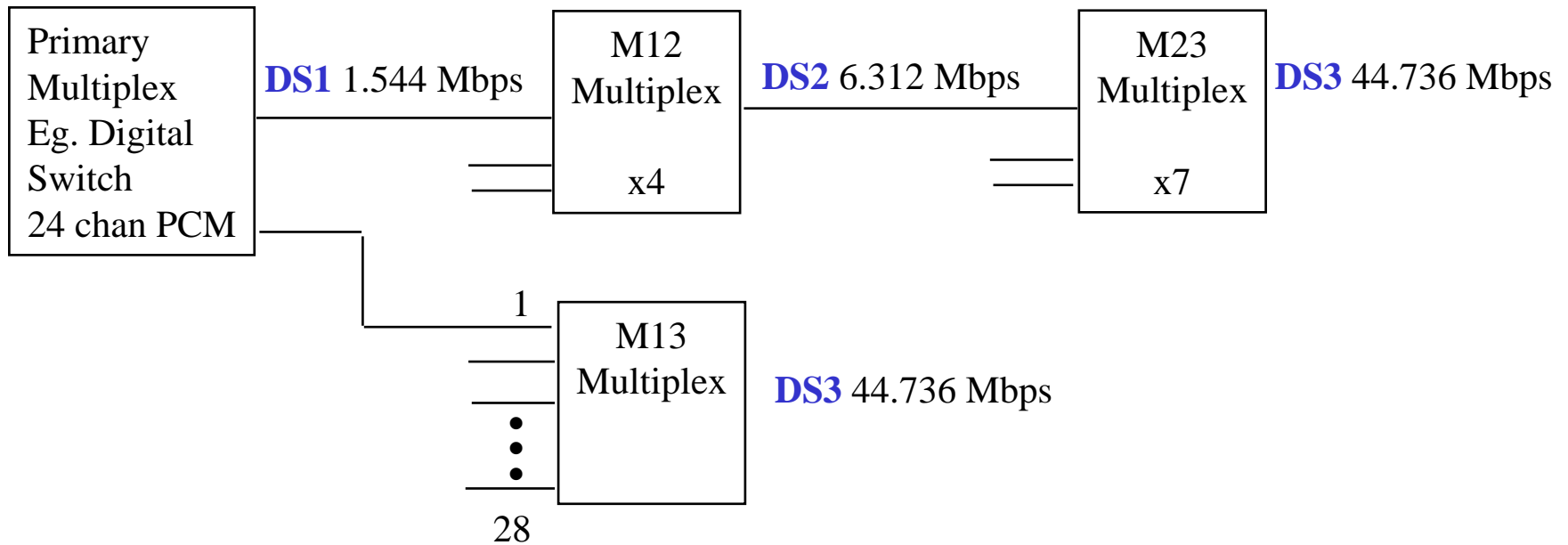


# Synchronous Optical Networks SONET

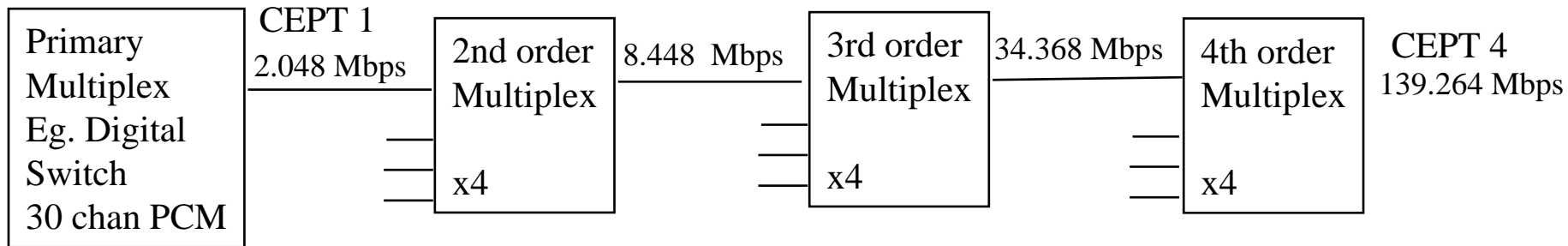
# Telephone Networks {Brief History}

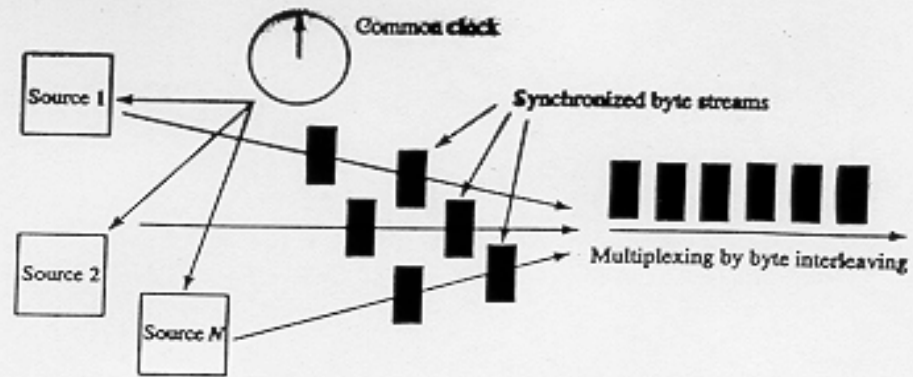
- Digital carrier systems
  - The hierarchy of digital signals that the telephone network uses.
  - Trunks and access links organized in **DS (digital signal) hierarchy**
  - Problem: rates are not multiples of each other.
- In the 1980's Bellcore developed the Synchronous Optical Network (**SONET**)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

## North American Digital Hierarchy



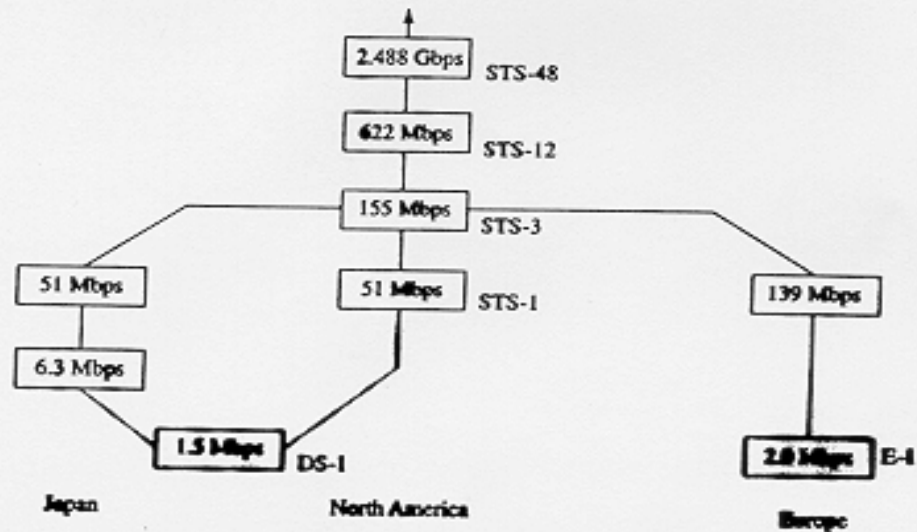
## European Digital Hierarchy





4.2  
FIGURE

SONET sources are synchronized to a common master clock. Different streams are multiplexed by byte interleaving.



