



# **Chapter 17 SONET/SDH**



## 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

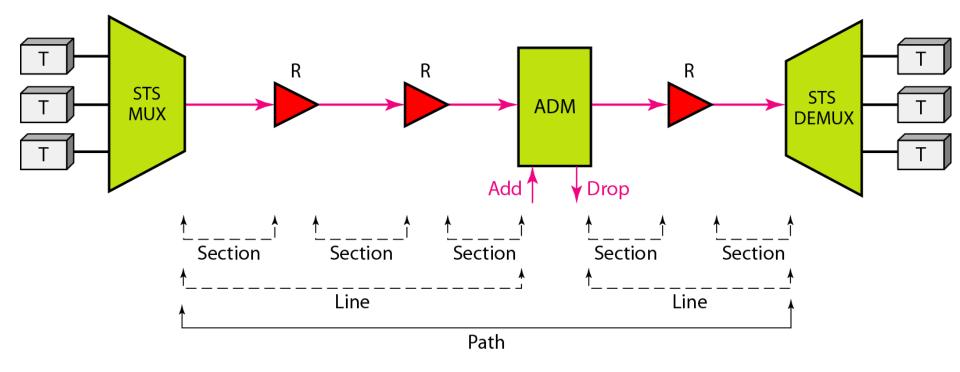
ADM: Add/drop multiplexer

STS MUX: Synchronous transport signal multiplexer

STS DEMUX: Synchronous transport signal demultiplexer

R: Regenerator

T: Terminal



### 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.

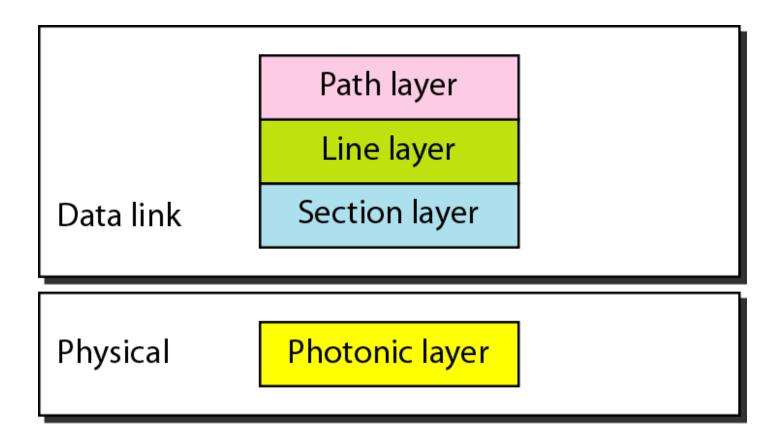
### Topics discussed in this section:

Path Layer
Line Layer
Section Layer
Photonic Layer
Device—Layer Relationships

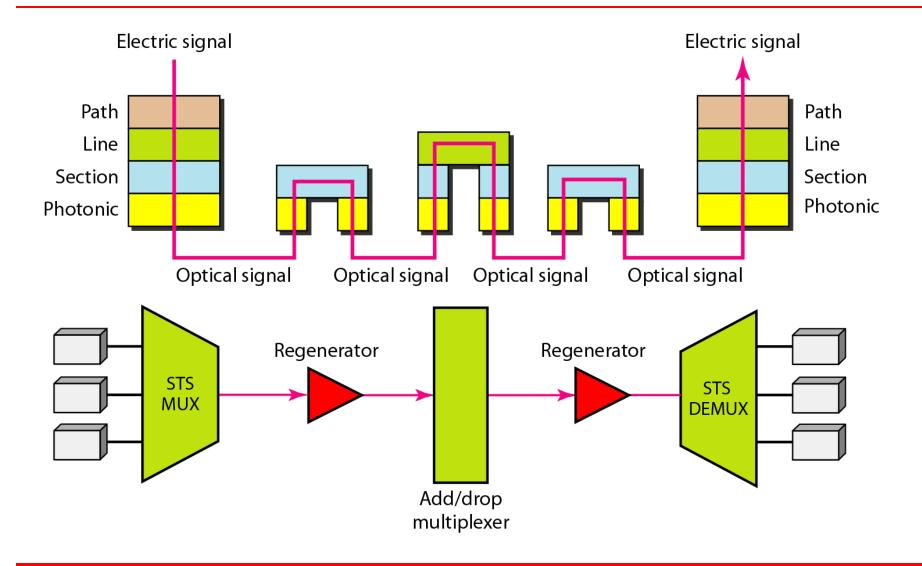


## SONET defines four layers: path, line, section, and photonic.

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



### Figure 17.3 Device—layer relationship in SONET



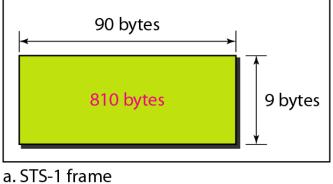
### 17-3 SONET FRAMES

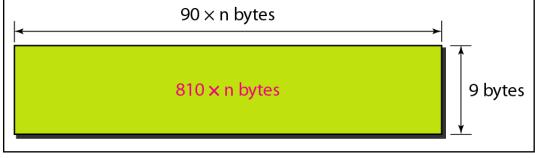
Each synchronous transfer signal STS-n is composed of 8000 frames. Each frame is a two-dimensional matrix of bytes with 9 rows by 90 × n columns.

### Topics discussed in this section:

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

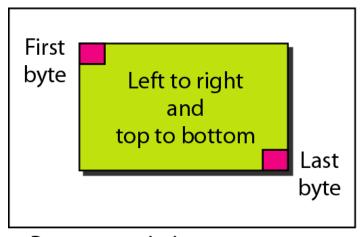
### Figure 17.4 An STS-1 and an STS-n frame



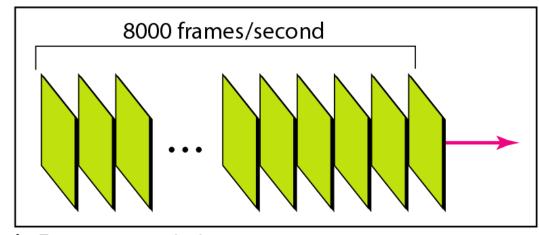


b. STS-n frame

### Figure 17.5 STS-1 frames in transmission



a. Byte transmission



b. Frame transmission



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



## 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  $(1 \times 90)$  bytes. Each byte is made of 8 bits. The data rate is

STS-1 data rate =  $8000 \times 9 \times (1 \times 90) \times 8 = 51.840$  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  $(3 \times 90)$  bytes. Each byte is made of 8 bits. The data rate is

STS-3 data rate =  $8000 \times 9 \times (3 \times 90) \times 8 = 155.52$  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?

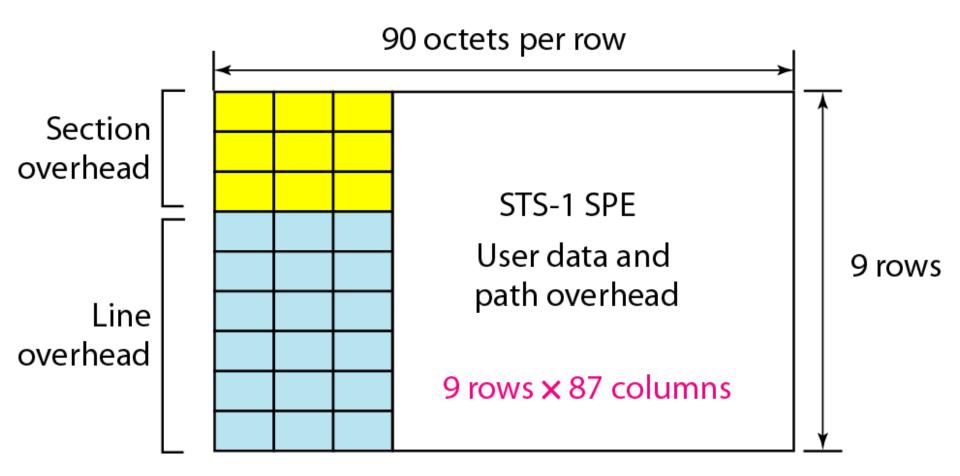
#### **Solution**

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.



