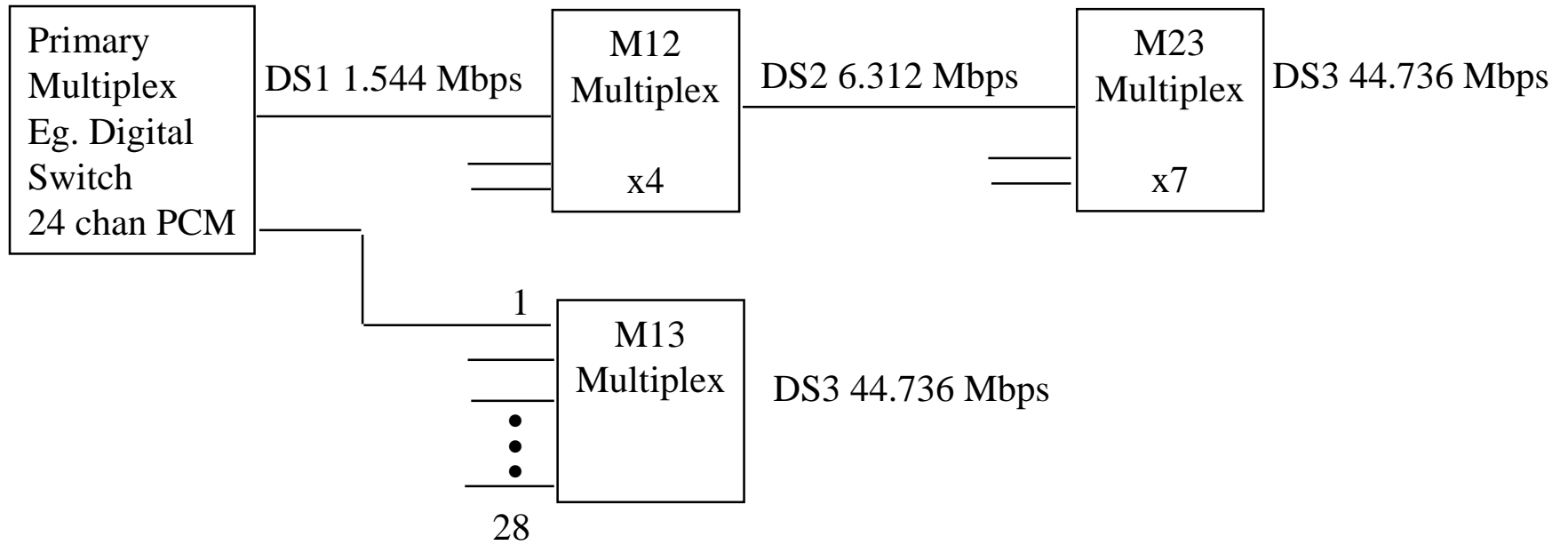# SONET

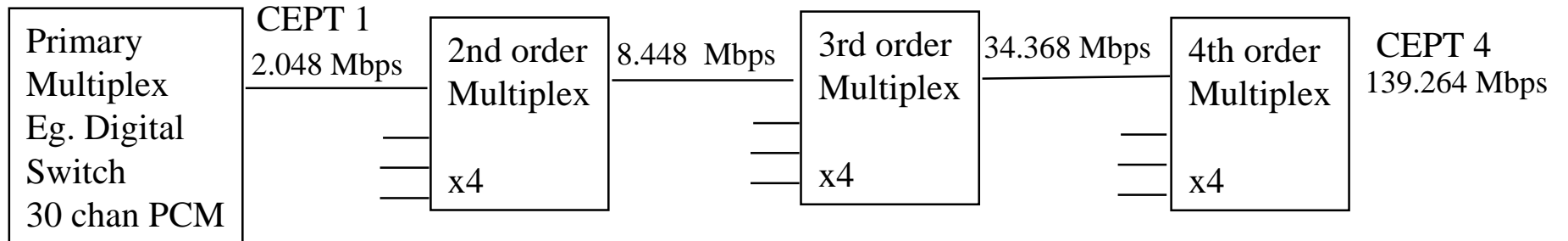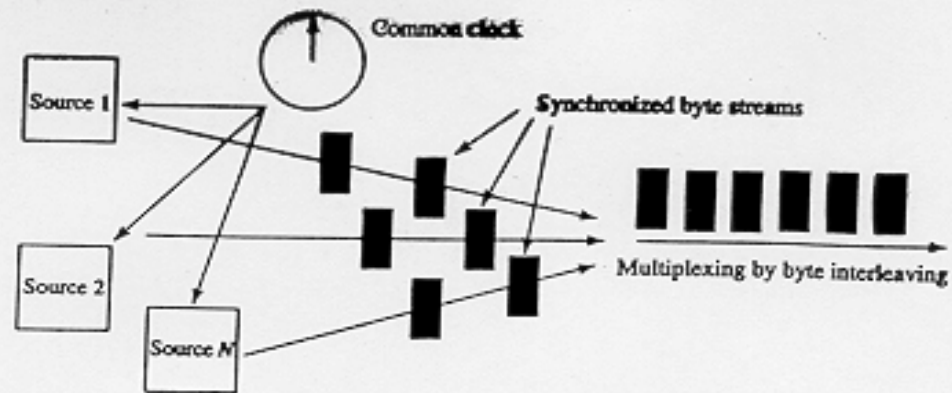# Telephone Networks {Brief History}

- Digital carrier systems
  - The hierarchy of digital signals that the telephone network uses.
  - Trunks and access links organized in **DS (digital signal) hierarchy**
  - Problem: rates are not multiples of each other.
- In the 1980's Bellcore developed the Synchronous Optical Network (SONET) standard.
- Previous efforts include: **ISDN** and **BISDN.**

North American Digital Hierarchy

Primary Multiplex Eg. Digital Switch 24 chan PCM	DS1 1.544 Mbps	M12 Multiplex x4	DS2 6.312 Mbps	M23 Multiplex x7	DS3 44.736 Mbps

1

M13 Multiplex   DS3 44.736 Mbps

28

European Digital Hierarchy

Primary Multiplex Eg. Digital Switch 30 chan PCM	CEPT 1 2.048 Mbps	2nd order Multiplex x4	8.448 Mbps	3rd order Multiplex x4	34.368 Mbps	4th order Multiplex x4	CEPT 4 139.264 Mbps