4.3  
FIGURE

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

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

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

# 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		

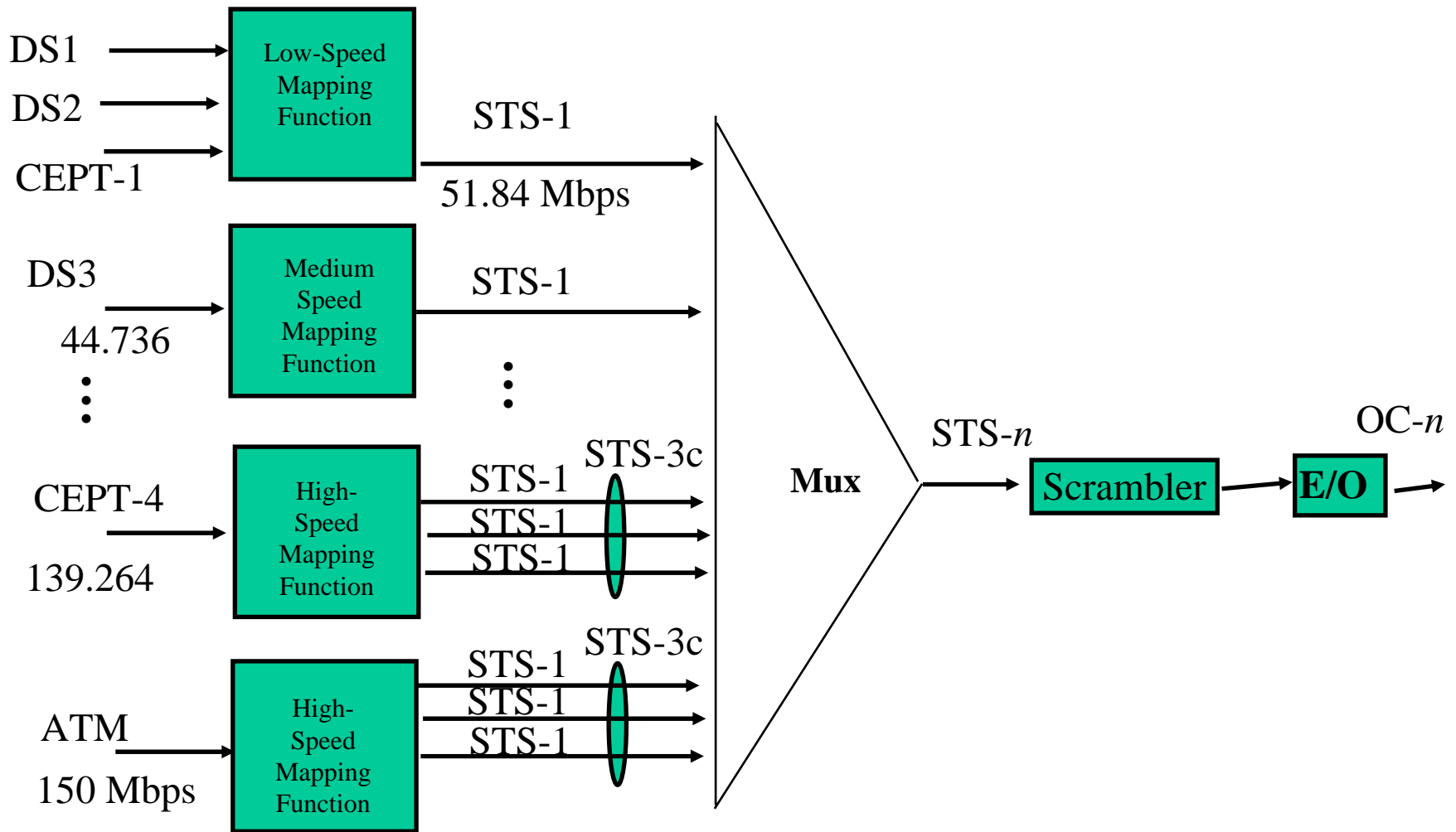
1.2  
TABLE

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.