# 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 D1, D2, D3: Management

B1: Parity byte E1: Order wire byte

C1: Identification F1: User

A1	A2	C1		
B1	E1	F1		STS-1 SPE
D1	D2	D3		



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

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

B2: Line parity byte

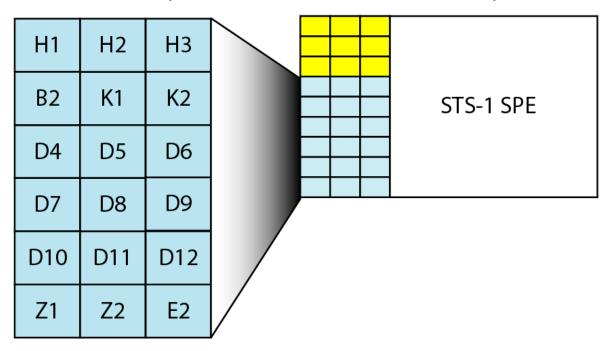
D4-D12: Management bytes

E2: Order wire byte

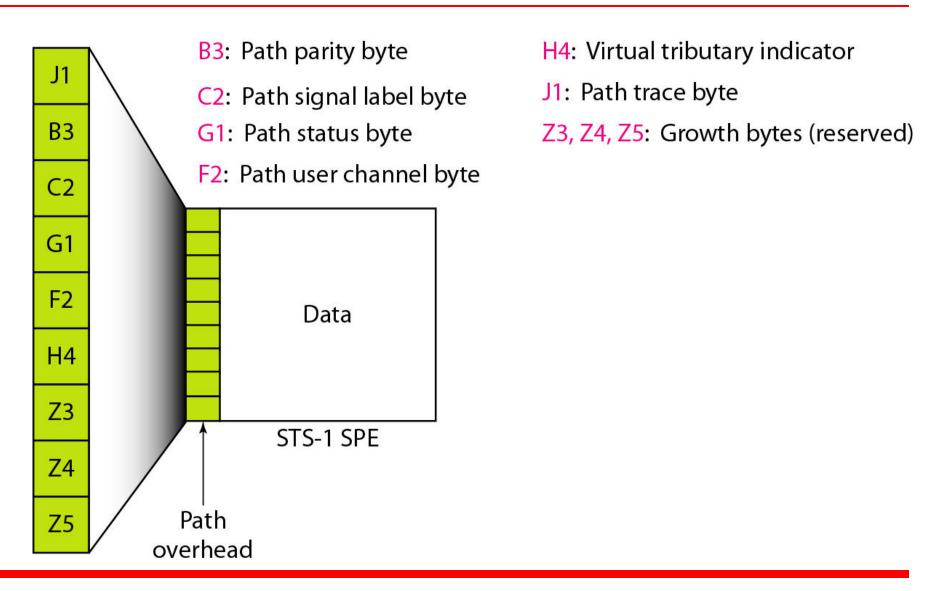
H1, H2, H3: Pointers

K1, K2: Automatic protection switching bytes

Z1, Z2: Growth bytes (reserved)



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





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	В3
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

