Data Communications and Networking Fourth Edition

Forouzan

# Chapter 17

# SONET/SDH

*Note*

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

# 17-1 ARCHITECTURE

***Let us first introduce the architecture of a SONET system: signals, devices, and connections.***

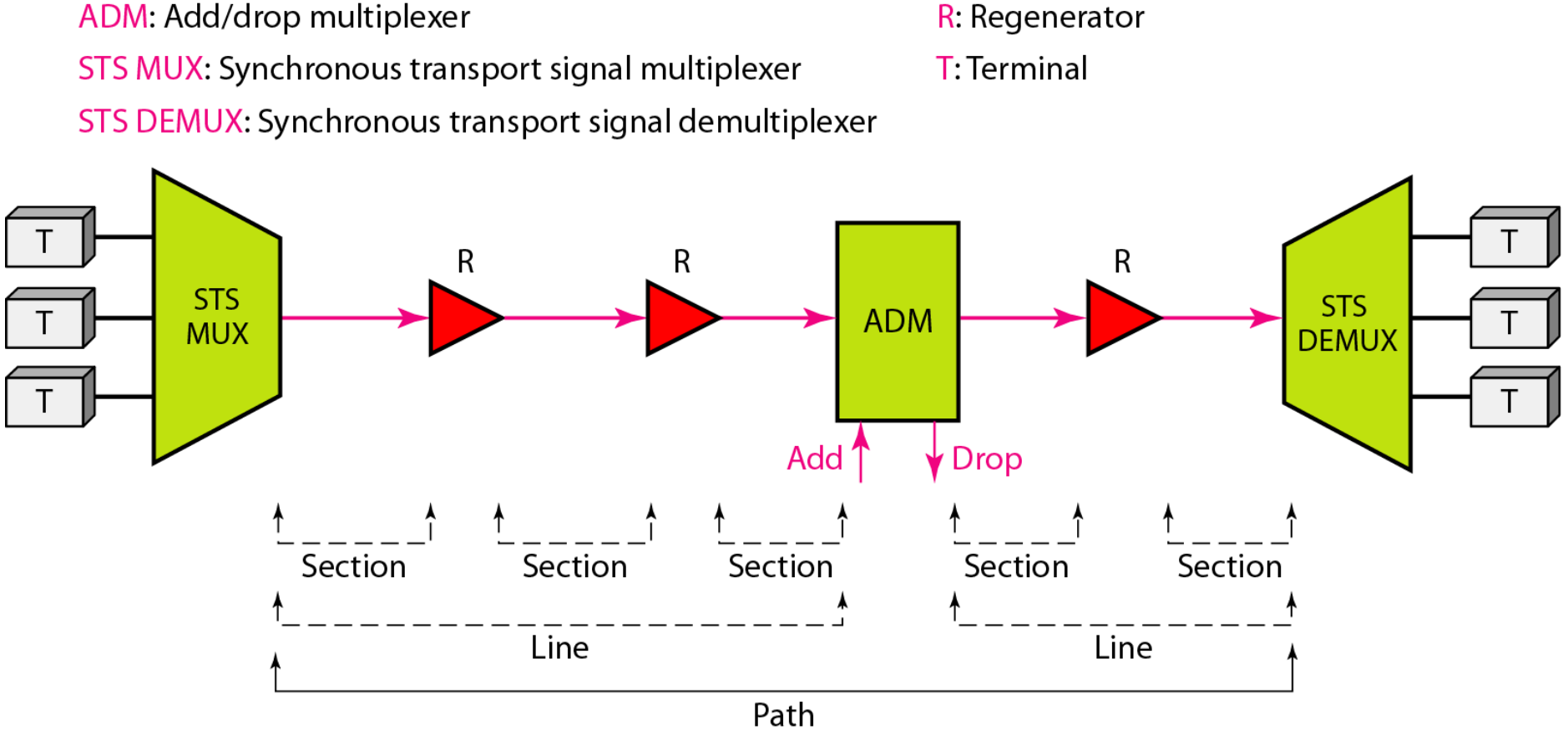
***Topics discussed in this section:***

**Signals**
**SONET Devices**
**Connections**

## Table 17.1 *SONET/SDH rates*

| *STS* | *OC* | *Rate (Mbps)* | *STM* |
|---|---|---|---|
| STS-1 | OC-1 | 51.840 | |
| STS-3 | OC-3 | 155.520 | **STM-1** |
| STS-9 | OC-9 | 466.560 | **STM-3** |
| STS-12 | OC-12 | 622.080 | **STM-4** |
| STS-18 | OC-18 | 933.120 | **STM-6** |
| STS-24 | OC-24 | 1244.160 | **STM-8** |
| STS-36 | OC-36 | 1866.230 | **STM-12** |
| STS-48 | OC-48 | 2488.320 | **STM-16** |
| STS-96 | OC-96 | 4976.640 | **STM-32** |
| STS-192 | OC-192 | 9953.280 | **STM-64** |

