 8

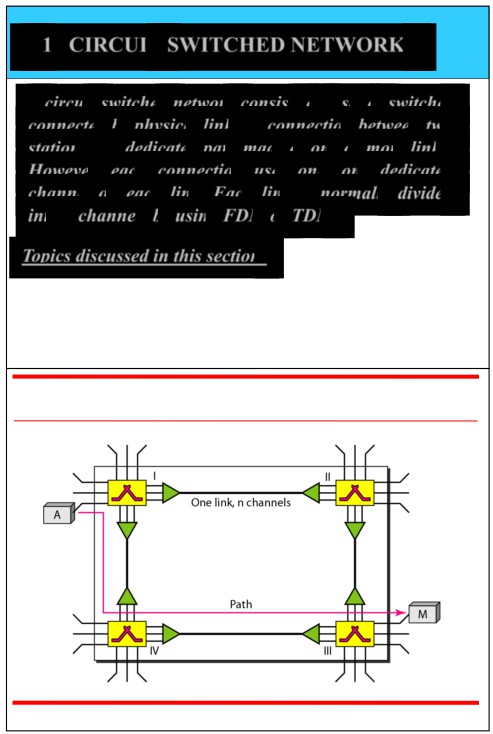
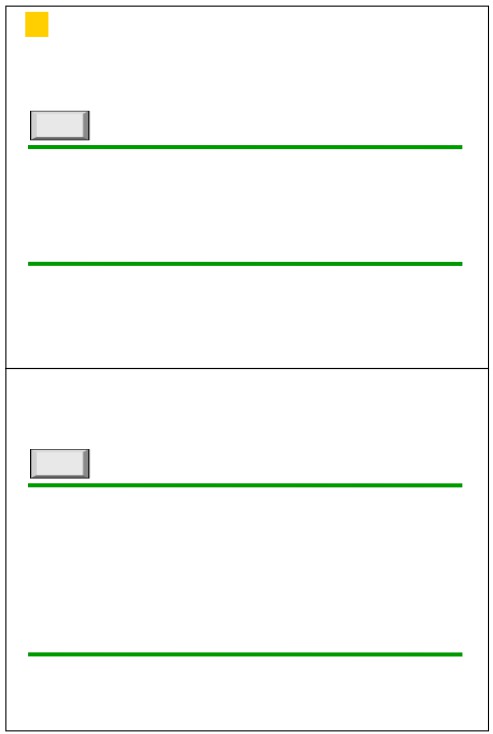
Switching

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Figure 8.1 *Switched network* Figure 8.2 *Taxonomy of switched networks*

8.2

8.3



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:*

Efficiency Delay

Circuit-Switched Technology in Telephone Networks

8.4

Figure 8.3 *A trivial circuit-switched network*

*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.

8.5

*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.

8.6

8.7

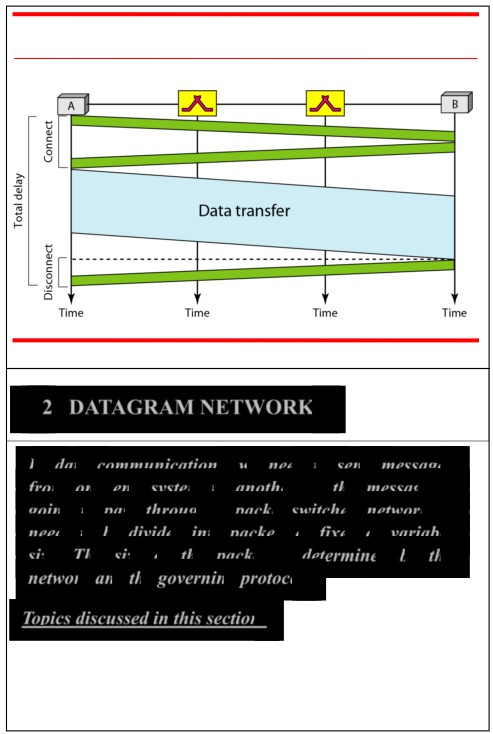
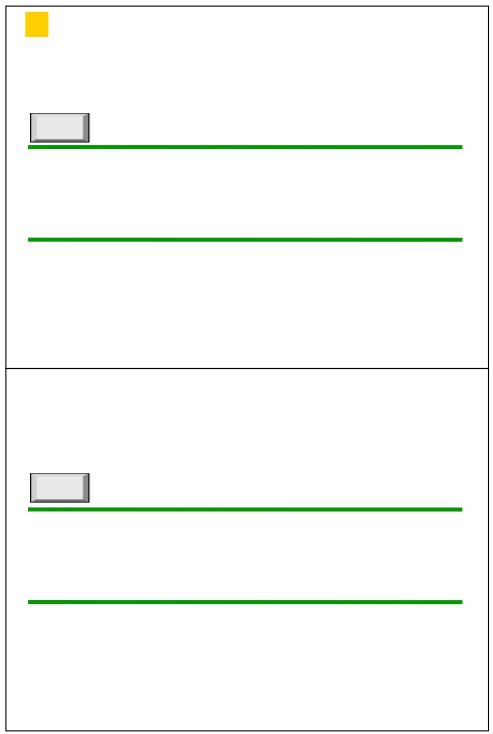