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Figure 4.5

SONET sources are synchronized to a common master clock. Different streams are multiplexed by byte interleaving.
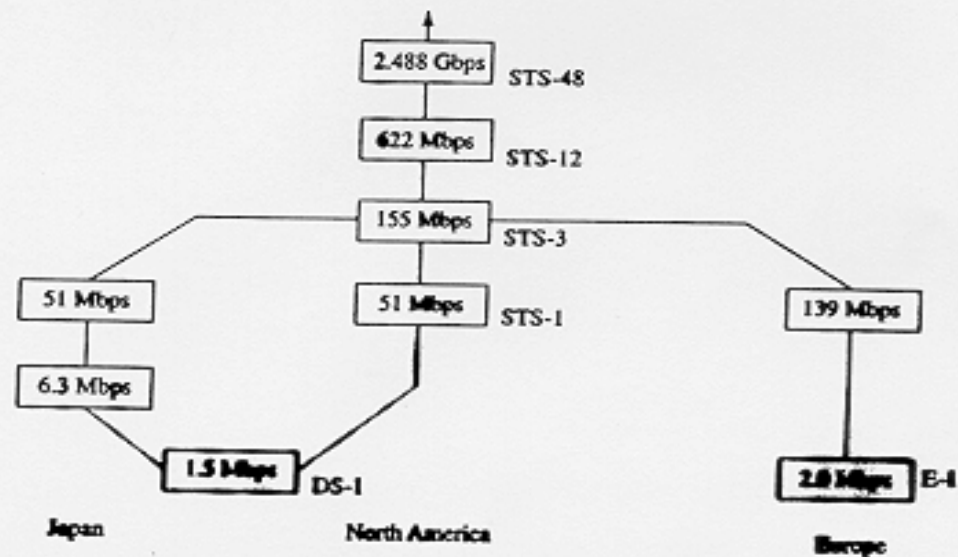
The STS-*n* signal has a rate equal to $n \times 51.84$ Mbps. In Europe the hierarchy starts at 155.52 Mbps. All the standards become compatible at speeds of 155 Mbps.

SONET

- Transmission links of the telephone network have been changing to *SONET* where rates are arranged in **STS** (Synchronous Transfer Signal) hierarchy.
- The hierarchy is called **SDH** (Synchronous Digital Hierarchy) defined by CCITT.
- It is an ITU standard.

Medium	Signal	voice circuits	North America	Japan	Europe
T-1 paired cable	DS-1	24	1.5	1.5	2.0
T-1C paired cable	DS-1C	48	3.1		
T-2 paired cable	DS-2	96	6.3	6.3	8.4
T-3 coax, radio, fiber	DS-3	672	45.0	34.0	32.0
Coax, waveguide, radio, fiber	DS-4	4032	274.0		

1.2

TABLE

Digital carrier systems. This is the hierarchy of digital signals that the telephone network uses. Note that the bit rate of a DS-1 signal is greater than 24 times the rate of a voice signal (64 Kbps) because of the additional framing bits required.

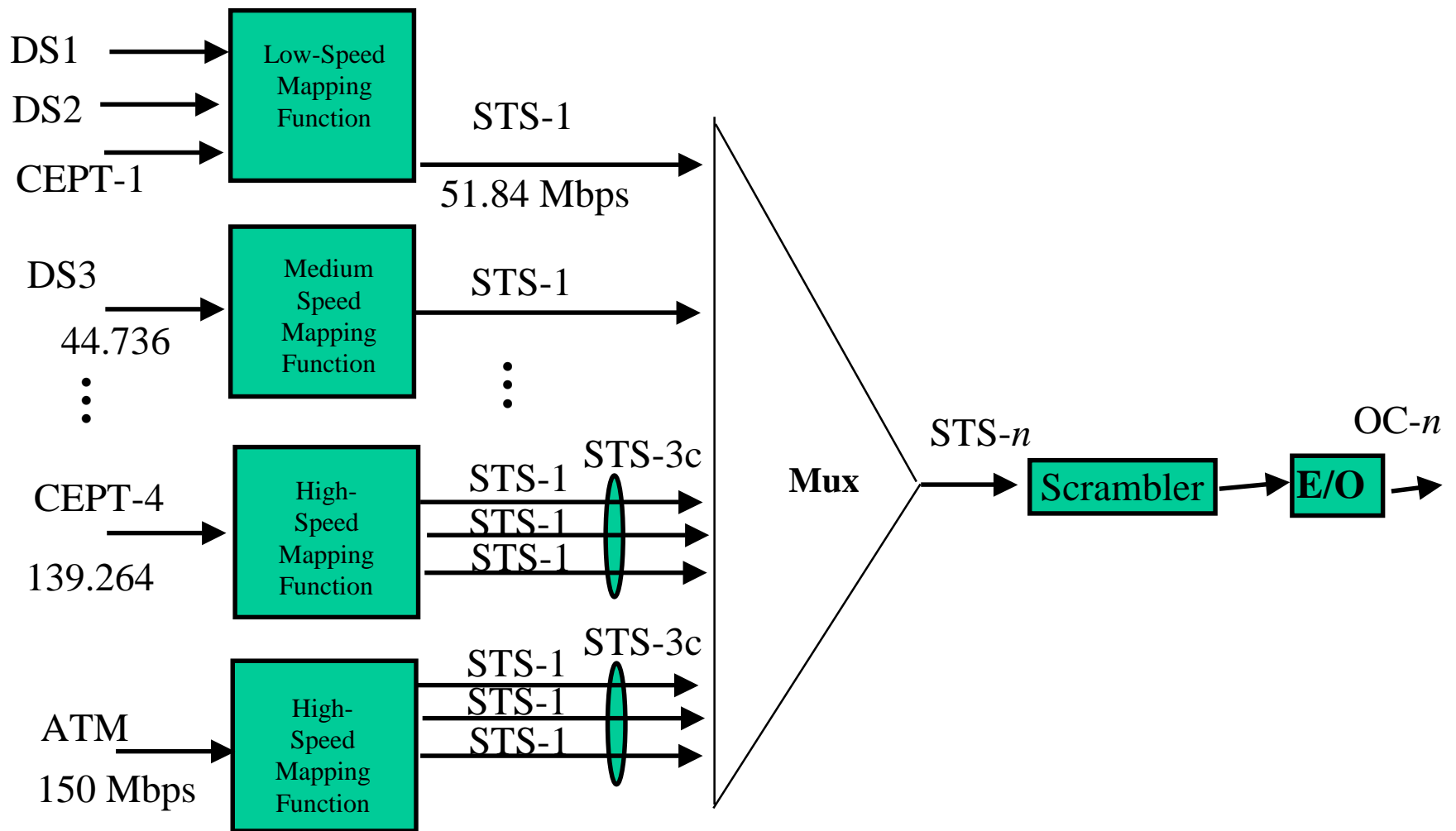| Carrier	Signal	Rate in Mbps
OC-1	STS-1	51.840
OC-3	STS-3	155.520
OC-9	STS-9	466.560
OC-12	STS-12	622.080
OC-18	STS-18	933.120
OC-24	STS-24	1244.160
OC-36	STS-36	1866.240
OC-48	STS-48	2488.320

1.3

TABLE

SONET rates. The rates of multiplexed STS-1 signals are exact multiples; no additional framing bits are used.

SONET

SONET:: encodes bit streams into optical signals propagated over optical fiber. SONET defines a technology for carrying many signals of different capacities through a <u>synchronous, flexible,</u> optical hierarchy.

- A bit-way implementation providing end-to-end transport of bit streams.
- All clocks in the network are locked to a common <u>master clock</u> so that simple TDM can be used.
- Multiplexing done by *byte interleaving*.
- *SONET* is backward compatible to DS-1 and E-1 and forward compatible to ATM cells.
- Demultiplexing is easy.