## Figure 17.1 *A simple network using SONET equipment*



# 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.***

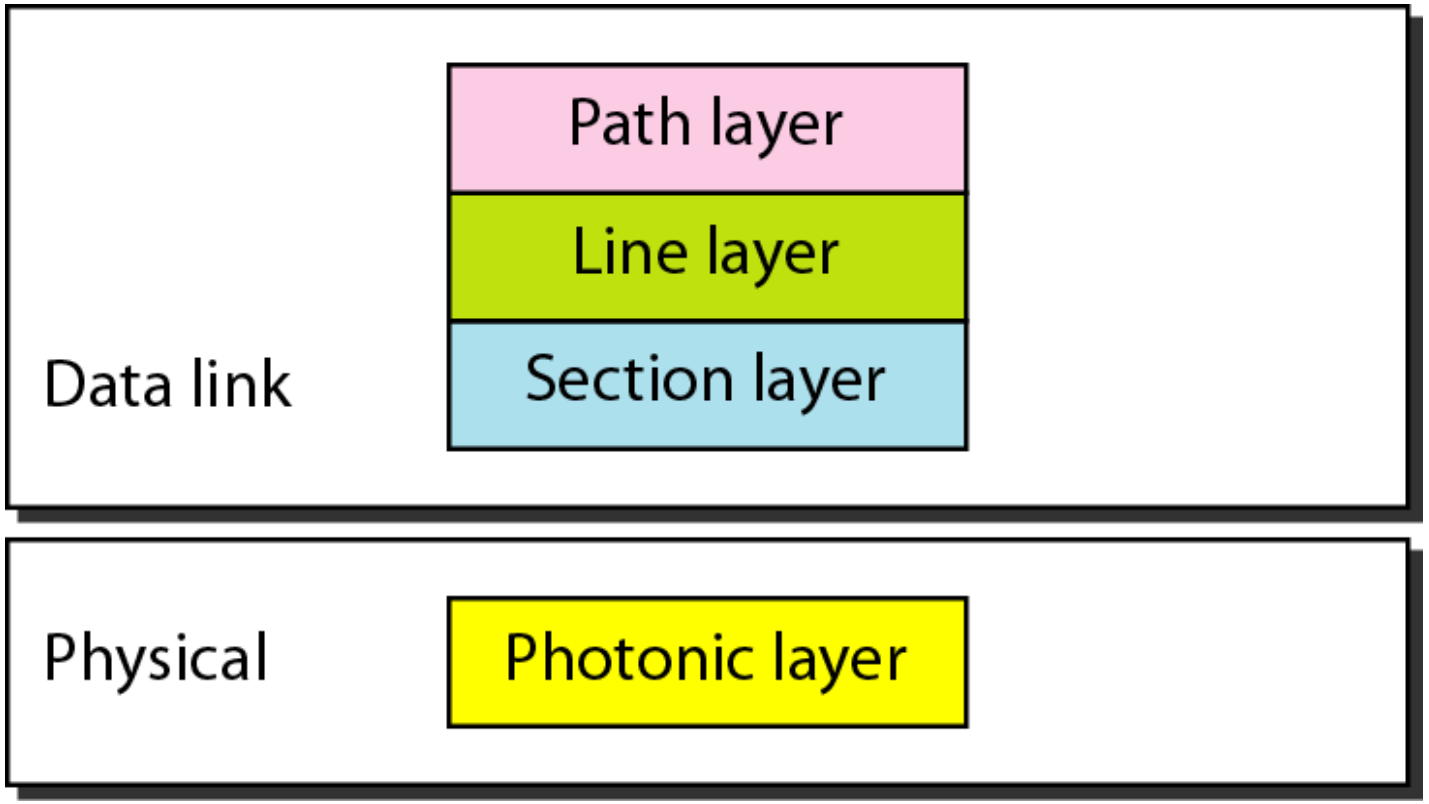
***Topics discussed in this section:***

**Path Layer**
**Line Layer**
**Section Layer**
**Photonic Layer**
**Device–Layer Relationships**

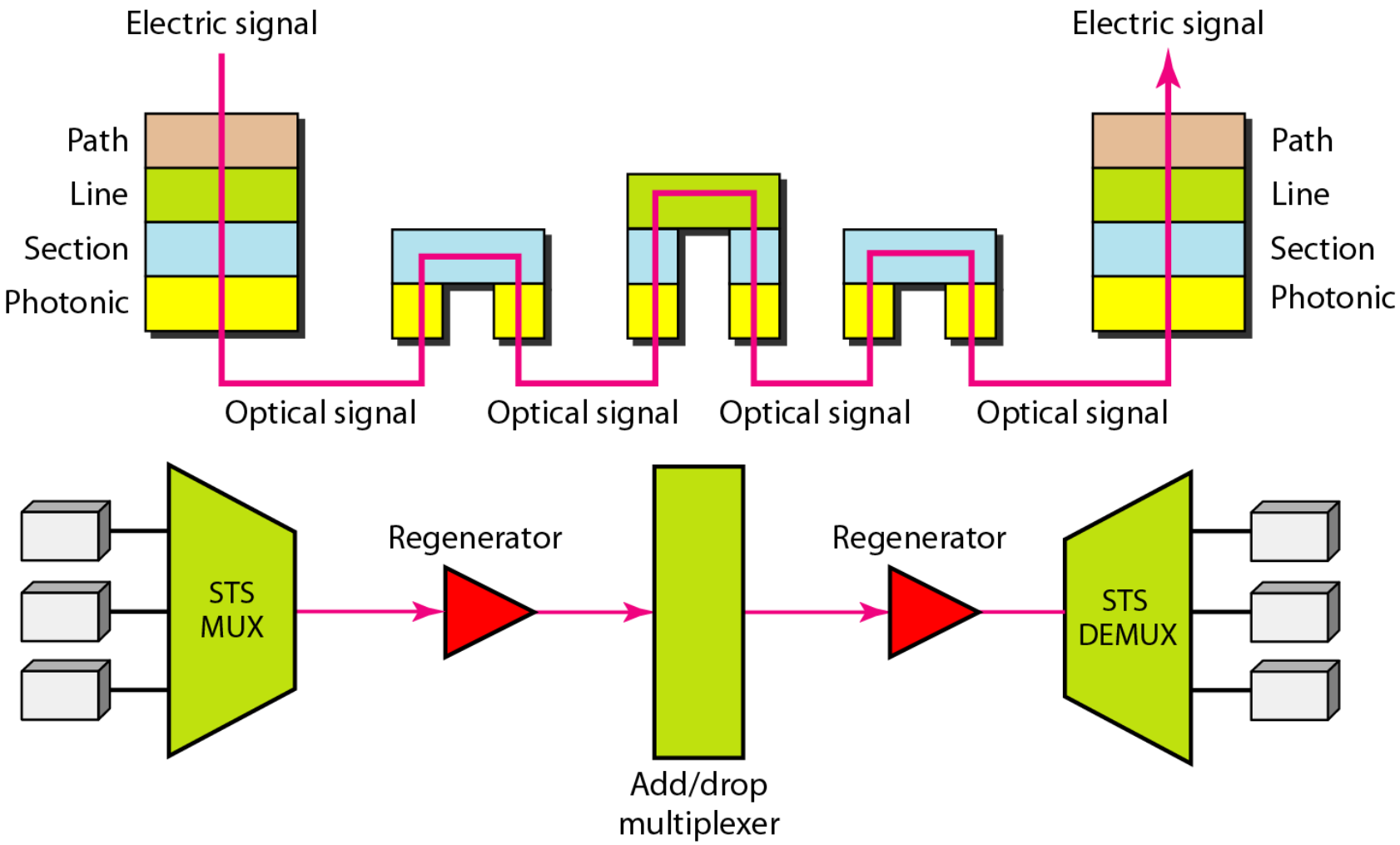
*Note*

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

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



## Figure 17.3 *Device–layer relationship in SONET*



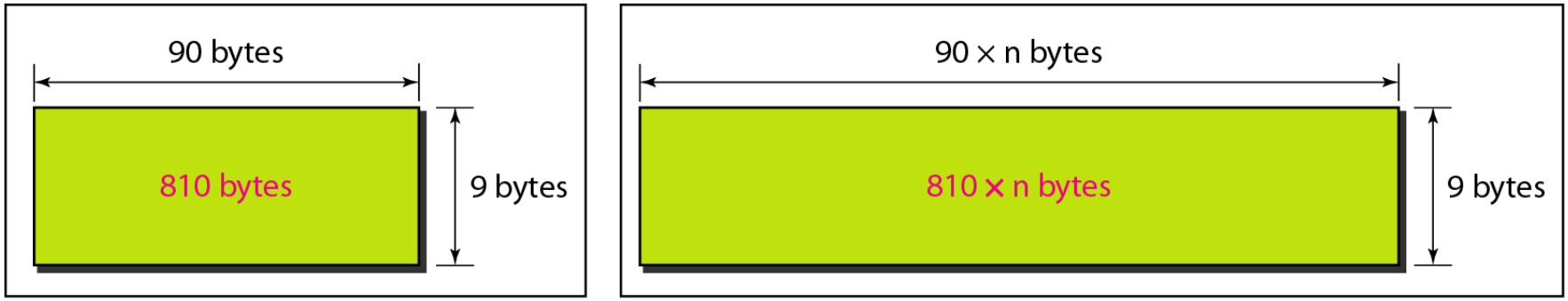
# 17-3 SONET FRAMES

***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:***

**Frame, Byte, and Bit Transmission**
**STS-1 Frame Format**
**Encapsulation**

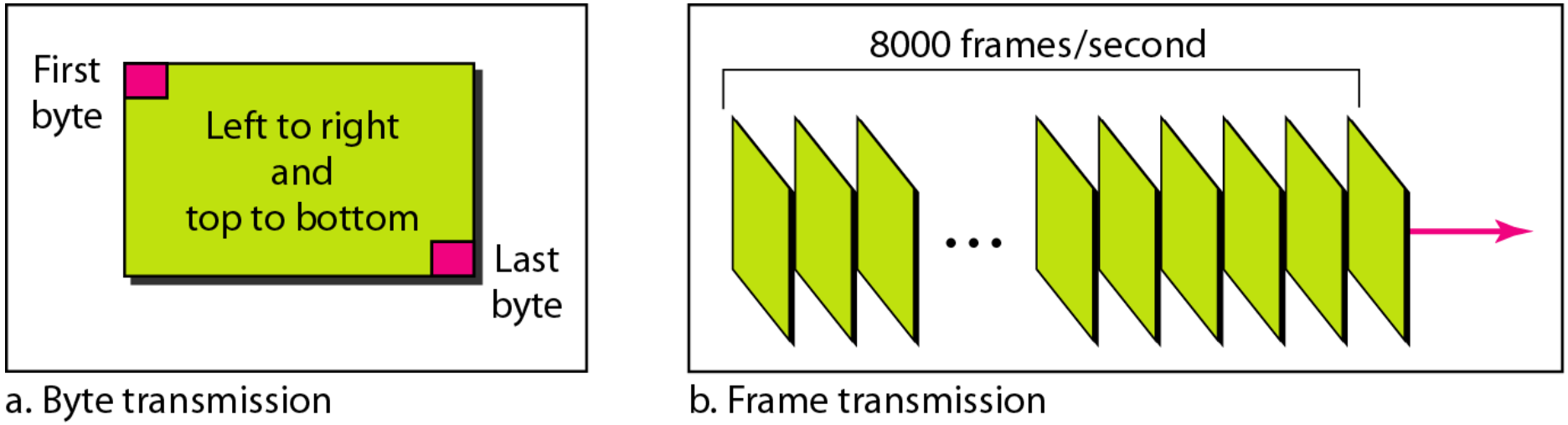
## Figure 17.4 *An STS-1 and an STS-n frame*




a. STS-1 frame

b. STS-n frame

## Figure 17.5 *STS-1 frames in transmission*




a. Byte transmission

b. Frame transmission

*Note*

**A SONET STS-n signal is transmitted at 8000 frames per second.**

*Note*

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

# Example 17.1

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

***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***

$$\text{STS-1 data rate} = 8000 \times 9 \times (1 \times 90) \times 8 = 51.840 \text{ Mbps}$$

# 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*

$$\text{STS-3 data rate} = 8000 \times 9 \times (3 \times 90) \times 8 = 155.52 \text{ Mbps}$$

