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.

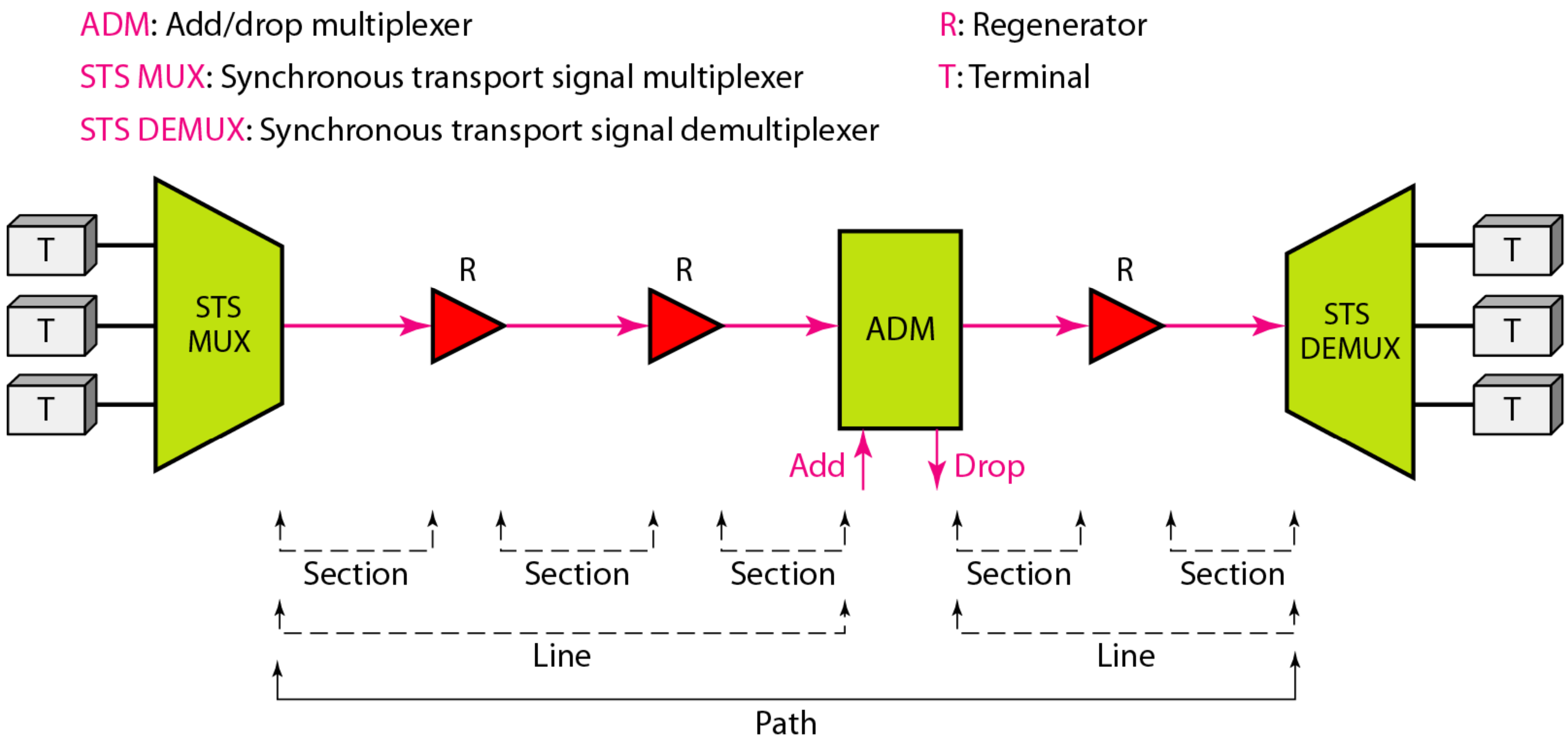
Topics discussed in this section:

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*

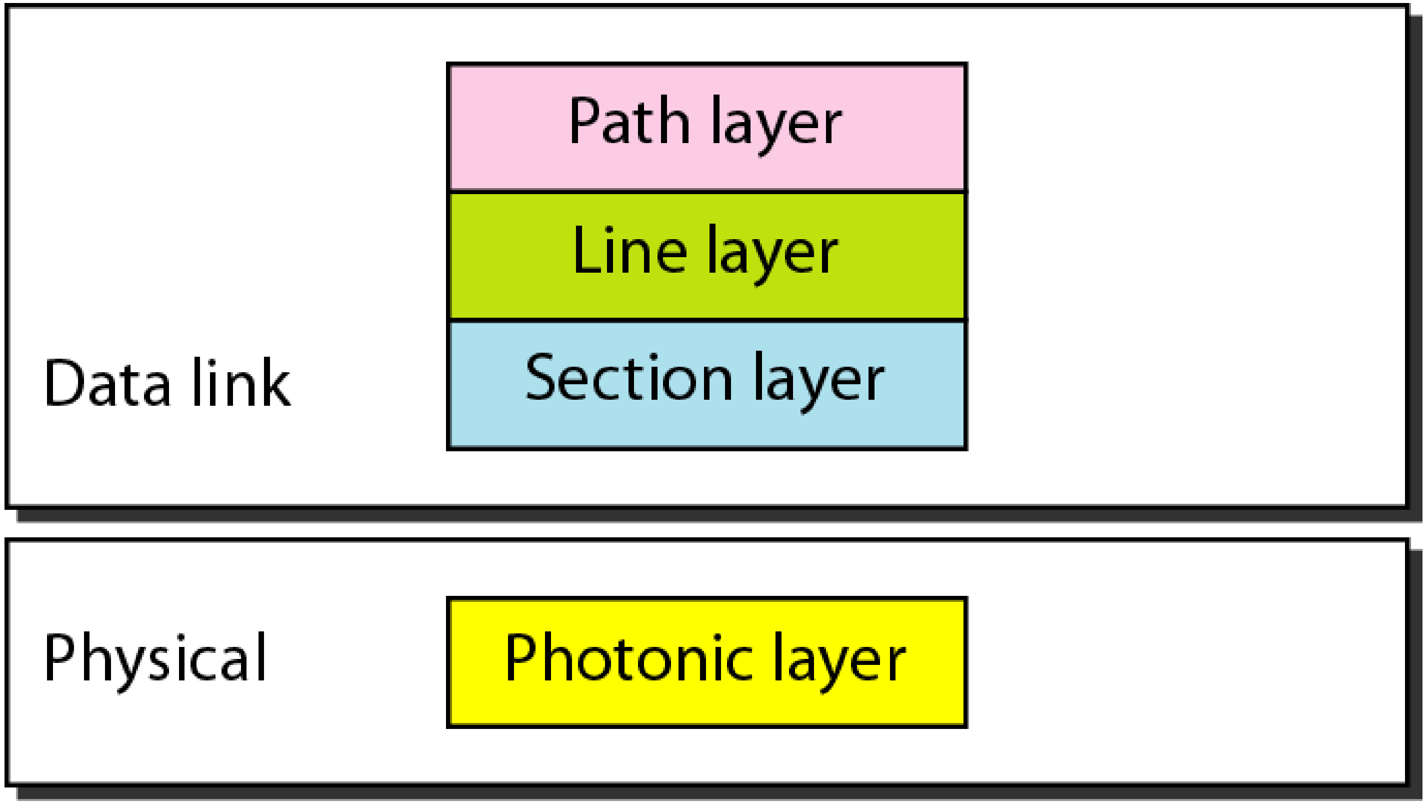
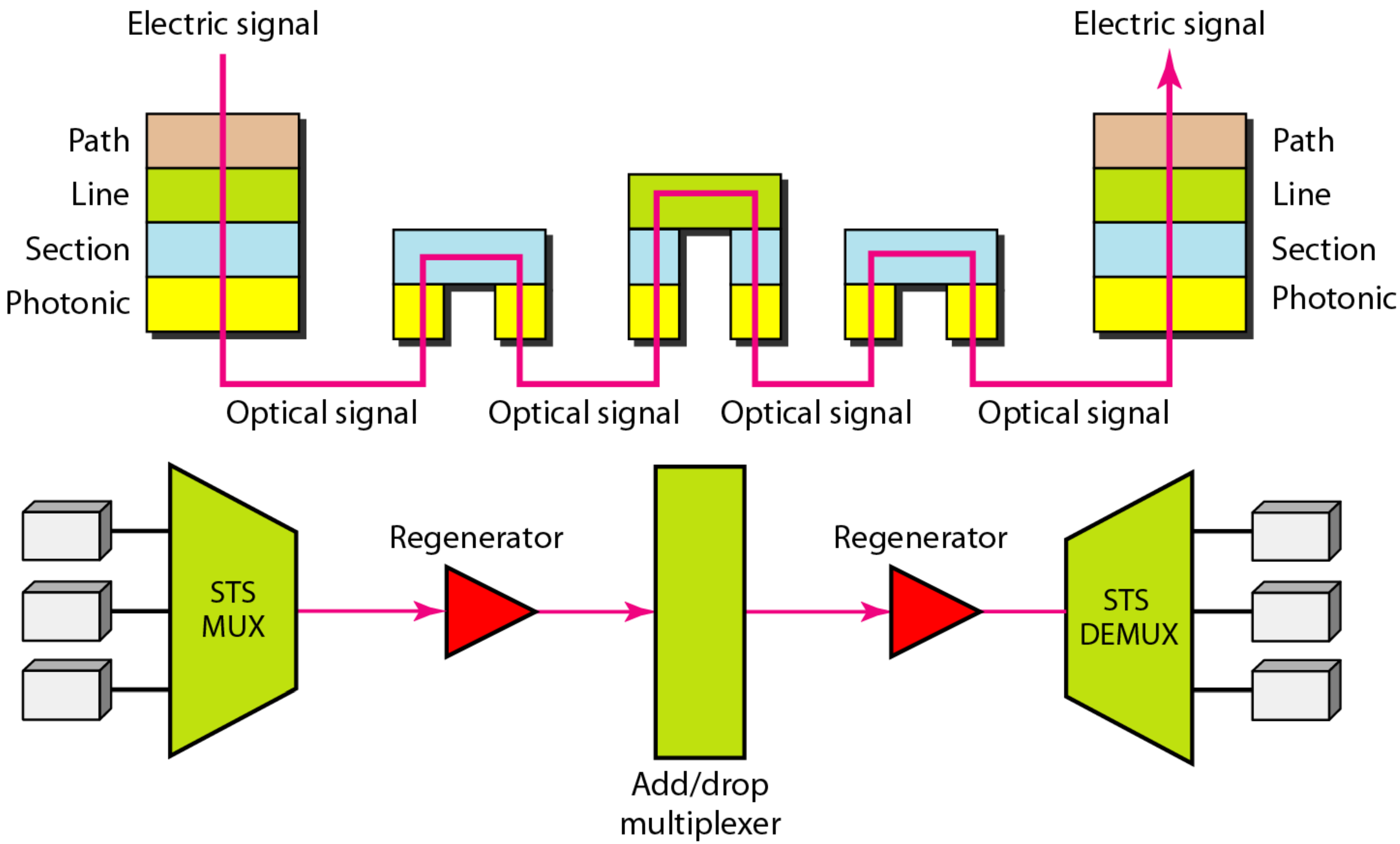