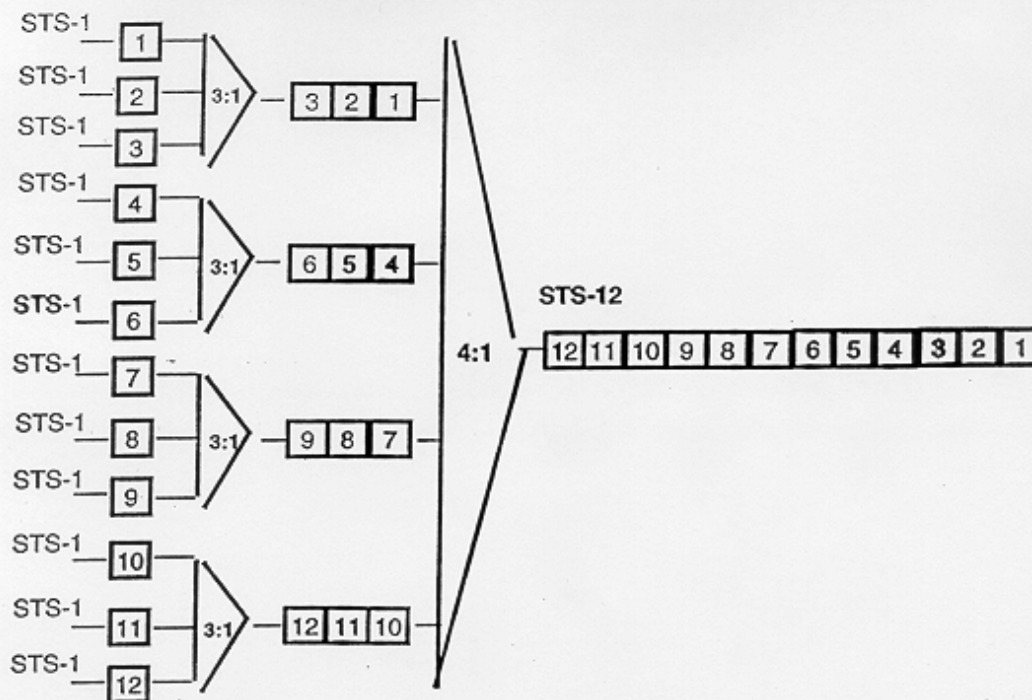


## INTERLEAVING

**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.**

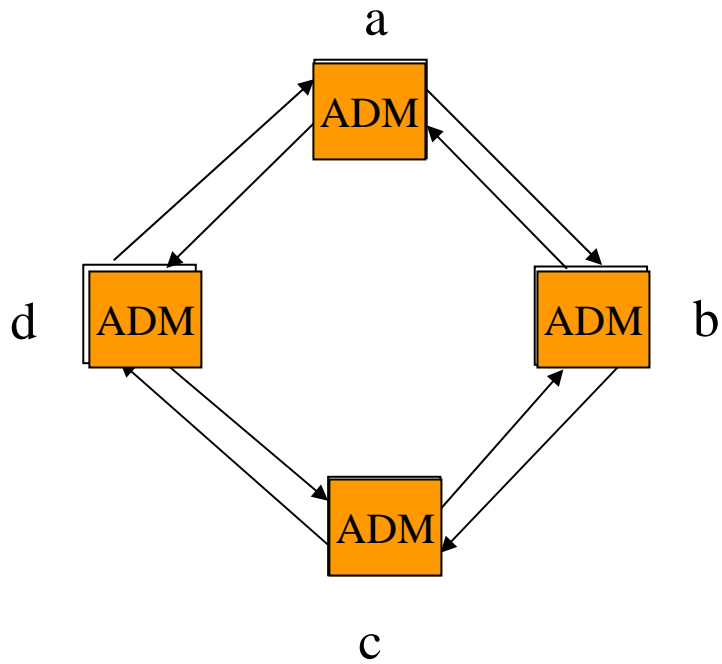
### FIRST ALIGN STS-1 FRAMES

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

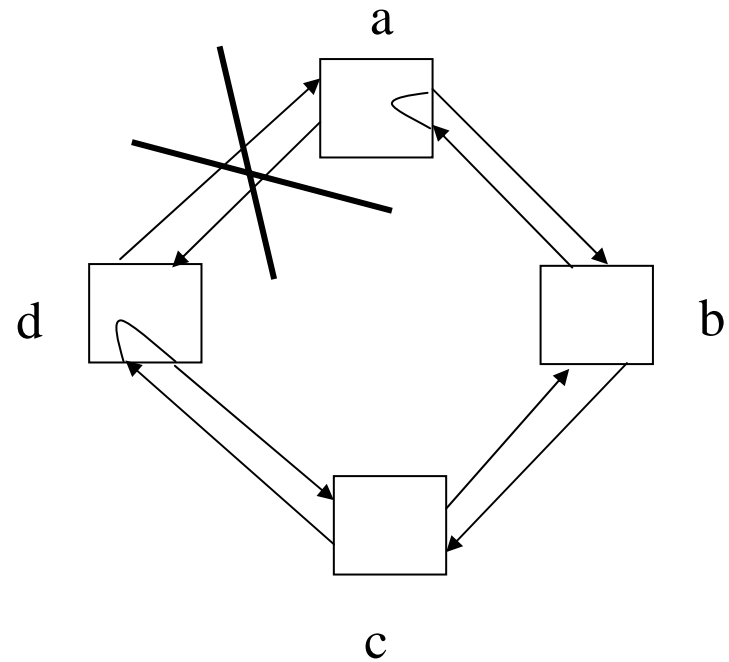


# SONET Architecture

- **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.