DS1 →

DS2 →

CEPT-1 → Low-Speed Mapping Function → STS-1 51.84 Mbps →

DS3 44.736 → Medium Speed Mapping Function → STS-1 →

CEPT-4 139.264 → High-Speed Mapping Function → STS-1 STS-1 STS-1 STS-3c →

ATM 150 Mbps → High-Speed Mapping Function → STS-1 STS-1 STS-1 STS-3c →

Mux → STS-n → **Scrambler** → **E/O** → OC-n

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Figure 4.8

INTERLEAVING

STS-1 SIGNALS ARE *BYTE INTERLEAVED* TO CREATE A **STS-N** SIGNAL BY COMBINING EACH BYTE IN THE VARIOUS DATA STREAMS IN A WAY SUCH THAT EACH BYTE IS IN A UNIQUELY SPECIFIED LOCATION FACILITATING DEMULTIPLEXING.
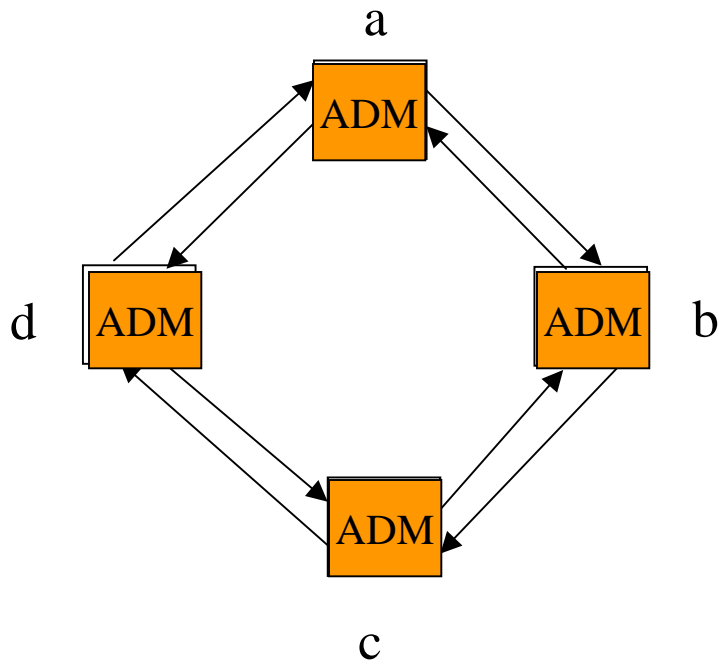
FIRST ALIGN STS-1 FRAMES

- NEXT BYTE INTERLEAVE TO FORM STS-N SIGNAL
- THE TRANSPORT OVERHEAD IS NOW 3 X N
- THE SPE (SYNCHRONOUS PAYLOAD ENVELOP - "DATA") IS NOW N X 87 COLUMNS
- BYTE SEQUENCE IS ROW 1 COLUMN 1 TO ROW 9 COLUMN 90
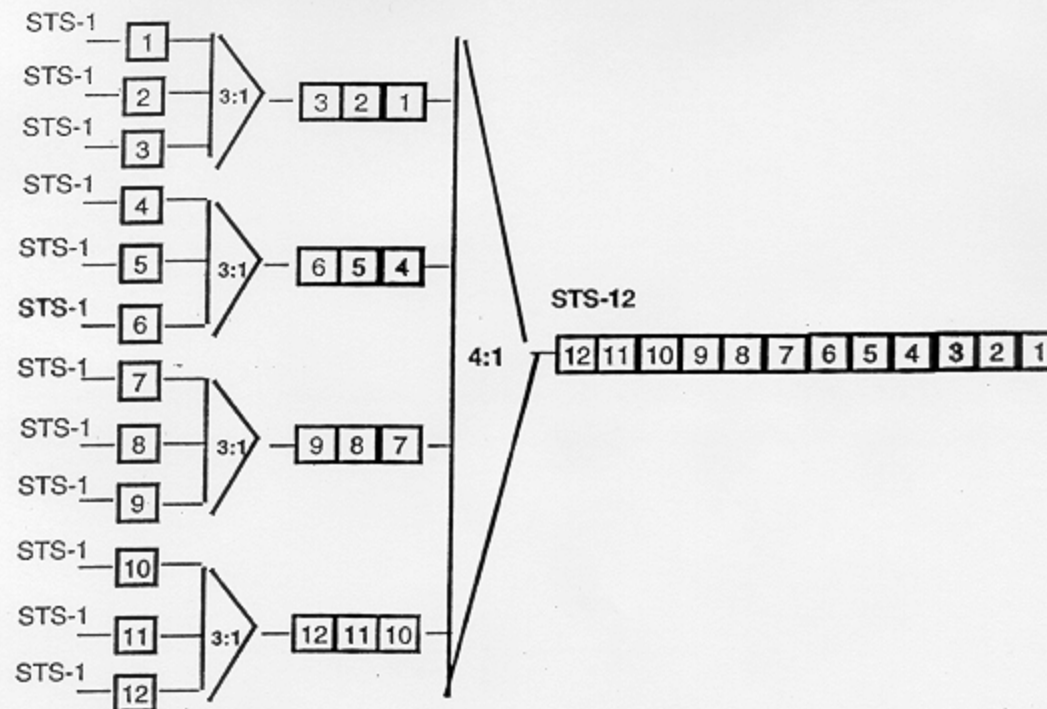
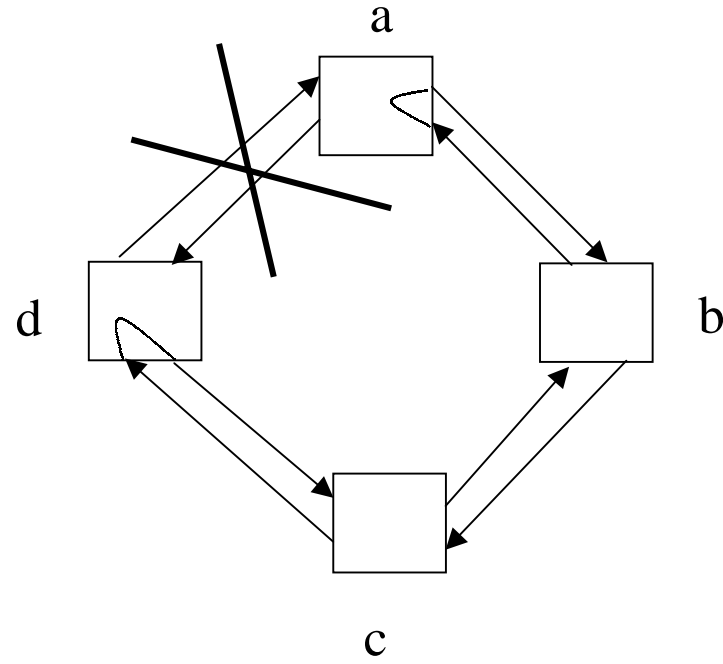# SONET Architecture

- SONET topology can be a mesh, but most often it is a dual ring.