Figure 17.3 *Device–layer relationship in SONET*



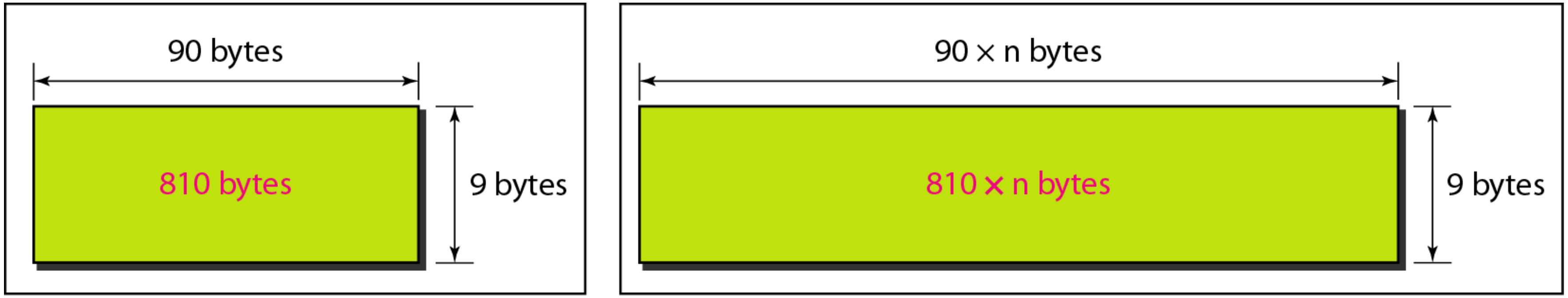
17-3 SONET FRAMES

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

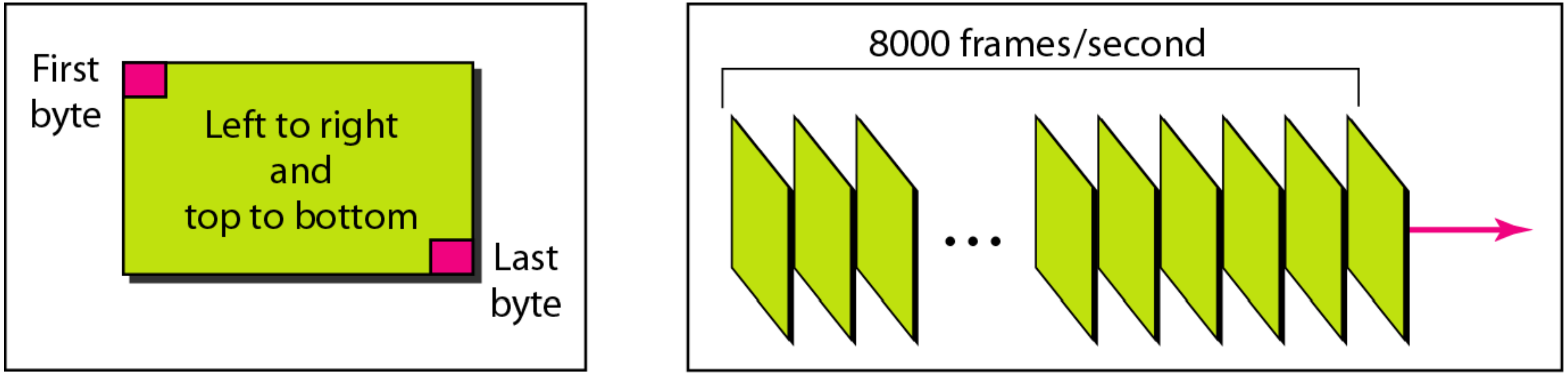
Figure 17.4 *An STS-1 and an STS-n frame*



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*

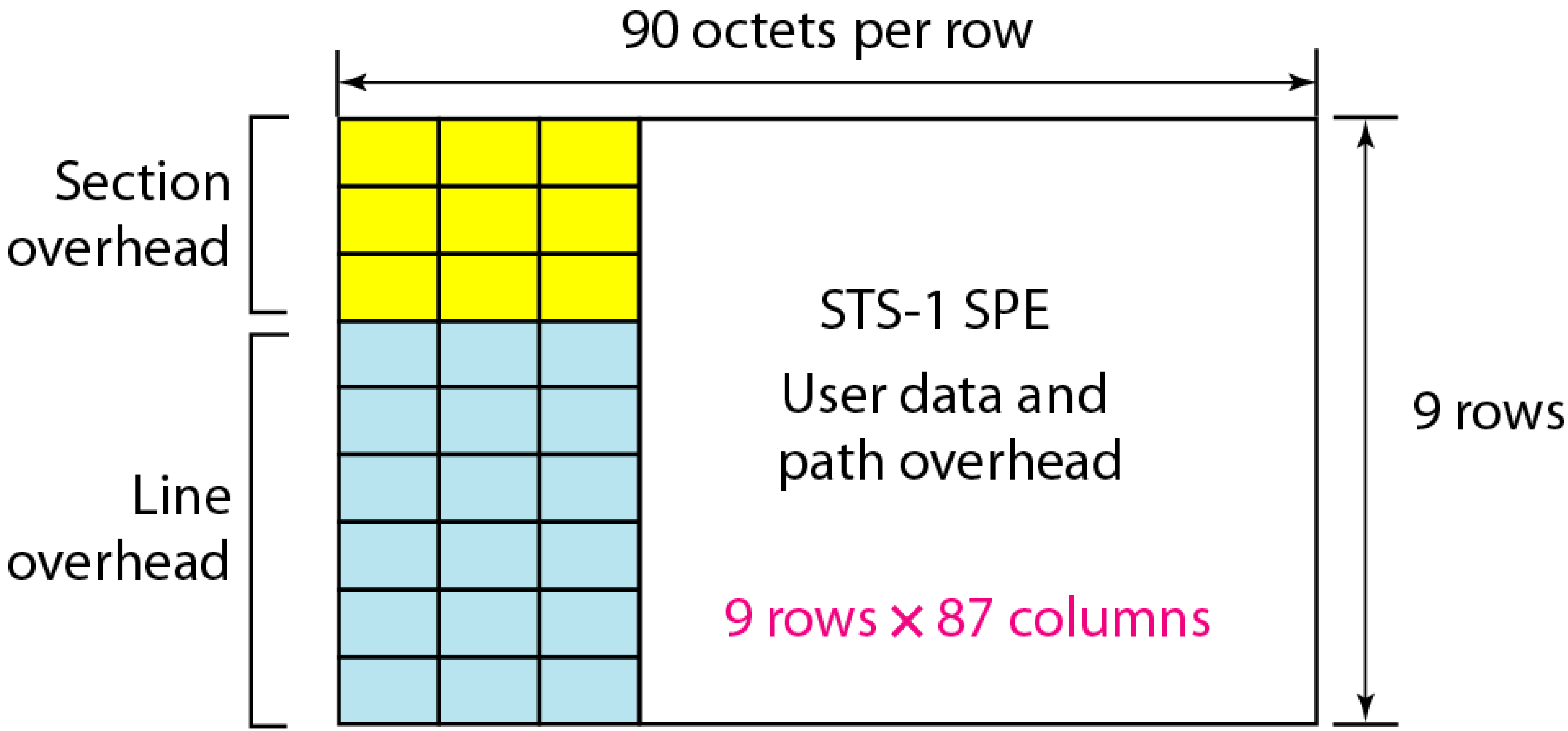
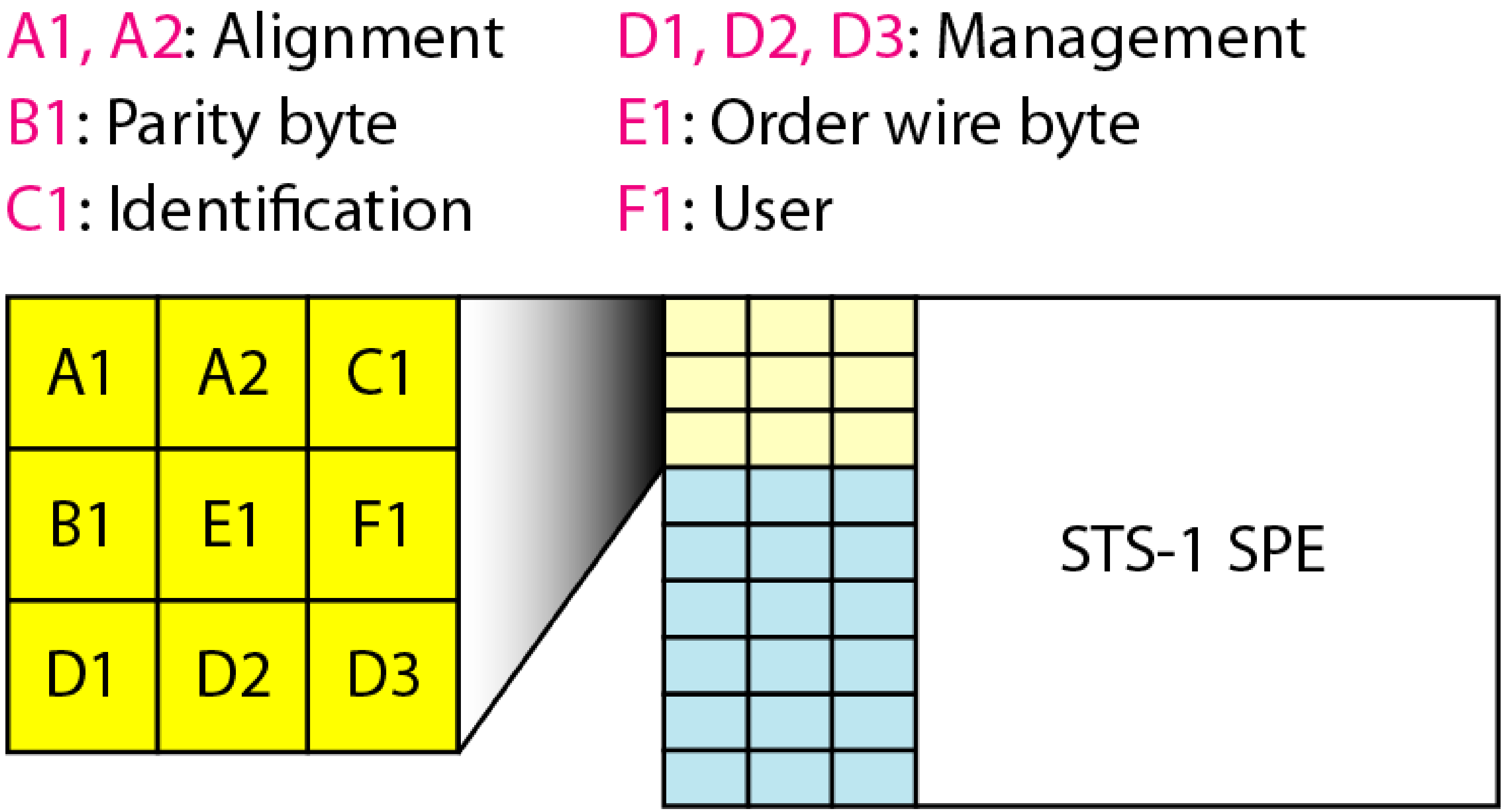


