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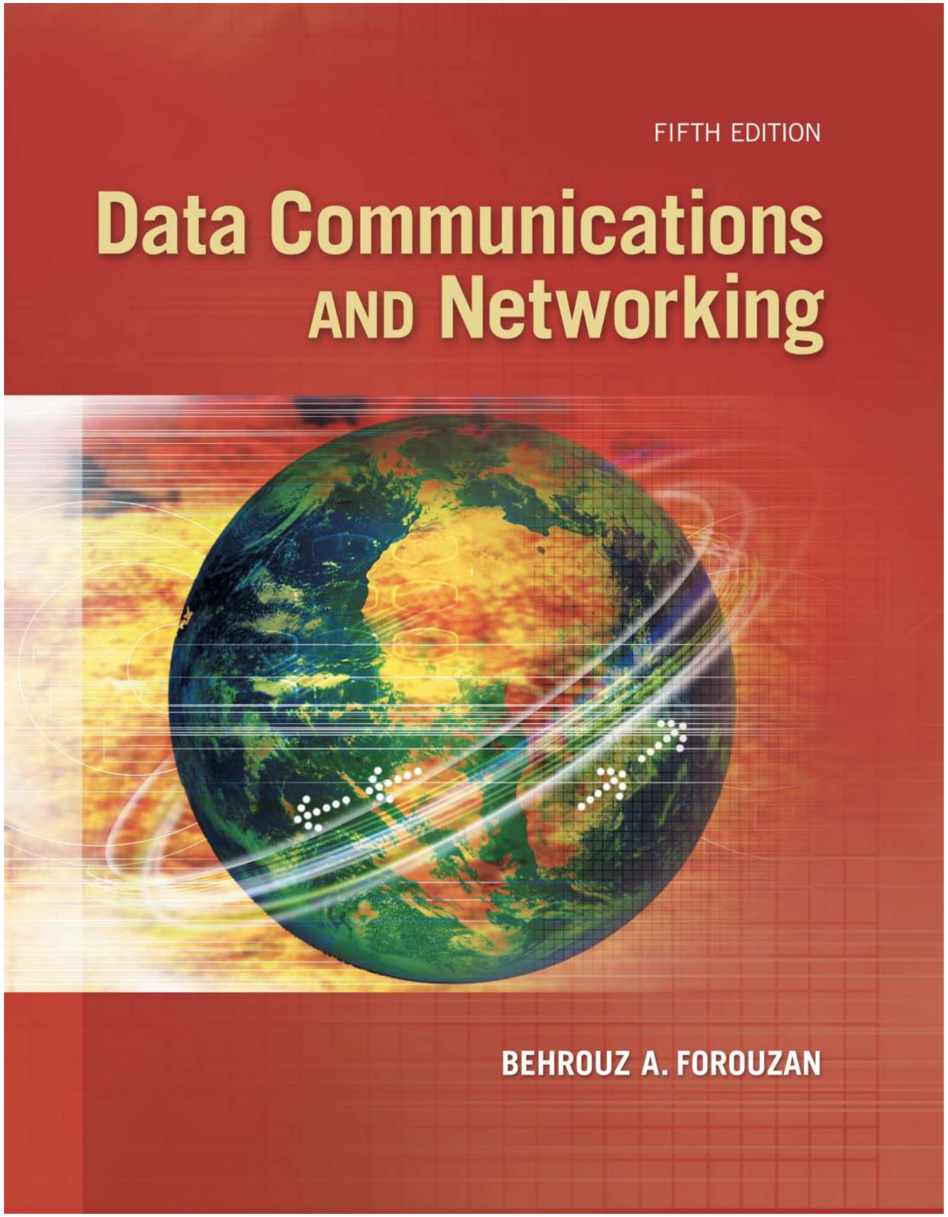
Chapter 14

Other Wired Networks



Chapter 14: Outline

14.1 TELEPHONE NETWORKS

14.2 CABLE NETWORKS

14.3 SONET

14.4 ATM

Chapter 14: Objective

- ***The first section discusses the telephone network. It describes the telephone network as a voice network. It then shows how the voice network has been used for data transmission either as a dial-up service or DSL service.***

- ***The second section discusses the cable network. It first briefly describes it as a video network. The section then shows how the video network has been used for data transmission.***

- ***The third section discusses SONET, both as a fiber-optic technology and a network. The section shows how the technology can be used for high-speed connection to carry data.***

- ***The fourth section discusses PTN, which can replace SONET as the carrier to create a high-speed wide area network (WAN). PTN is a Packet based network that uses a Ethernet frame as the unit of transmitted data.***

14-1 TELEPHONE NETWORK

The telephone network had its beginnings in the late 1800s. The entire network was originally an analog system using analog signals to transmit voice. With the advent of the computer era, the network, in the 1980s, began to carry data in addition to voice. During the last decade, the telephone network has undergone many technical changes. The network is now digital as well as analog.

Figure 14. 1: A telephone system

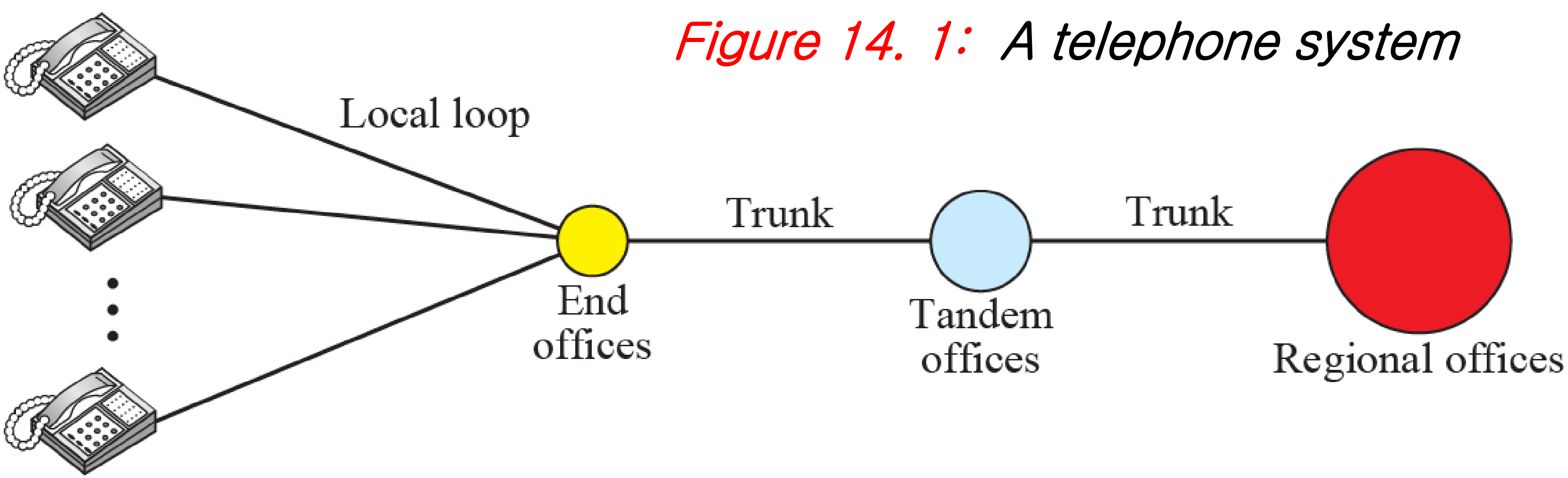
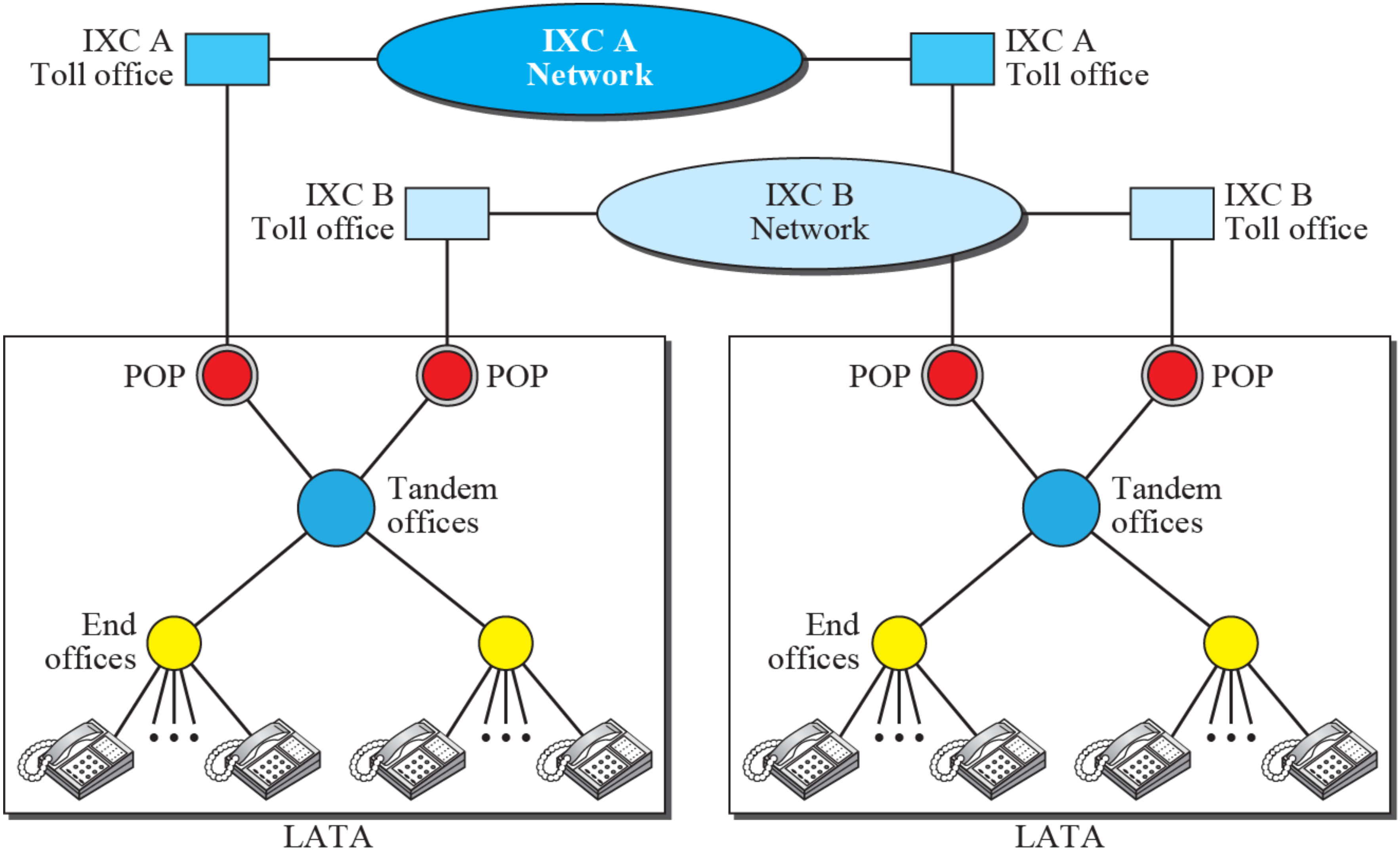


Figure 14. 3: Points of presence (POPs)



14.14.3 Signaling

The telephone network, at its beginning, used a circuit-switched network with dedicated links to transfer voice communication. The operator connected the two parties by using a wire with two plugs inserted into the corresponding two jacks. Later, the signaling system became automatic. Rotary telephones were invented that sent a digital signal defining each digit in a multi-digit telephone number. As telephone networks evolved into a complex network, the functionality of the signaling system increased. The signaling system was required to perform other tasks.