- Standard component of SONET ring is an **ADM** (Add/Drop Multiplexer)
  - Drop one incoming multiplexed stream and replace it with another stream.
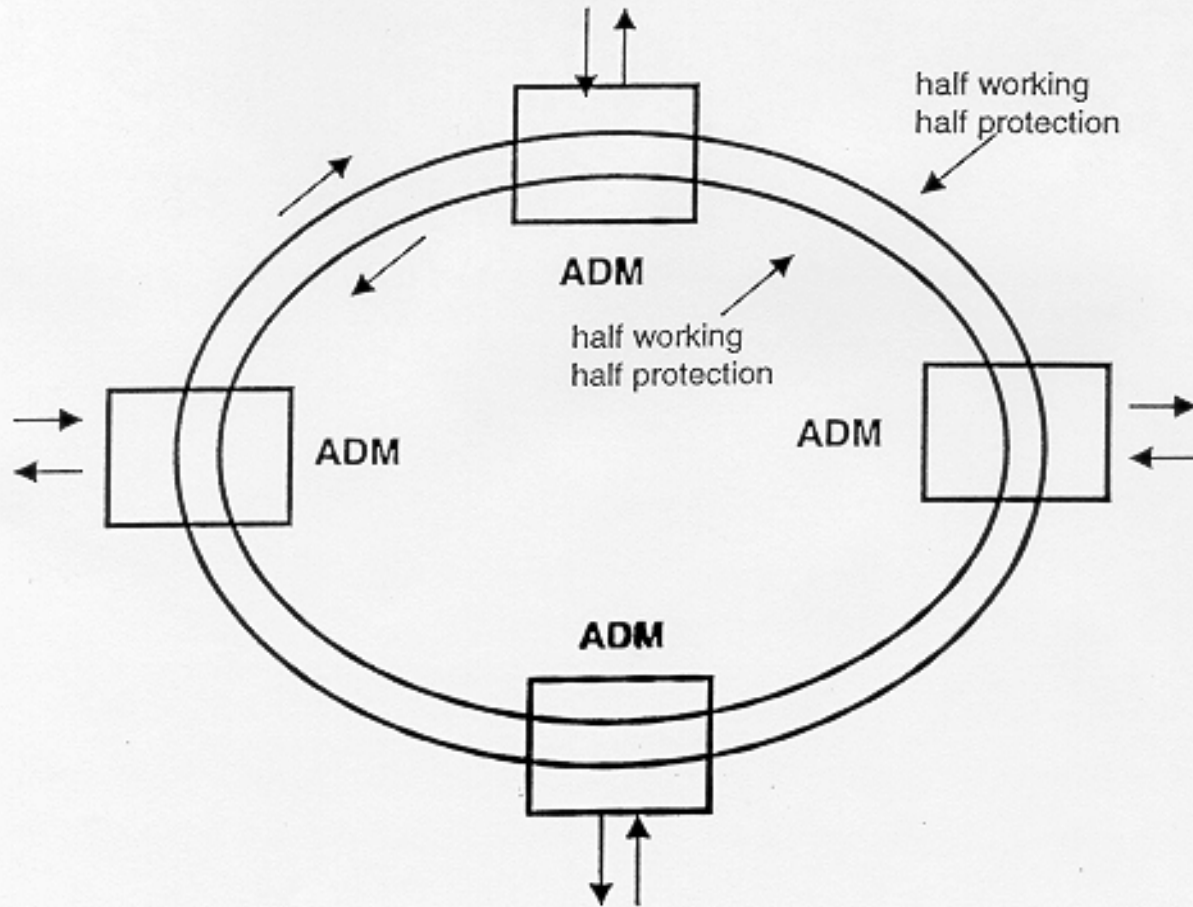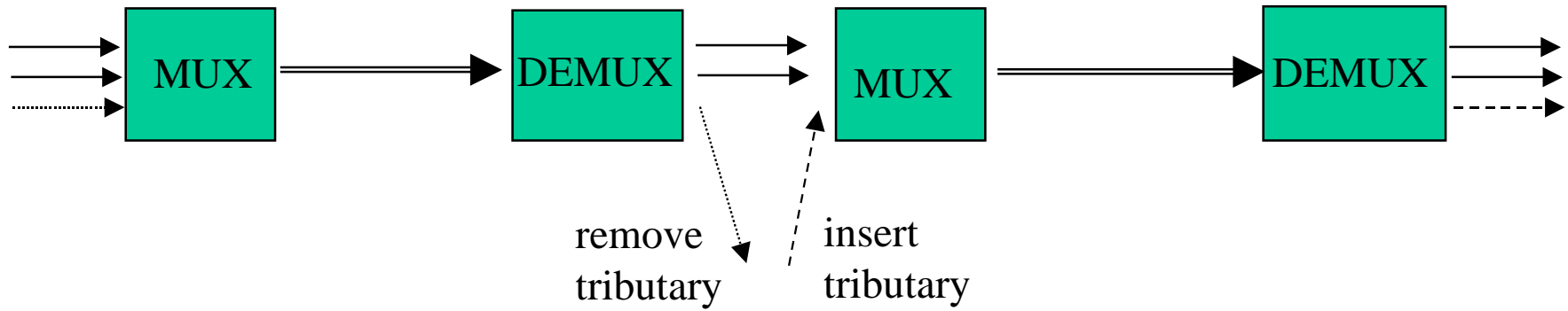 - Used to make up bi-directional line switching rings.