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

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

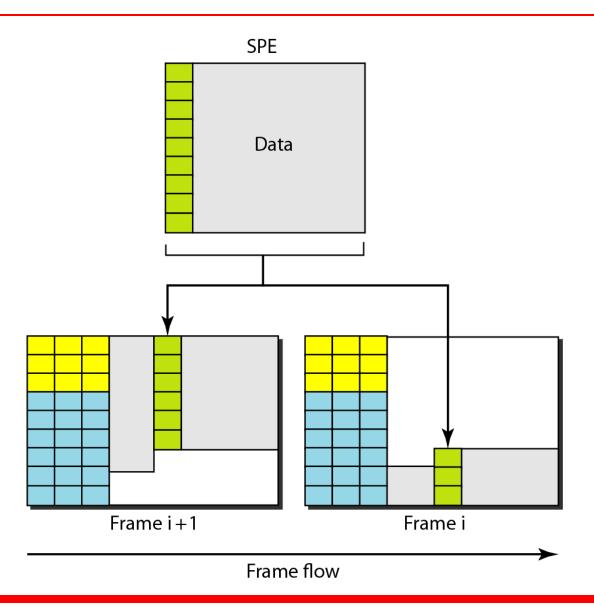
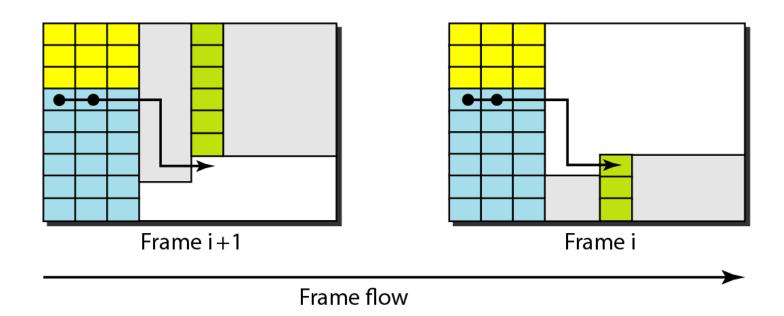


Figure 17.11 The use of H1 and H2 pointers to show the start of an SPE in a frame



### 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.

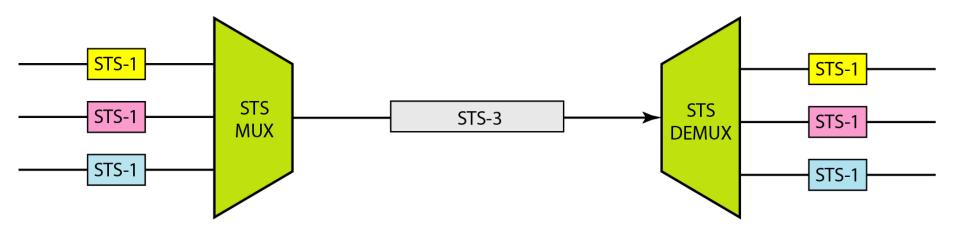
### 17-4 STS MULTIPLEXING

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

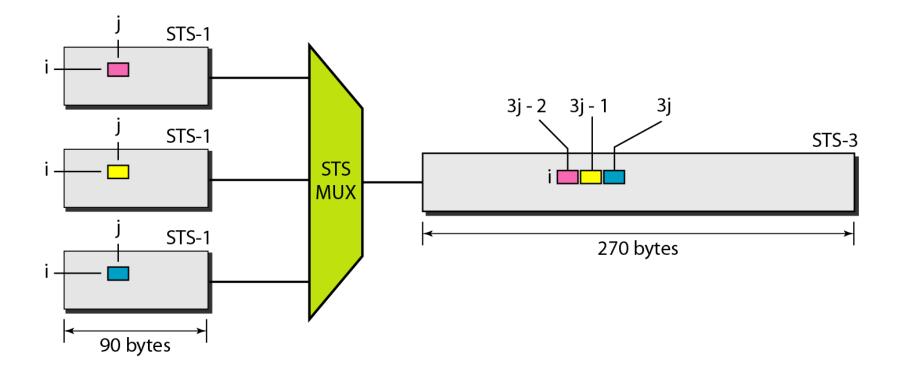
### Figure 17.12 STS multiplexing/demultiplexing