Figure 14. 4: Data transfer and signaling network

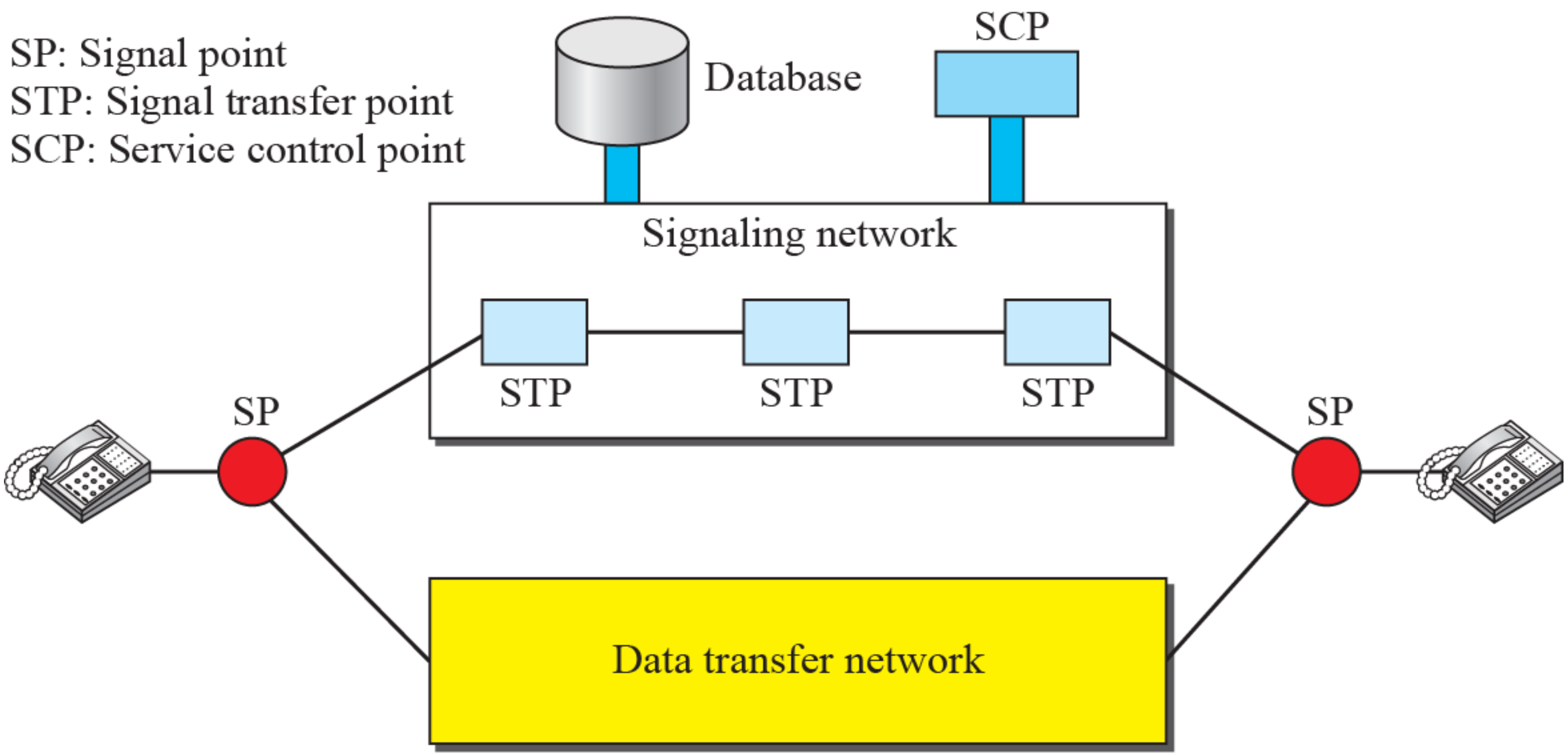
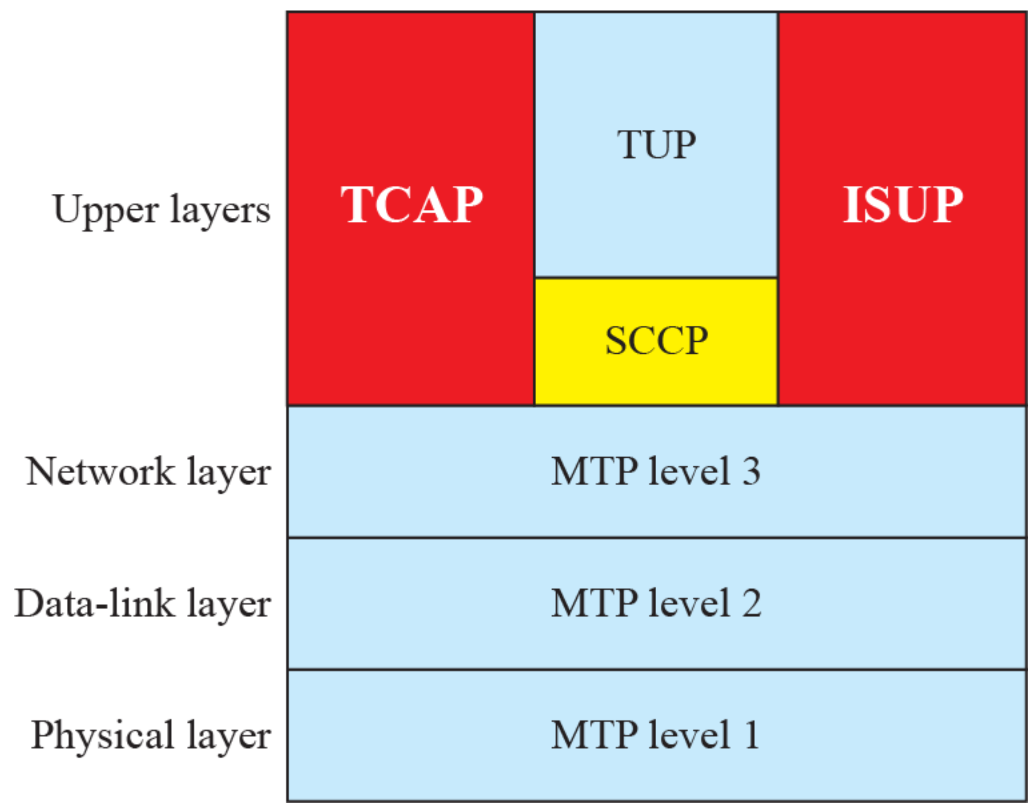


Figure 14. 5: Layers in SS7

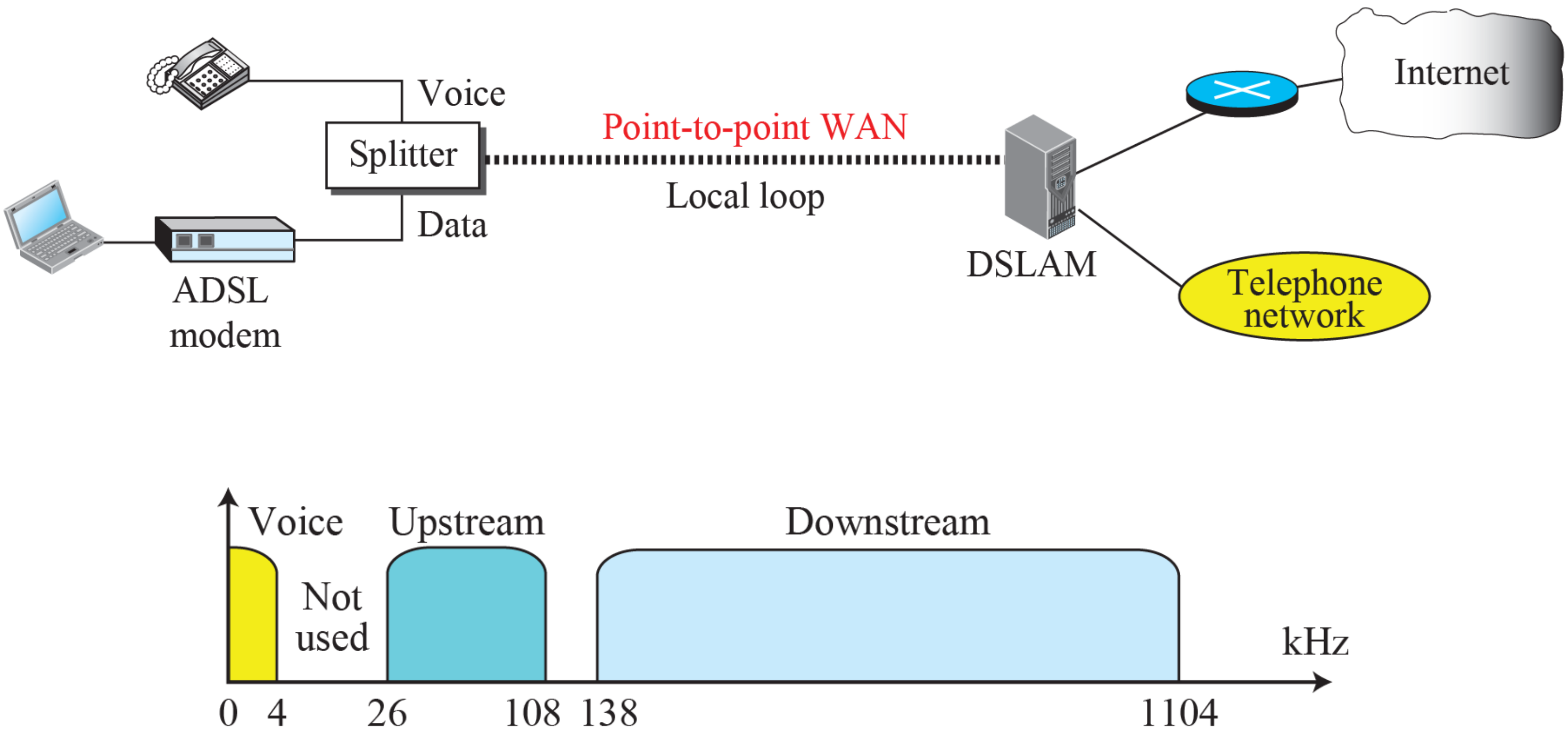
MTP: Message transfer part
SCCP: Signaling connection control point
TCAP: Transaction capabilities application port
TUP: Telephone user port
ISUP: ISDN user port



14.14.6 Digital Subscriber Line (DSL)

After traditional modems reached their peak data rate, telephone companies developed another technology, DSL, to provide higher-speed access to the Internet. Digital subscriber line (DSL) technology is one of the most promising for supporting high-speed digital communication over the existing telephone. DSL technology is a set of technologies, each differing in the first letter (ADSL, VDSL, HDSL, and SDSL).

Figure 14.9: ASDL point-to-point network



14-3 SONET

In this section, we introduce a wide area network (WAN), SONET, that is used as a transport network to carry loads from other WANs. We first discuss SONET as a protocol, and we then show how SONET networks can be constructed from the standards defined in the protocol.

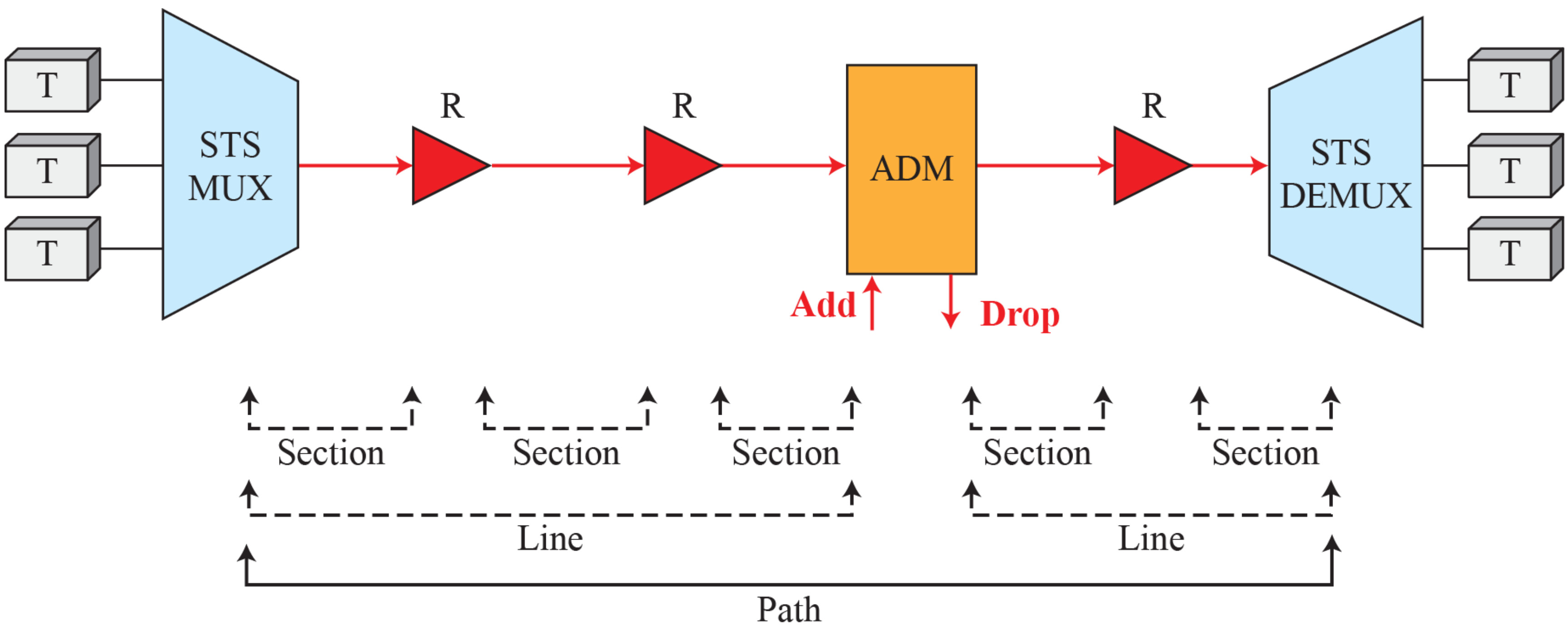
14.3.1 Architecture

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

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 14.14: A simple network using SONET equipment

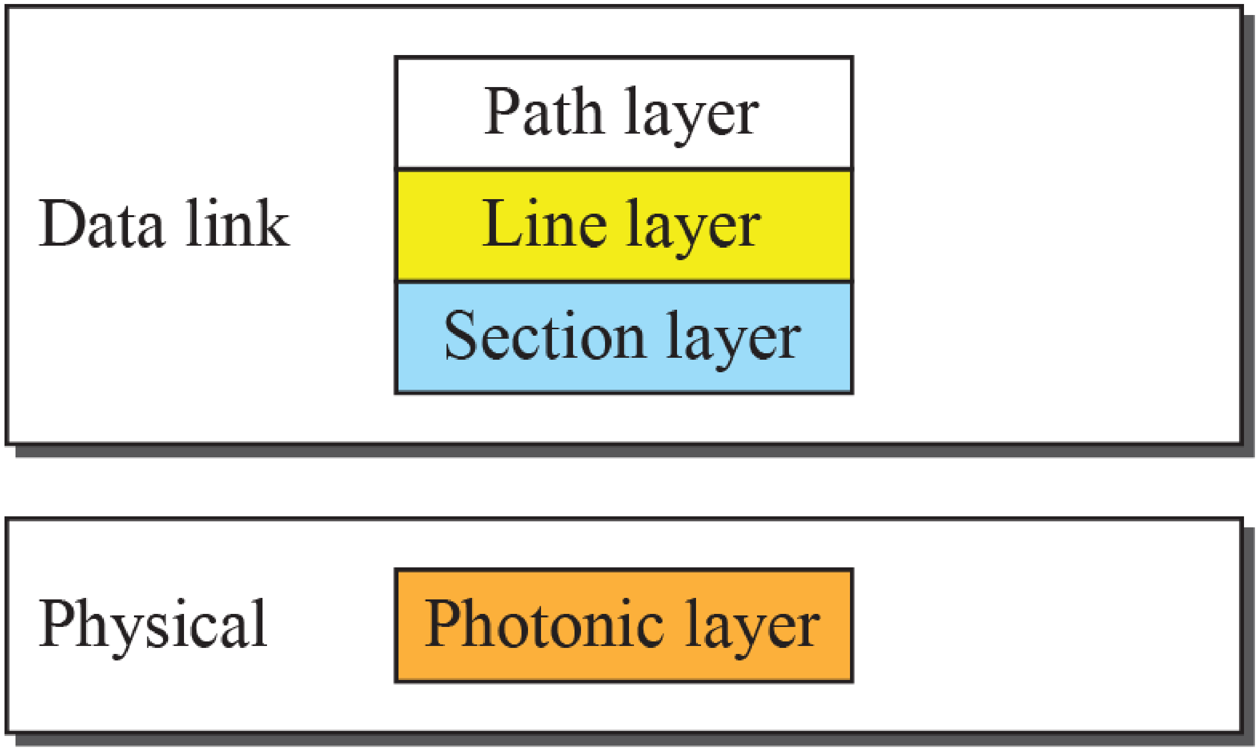
ADM: Add/drop multiplexer
STS MUX: Synchronous transport signal multiplexer
STS DEMUX: Synchronous transport signal demultiplexer
R: Regenerator
T: Terminal



14.3.2 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 (see Figure 14.15). The headers added to the frame at the various layers are discussed later in this chapter.