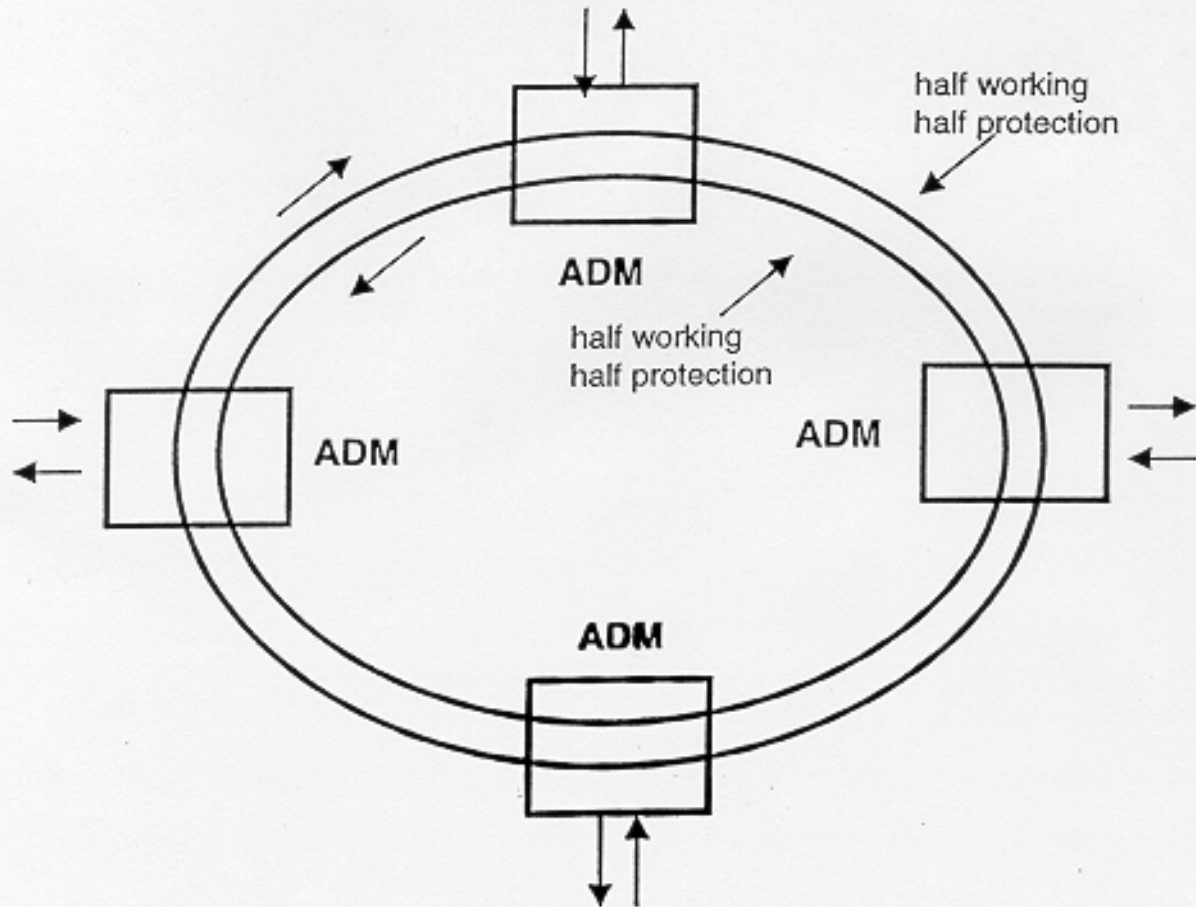


(a) Dual ring



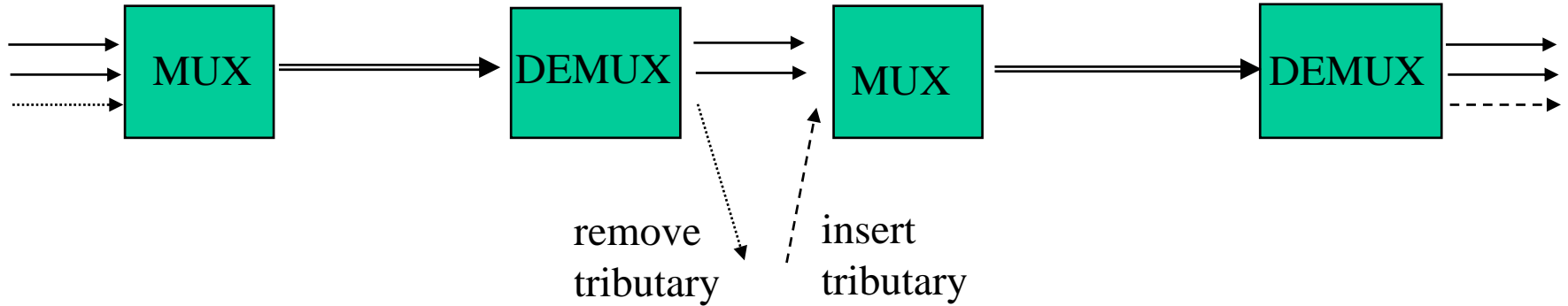
(b) Loop-around in response to fault

# TWO FIBER BI-DIRECTIONAL LINE SWITCHING RING

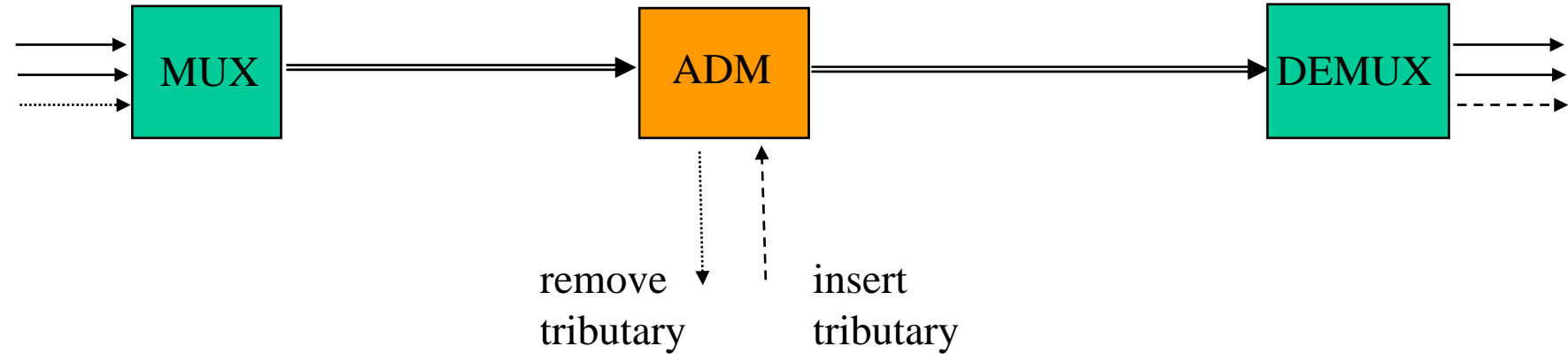


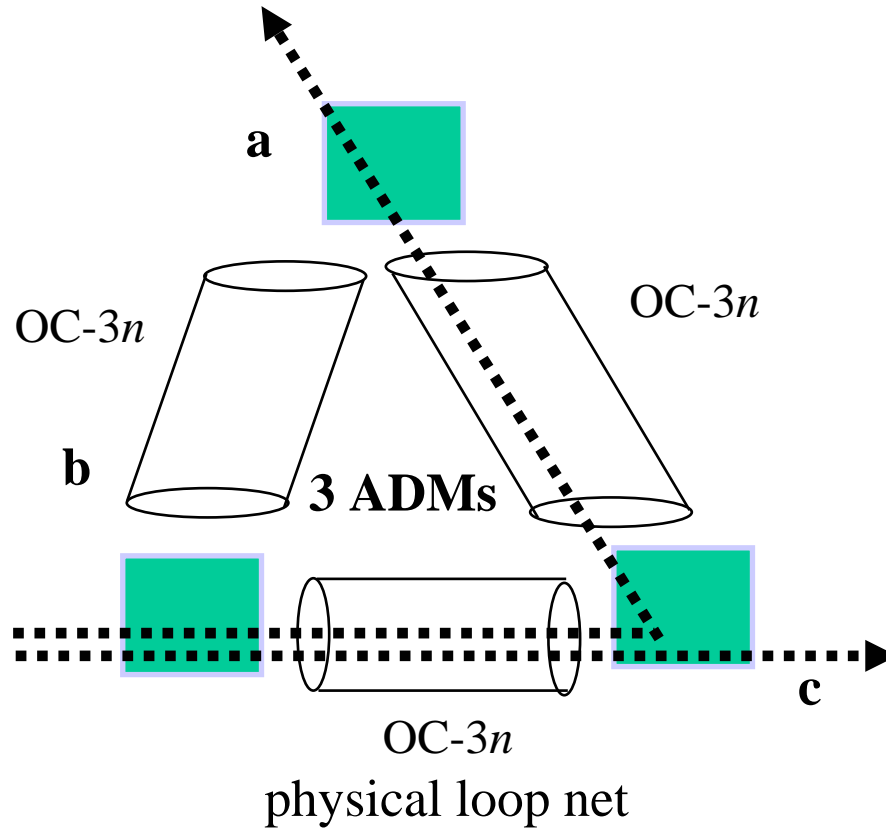
SONET Ring

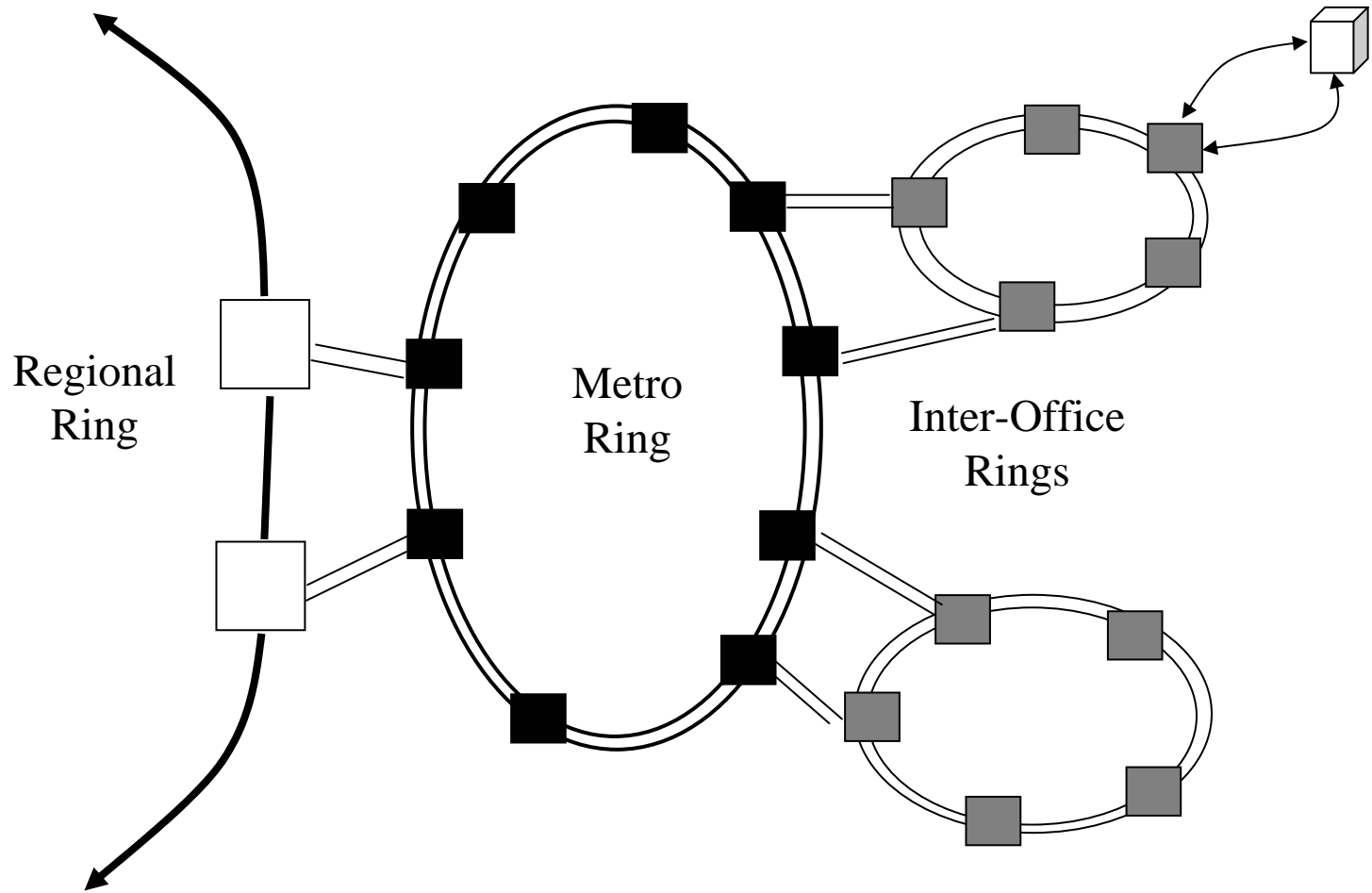