*Note*

**In SONET, the data rate of an STS-n signal is *n* times the data rate of an STS-1 signal.**

# Example 17.3

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

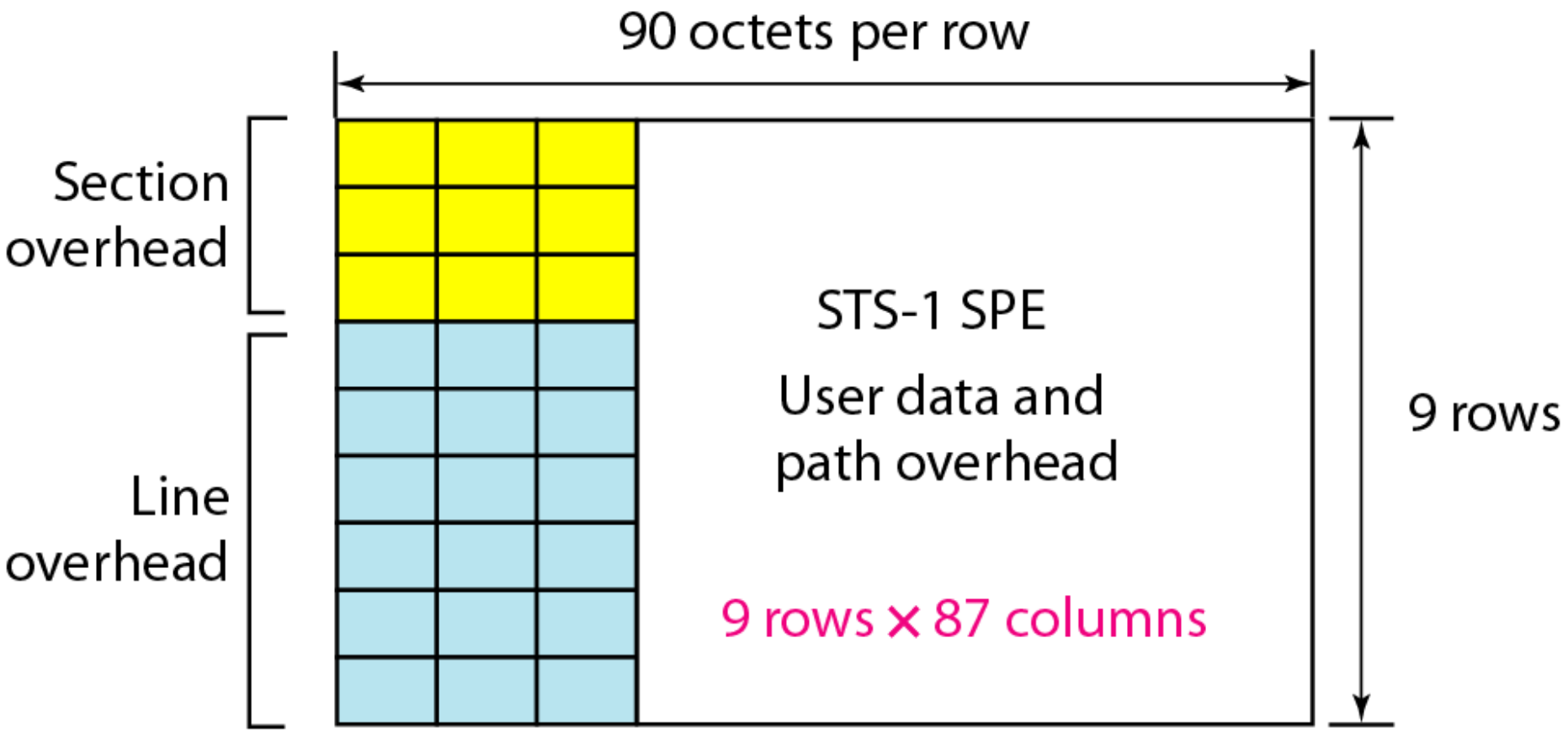
***Solution***

***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.***

*Note*

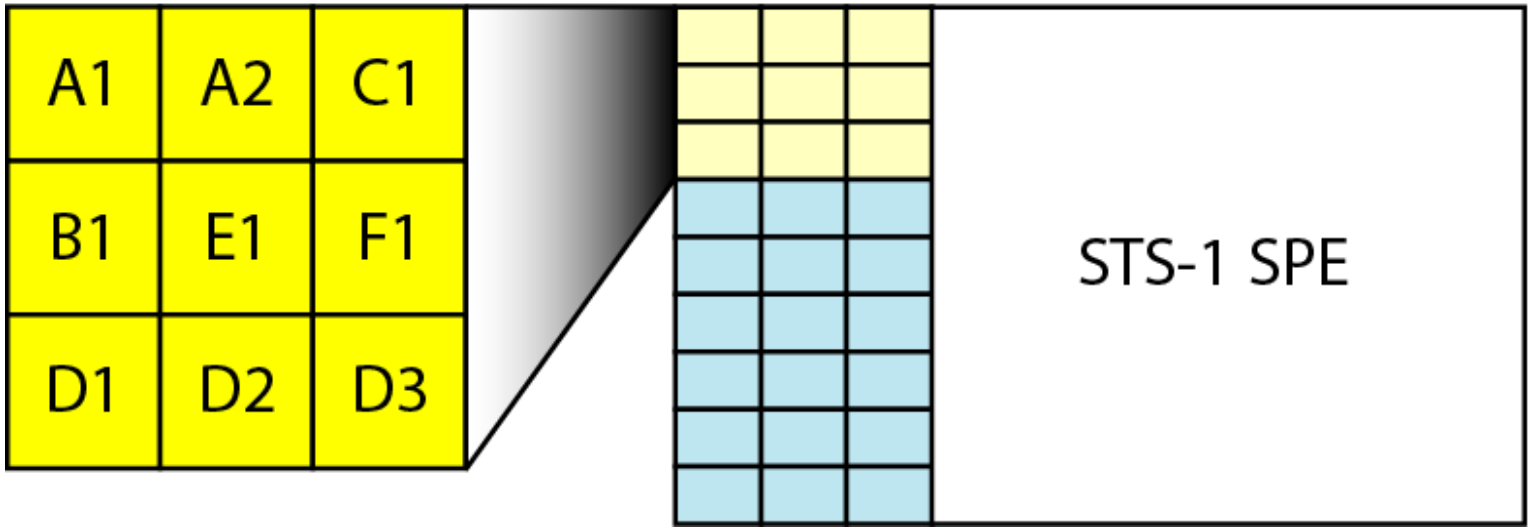
**In SONET,**
**the duration of any frame is 125 μs.**

**Figure 17.6** *STS-1 frame overheads*



## Figure 17.7 *STS-1 frame: section overhead*

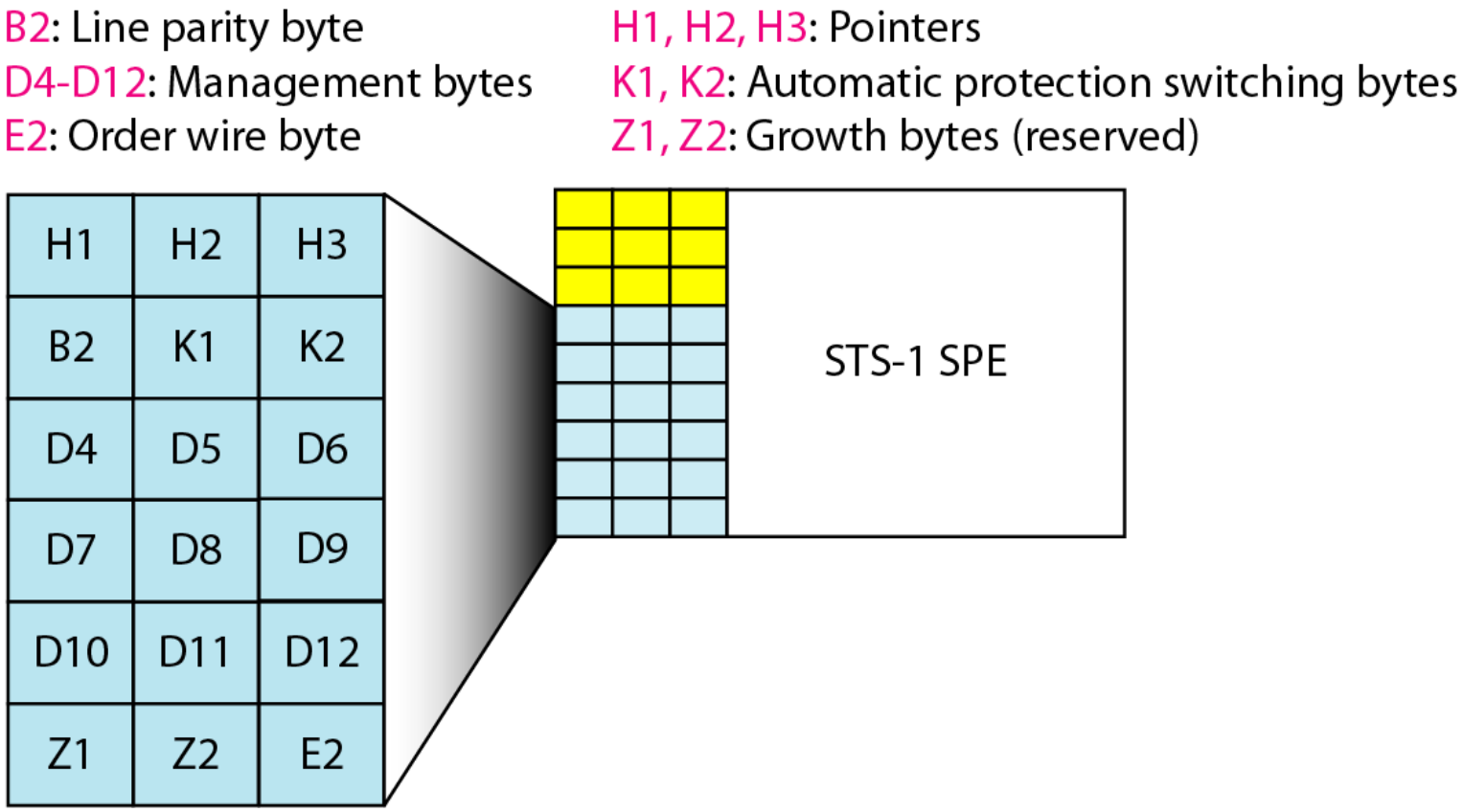
A1, A2: Alignment
B1: Parity byte
C1: Identification
D1, D2, D3: Management
E1: Order wire byte
F1: User



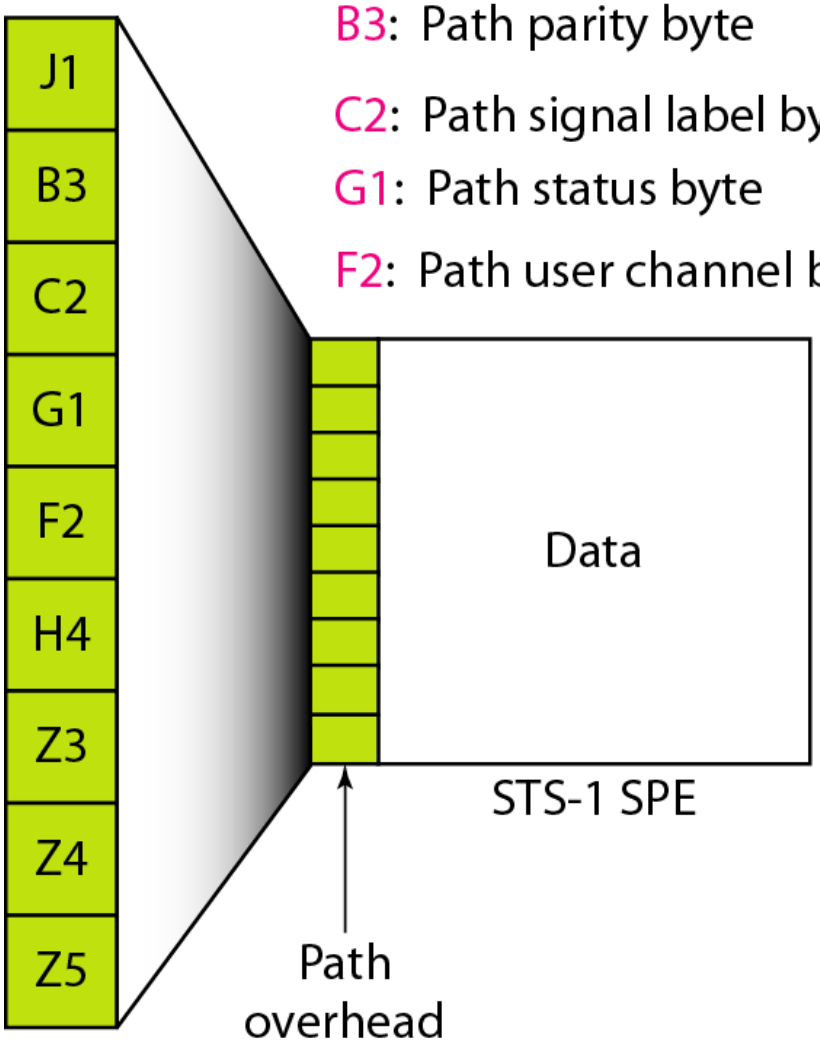
*Note*

**Section overhead is recalculated for each SONET device (regenerators and multiplexers).**

## Figure 17.8 *STS-1 frame: line overhead*



## Figure 17.9 *STS-1 frame: path overhead*




B3: Path parity byte

C2: Path signal label byte

G1: Path status byte

F2: Path user channel byte

H4: Virtual tributary indicator

J1: Path trace byte

Z3, Z4, Z5: Growth bytes (reserved)