Figure 8.6 *Delay in a circuit-switched network*

*Note*

Switching at the physical layer in the   
traditional telephone network uses

the circuit-switching approach.

8.8

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.*

8.9

*Note*

In a packet-switched network, there   
 is no resource reservation;

resources are allocated on demand.

*Topics discussed in this section:*

Efficiency

Delay

Datagram Networks in the Internet

8.10 8.11

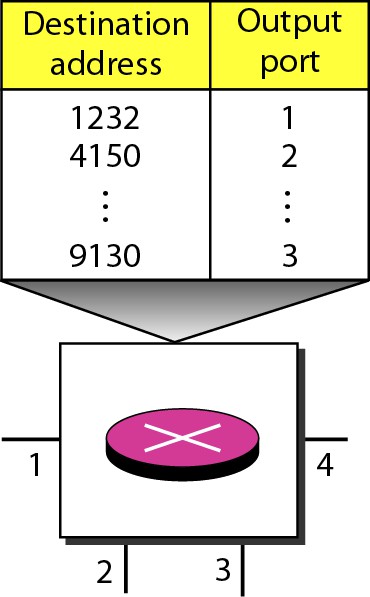
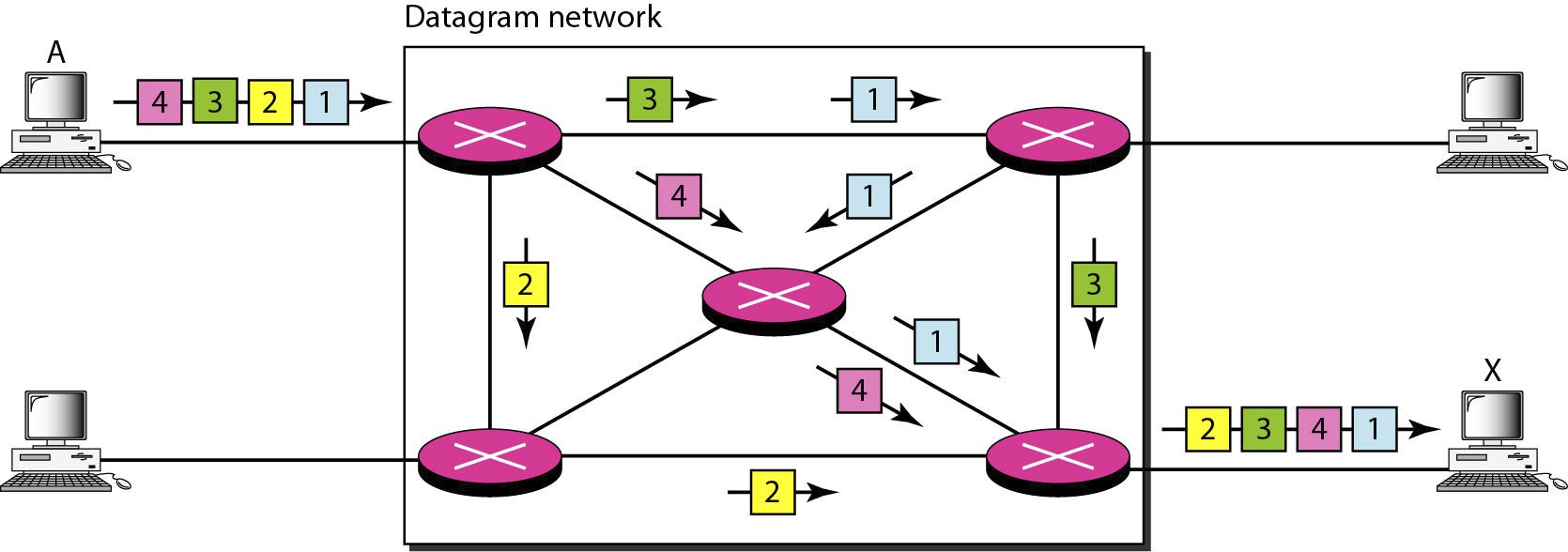