Figure 17.7 *STS-1 frame: section overhead*



Note

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

Figure 17.8 *STS-1 frame: line overhead*

B2: Line parity byte
D4-D12: Management bytes
E2: Order wire byte

H1, H2, H3: Pointers
K1, K2: Automatic protection switching bytes
Z1, Z2: Growth bytes (reserved)

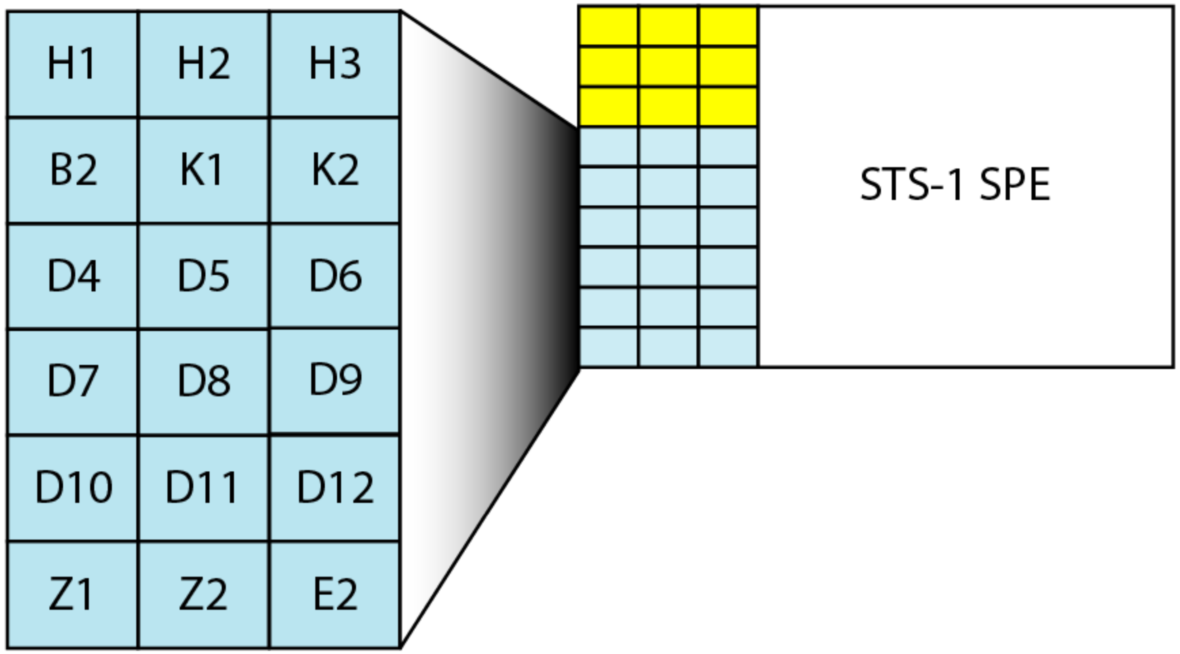
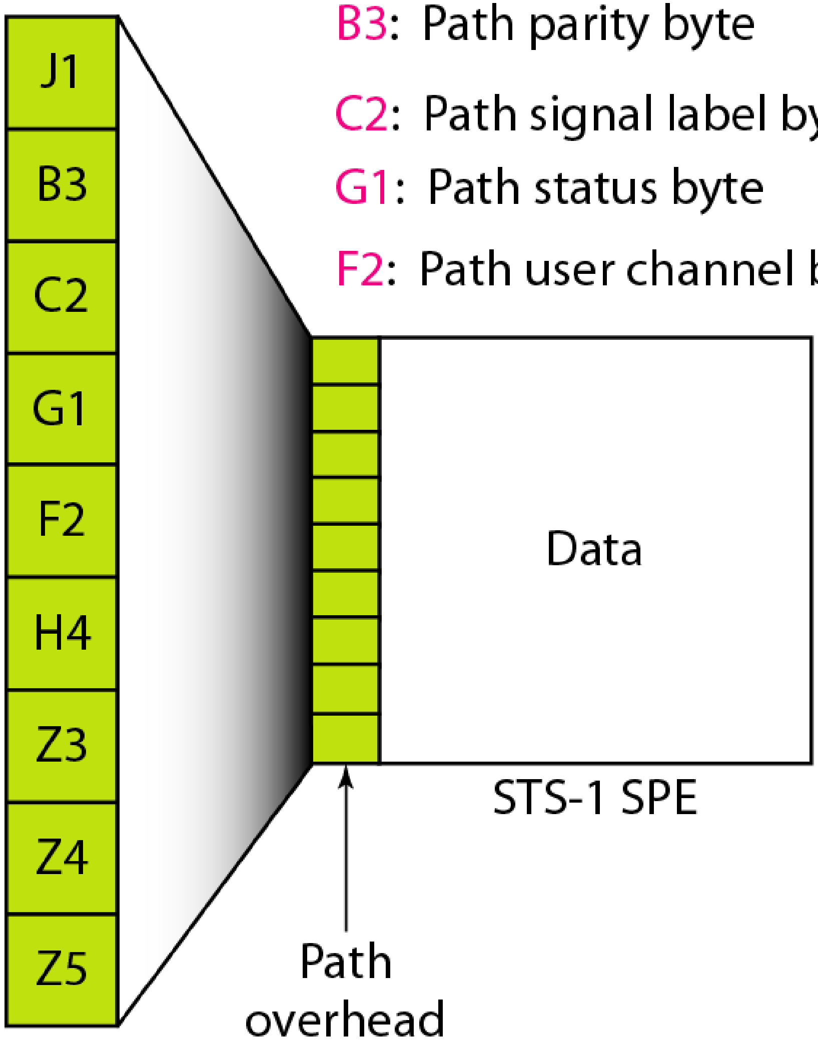