*Note*

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

## Table 17.2 *Overhead bytes*

| *Byte Function* | *Section* | *Line* | *Path* |
|---|---|---|---|
| Alignment | A1, A2 | | |
| Parity | B1 | B2 | B3 |
| Identifier | C1 | | C2 |
| OA&M | D1–D3 | D4–D12 | |
| Order wire | E1 | | |
| User | F1 | | F2 |
| Status | | | G1 |
| Pointers | | H1– H3 | H4 |
| Trace | | | J1 |
| Failure tolerance | | K1, K2 | |
| Growth (reserved for future) | | Z1, Z2 | Z3–Z5 |

# Example 17.4

***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***

$$\text{STS-1 user data rate} = 8000 \times 9 \times (1 \times 86) \times 8 = 49.536 \text{ Mbps}$$

## Figure 17.10 *Offsetting of SPE related to frame boundary*

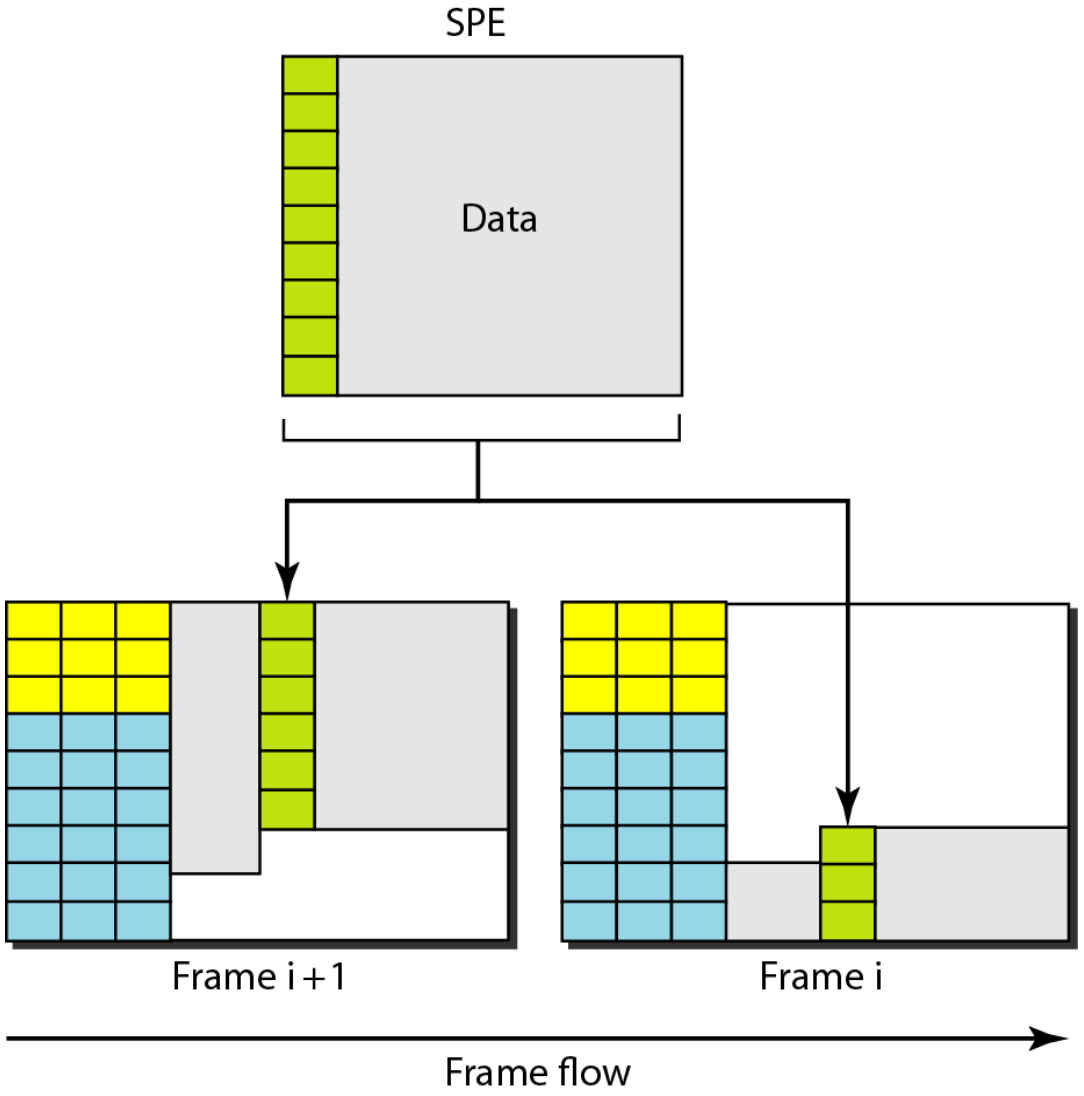
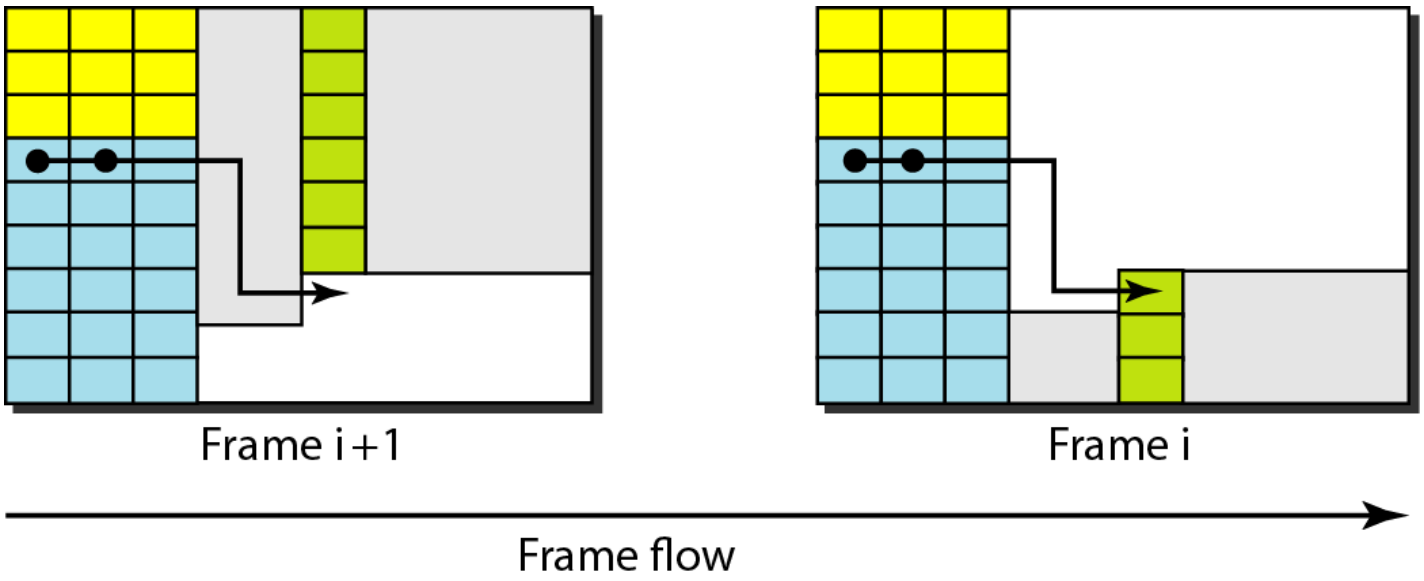