a

ADM

d ADM ADM b

ADM

c

(a) Dual ring

a

d b

c

(b) Loop-around in response to fault

Leon-Garcia & Widjaja: *Communication Networks* Figure 4.12

TWO FIBER
BI-DIRECTIONAL
LINE SWITCHING RING

half working
half protection

half working
half protection

ADM

ADM

ADM

ADM

SONET Ring

(a) pre-SONET multiplexing

remove
tributary

insert
tributary

(b) SONET Add-Drop multiplexing

remove
tributary

insert
tributary

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Figure 4.9

a

OC-3n

OC-3n

b

3 ADMs

OC-3n

physical loop net

c

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Figure 4.10

Regional
Ring

Metro
Ring

Inter-Office
Rings

Leon-Garcia & Widjaja: *Communication Networks*   Figure 4.13

SONET Architecture
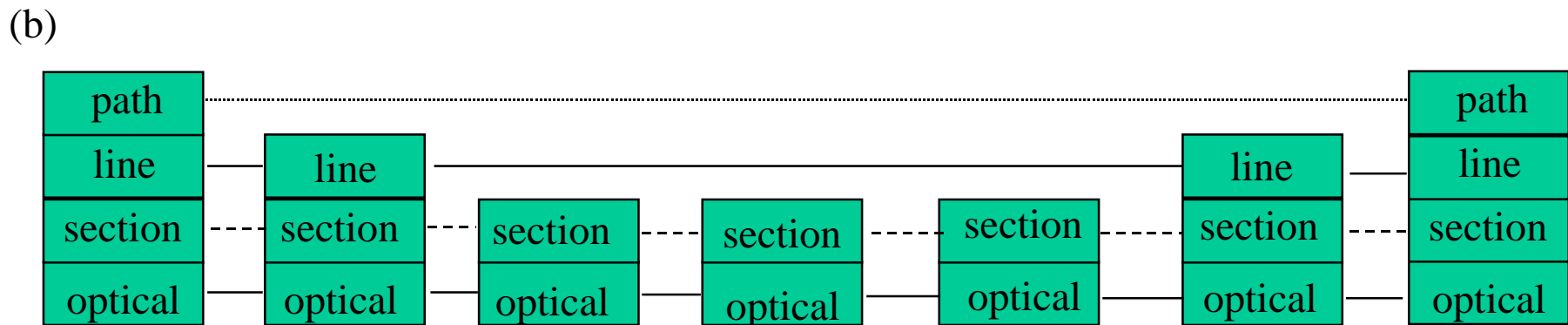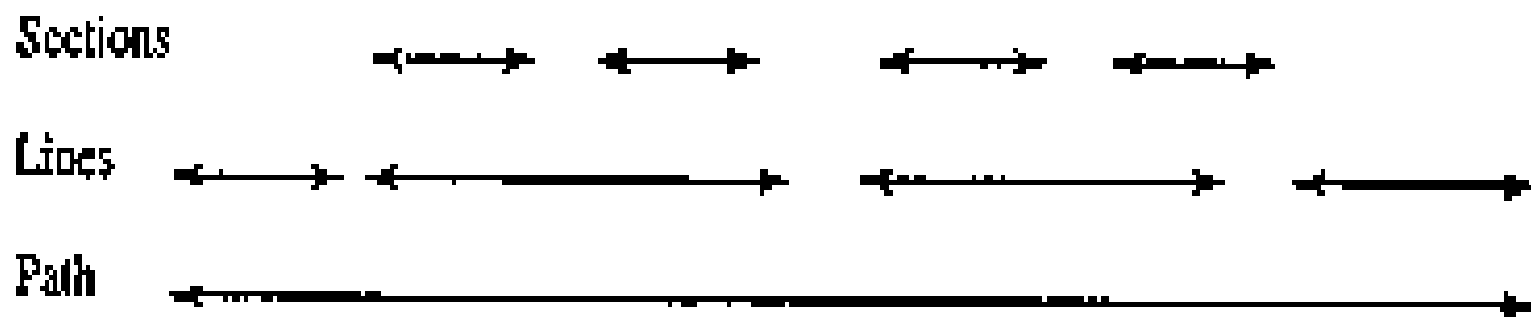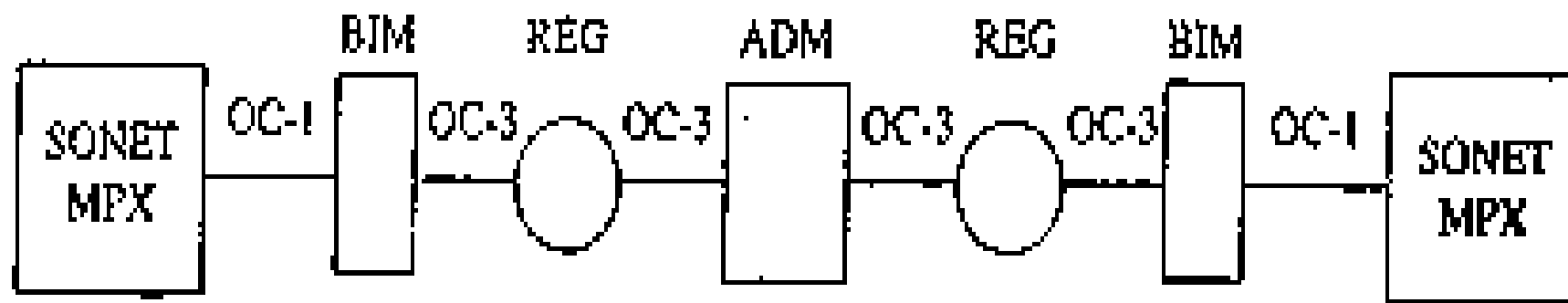
(a)
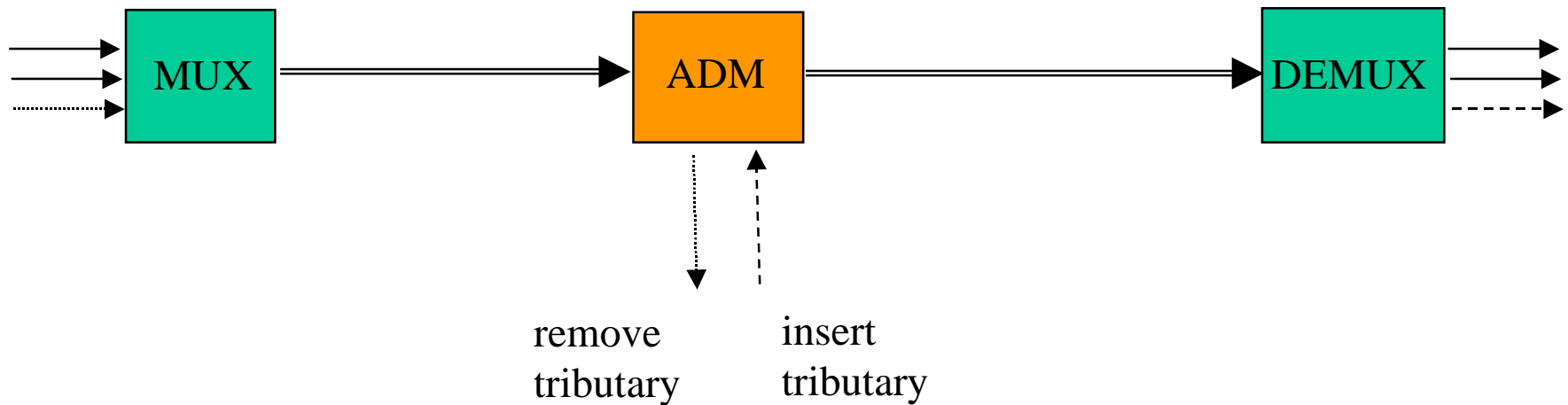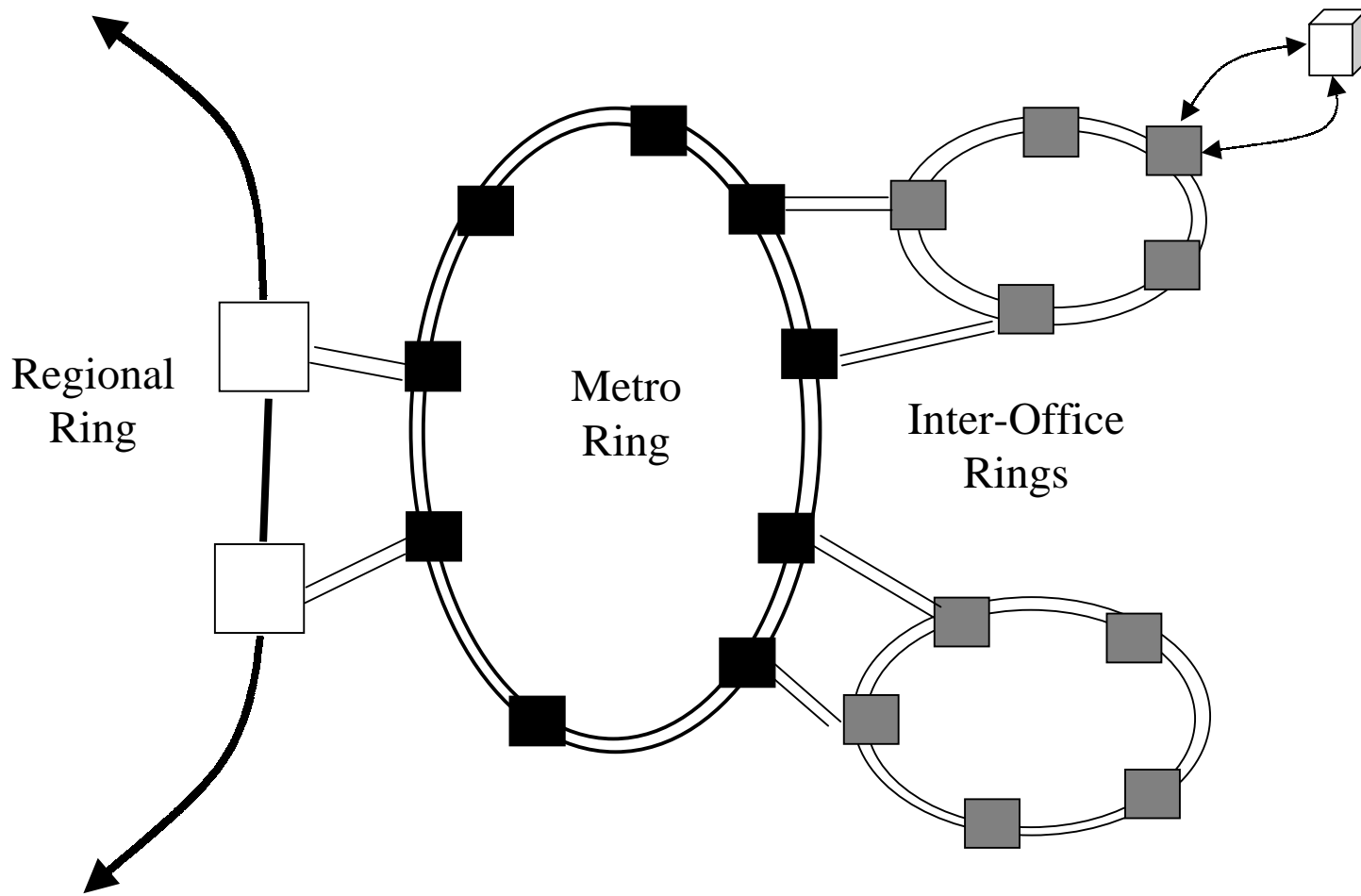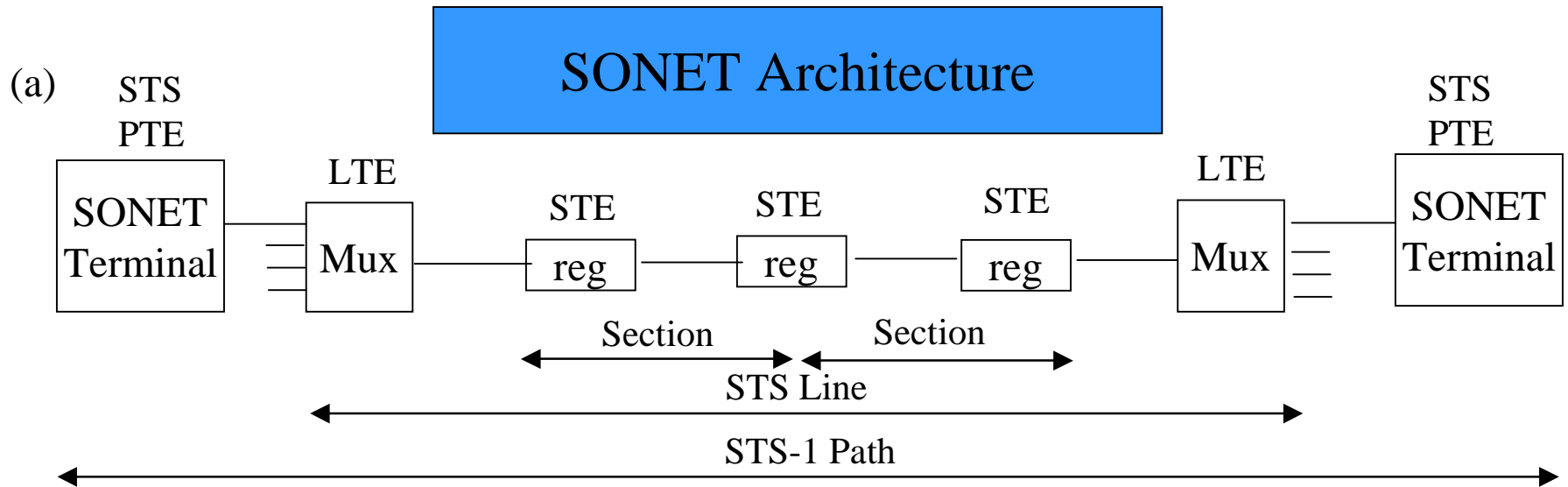
STE: Section Terminating Equipment, e.g. a repeater
LTE: Line Terminating Equipment, e.g. a STS-1 to STS-3 multiplexer
PTE: Path Terminating Equipment, e.g. an STS-1 multiplexer