Figure 14.15: SONET layers compared with OSI or the Internet layers



14.3.3 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. For example, an STS-1 frame is 9 rows by 90 columns (810 bytes), and an STS-3 is 9 rows by 270 columns (2430 bytes). Figure 14.17 shows the general format of an STS-1 and an STS-n.

Figure 14.16: Device–Layer relationship in SONET

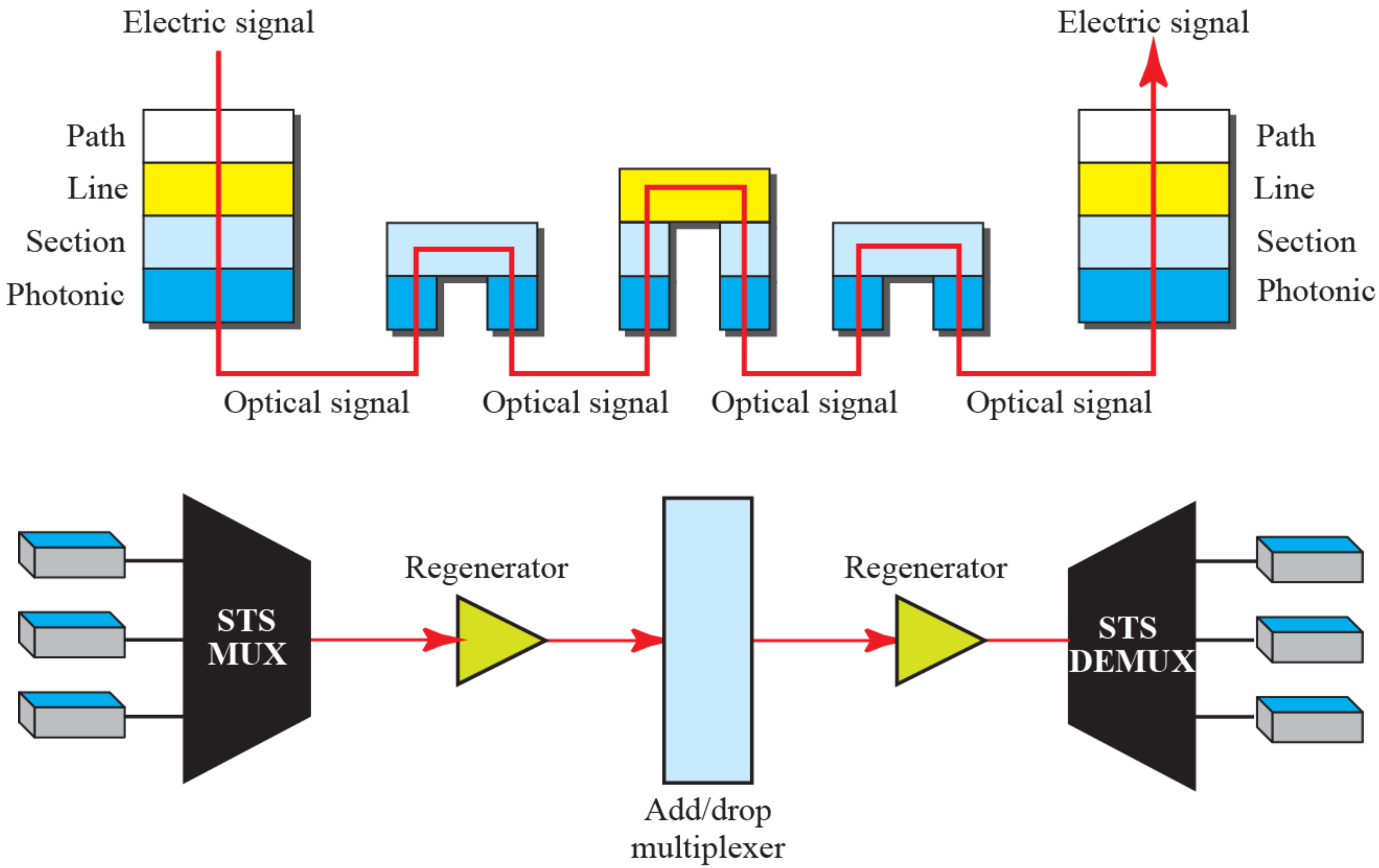


Figure 14.17: An STS–1 and an STS–n frame

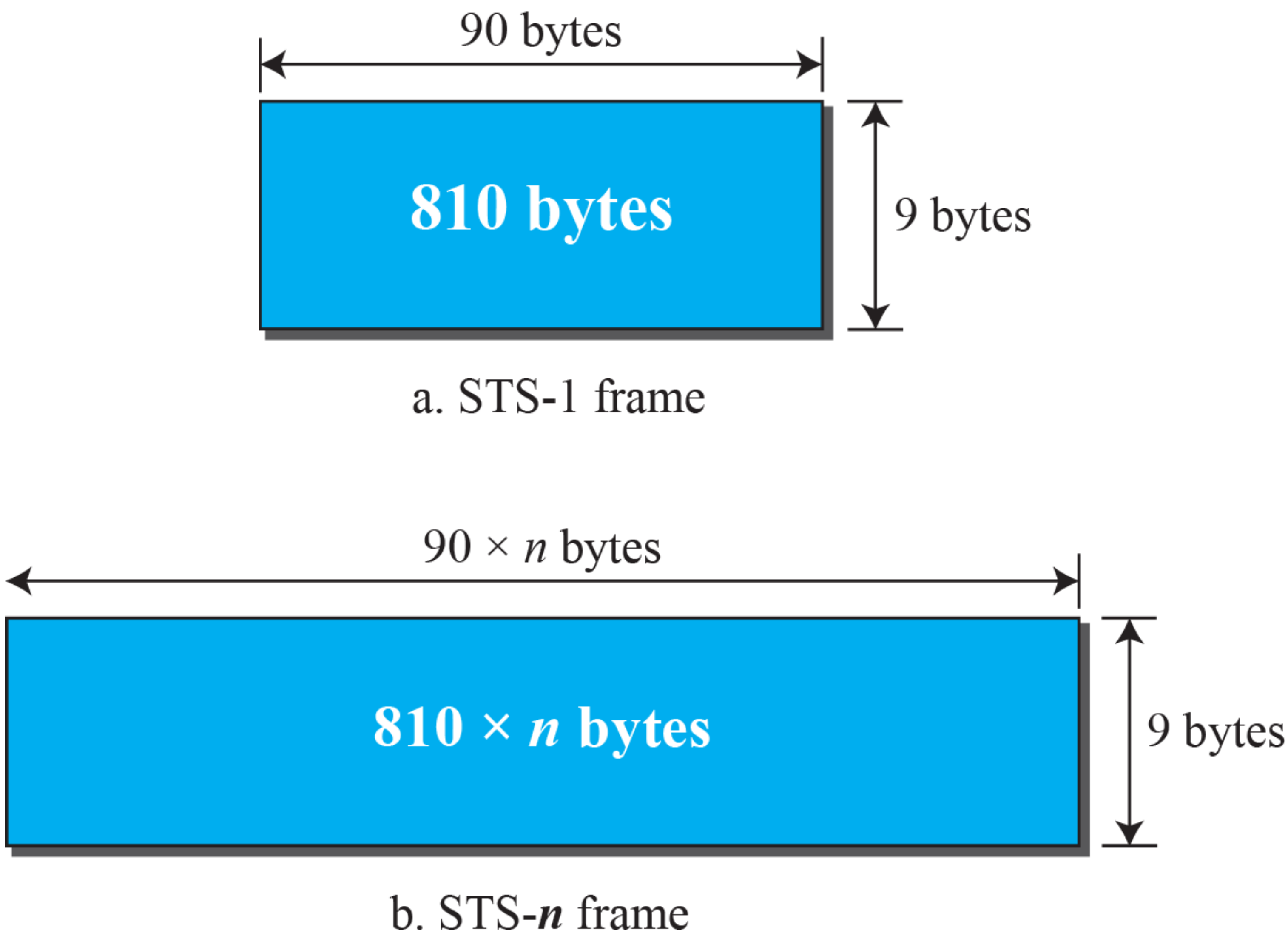
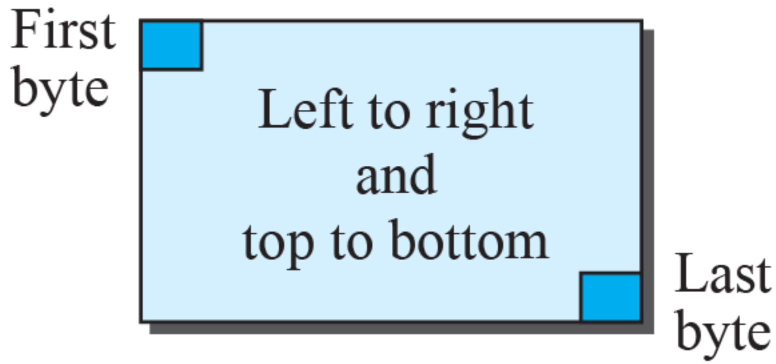
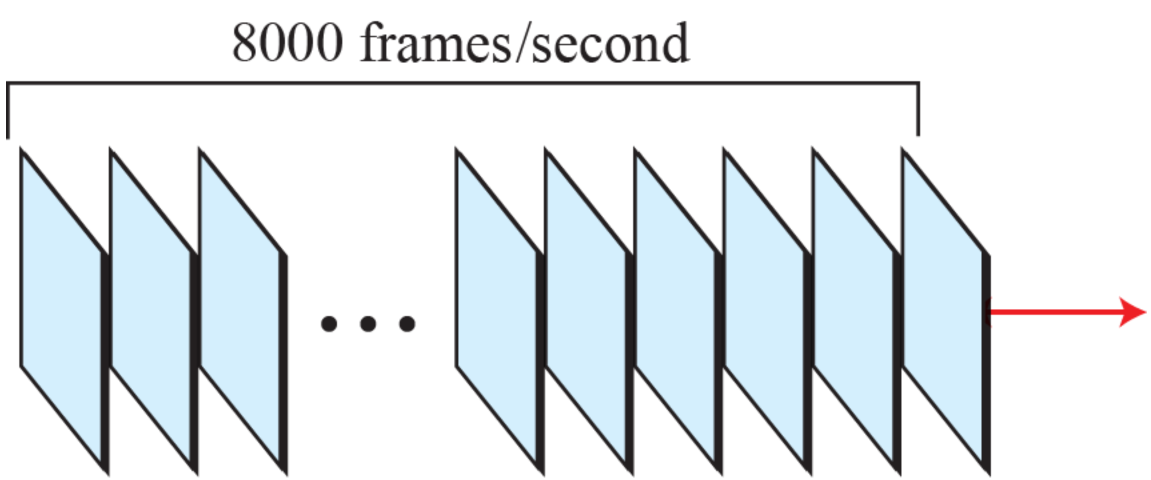


Figure 14.18: STS-1 frames in transition



a. Byte transmission



b. Frame transmission

Example 14.1

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 14.2

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

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

Example 14.3

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.