**Figure 17.11** *The use of H1 and H2 pointers to show the start of an SPE in a frame*



# Example 17.5

***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.***

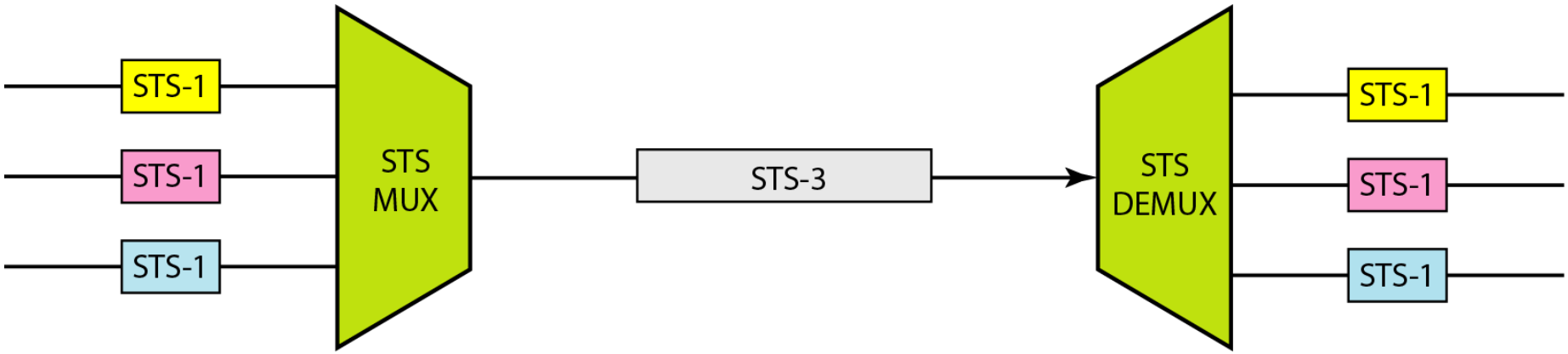
# 17-4 STS MULTIPLEXING

***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:***

**Byte Interleaving**
**Concatenated Signal**
**Add/Drop Multiplexer**

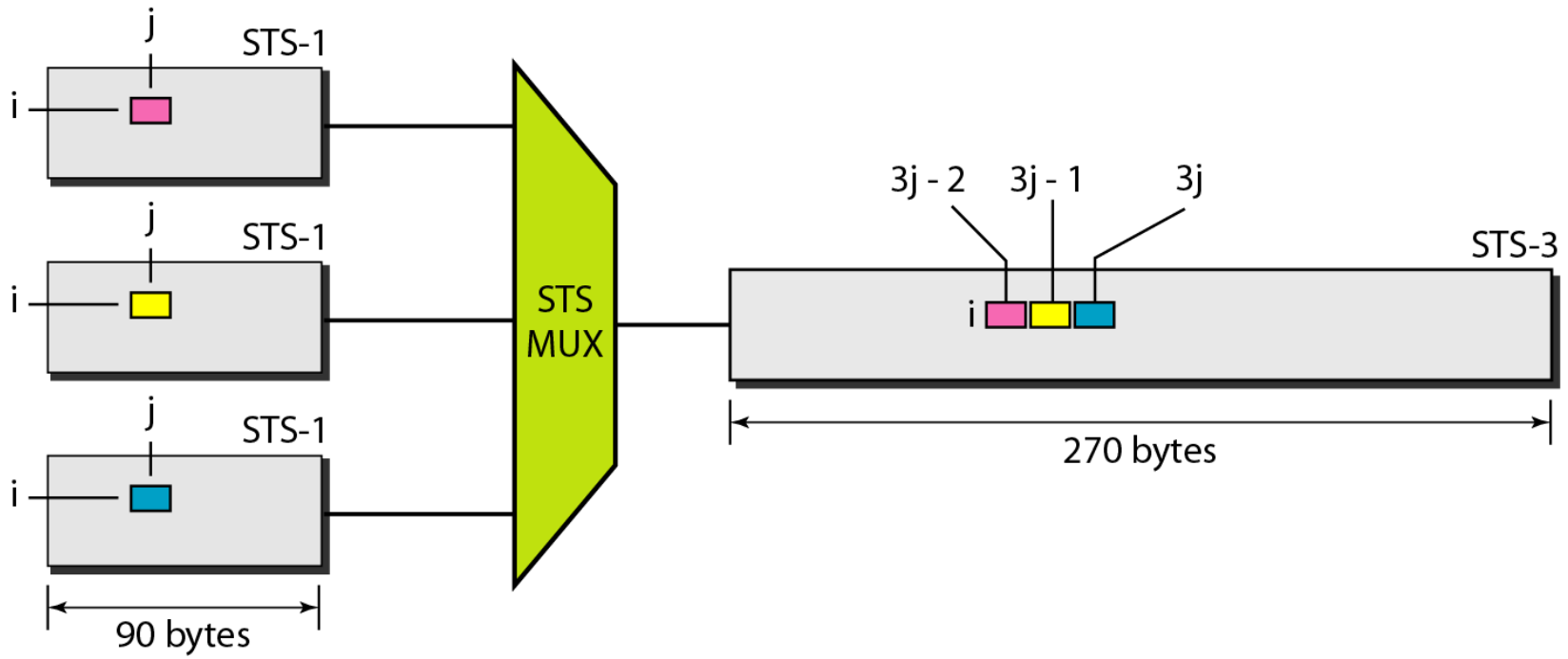
## Figure 17.12 *STS multiplexing/demultiplexing*



*Note*

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

## Figure 17.13 *Byte interleaving*



# Figure 17.14 *An STS-3 frame*

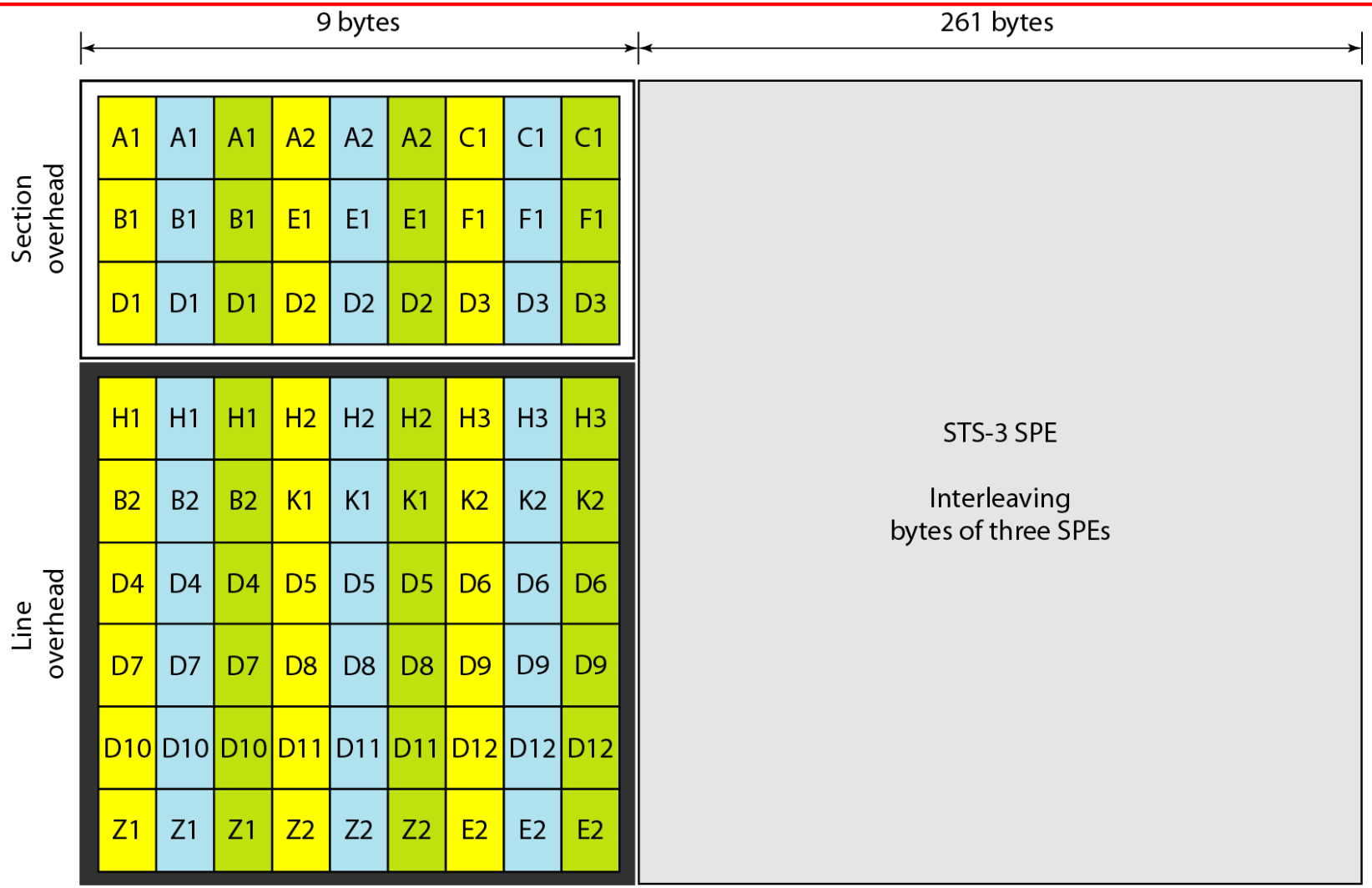
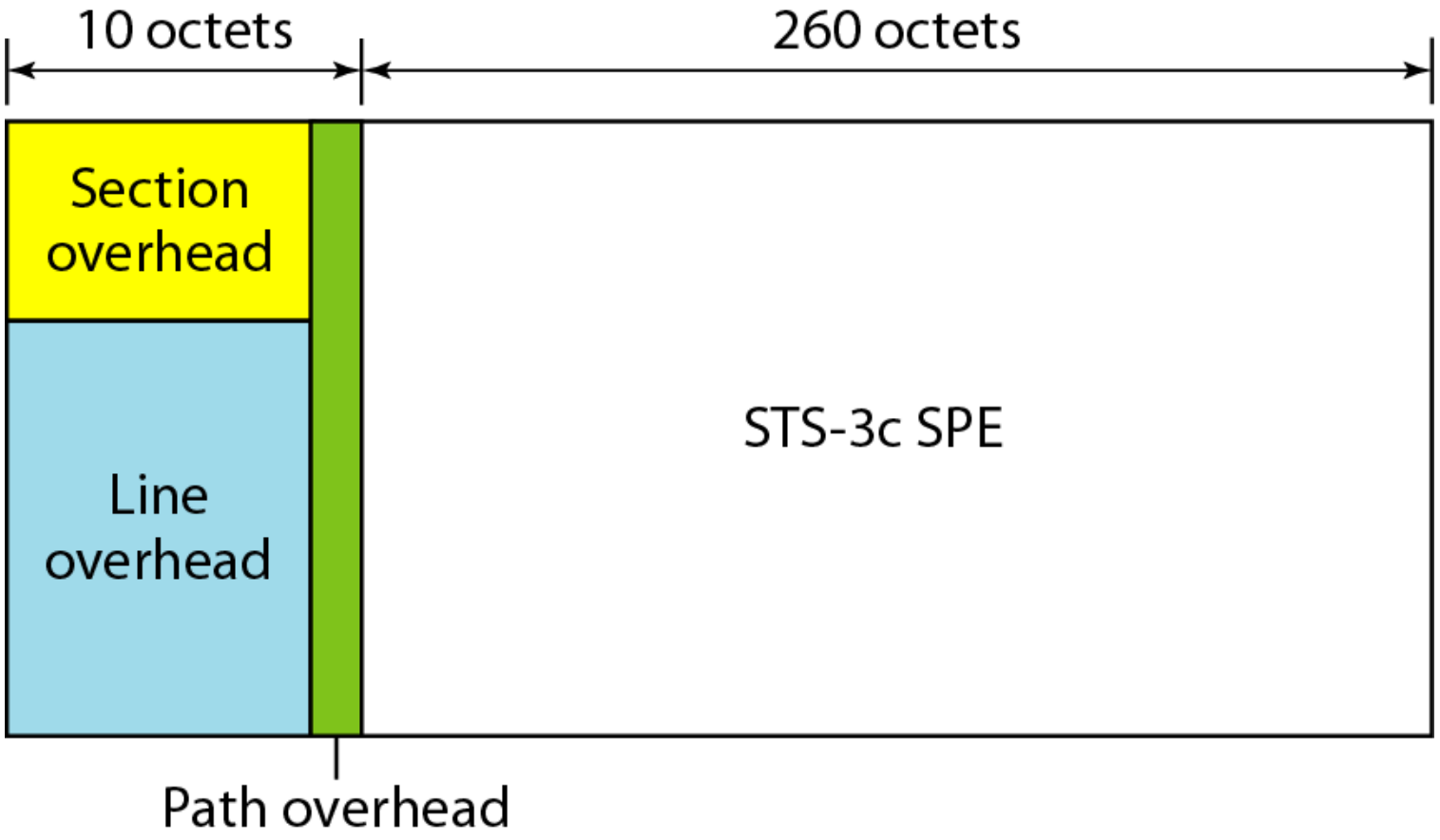