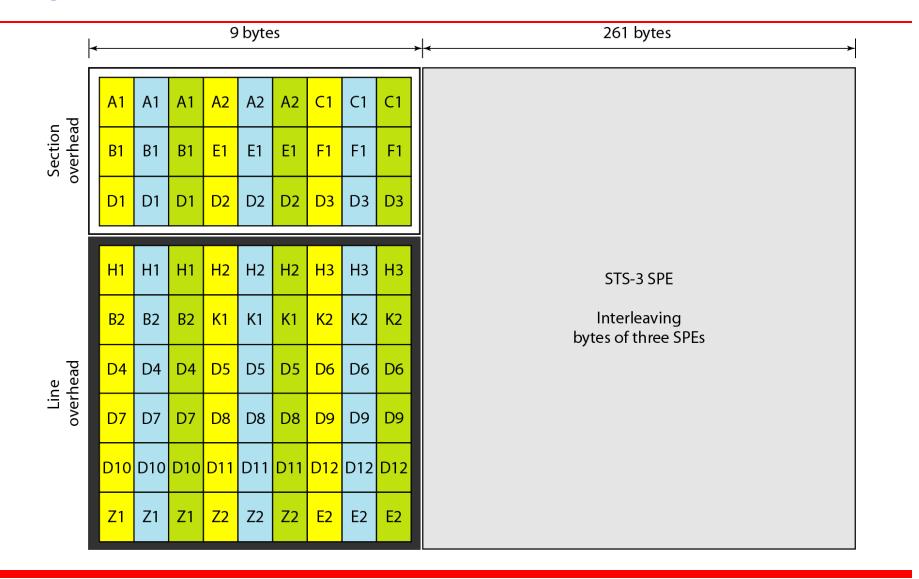


In SONET, all clocks in the network are locked to a master clock.