(a) pre-SONET multiplexing

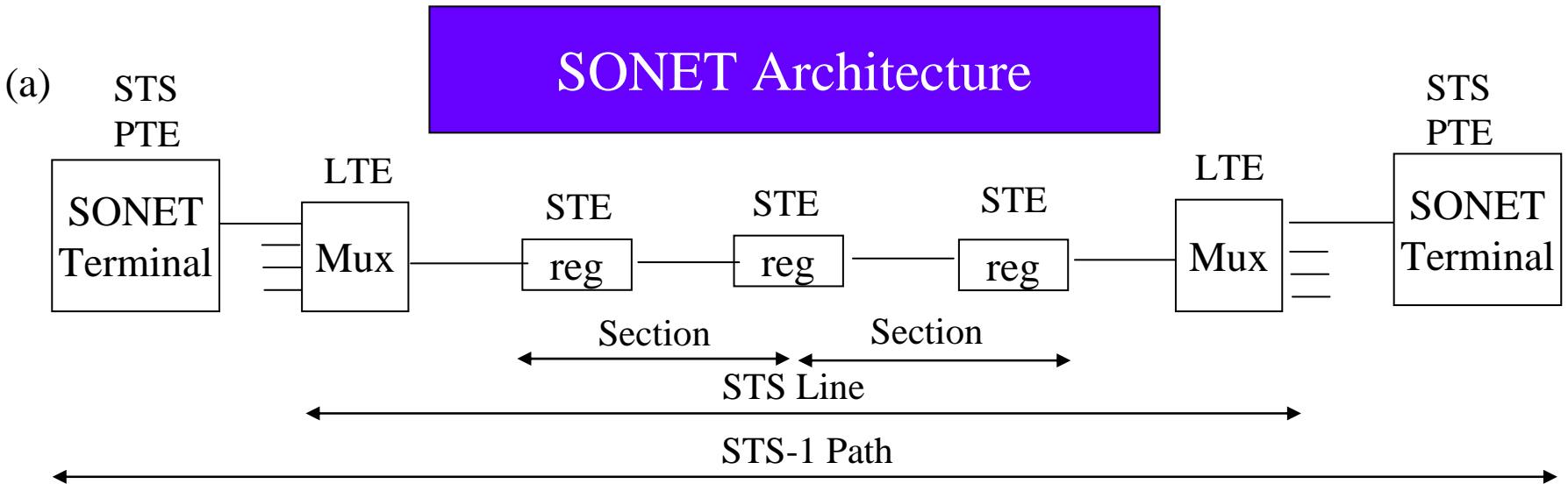


(b) SONET Add-Drop multiplexing

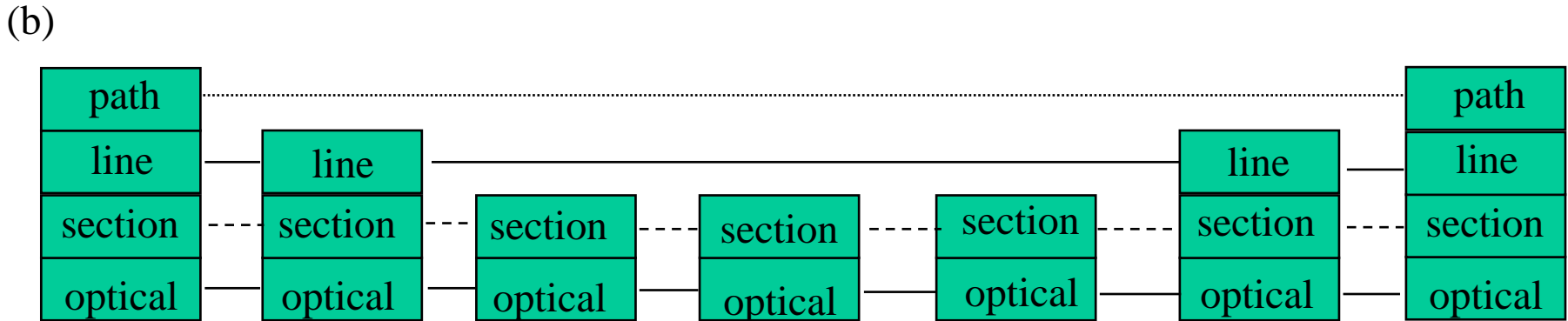




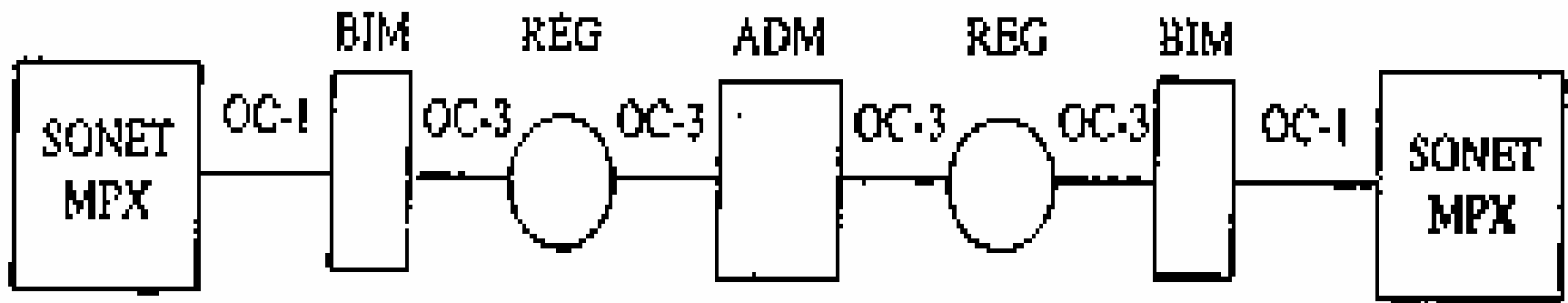




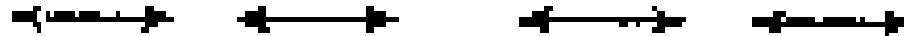
STE: Section Terminating Equipment, e.g. a repeater  