Figure 14.19: STS-1 frame overheads

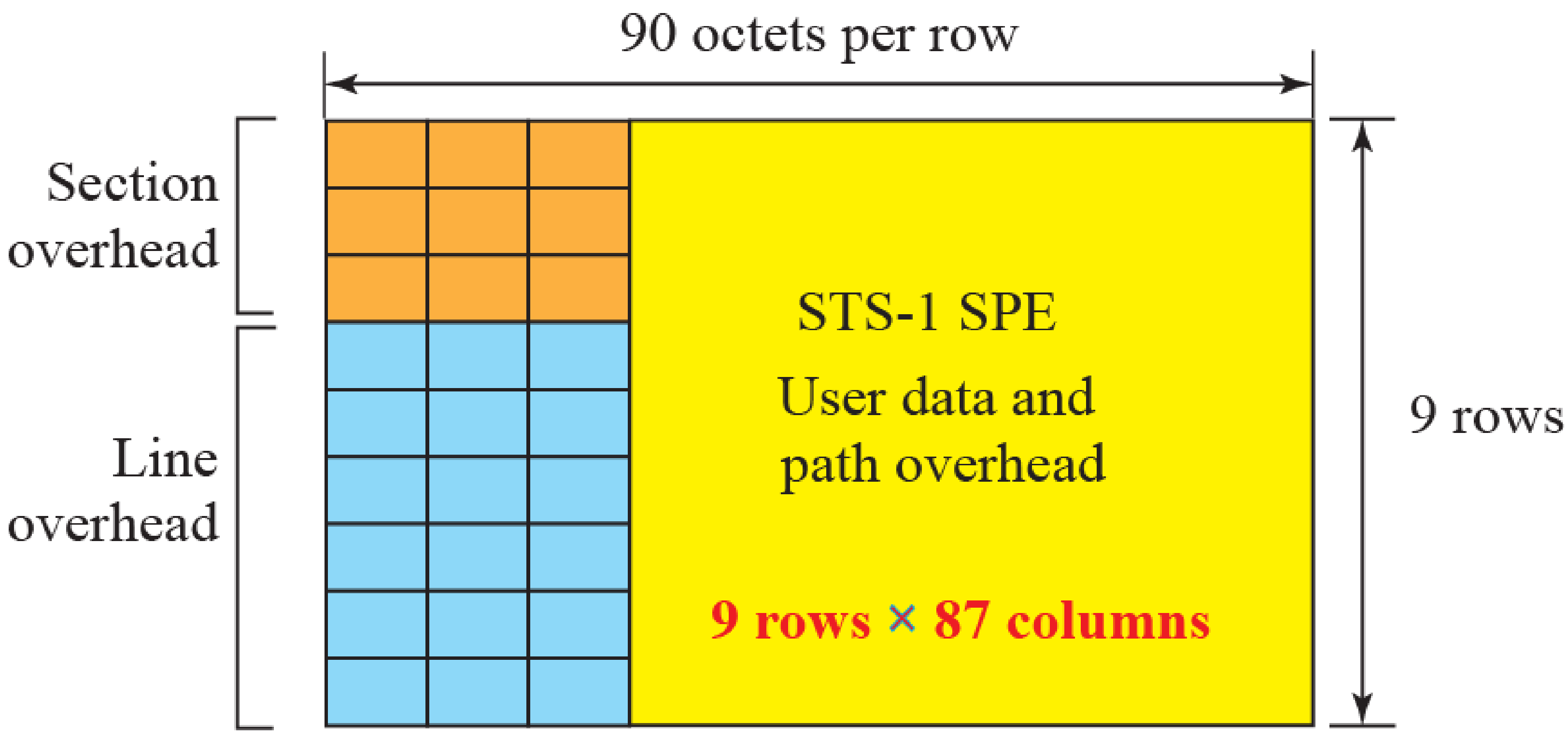


Figure 14.20: STS-1 frame: section overheads

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

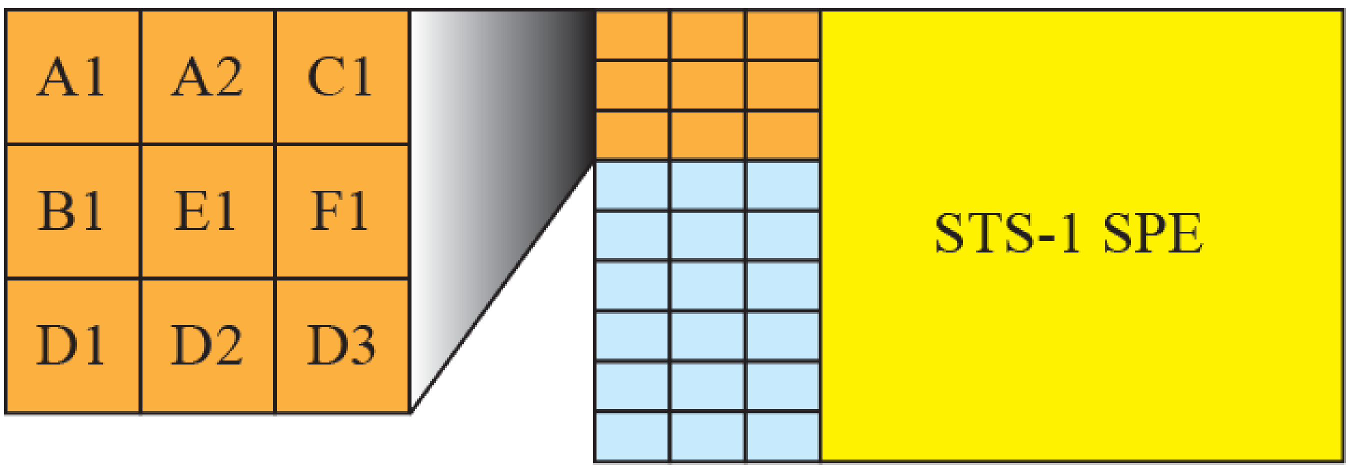


Figure 14.21: STS-1 frame: line overhead

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)

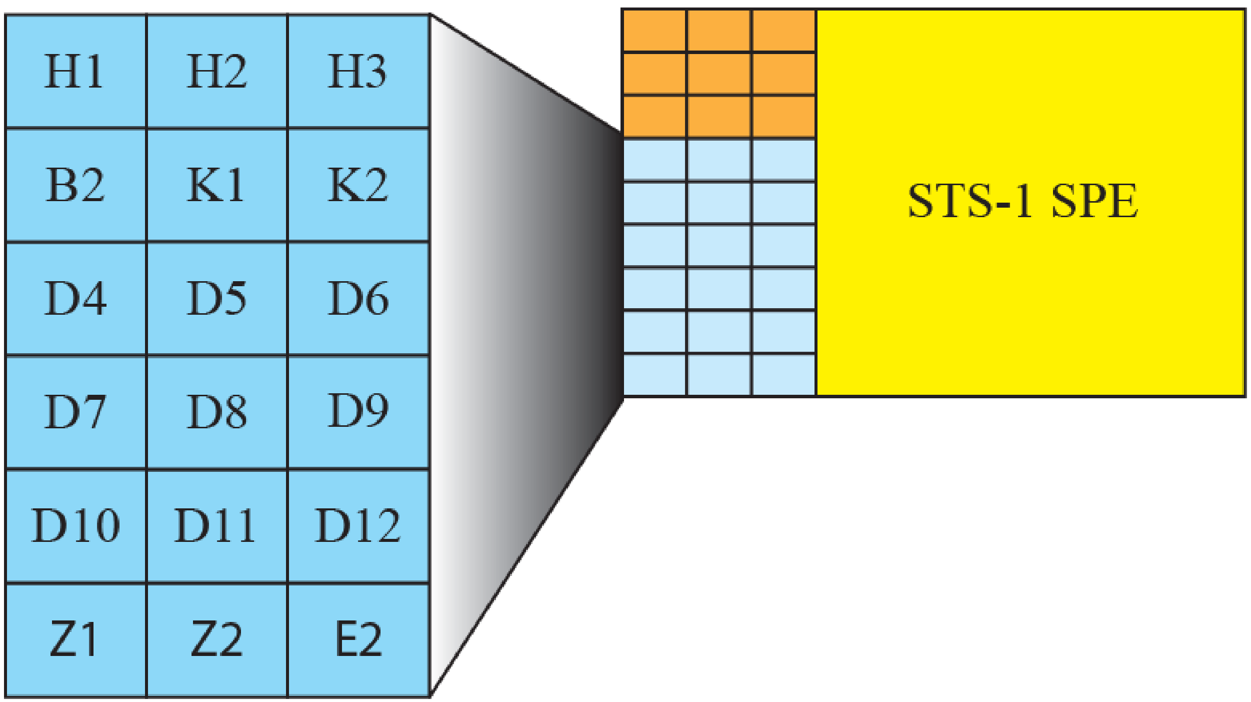


Figure 14.22: STS-1 frame path overhead

B3: **Path parity byte**

C2: **Path signal label byte**

F2: **Path user channel byte**

G1: **Path status byte**

H4: **Multiframe indicator**

J1: **Path trace byte**

Z3, Z4, Z5: **Growth bytes (reserved)**

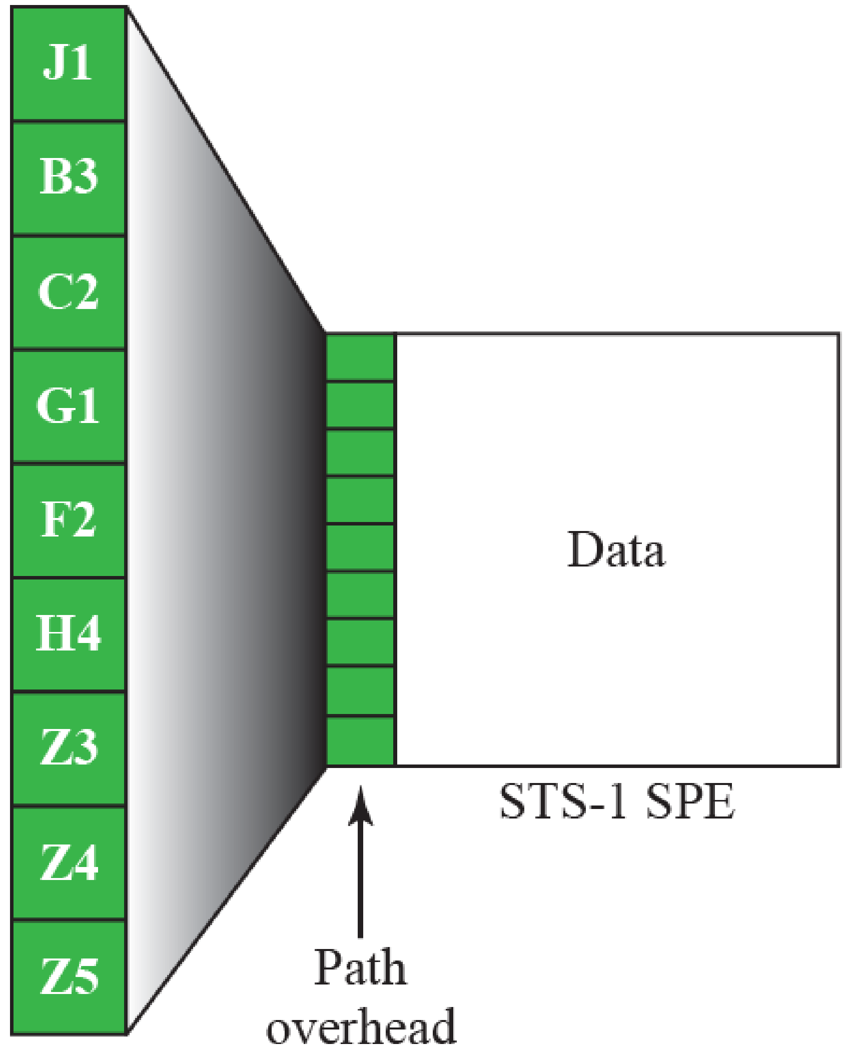


Table 14.2: SONETs overhead

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 14.4

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

Solution

The user data part of 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 14.23: Offsetting of SPE related to frame boundary