(b)

Leon-Garcia & Widjaja: *Communication Networks*   Figure 4.14

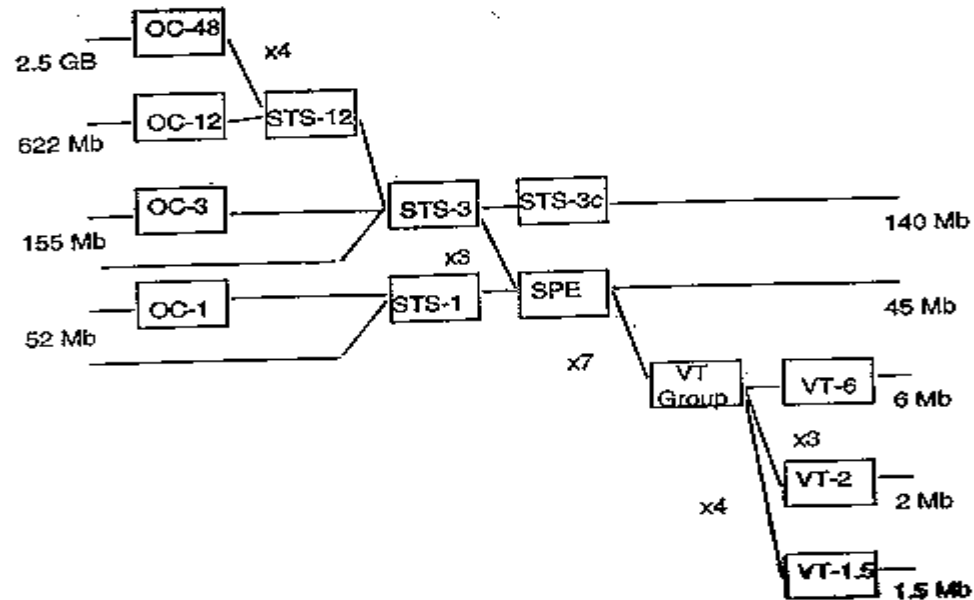The main SONET network elements.