 LTE: Line Terminating Equipment, e.g. a STS-1 to STS-3 multiplexer  
 PTE: Path Terminating Equipment, e.g. an STS-1 multiplexer







Sections



Lines



Path



BIM = Byte-interleaved multiplexer      REG = Regenerator

The main SONET network elements.

Mux

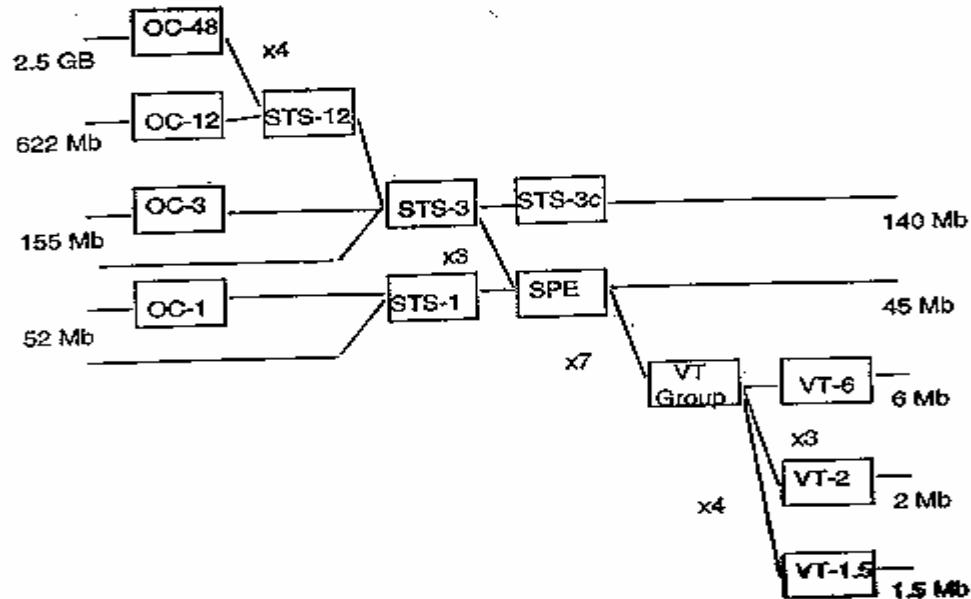
= BIM (Byte Interleaved Multiplexer)