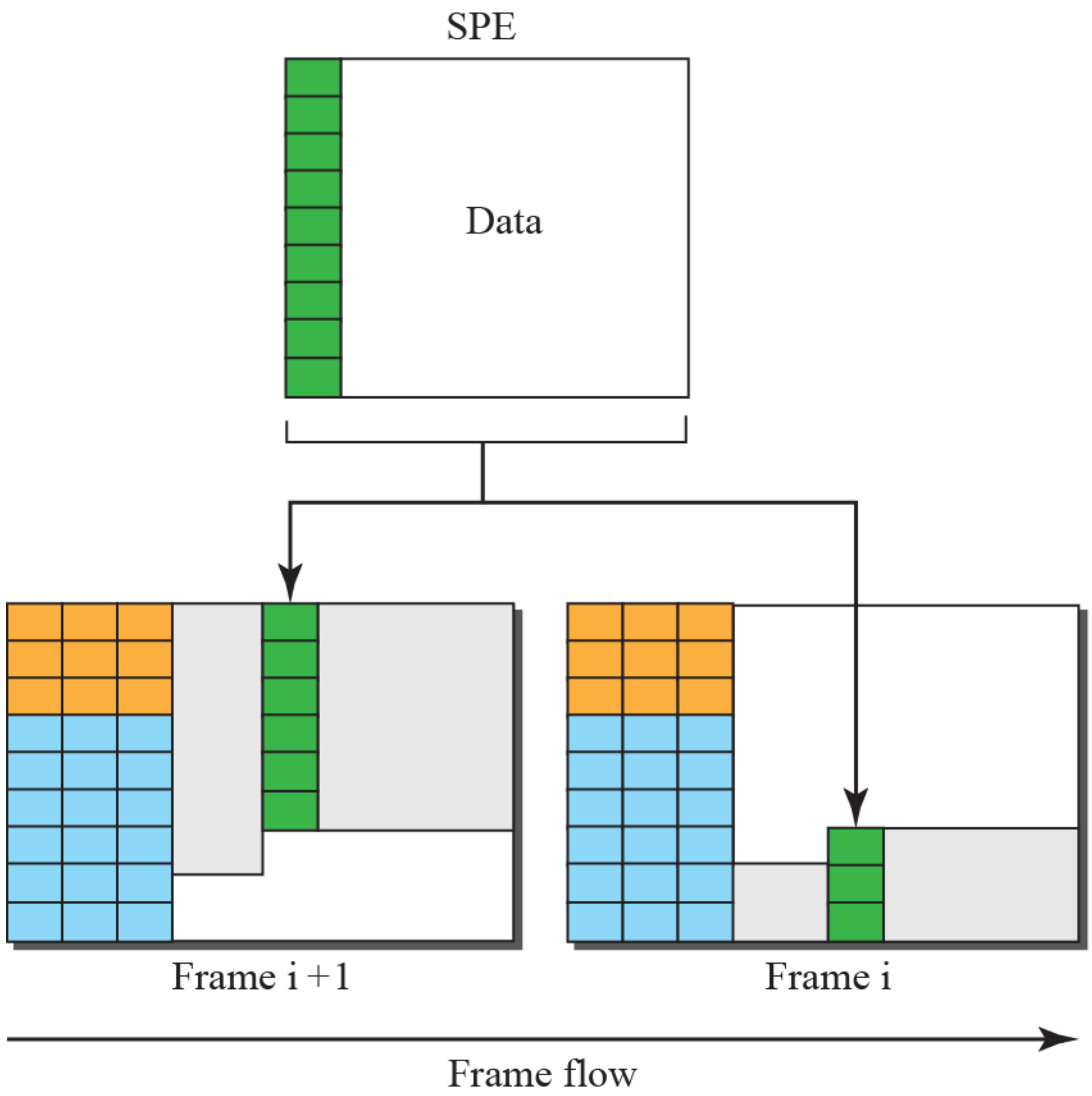
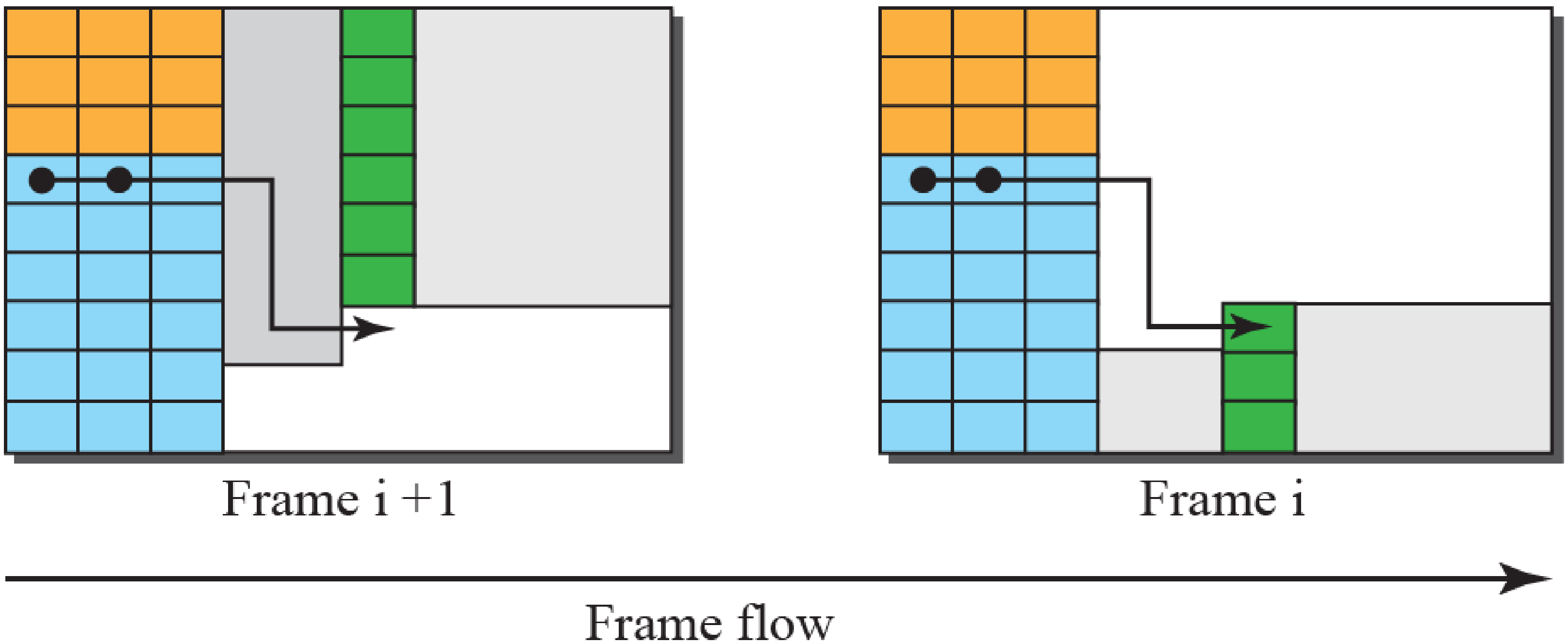


Figure 14.24: The use of H1 and H2 to show the start of SPE



Example 14.5

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.

14.3.4 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, as shown in Figure 14.25.