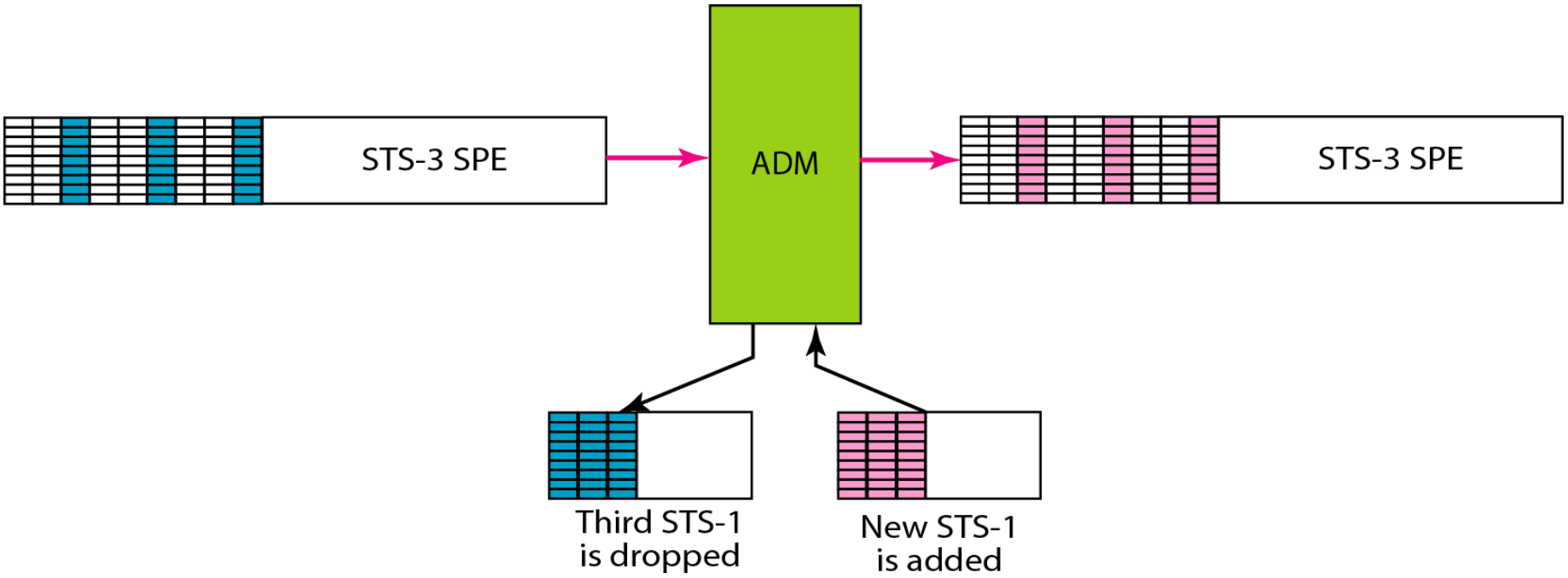
**Figure 17.15** *A concatenated STS-3c signal*



*Note*

**An STS-3c signal can carry 44 ATM cells as its SPE.**

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



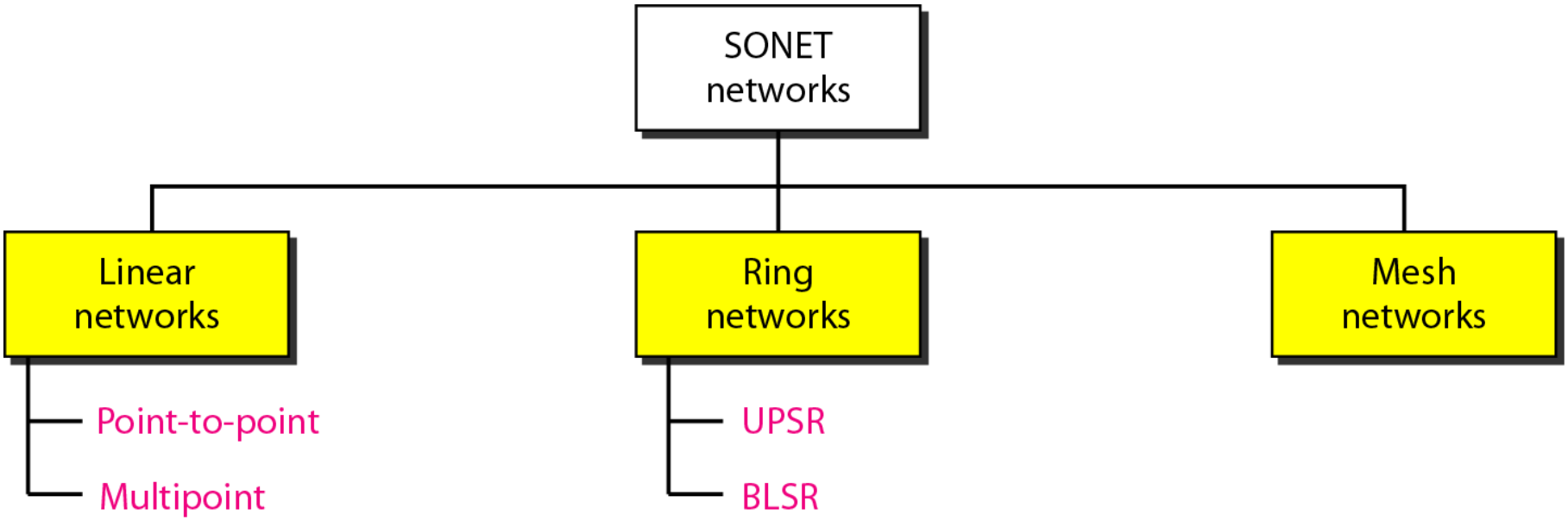
# 17-5 SONET NETWORKS

***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.***

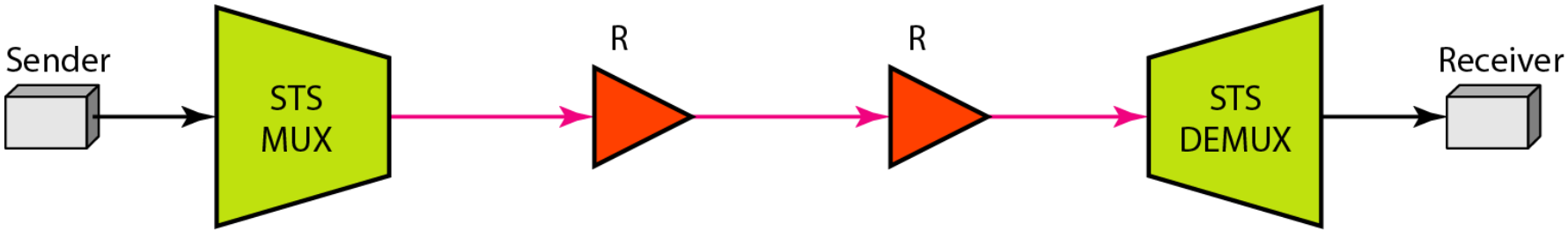
***Topics discussed in this section:***

**Linear Networks**
**Ring Networks**
**Mesh Networks**

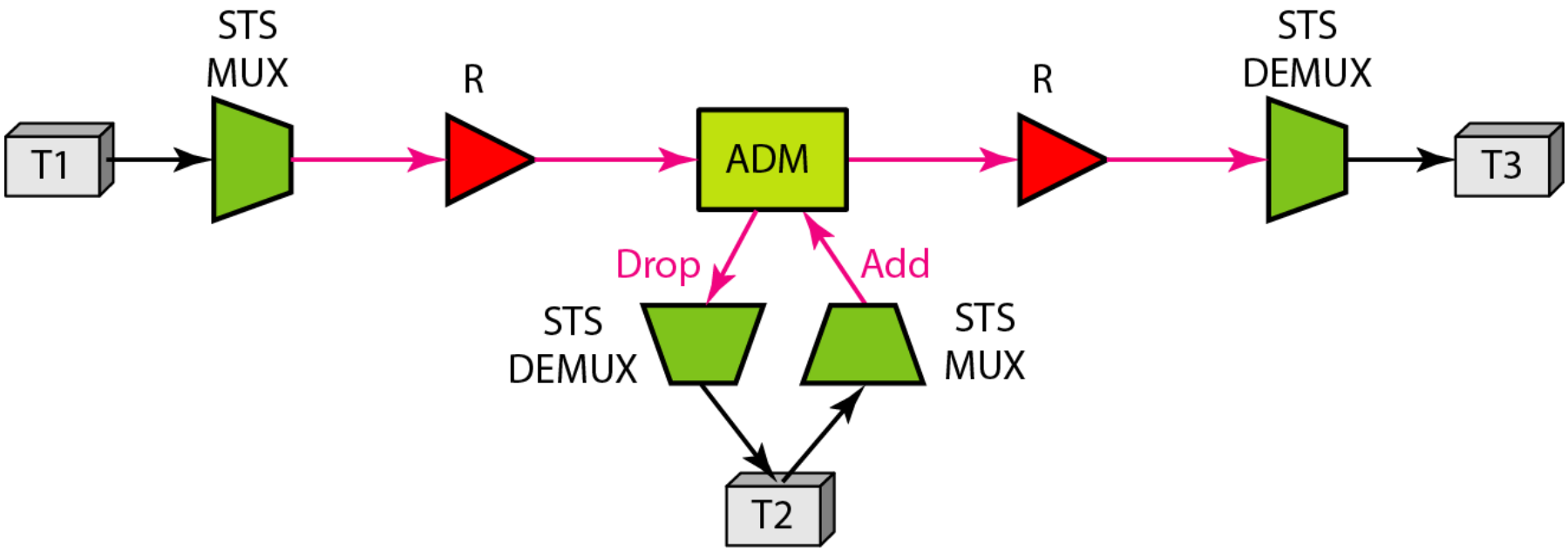
## Figure 17.17 *Taxonomy of SONET networks*



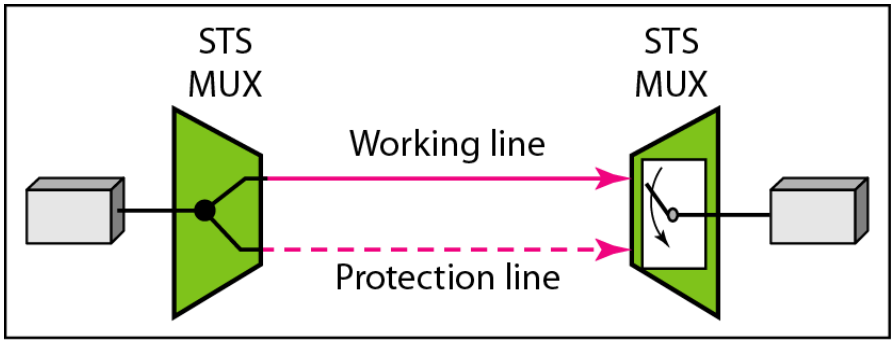
## Figure 17.18 *A point-to-point SONET network*