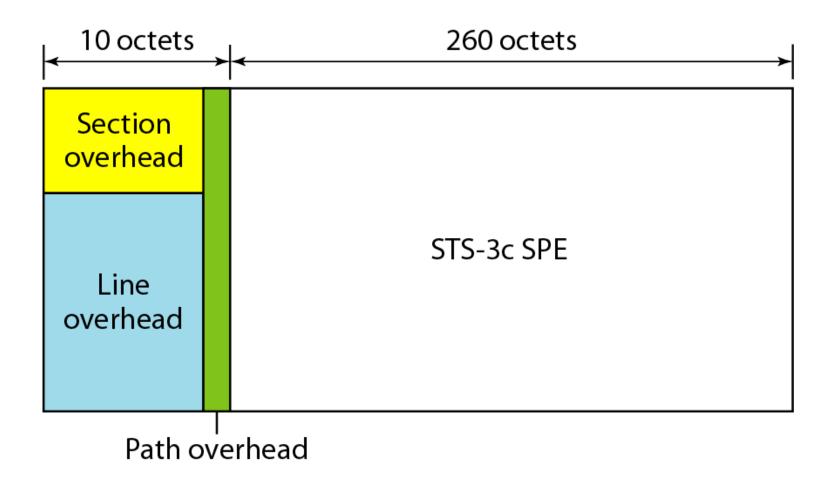
### Figure 17.13 Byte interleaving



### Figure 17.14 An STS-3 frame



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

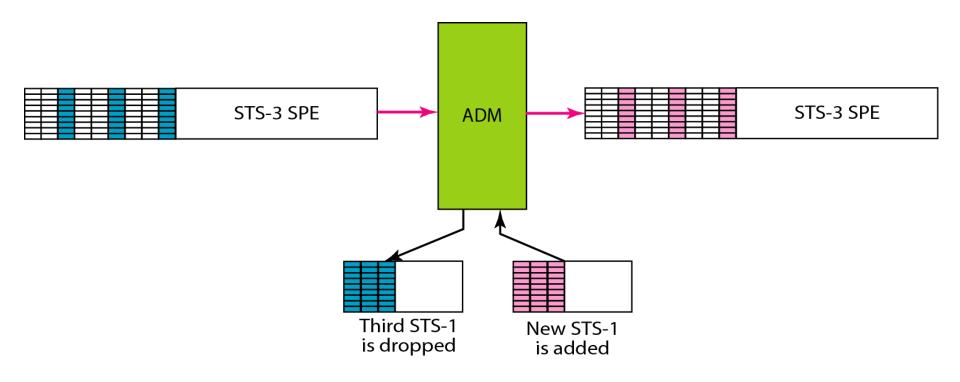


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# Note

# 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



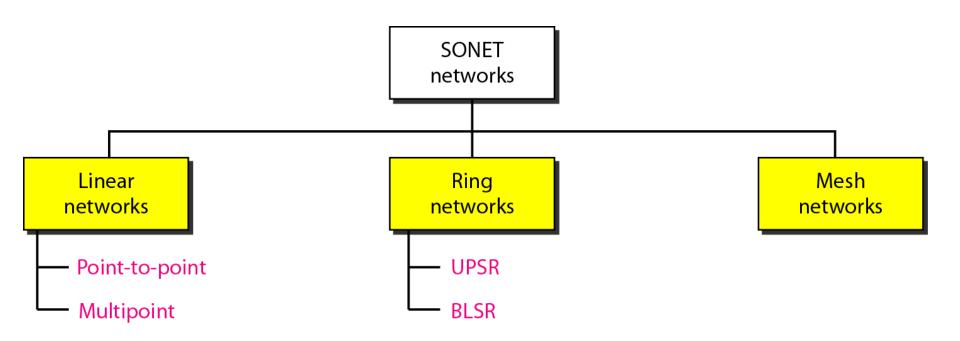
# 17-5 SONET NETWORKS

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.

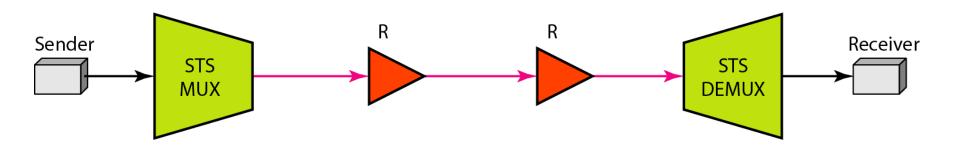
# Topics discussed in this section:

Linear Networks
Ring Networks
Mesh Networks

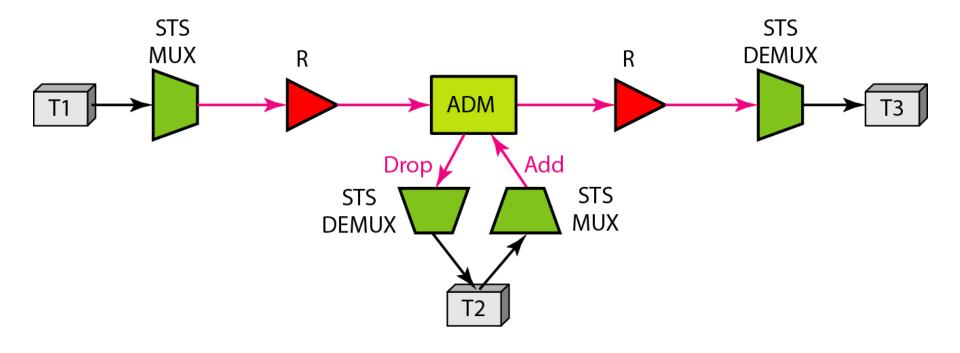
#### Figure 17.17 Taxonomy of SONET networks