Figure 14.25: STS multiplexing/demultiplexing

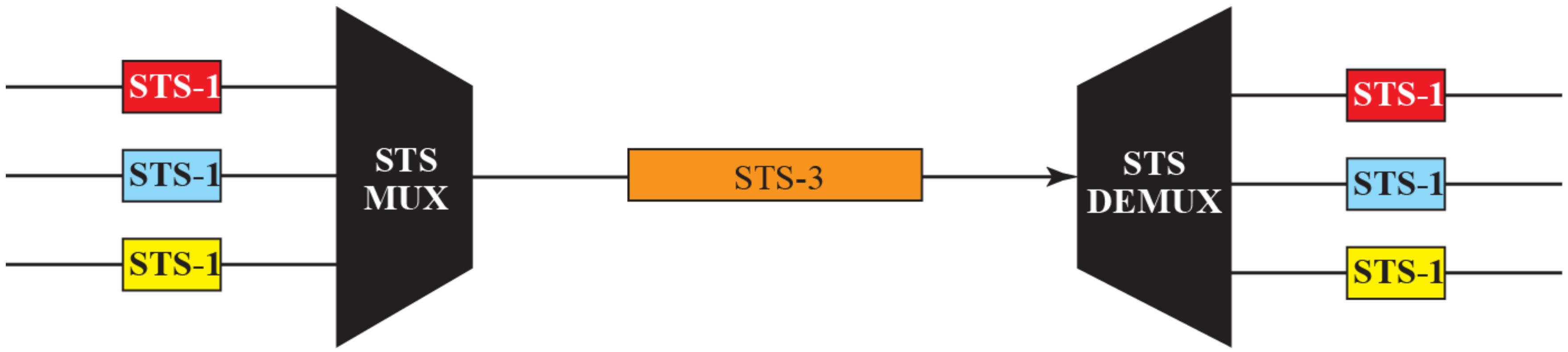


Figure 14.26: Byte interleaving

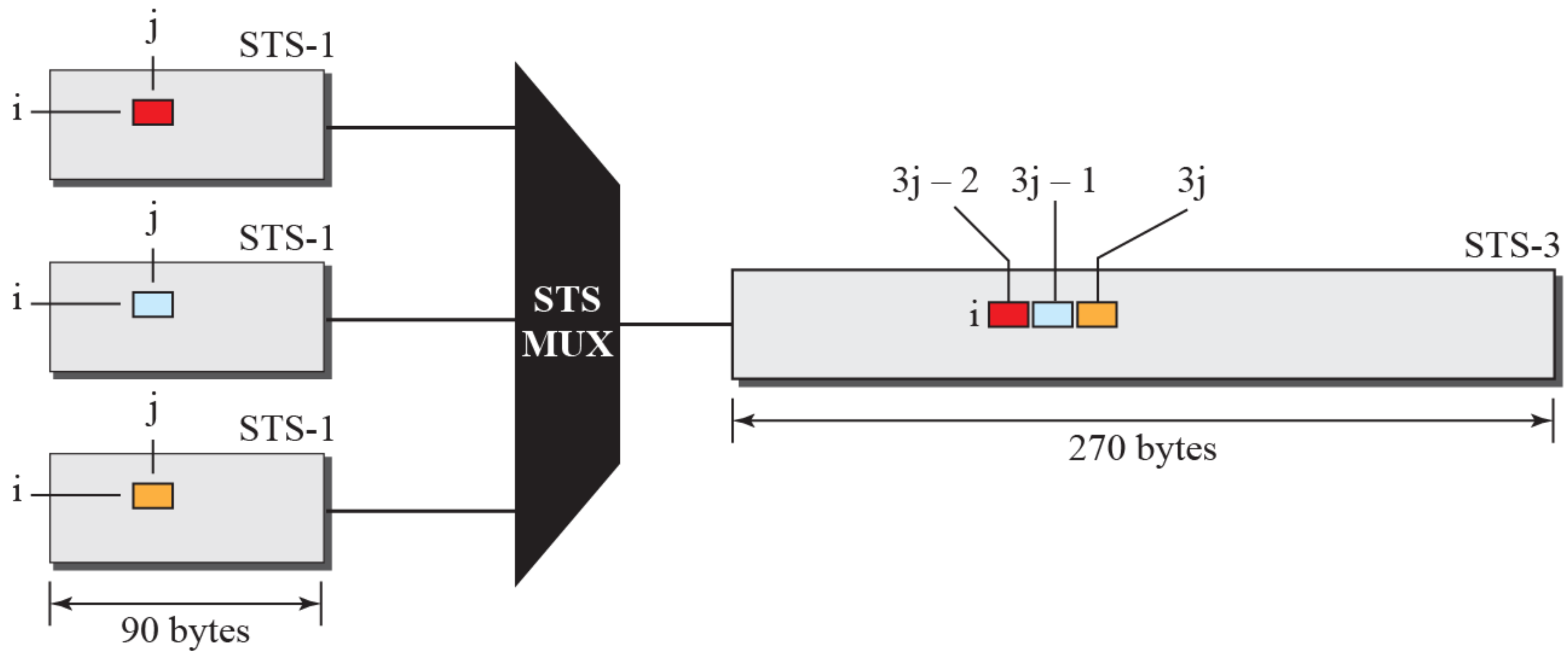


Figure 14.27: An STS-3 frame

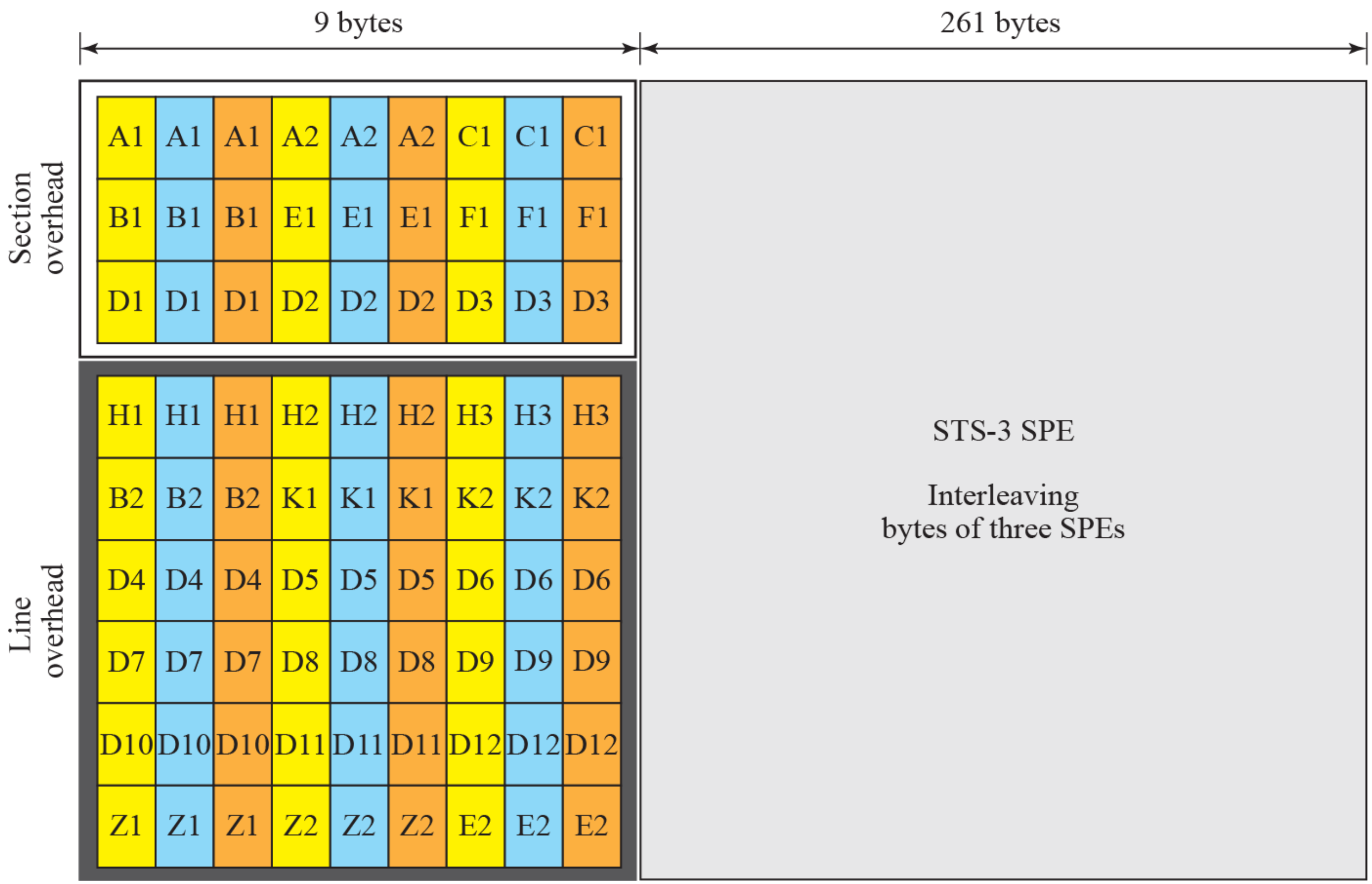


Figure 14.28: A concatenated STS-3c signal

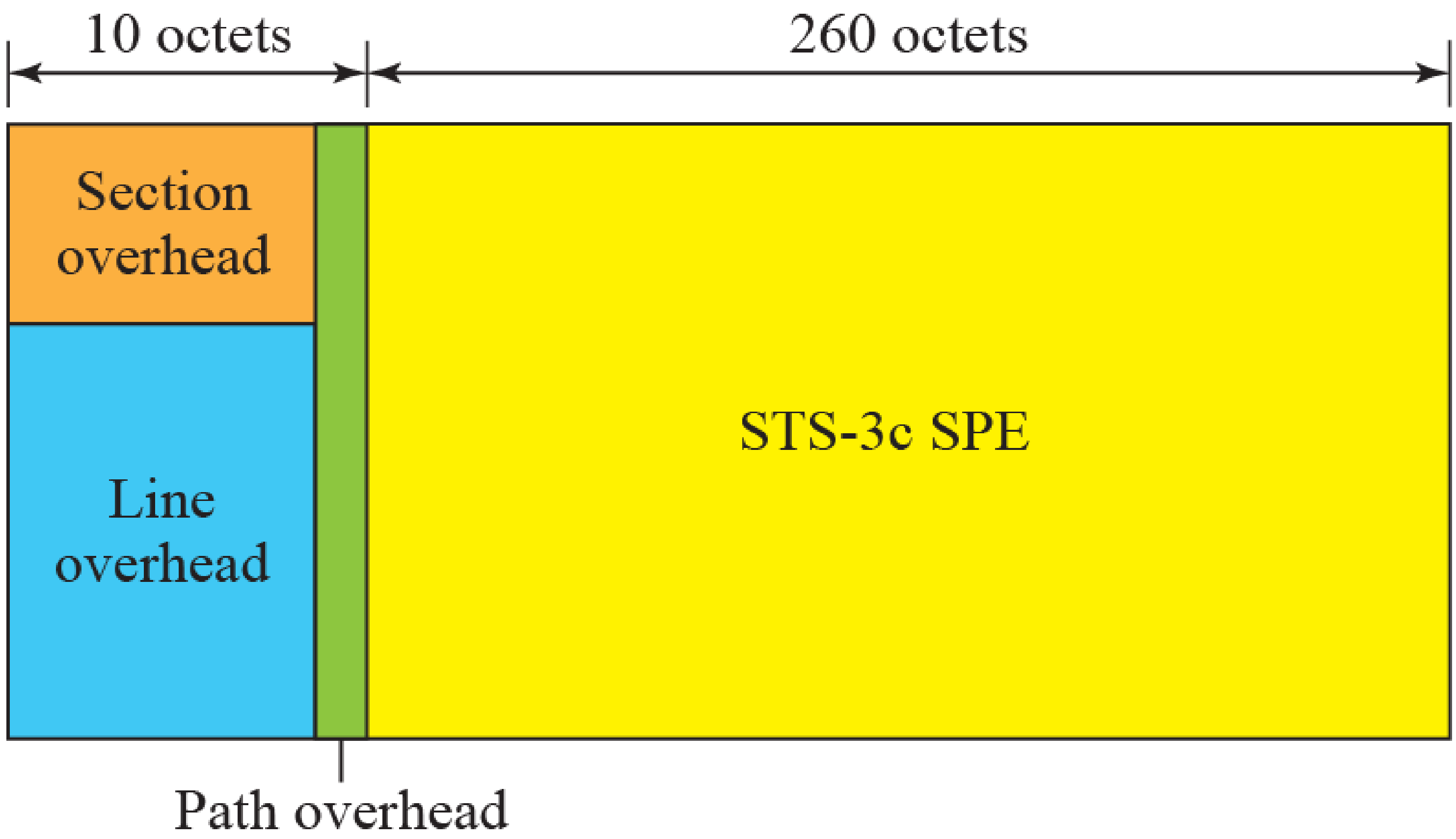
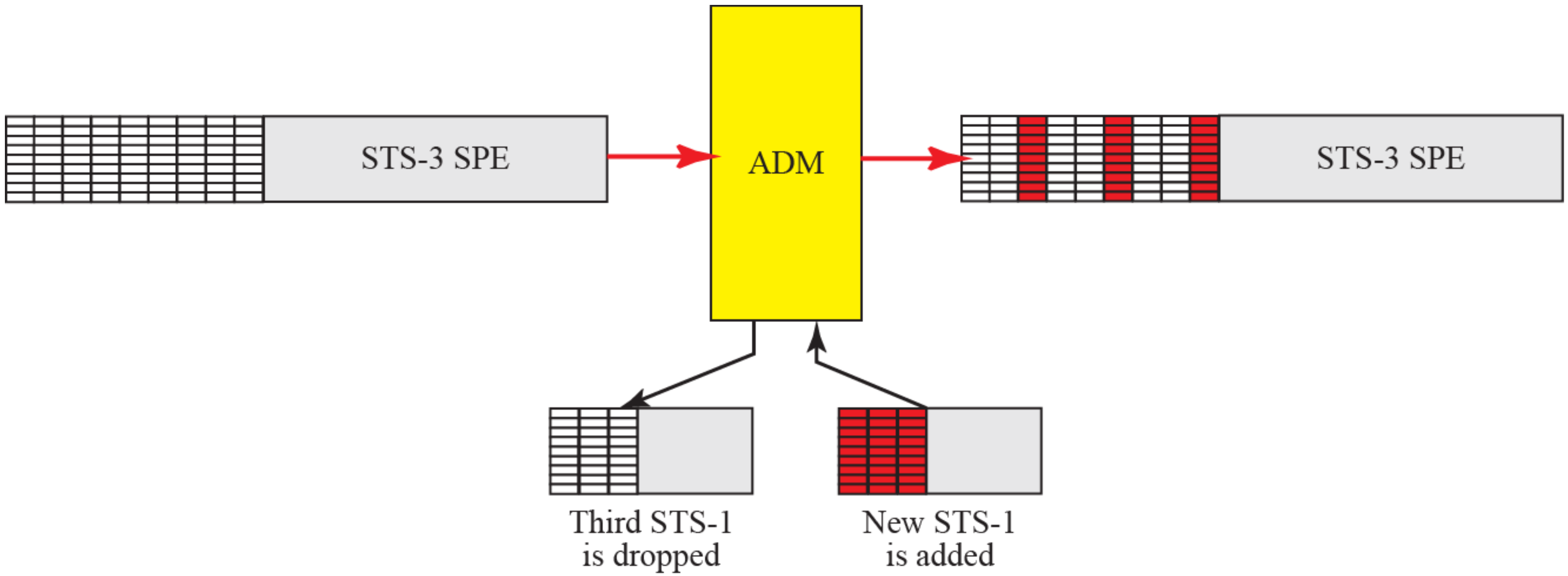


Figure 14.29: Dropping and adding frames in an add/drop multiplexer



14.3.5 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 such as ATM (Section 14.4) or IP (Chapter 19). We can roughly divide SONET networks into three categories: linear, ring, and mesh networks, as shown in Figure 14.30..

Figure 14.30: Taxonomy of SONET networks

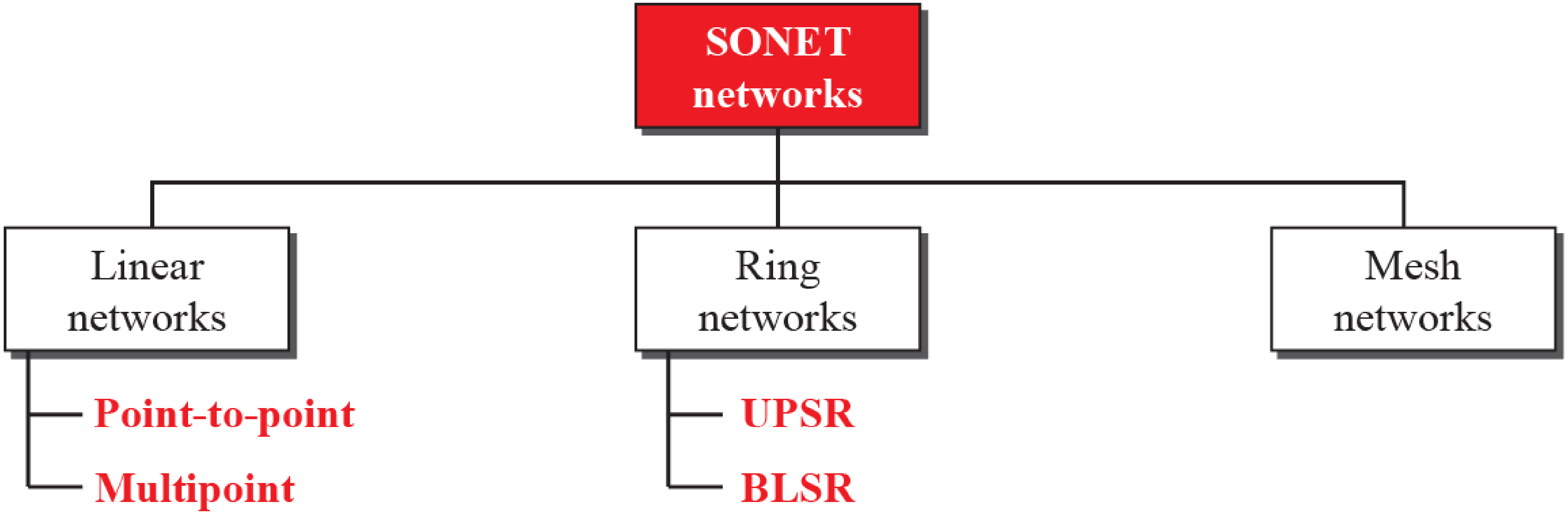


Figure 14.31: A point-to-point SONET network

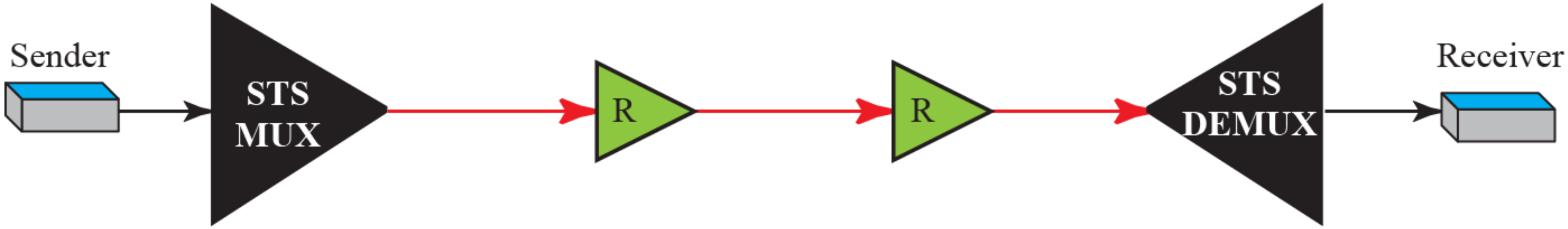


Figure 14.32: *A linear SONET network*

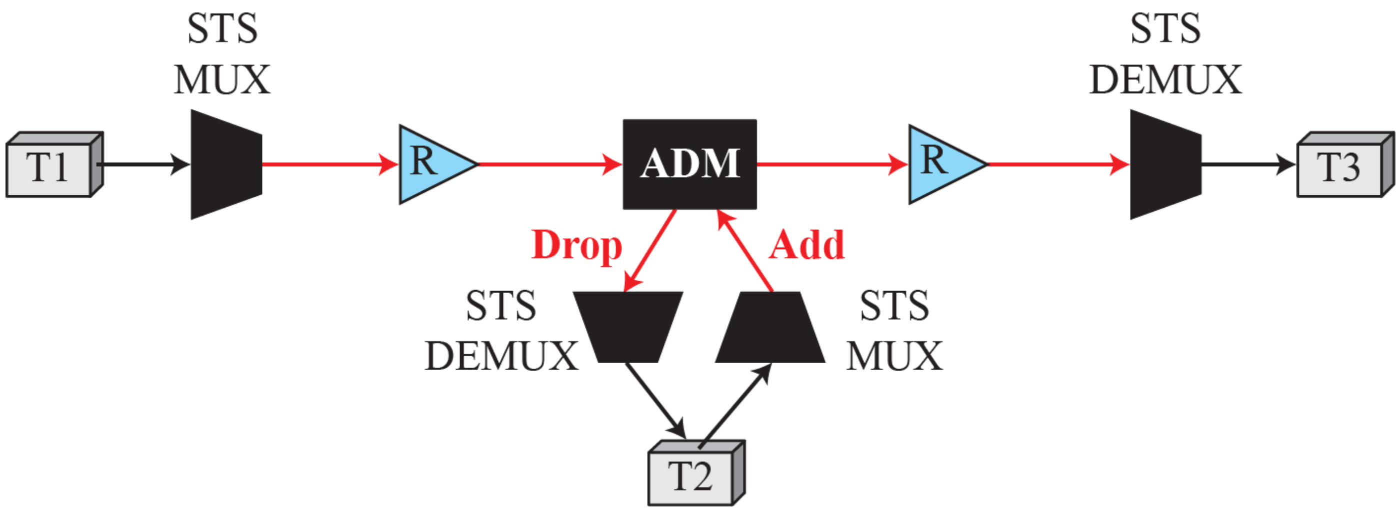
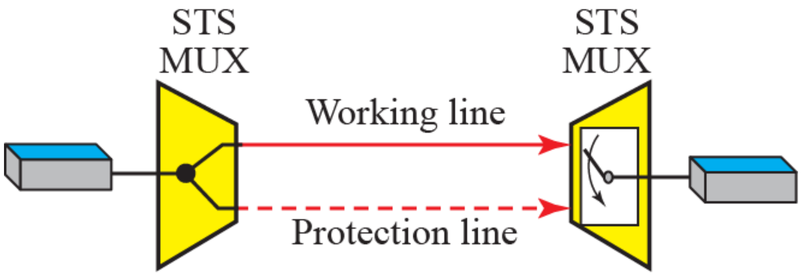
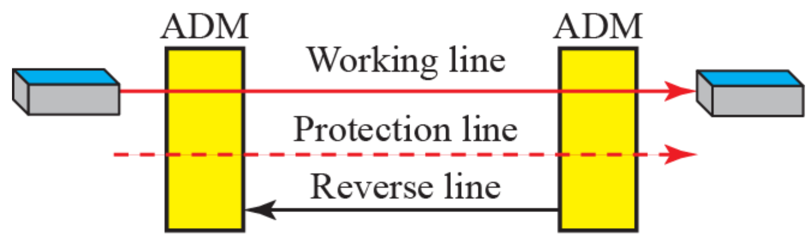