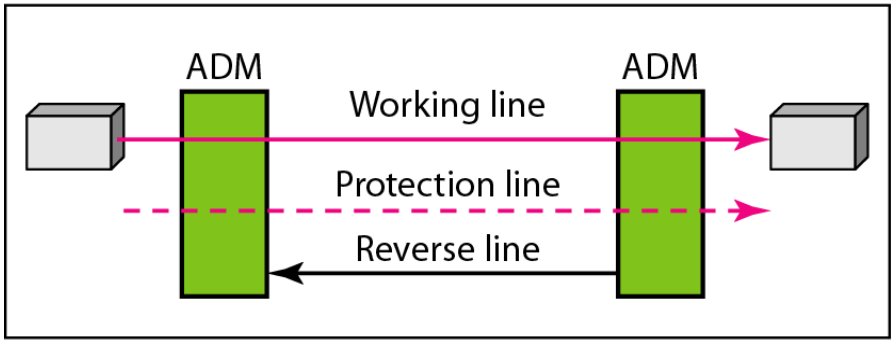
## Figure 17.19 *A multipoint SONET network*



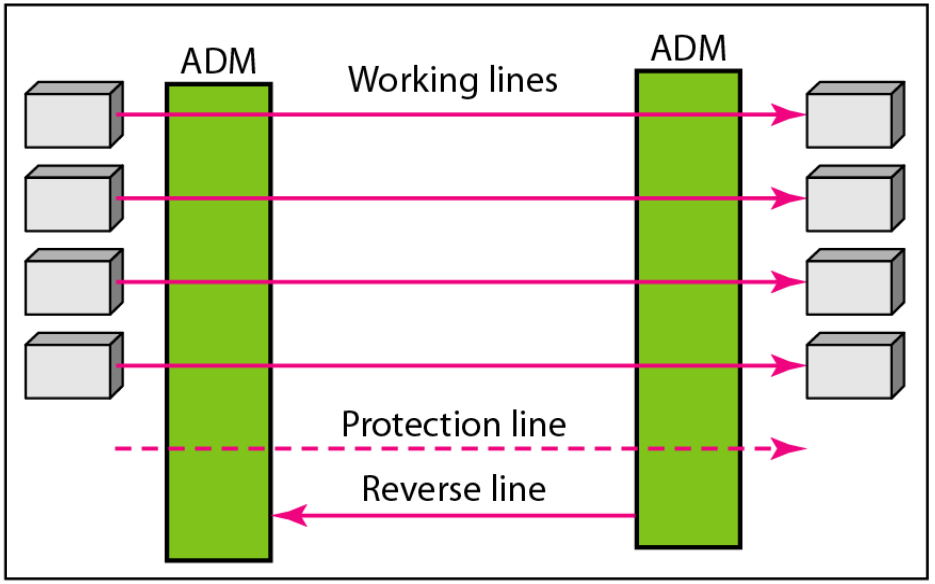
## Figure 17.20 *Automatic protection switching in linear networks*