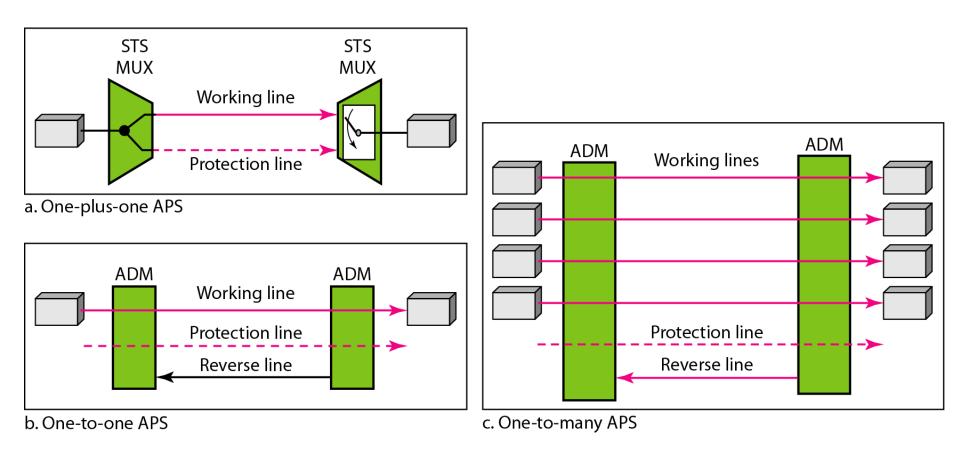
## Figure 17.18 A point-to-point SONET network



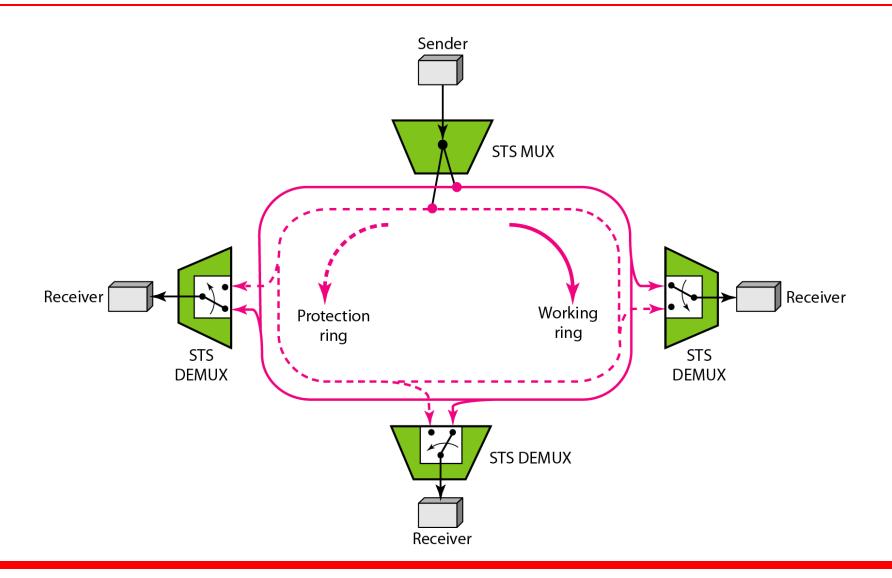
#### Figure 17.19 A multipoint SONET network



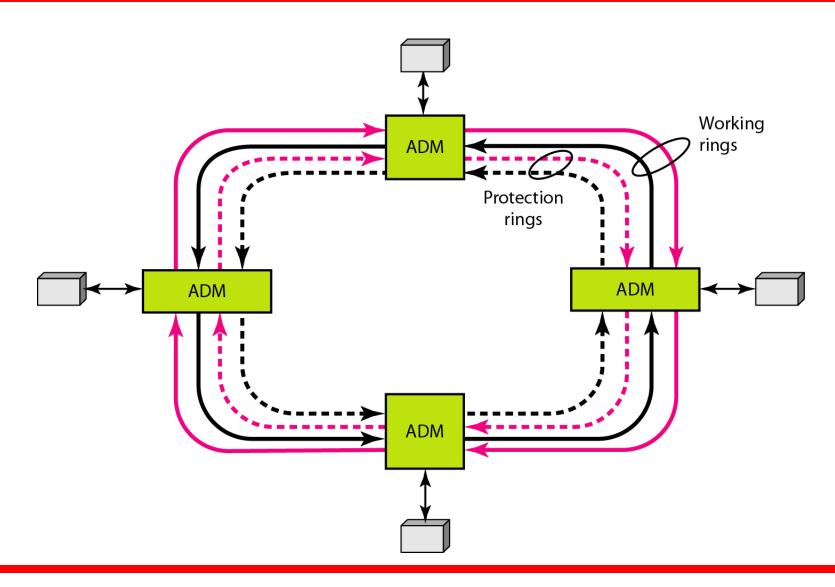
#### Figure 17.20 Automatic protection switching in linear networks



