



μ



SDH/SONET



μ 1960 μ .

TDM.

μ μ μ

ISDN

μ $\mu\mu$ (leased lines)



-PDH

□

?

□

:

μ

,

μ

□

μ

□

:

μ

bits μ bit stuffing

□

?

□

$\mu\mu$

μ

.



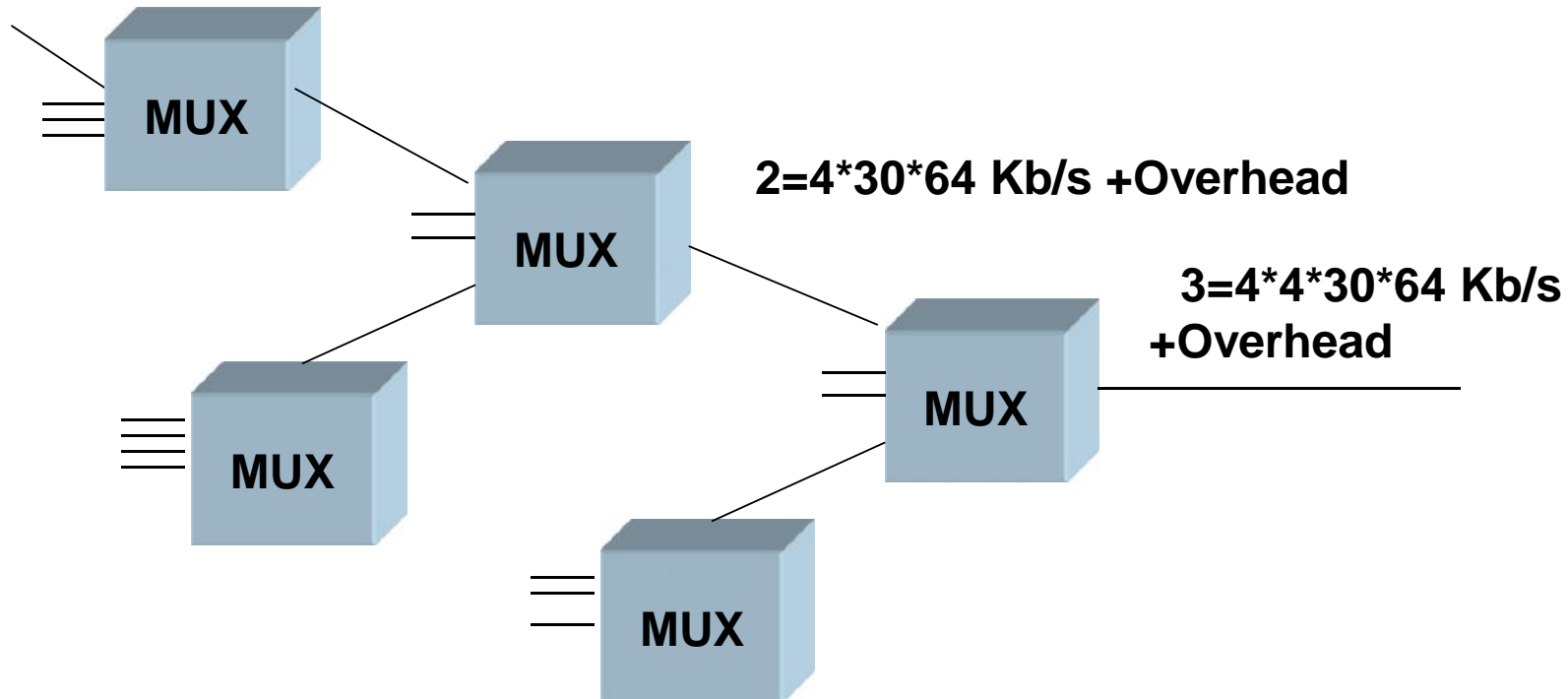
μ PDH

64 Kb/s

μ :

PDH

$$1 = 30 \cdot 64 \text{ Kb/s} + \text{Overhead}$$





. μ

ANSI

DS-n=

μ μ n
:T1,T2...

ETSI

CEPT-n= ITU-T

μ n
:E1,E2...