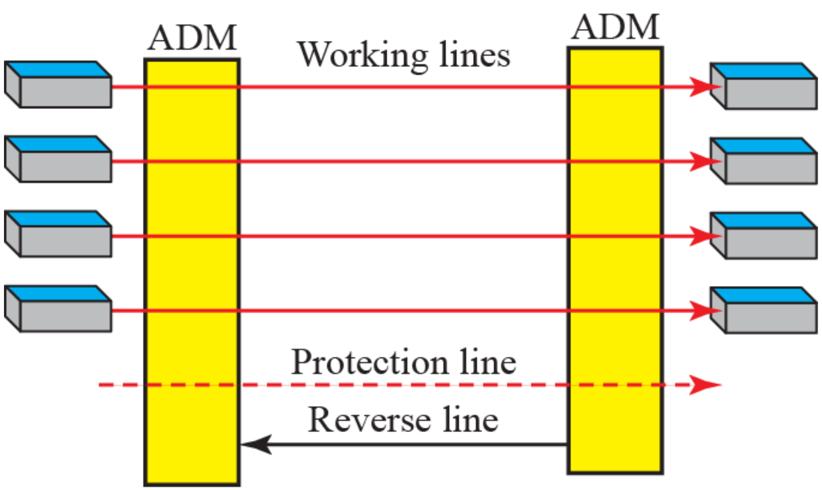
Figure 14.33: Automatic protection switching in linear networks



a. One-plus-one APS



b. One-to-one APS



c. One-to-many APS

Figure 14.34: A unidirectional path switching ring

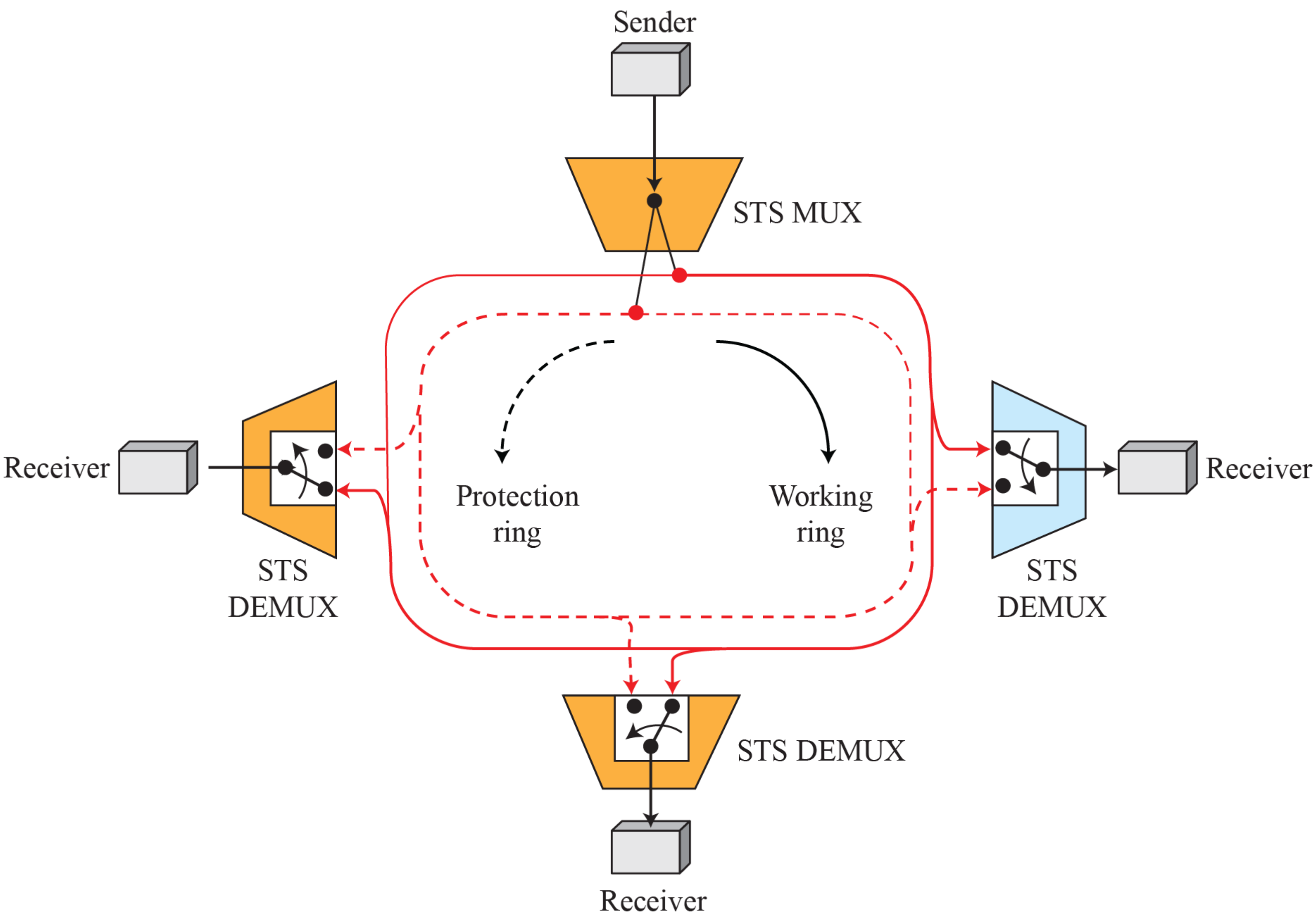


Figure 14.35: A bidirectional switching ring

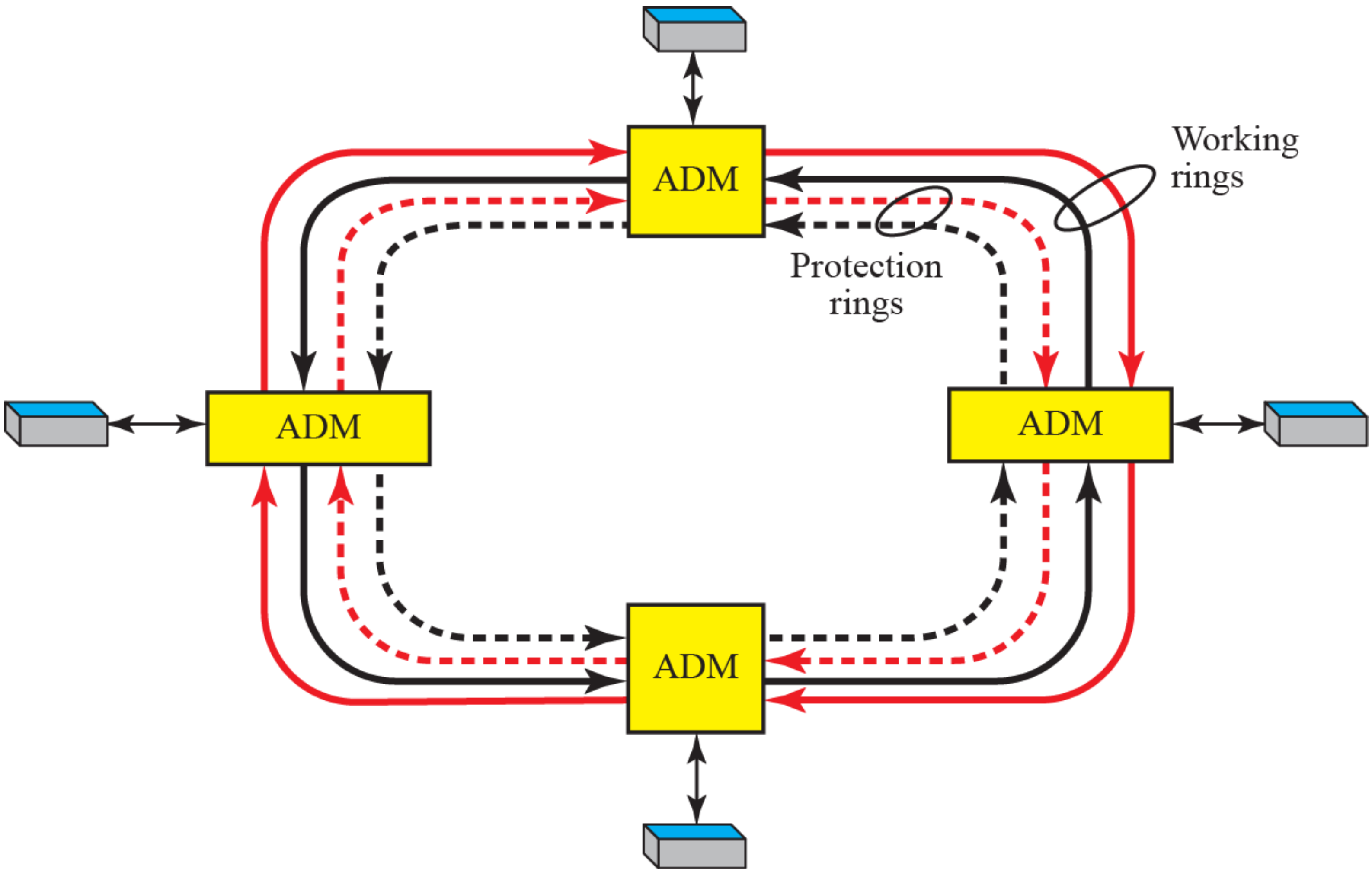


Figure 14. 36: A combination of rings

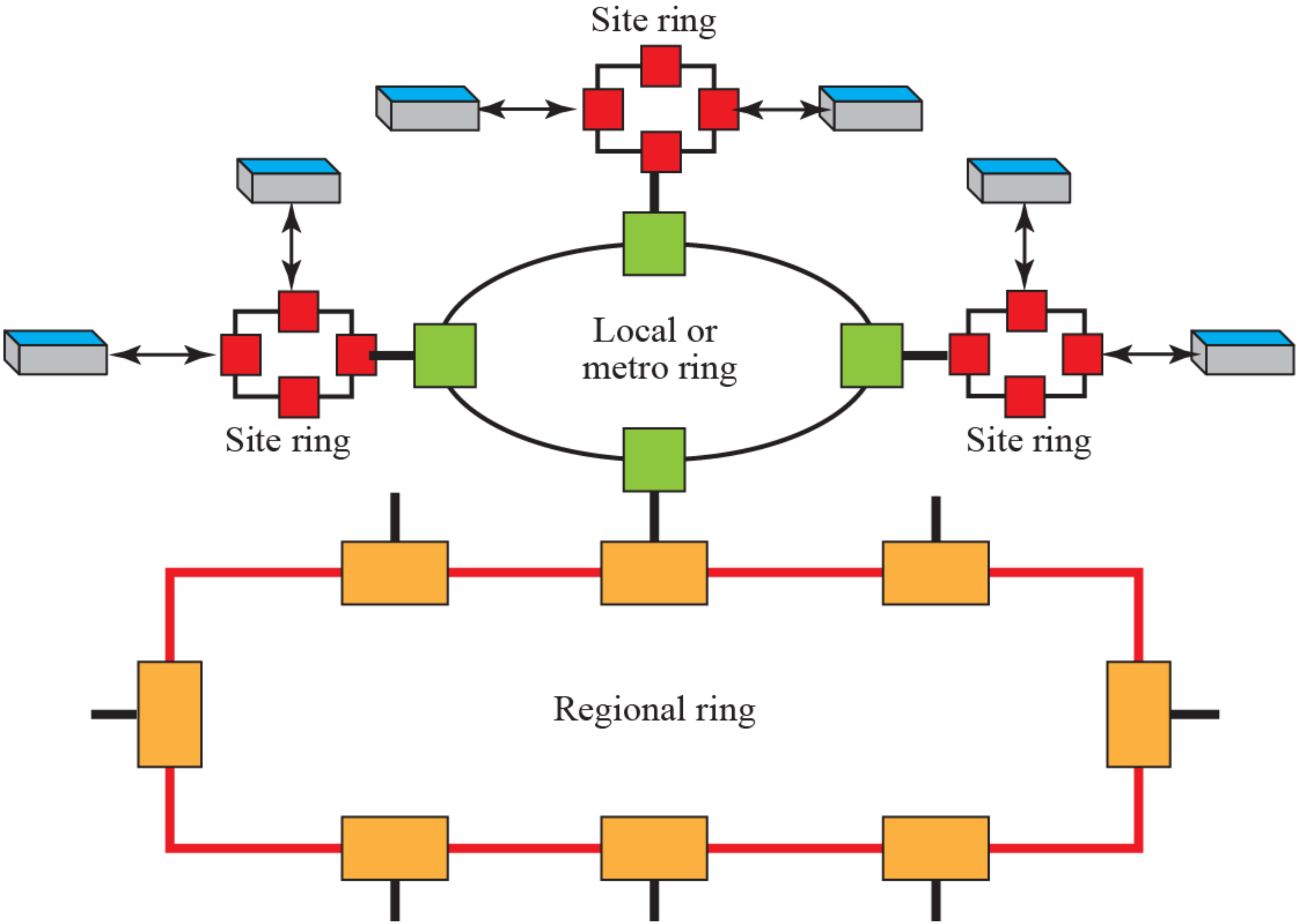
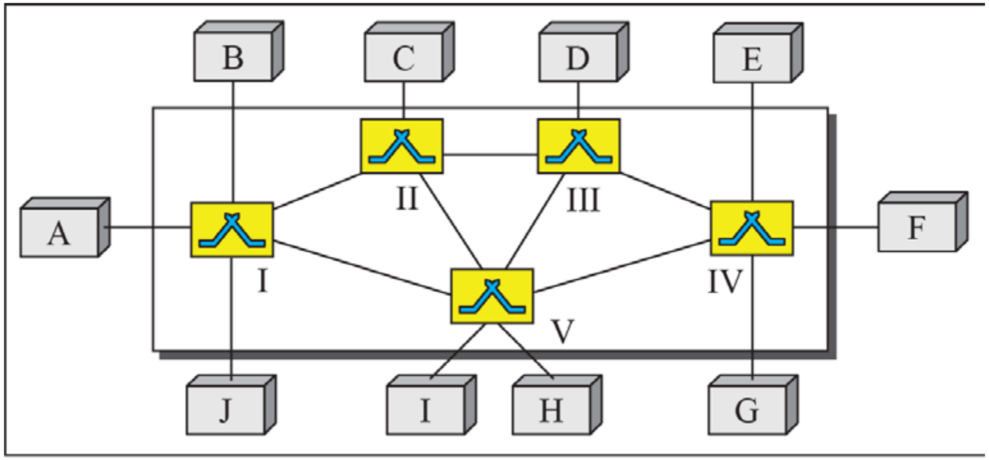
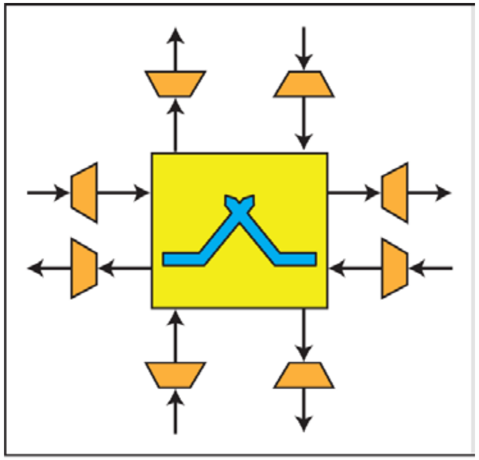