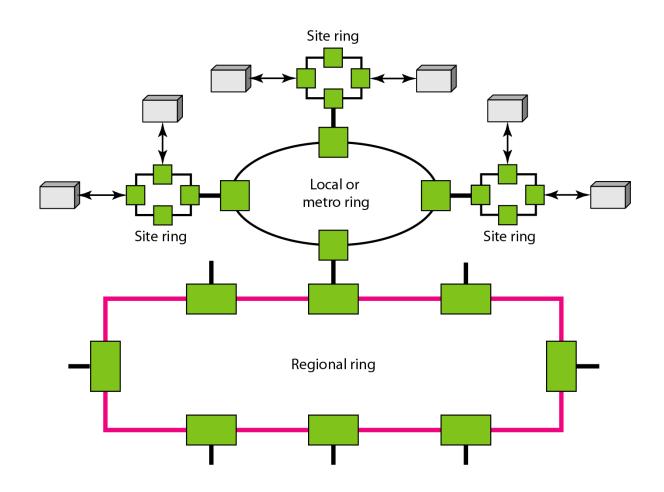
# Figure 17.21 A unidirectional path switching ring



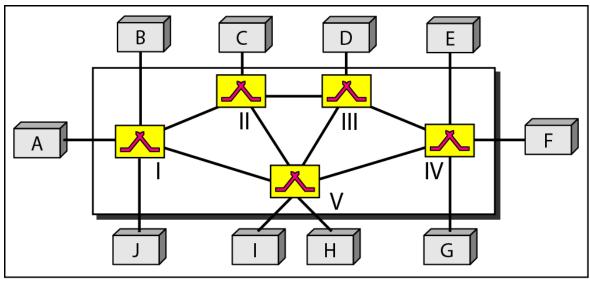
# Figure 17.22 A bidirectional line switching ring



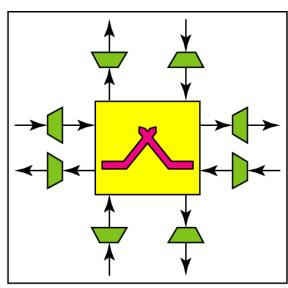
# Figure 17.23 A combination of rings in a SONET network



# Figure 17.24 A mesh SONET network



a. SONET mesh network



b. Cross-connect switch

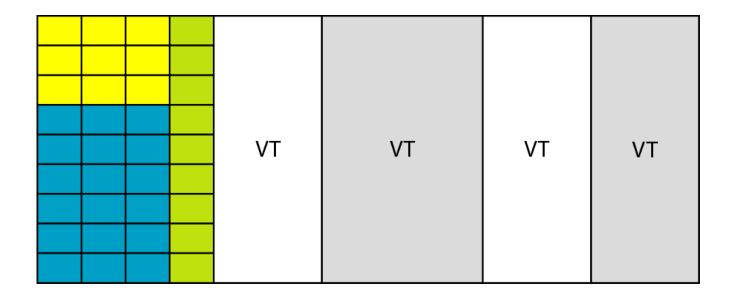
# 17-6 VIRTUAL TRIBUTARIES

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