Figure 8.7 *A datagram network with four switches (routers)* Figure 8.8 *Routing table in a datagram network*

8.12 8.13

*Note* *Note*

A switch in a datagram network uses a The destination address in the header of

routing table that is based on the a packet in a datagram network

destination address. remains the same during the entire

journey of the packet.

8.14

8.15

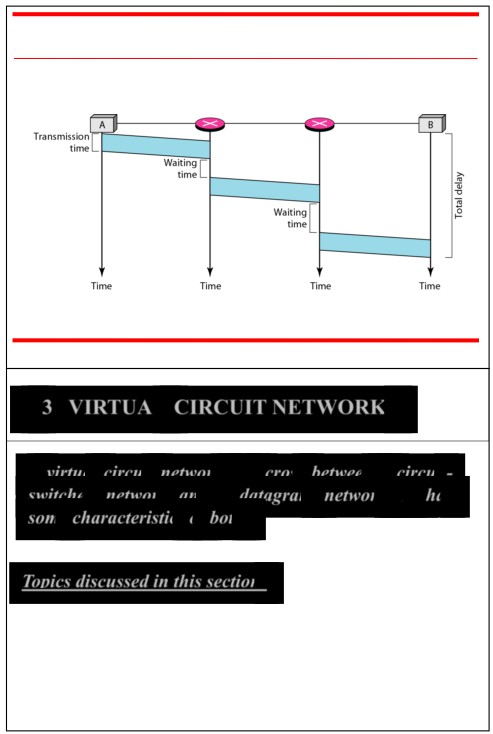
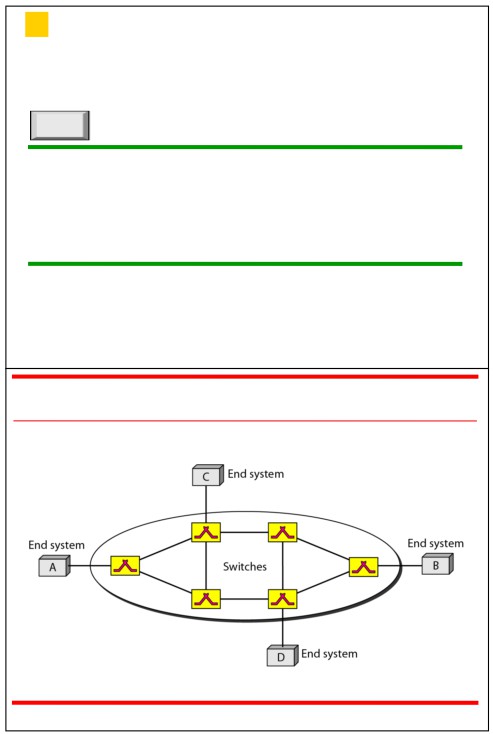


Figure 8.9 *Delay in a datagram network*

*Note*

Switching in the Internet is done by   
 using the datagram approach

to packet switching at

the network layer.

8.16

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:*

Three Phases Efficiency

Delay

Circuit-Switched Technology in WANs

8.18

8.17

Figure 8.10 *Virtual-circuit network*

8.19