Reg

= Regenerator

- Boosts power of optical signal
  - Optical signal *converted to* electrical signal.
  - Amplify electrical signal.
  - Amplified 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)

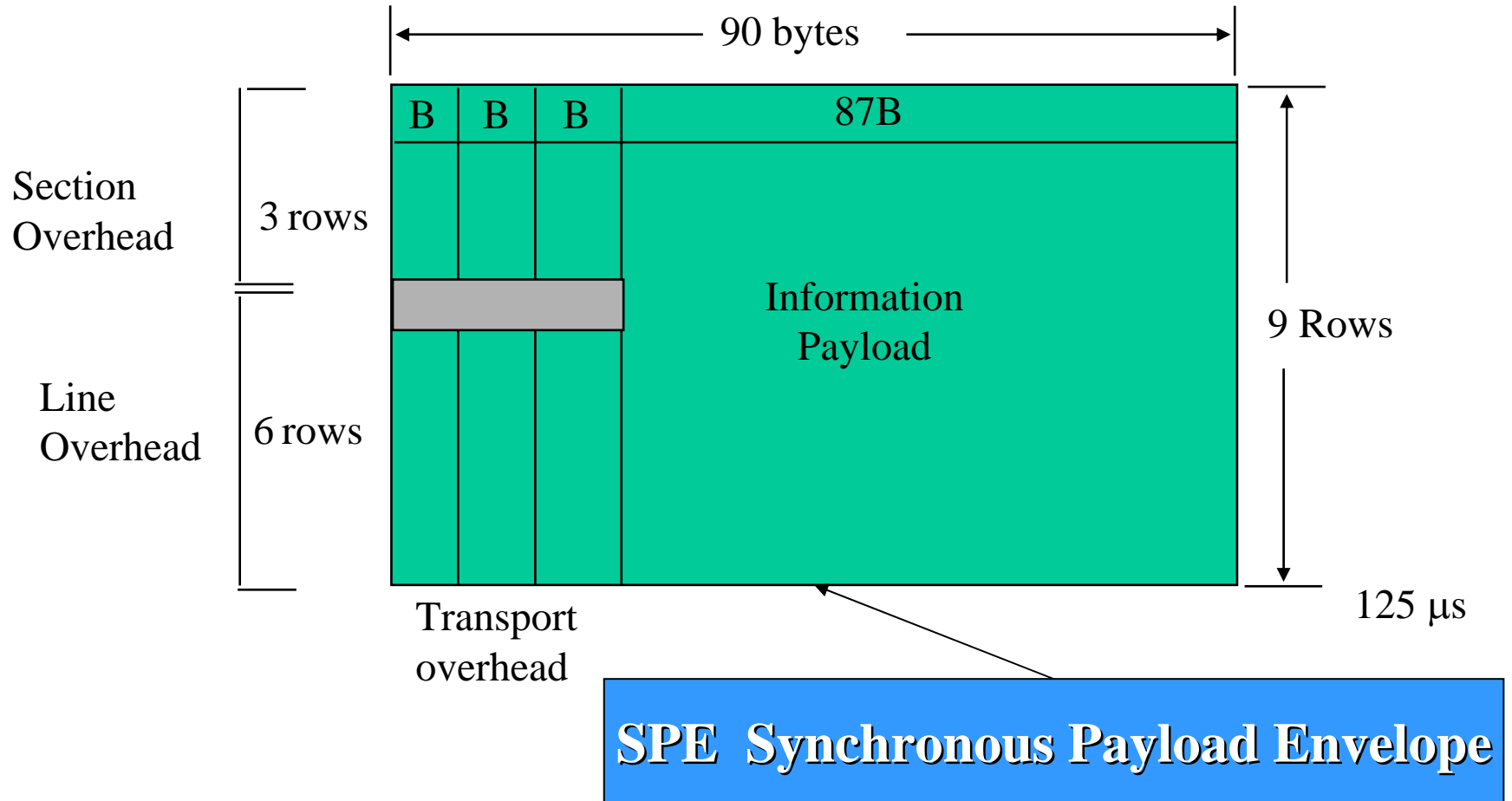
## **MULTIPLEXING LOWER THAN STS-1 DATA RATES INTO BASIC SONET STS-1**

- 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

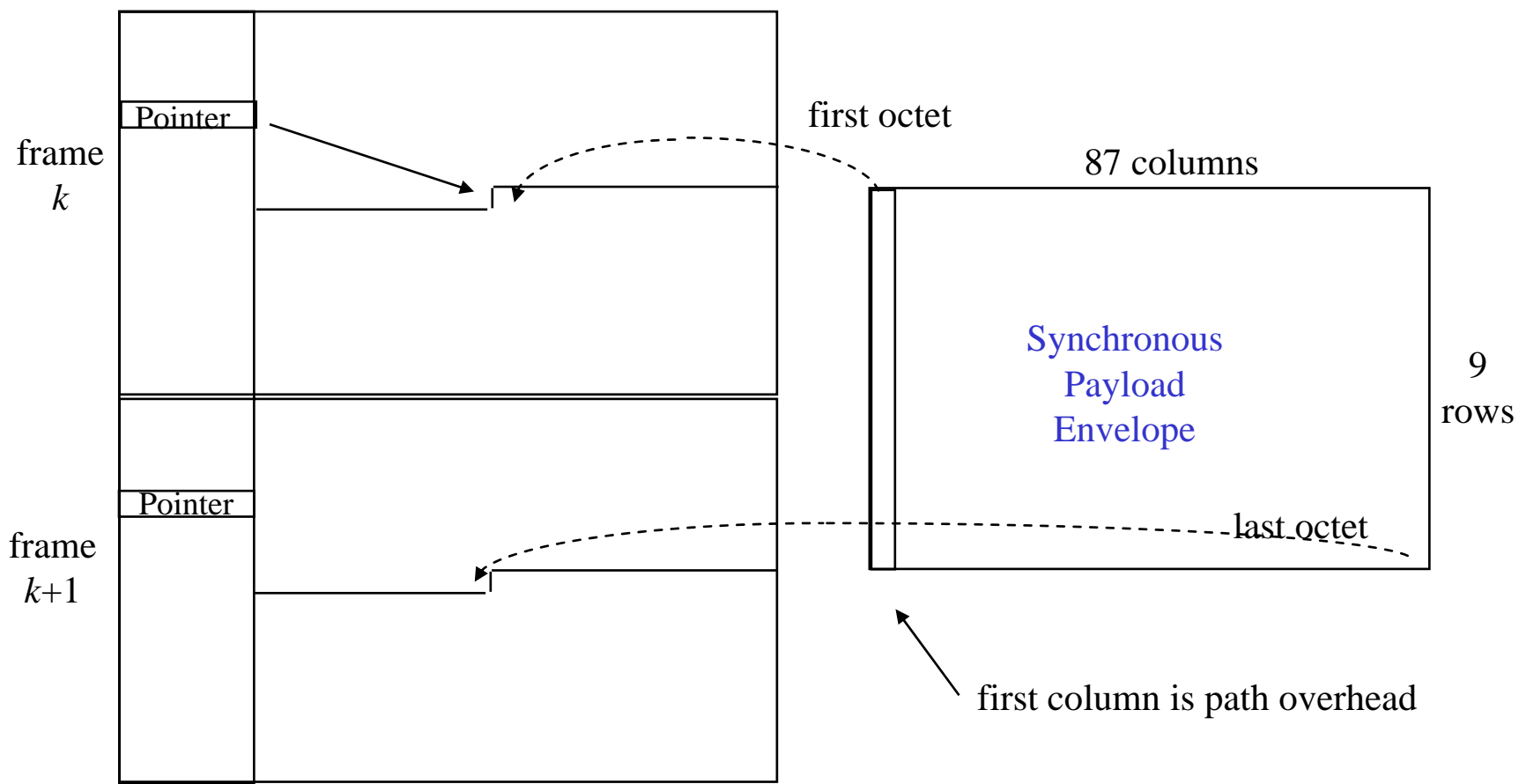
<i>SONET HEIRARCHY</i>	<i>Digital Signals</i>	<i>SPE frame columns</i>
28 X DS1	DS3 (44.736 Mb/s)	