Figure 17.9 *STS-1 frame: path overhead*

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*

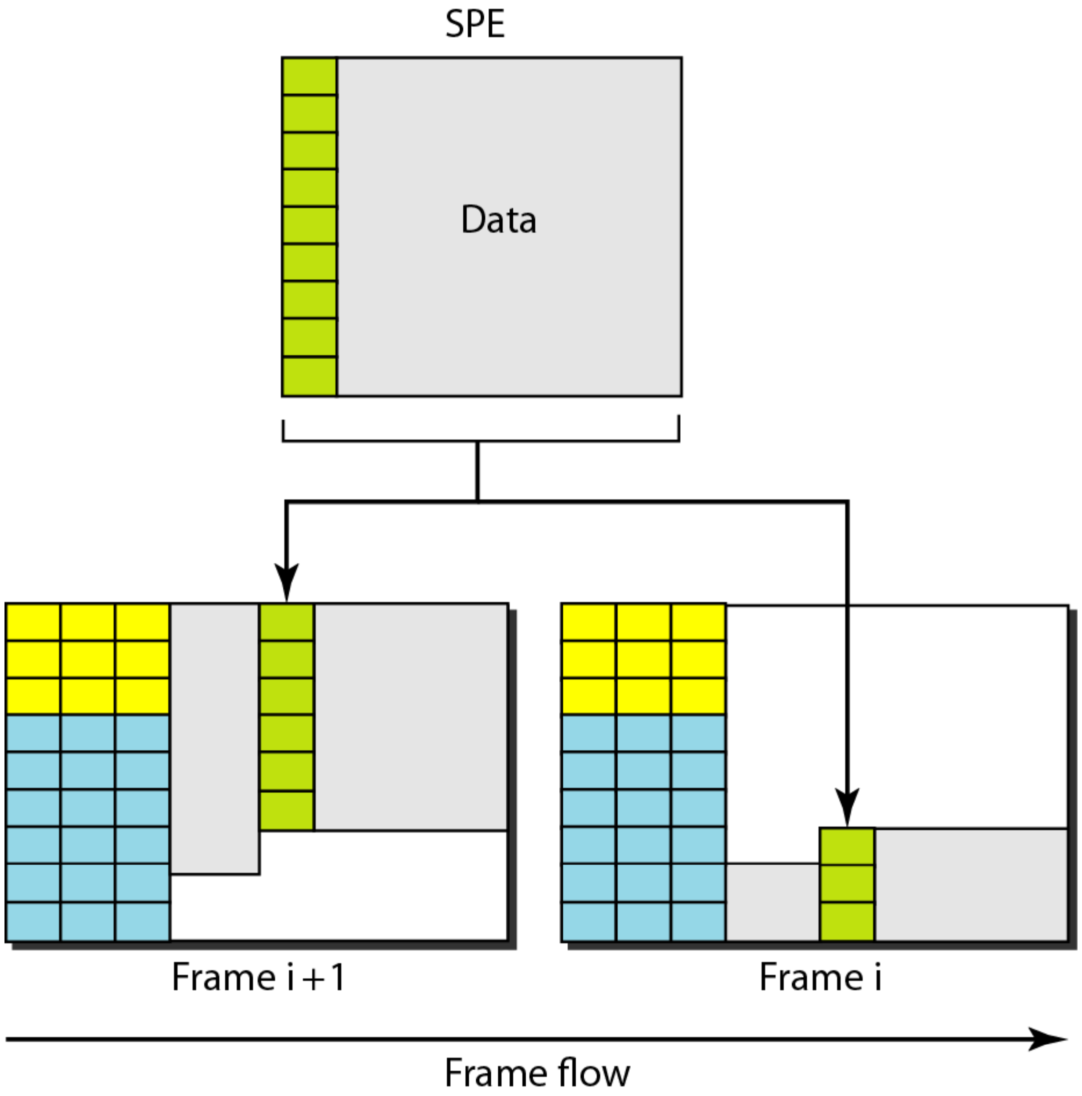
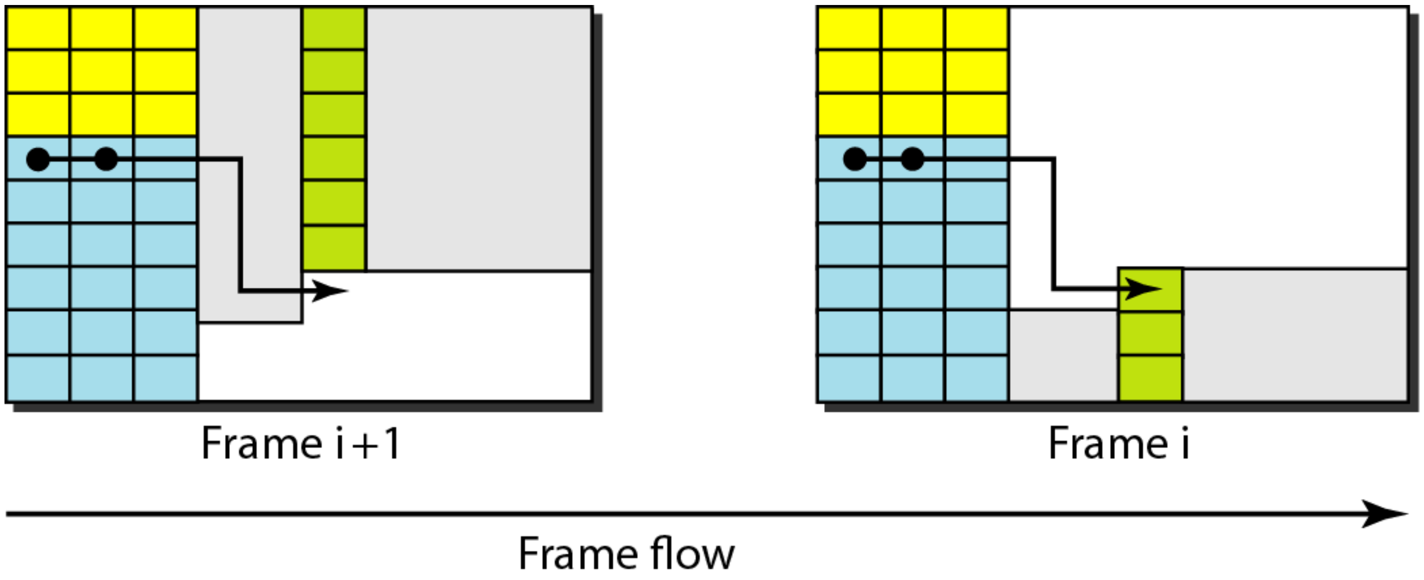


Figure 17.11 *The use of H1 and H2 pointers to show the start of an SPE in a frame*



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.