Figure 14.37: A mesh SONET network



a. SONET mesh network


b. Cross-connect switch

14.3.6 Virtual Tributaries

SONET is designed to carry broadband payloads. Current digital hierarchy data rates (DS-1 to DS-3), however, are lower than STS-14. To make SONET backward-compatible with the current hierarchy, its frame design includes a system of virtual tributaries (VTs) (see Figure 14.38). A virtual tributary is a partial payload that can be inserted into an STS-1 and combined with other partial payloads to fill out the frame. Instead of using all 86 payload columns of an STS-1 frame for data from one source, we can subdivide the SPE and call each component a VT.

Figure 14.38: Virtual tributaries

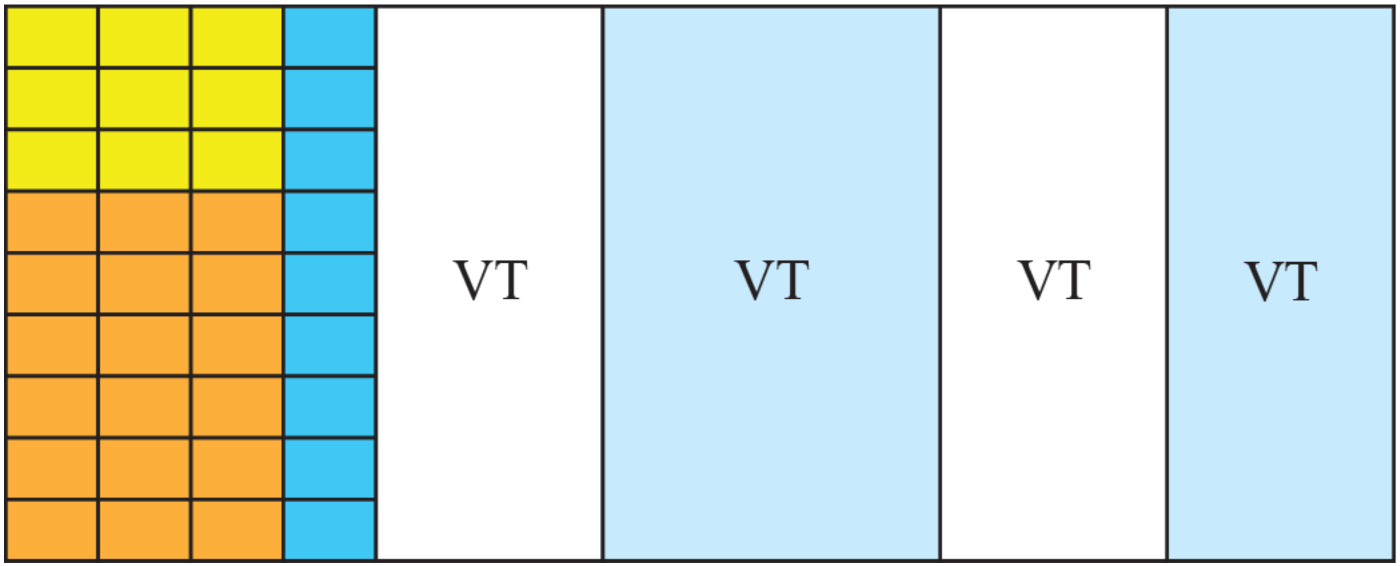
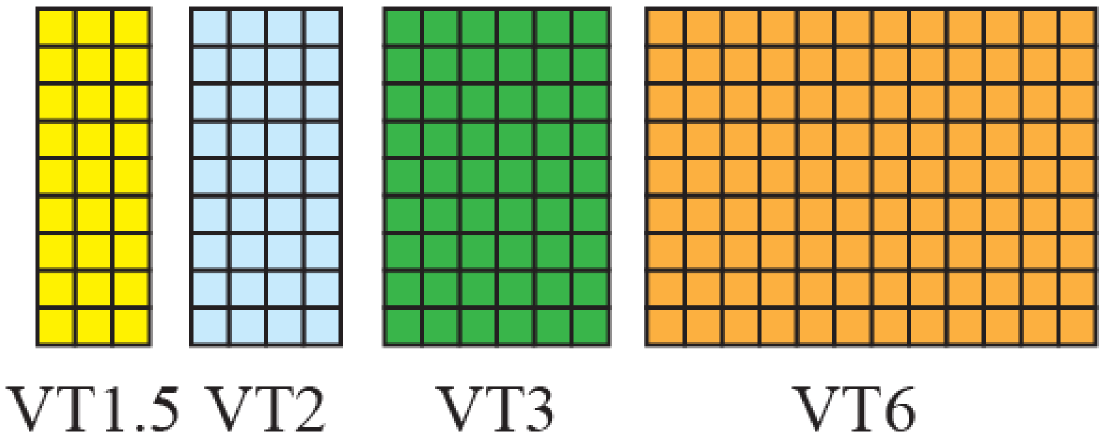


Figure 14.39: *Virtual tributary types*



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

Packet Transport Network

Ethernet Transport Network

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Mir Lab (MiRLab)
http://mir.hanyang.ac.kr/

Background: Ethernet Evolution Events

Effect: Carrier Ethernet becomes Leading Transport Technology

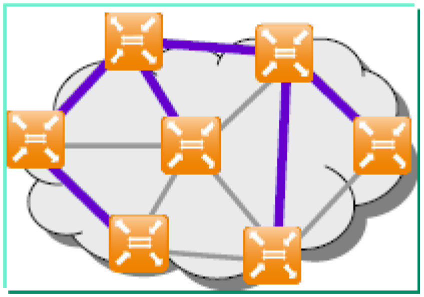
Ref: 2011 Rick Gregory(Ciena)

Events	*Effects*
International standardization	**Ethernet is the first global Packet Transport network & access technology**
Unrivaled success in enterprise	**Ethernet in Access, metro, and wide-area applications**
Large number of component and equipment manufacturers	**Lowest cost per megabit; < 8¢ per megabit for triple-speed NIC**
Mature, transparent layer 2 technology	**Simple plug-and-play installation**

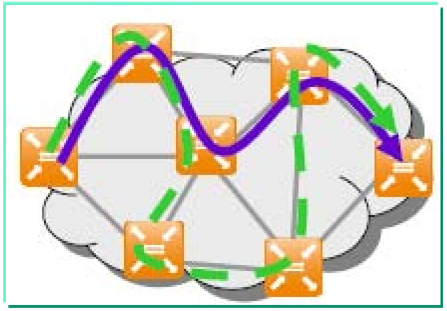
Ethernet over any media…any service over Ethernet

Evolution to **Ethernet Transport**

- Scalable Ethernet -Connectionless
  - Limited traffic engineering possibility
  - Very complex optimization task when using MSTP
  - Slow restoration upon failure (seconds)
  - Flat switching hierarchy (broadcast if unknown)
  - Forwarding based on Spanning Tree

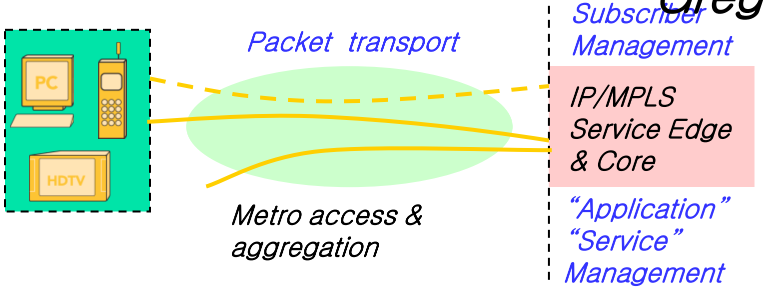


- Ethernet Transport – **Connection Oriented**
  - Predictable QOS: Carrier Graded Service
  - Establishment of virtual Conns (TE tunnels)
  - transport label (or MAC) not on customer MAC
  - Predictable Resilience: Ring Protection (G.8032)
  - Disabled Broadcast for unknown
  - Centralized management or distributed control plane (e.g., NMS, GMPLS, MPLS_TP)



Technology Options for Packet Transport

Ref: 2011 Rick Gregory(Ciena)



- Routing, i.e., forward IP packets
  - IP -over- {IPsec, GRE -over-} MPLS — *IP/MPLS (L3)*
  - IP -over- {IPsec, GRE -over-} IP
  - MPLS -over- L2TPv3 -over- IP
  - Ethernet -over- L2TPv3 -over- IP

  } — *IP/Ethernet*

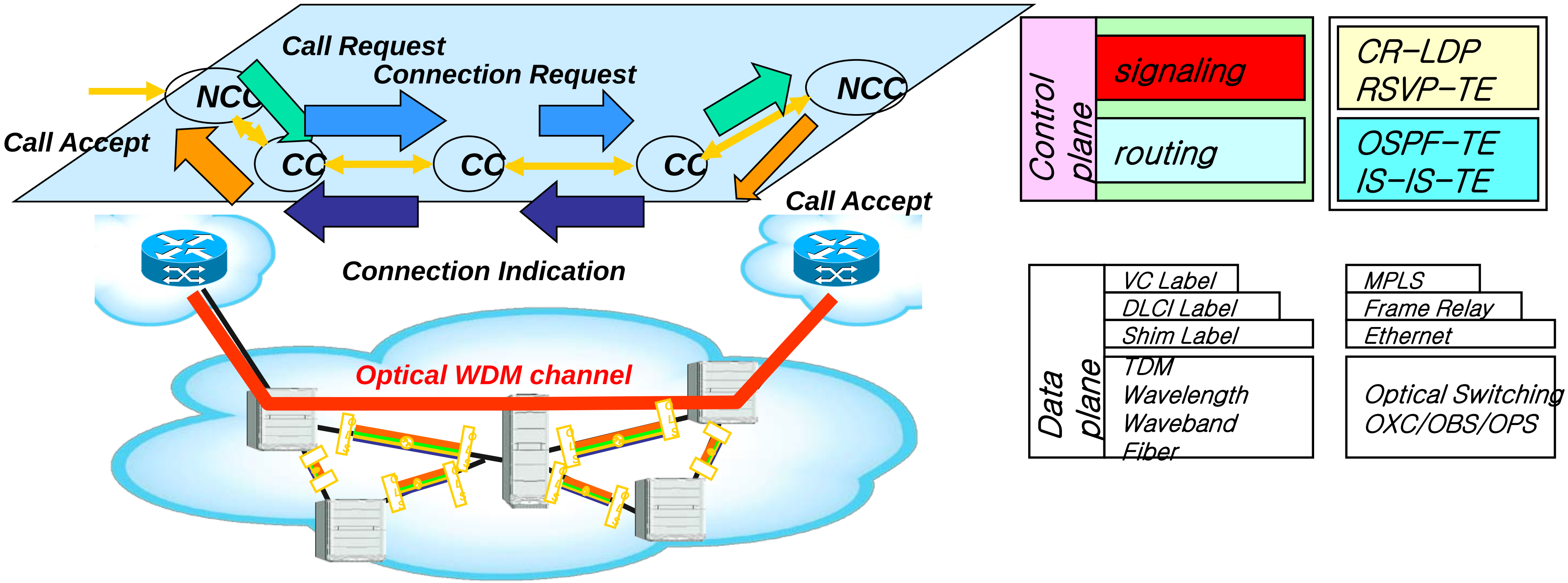
Bridging, i.e., forward Ethernet frames based on MAC DA
- Ethernet -over- Ethernet: PBB — *PBB*
- Ethernet -over- MPLS: VPWS & VPLS — *MPLS (L2)*

Switching, i.e., forward of Ethernet frames based on tunnel label
- Ethernet -over- Ethernet: PBB-TE — *PBB-TE*
- Ethernet -over- MPLS-TP — *MPLS-TP*

Goal: cost-effective, high-performance & Reliable transport

Technical Trend in Packet Transport Tech.

- The PTN as the Infrastructure for Next-Generation Internet Backbones
  - IP centric Optical Transport Networks Architecture: OAM & Protection G.8032)
  - IP centric Control/management Plane: Provisioning (Connection Setup)



Future Network virtualizations Concepts

- Multiple virrual networks operating simultaneously
  (Virtual Overlay & Underlay Networks) over the PTN Infrastructure