VT-6 (6.912 Mb/s)	DS2 (6.312 Mb/s)	12
VT-3 (3.456 Mb/s)	DS1C (3.152 Mb/s)	6
VT-2 (2.304 Mb/s)	CEPT-1 (2.048 Mb/s)	4
VT-1.5 (1.728 Mb/s)	DS1 (1.544 Mb/s)	3
24 TDM/PCM CHANNEL	T1 (1.544 Mb/s)	
1 TDM/PCM CHANNEL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



# SPE straddling SONET frame



# SONET STS-3

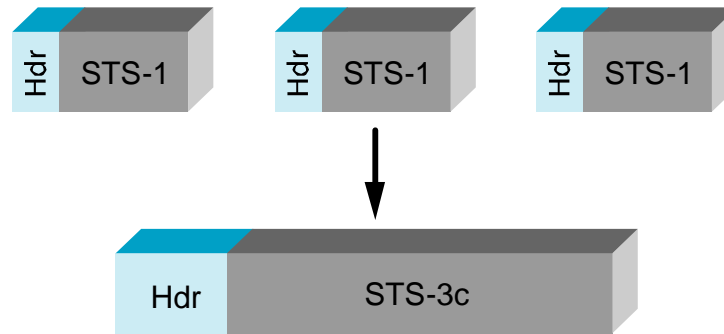
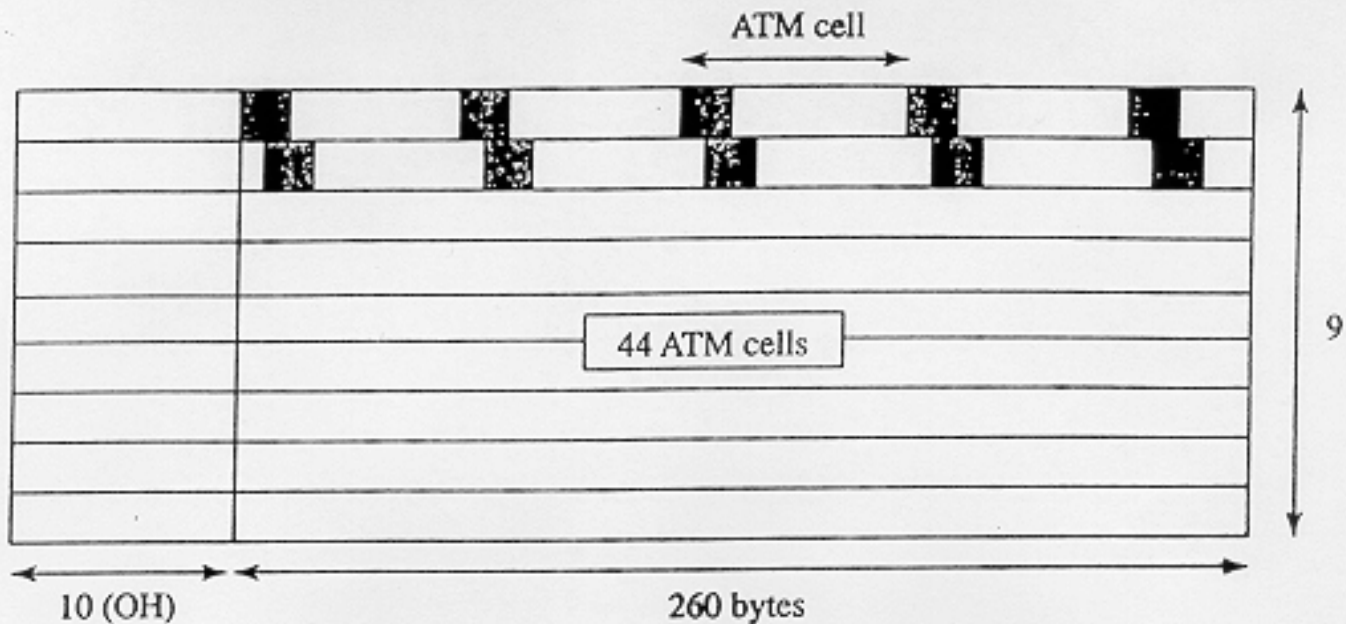


Figure 2.14

# ATM Cells in an STS-3 Frame



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



# Synchronous Multiplexing in SONET