| Mux | = BIM (Byte Interleaved Multiplexer)

| Reg | = Regenerator

- Boosters power of optical signal
  - Optical signal *converted to* electrical signal
  - Amplify electrical signal
  - Amplifed electrical signal *converted back to* optical signal
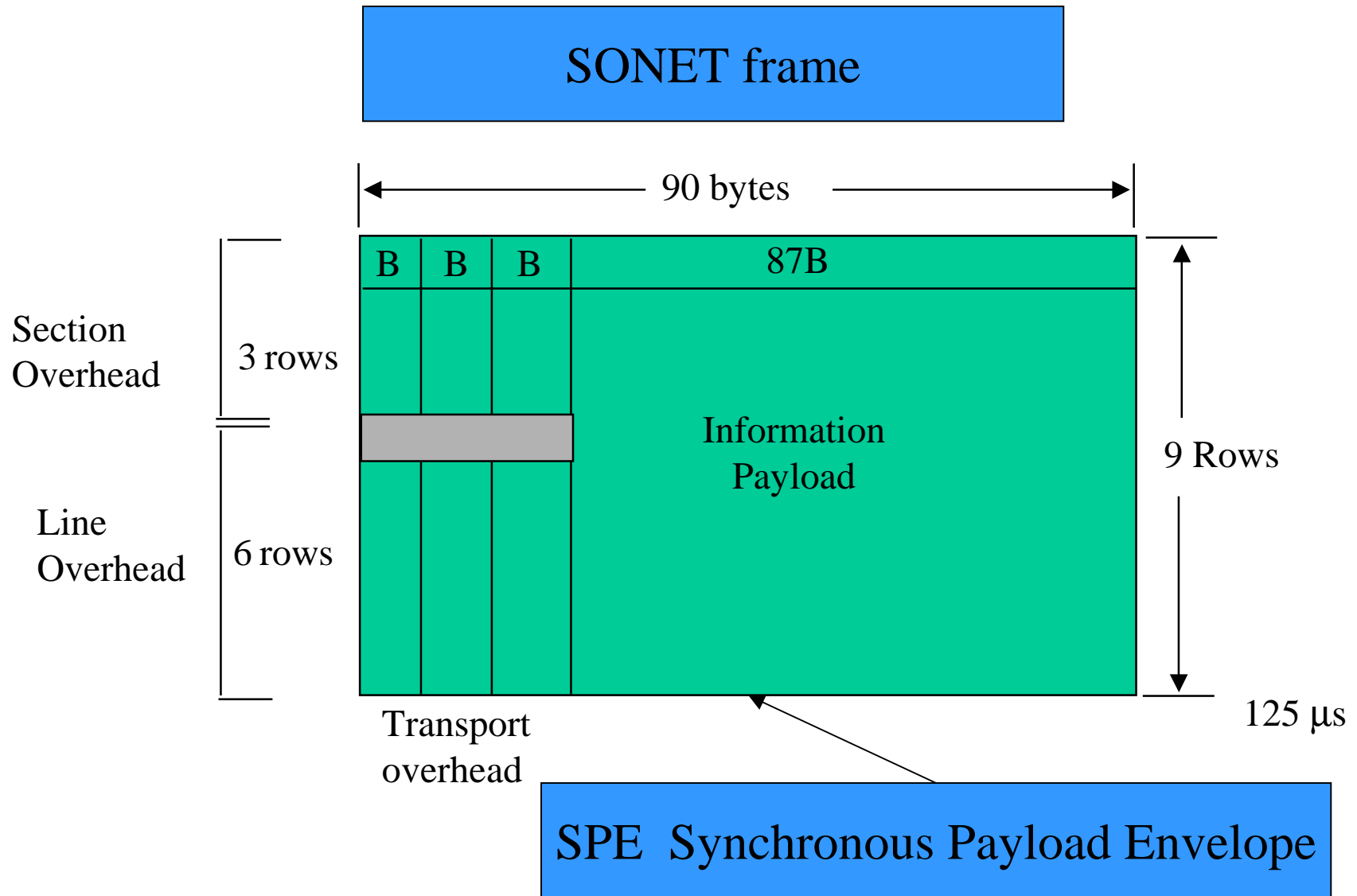
MULTIPLEXING HIERARCHY

- *SERVICE ADAPTORS* MAP VARIOUS SERVICES (VOICE, DATA, VIDEO...) INTO THE PAYLOAD ENVELOPE OF VIRTUAL TRIBUTARIES OR STS-1.
- STS-1 SIGNALS ARE MULTIPLEXED INTO STS-N (BYTE INTERLEAVE SYNCHRONOUS MULTIPLEXER)