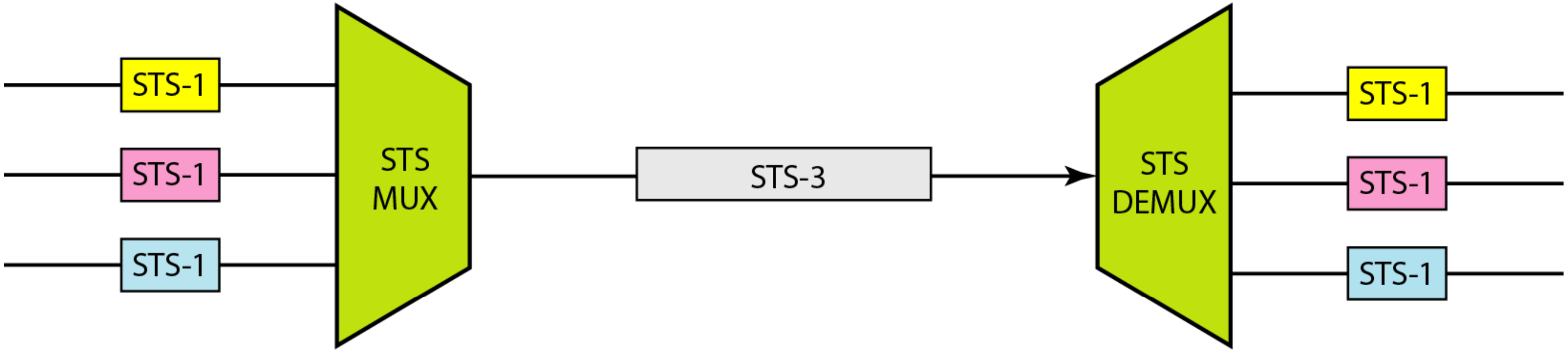
17-4 STS MULTIPLEXING

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*

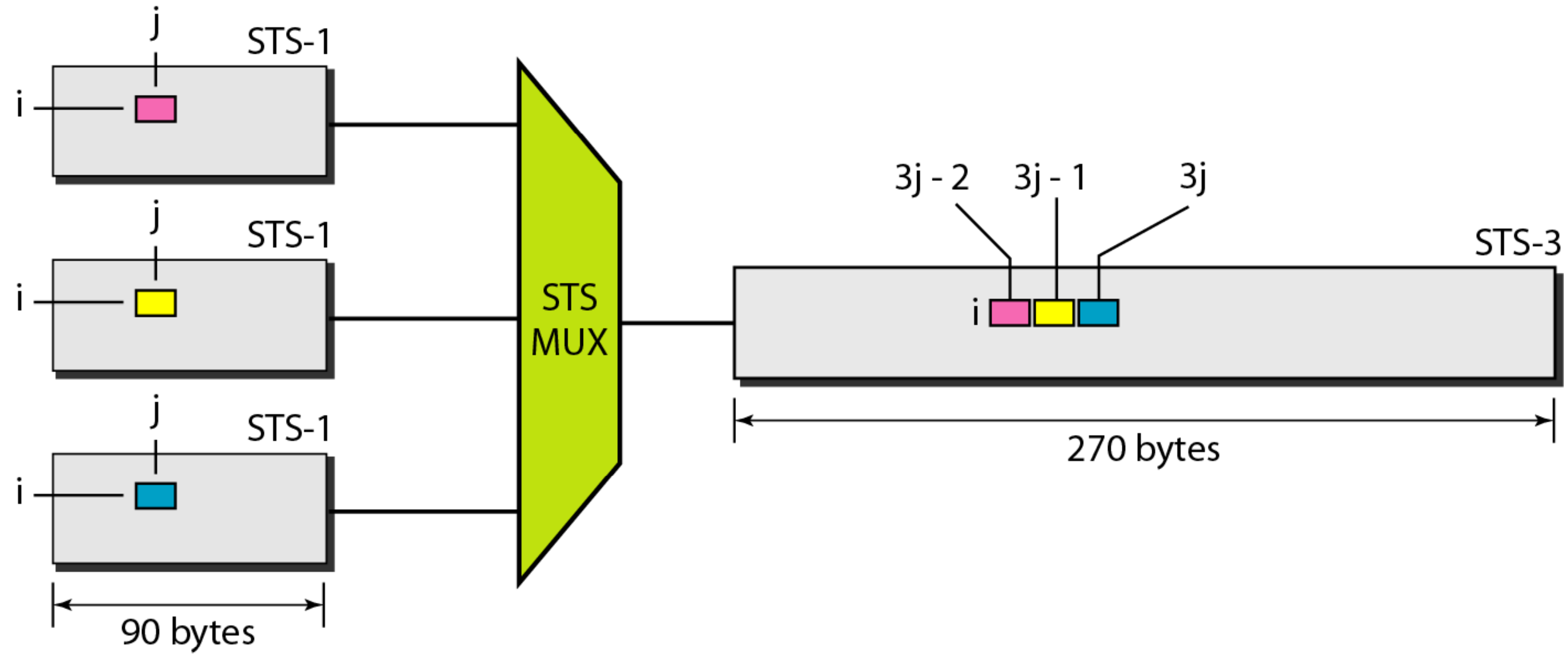


Figure 17.14 *An STS-3 frame*

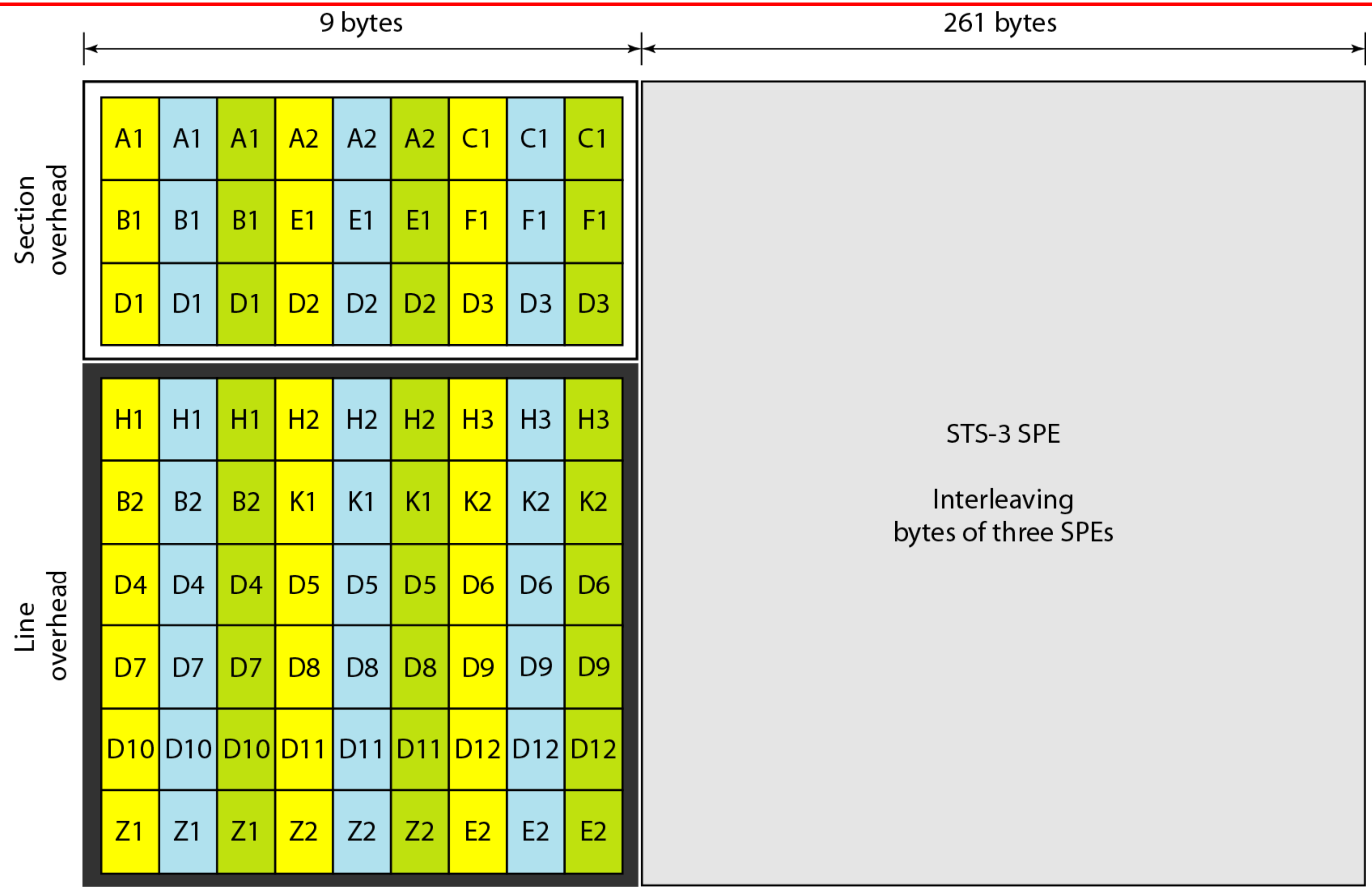
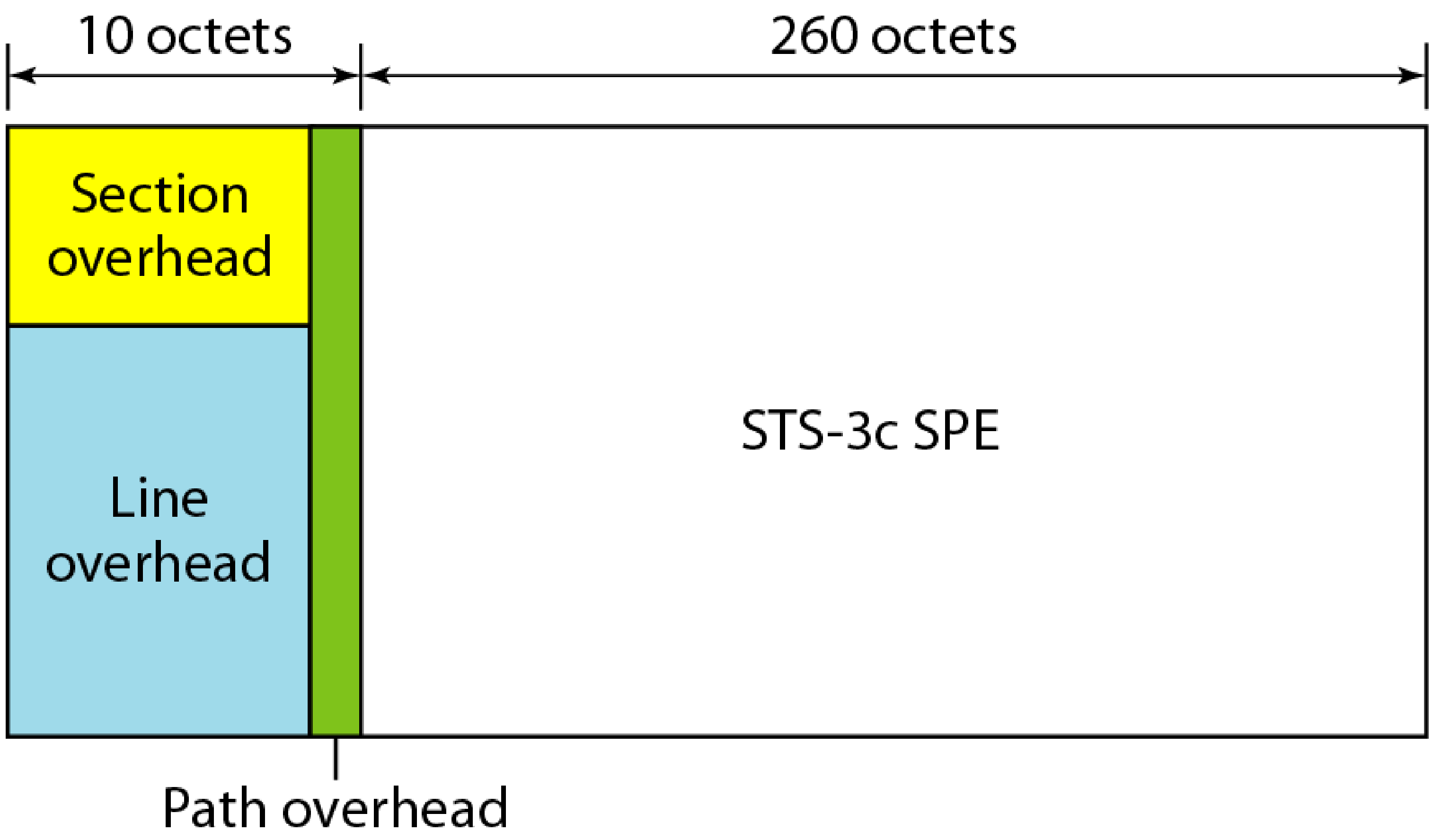