a. One-plus-one APS

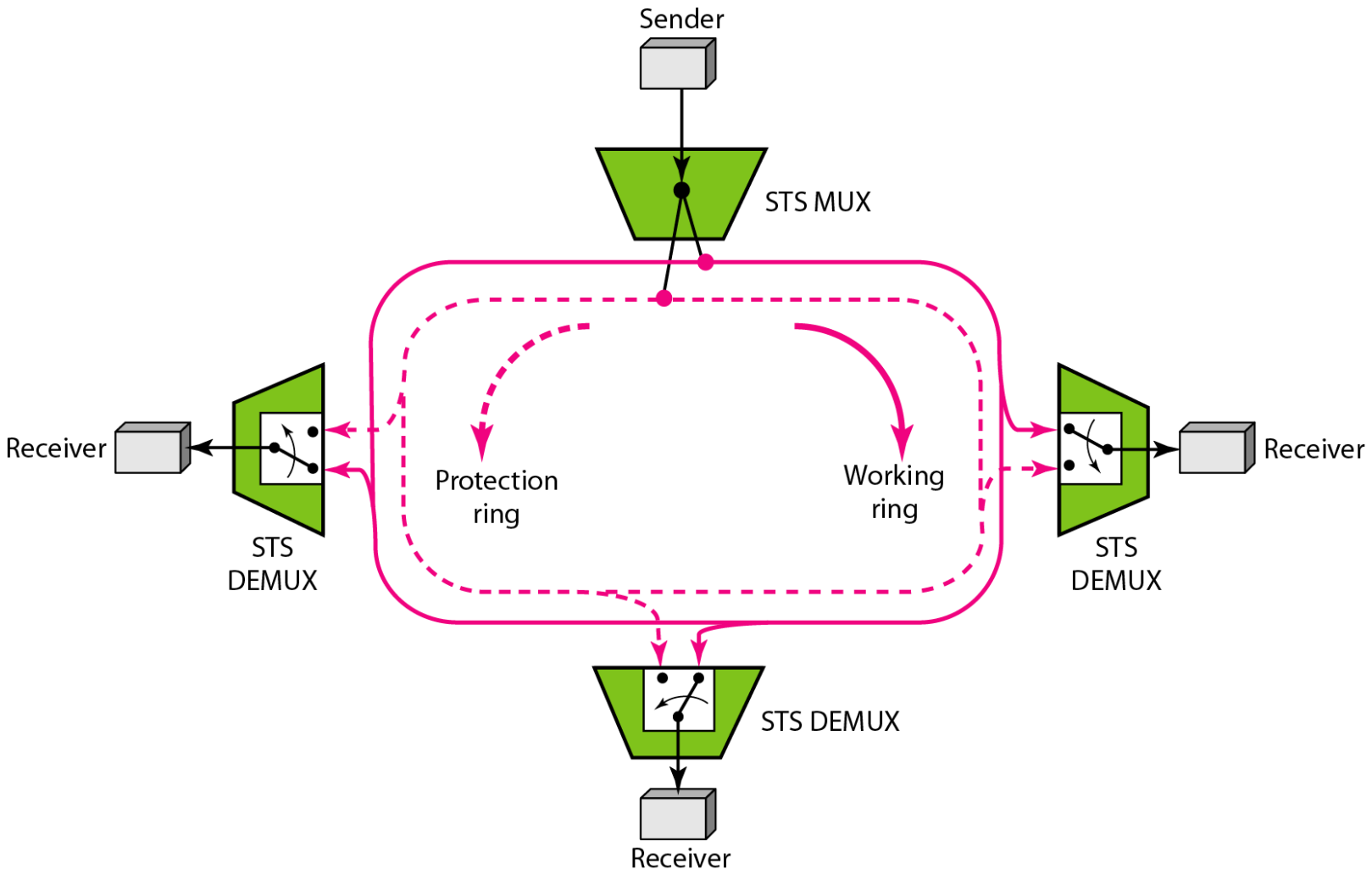



b. One-to-one APS

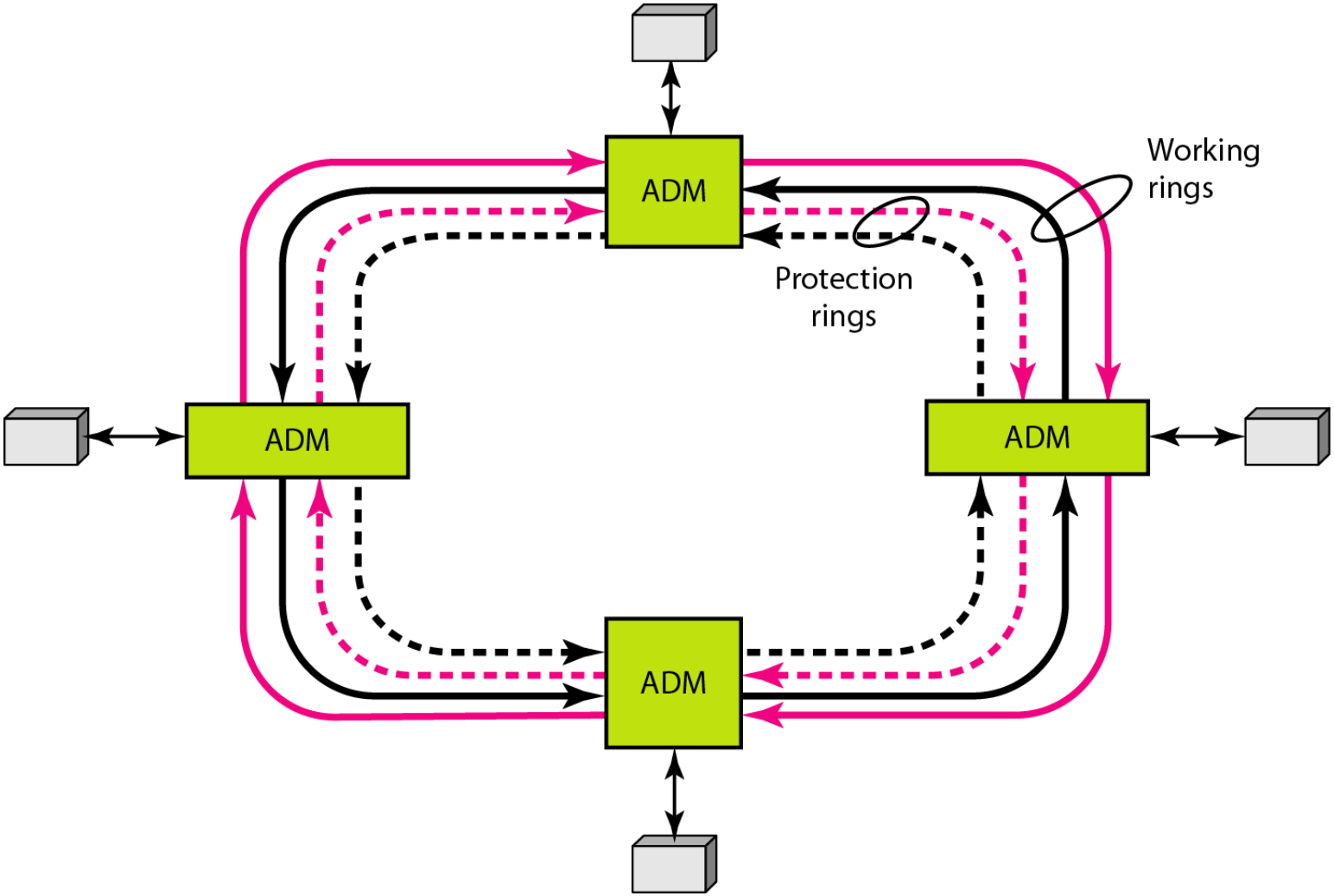



c. One-to-many APS

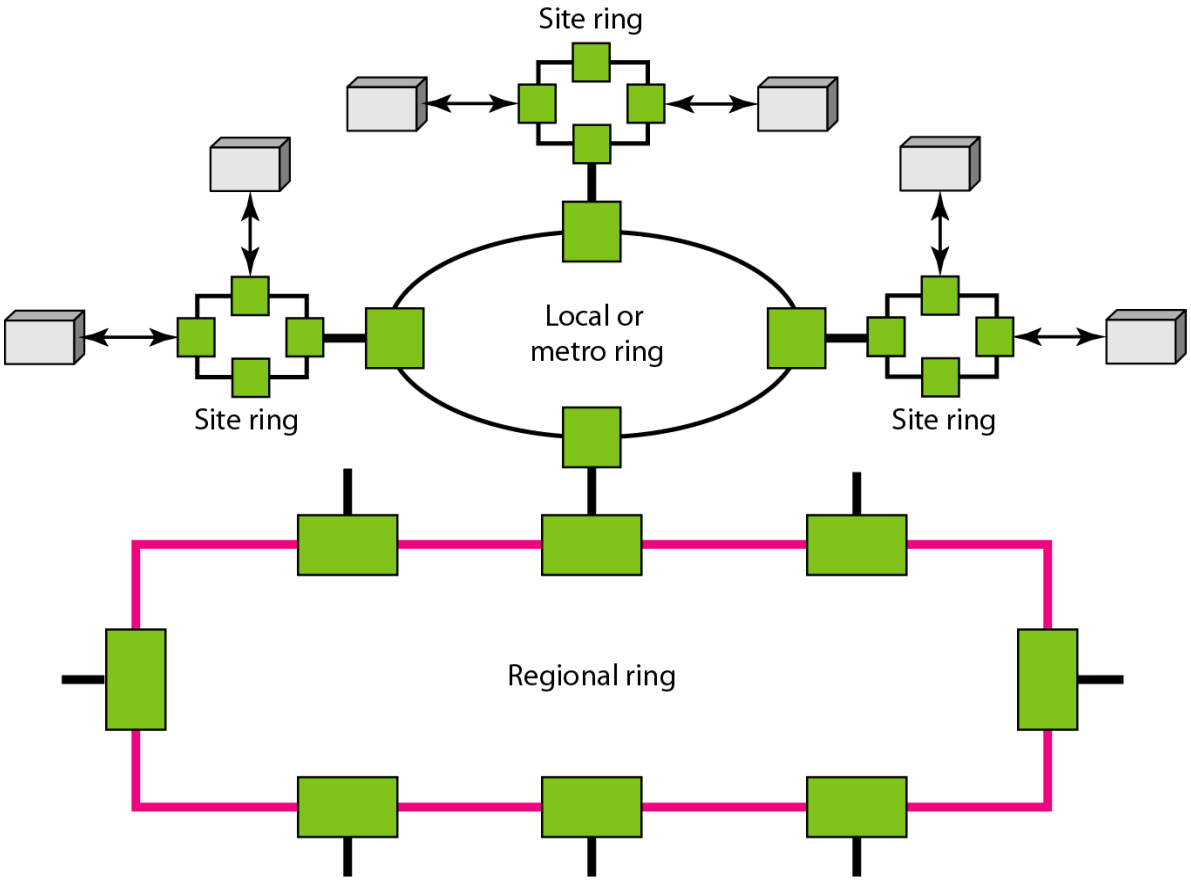
## Figure 17.21 *A unidirectional path switching ring*



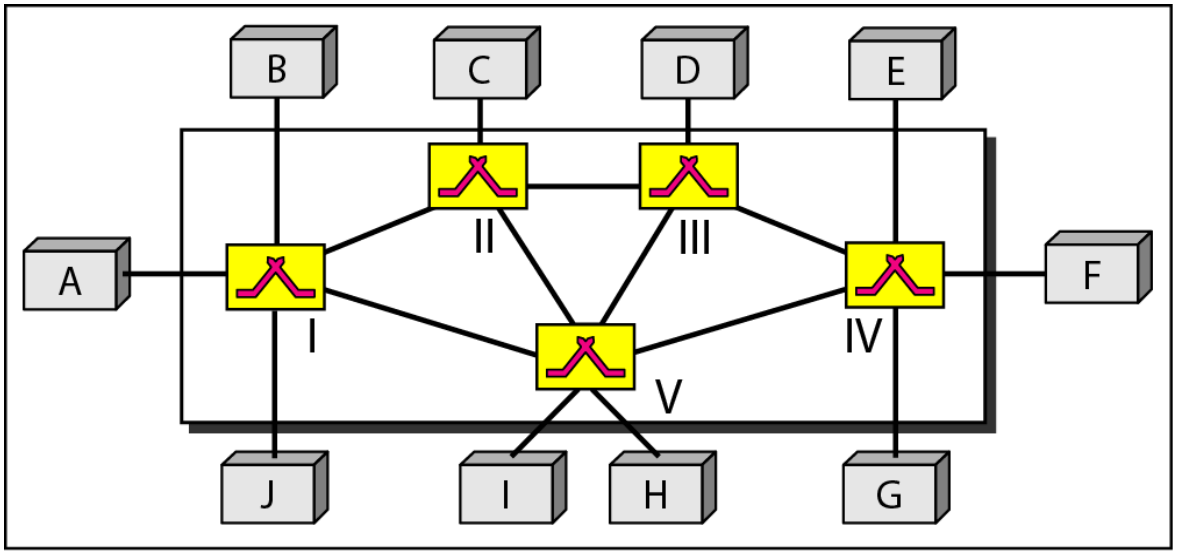
## Figure 17.22 *A bidirectional line switching ring*



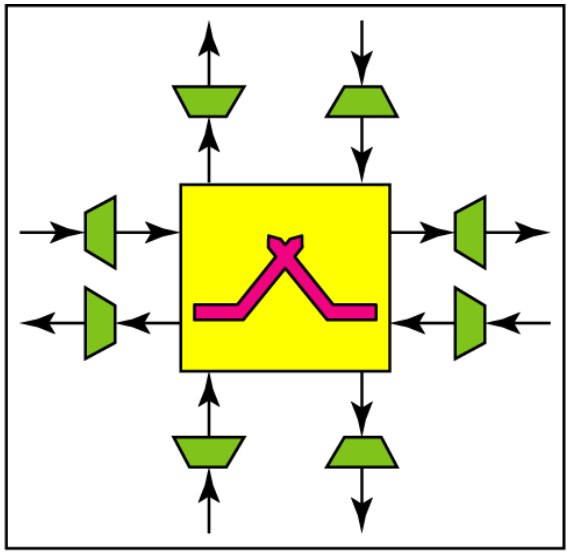
## Figure 17.23 *A combination of rings in a SONET network*



## Figure 17.24 *A mesh SONET network*




a. SONET mesh network



b. Cross-connect switch

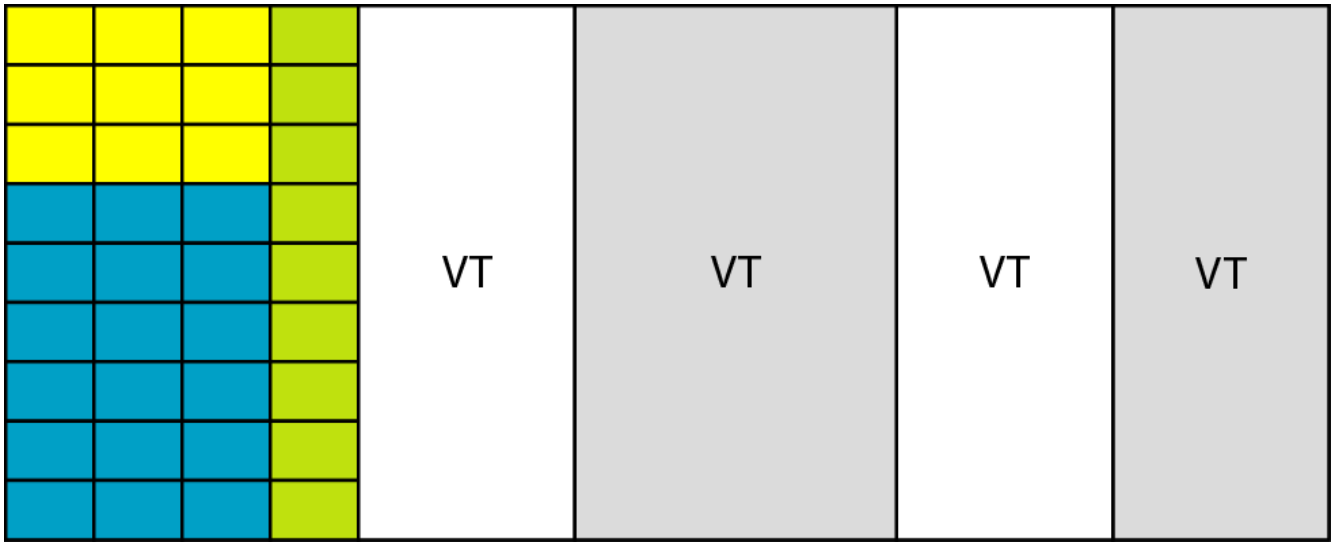
# 17-6 VIRTUAL TRIBUTARIES

***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:***

**Types of VTs**

## Figure 17.25 *Virtual tributaries*



## Figure 17.26 *Virtual tributary types*

VT1.5 = 8000 frames/s 3 columns 9 rows 8 bits = 1.728 Mbps
VT2 = 8000 frames/s 4 columns 9 rows 8 bits = 2.304 Mbps
VT3 = 8000 frames/s 6 columns 9 rows 8 bits = 3.456 Mbps
VT6 = 8000 frames/s 12 columns 9 rows 8 bits = 6.912 Mbps