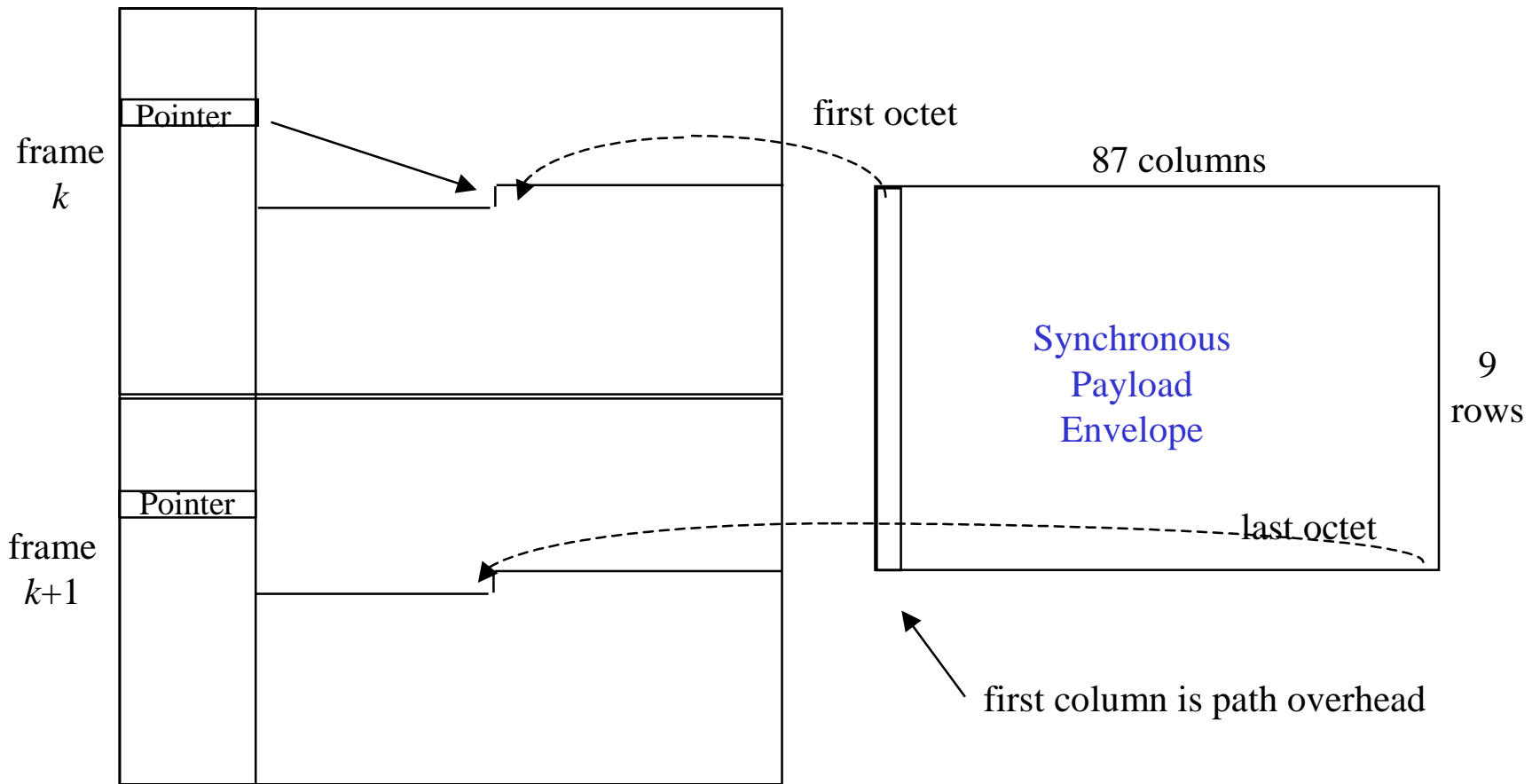# MULTIPLEXING LOWER THAN STS-1 DATA RATES INTO BASIC SONET STS-1

- VIRTUAL TRIBUTARY (VT) DEFINED FOR Sub-STS-1 SIGNALS
- GIVEN EACH SPE-1 COLUMN HAS CAPACITY OF 9 rows x 8 bits x 8000 SPE/sec = .576 Mb/s
- VT-6 TRIBUTARY REQUIRES 6.912 / .576 = 12 COLUMNS

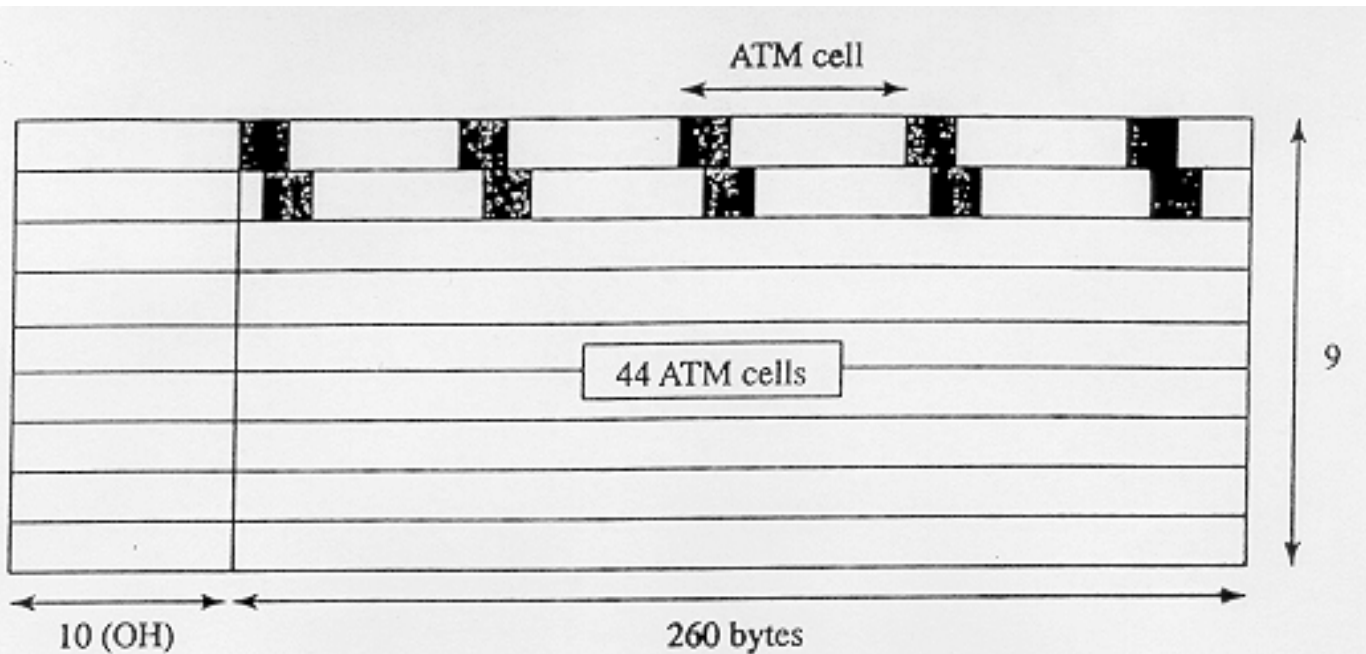| SONET HEIRARCHY	Digital Signals	SPE frame columns
28 X DS1	DS3 (44.736 Mb/s)	
VT-6 (6.912 Mb/s)	DS2 (6.312 Mb/s)	12
VT-3 (3.456 Mb/s)	DS1C (3.152 Mb/s)	6
VT-2 (2.304 Mb/s)	CEPT-1 (2.048 Mb/s)	4
VT-1.5 (1.728 Mb/s)	DS1 (1.544 Mb/s)	3
24 TDM/PCM CHANNEL	T1 (1.544 Mb/s)	
1 TDM/PCM CHANNEL	DS0 (64 Kb/s)	

- *VIRTUAL TRIBUTARY* GROUPS ARE DEFINED TO CONTAIN COMBINATIONS OF VARIOUS VTs SUCH THAT THE TOTAL IS 12 COLUMNS.

    1 X VT-6   = 12

    2 X VT-3   = 12

    3 X VT-2   = 12

    4 X VT-1.5 = 12

- SEVEN (87/12 col/VT-12) ARE MAPPED INTO 1 STE-1 WITH 1 COLUMN LEFT FOR PATH OVERHEAD AND 2 COLUMNS ARE *STUFFED.*

SONET frame

90 bytes

| B | B | B | 87B |

Section Overhead

3 rows

Line Overhead

6 rows

Information Payload

9 Rows

125 µs

Transport overhead

SPE Synchronous Payload Envelope

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Figure 4.15

SPE straddling SONET frame

frame
k

Pointer

first octet

frame
k+1

Pointer

87 columns

Synchronous
Payload
Envelope

9
rows

last octet

first column is path overhead

Leon-Garcia & Widjaja: *Communication Networks*   Figure 4.16

ATM Cells in an STS-3 Frame

ATM cell

44 ATM cells

9

10 (OH)

260 bytes

An STS-3 frame accommodates 44 ATM cells. No framing bits are provided to delimit the cell boundary.

Incoming
STS-1 Frames

Synchronized New
STS-1 Frames

STS-3

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