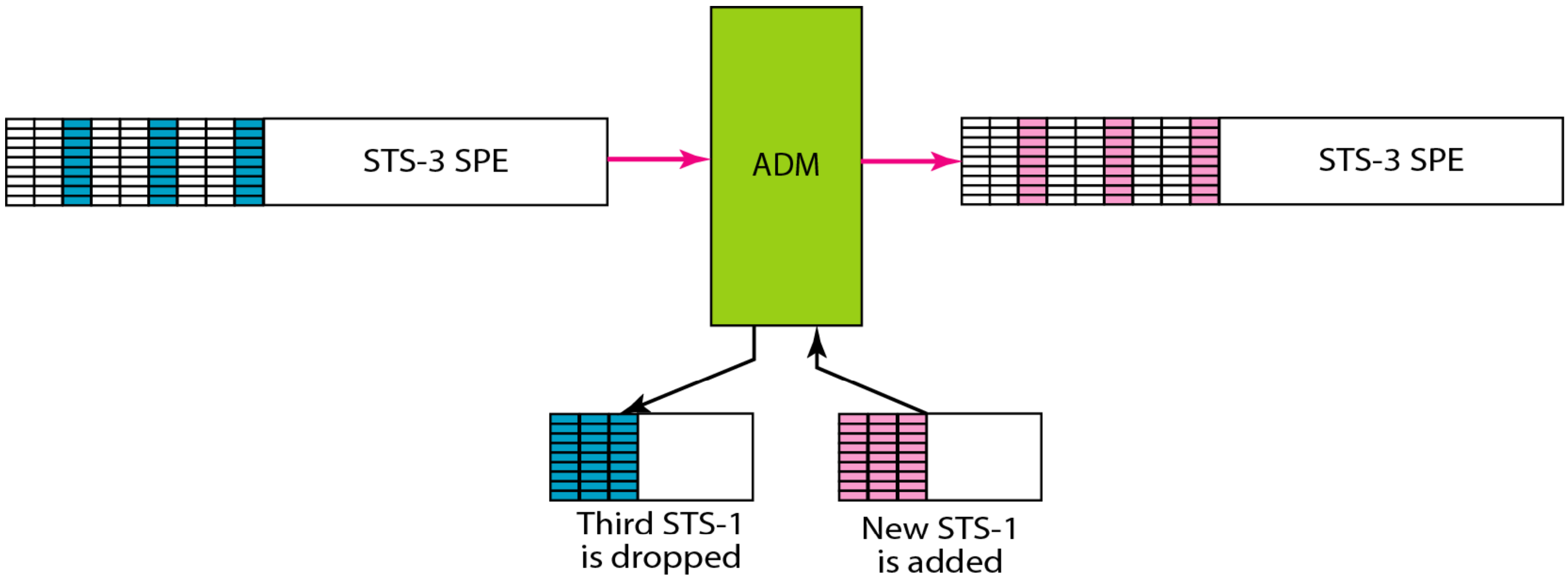
Figure 17.15 *A concatenated STS-3c signal*



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*

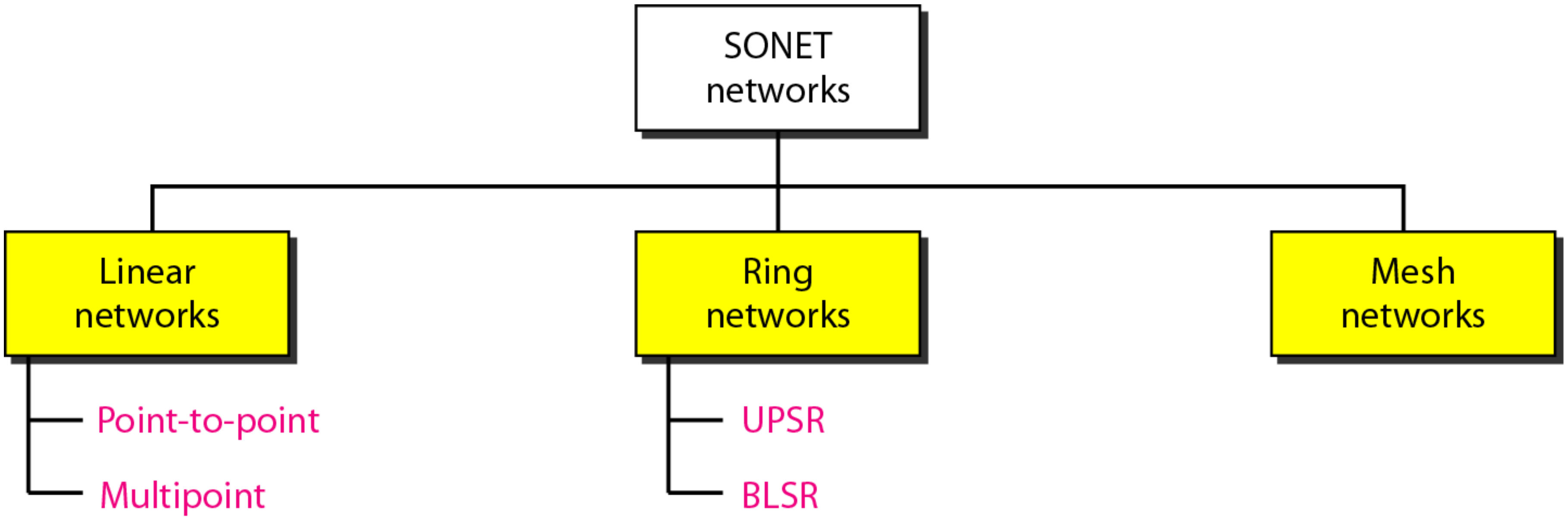


Figure 17.18 *A point-to-point SONET network*

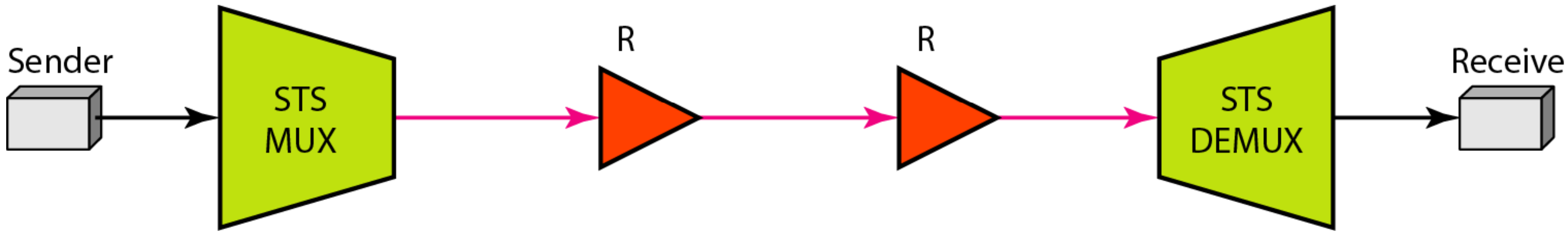


Figure 17.19 *A multipoint SONET network*

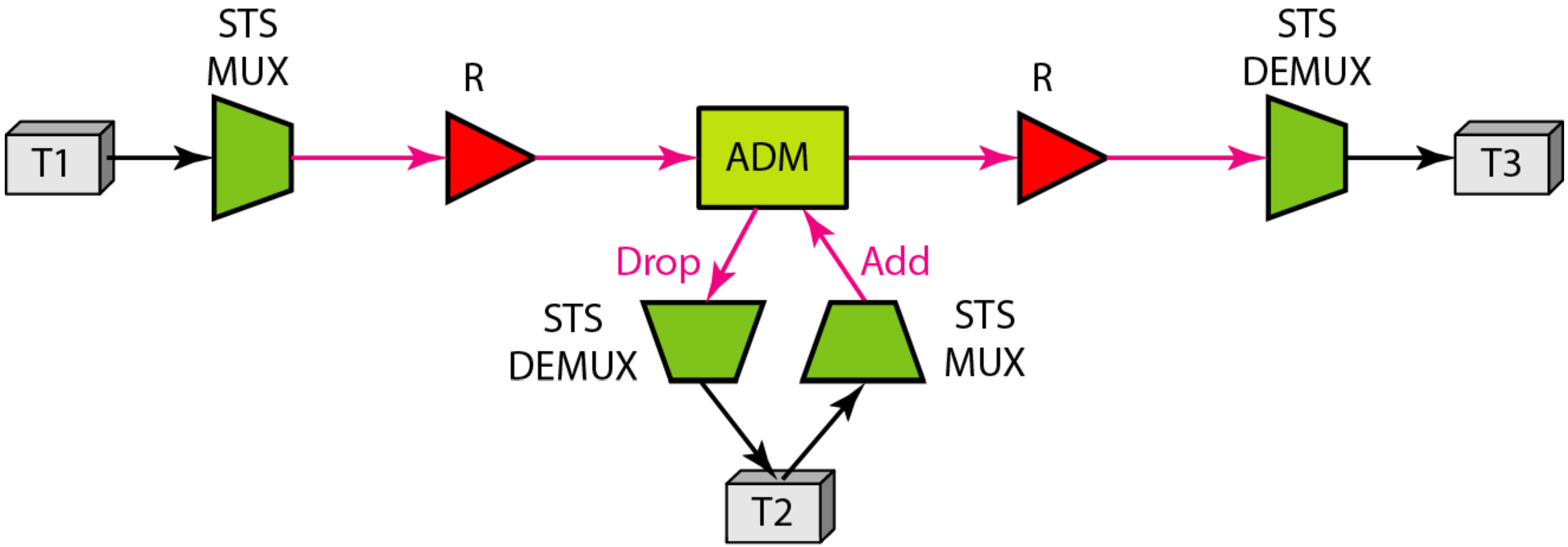


Figure 17.20 *Automatic protection switching in linear networks*

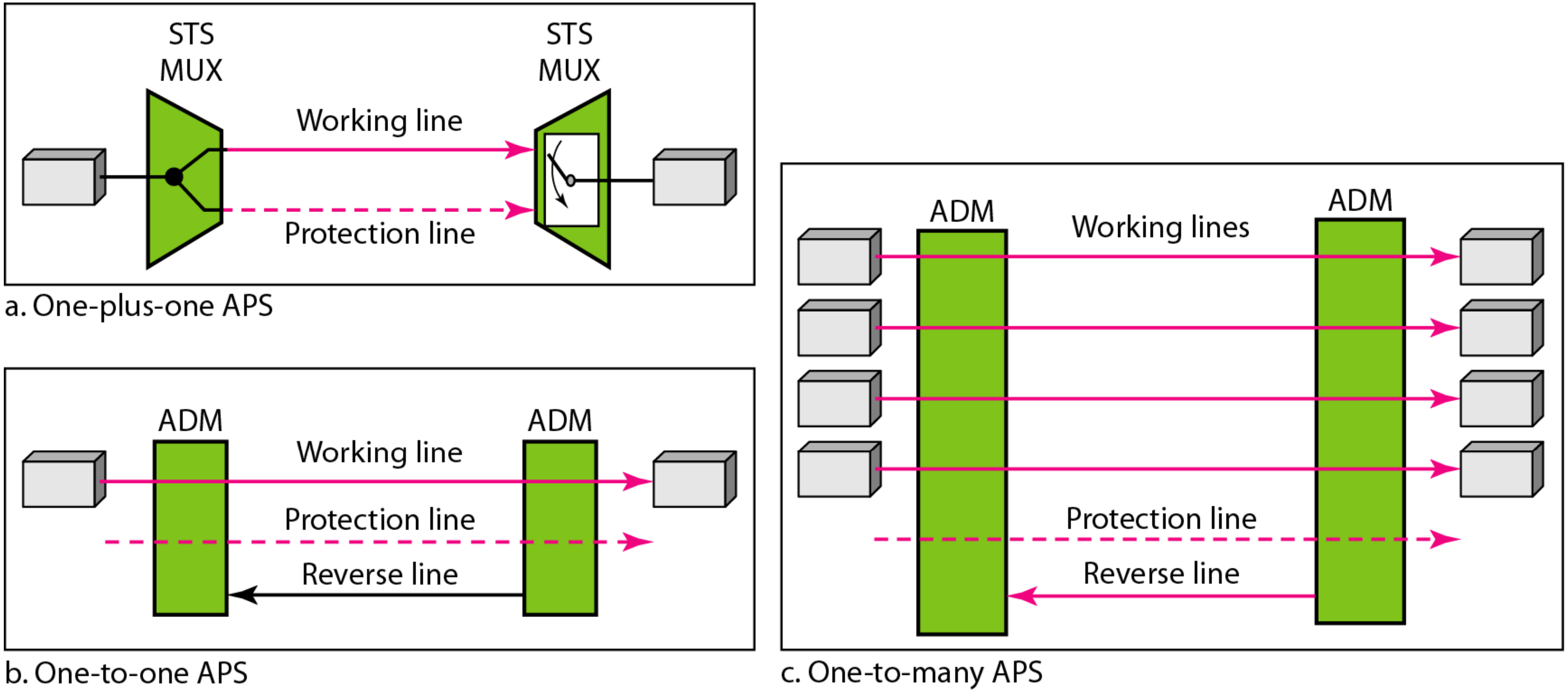


Figure 17.21 *A unidirectional path switching ring*

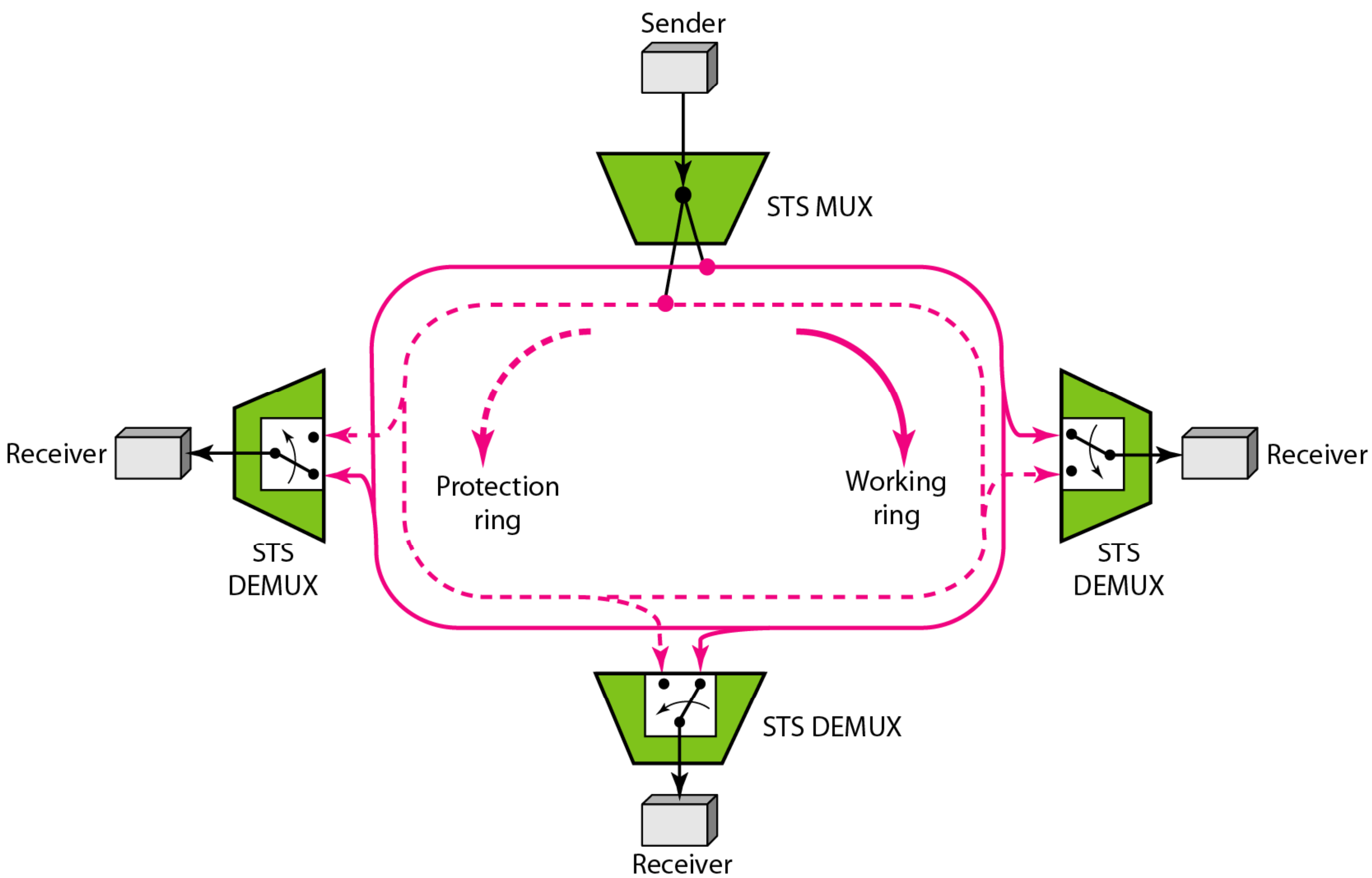


Figure 17.22 *A bidirectional line switching ring*

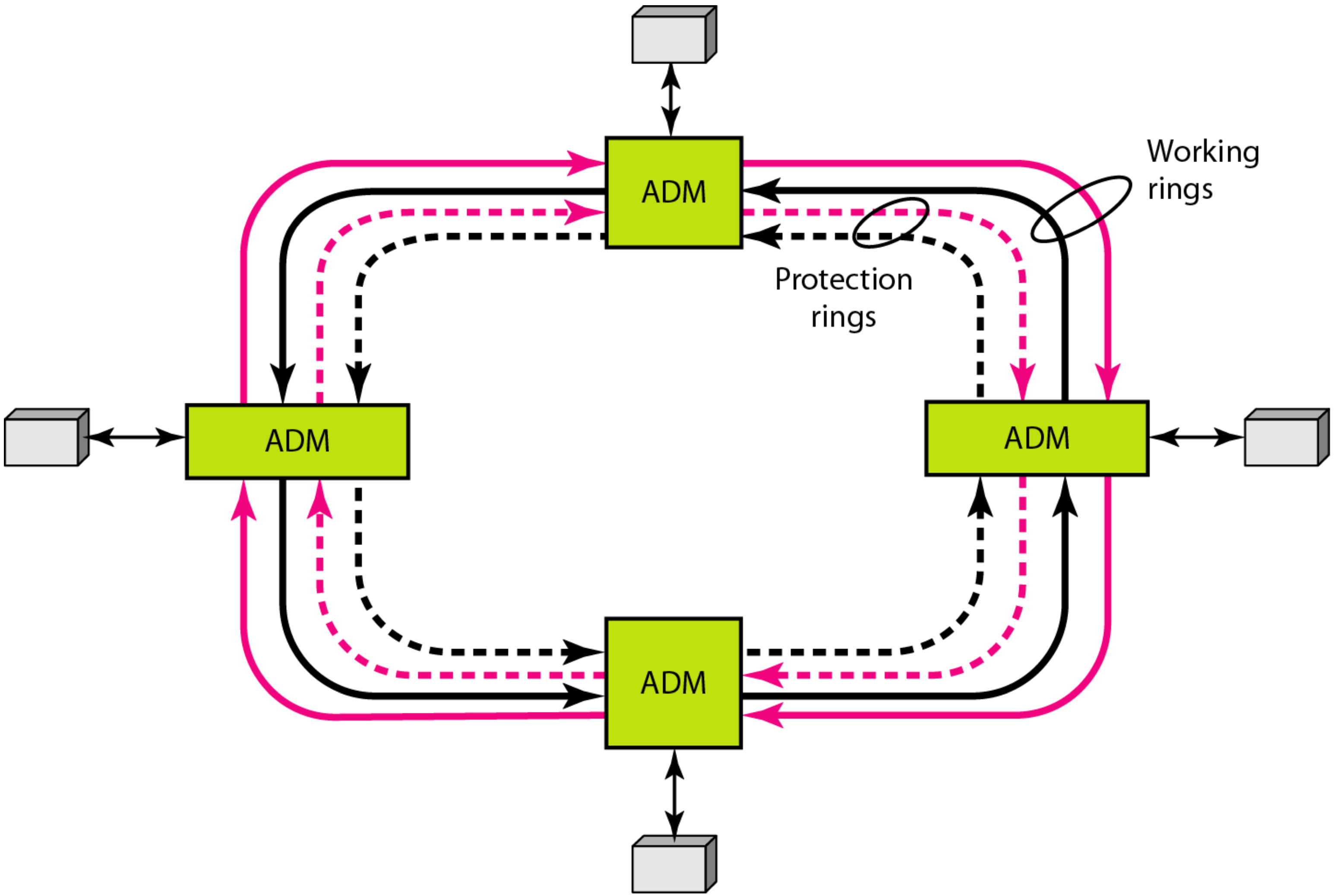


Figure 17.23 *A combination of rings in a SONET network*

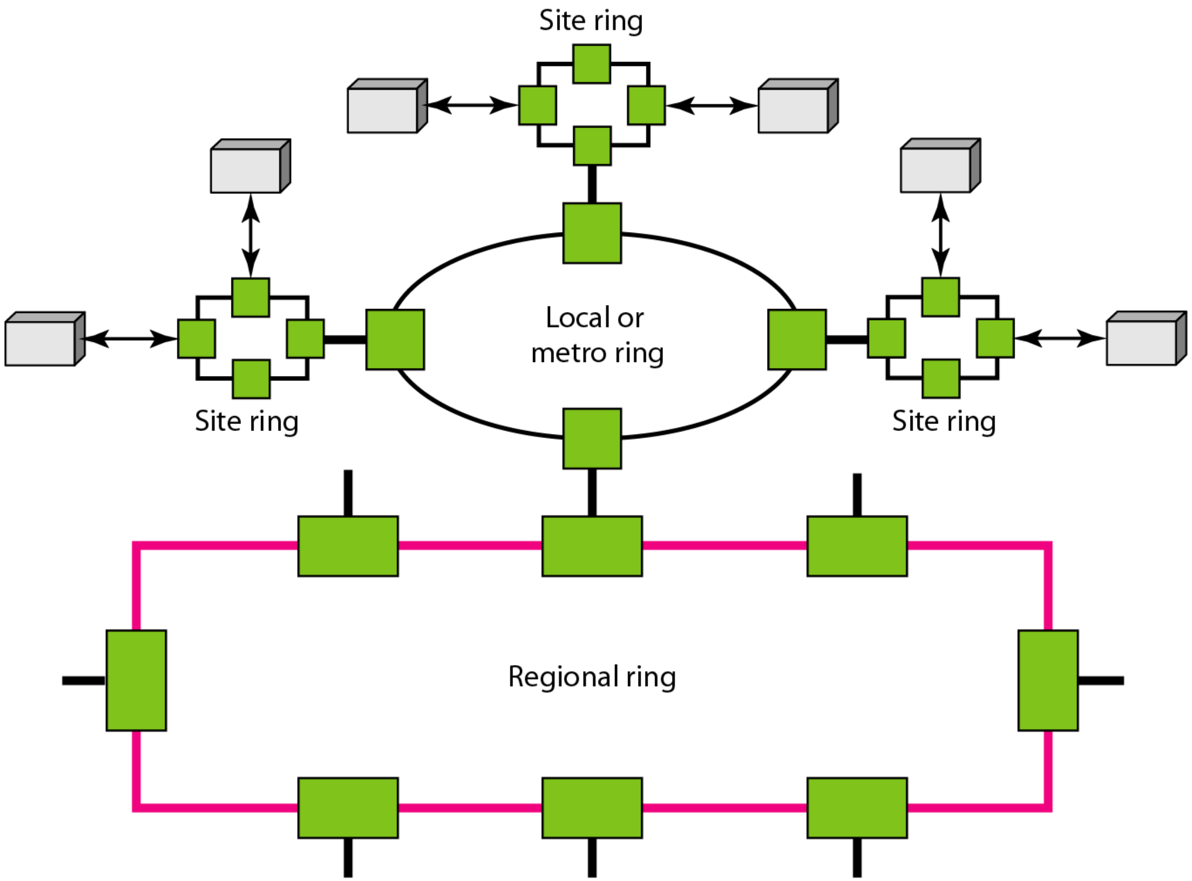
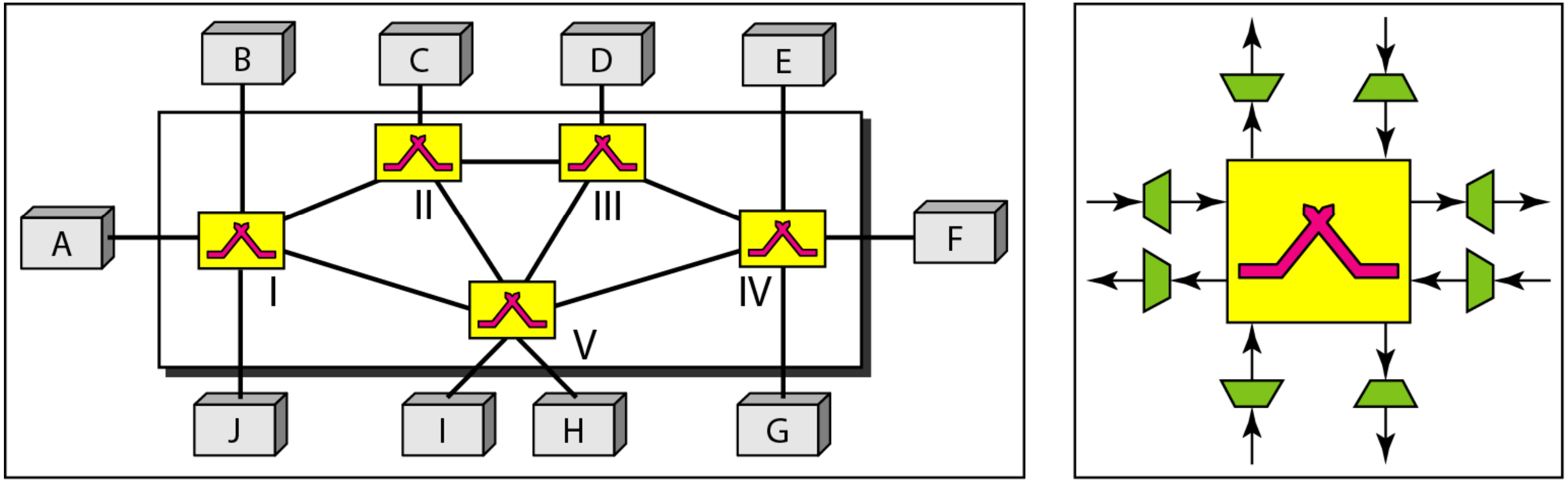


Figure 17.24 *A mesh SONET network*



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*

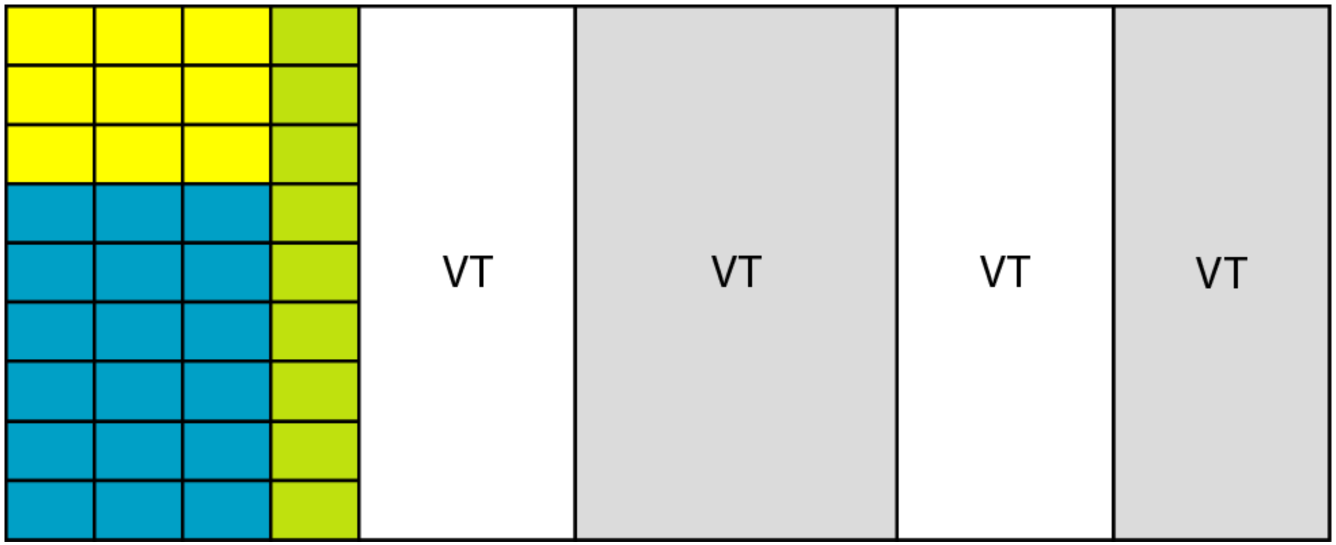


Figure 17.26 *Virtual tributary types*

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