μ

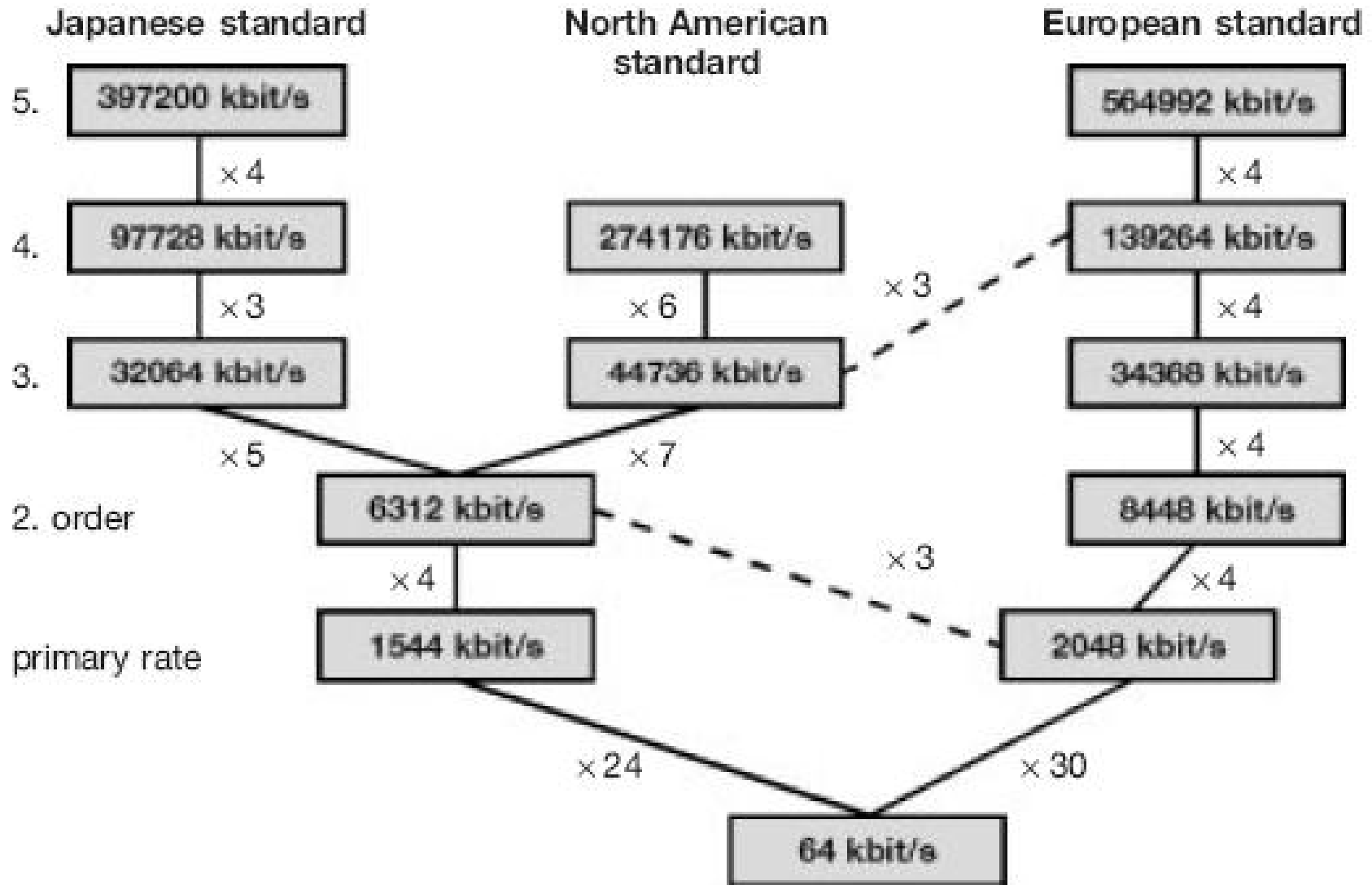
μ

μ			μ
DS0		1	0.064
DS1	T1	24	1.544
DS1C	T1C	48	3.152
DS2	T2	96	6.312
DS3	T3	672	44.736
DS4	T4	4032	246.176

μ			μ
DS0	E0	1	0.064
CEPT-1	E1	32	2.048
CEPT-2	E2	128	8.448
CEPT-3	E3	512	34.368
CEPT-4	E4	2048	139.264
CEPT-5	E5	8192	565.148



μ μ





□ ANSI

□ $DS1C = 2 * DS1$

□ $DS2 = 4 * DS1$

□ $DS3 = 7 * DS2$

□ $DS4/NA = 3 * DS3$

□ $DS4 = 6 * DS3$

□ ITU-T

□ $n+1 = 4 * n$



PDH

μ



μ

μ



μ

μ



μ

μ

μ

,

,

.

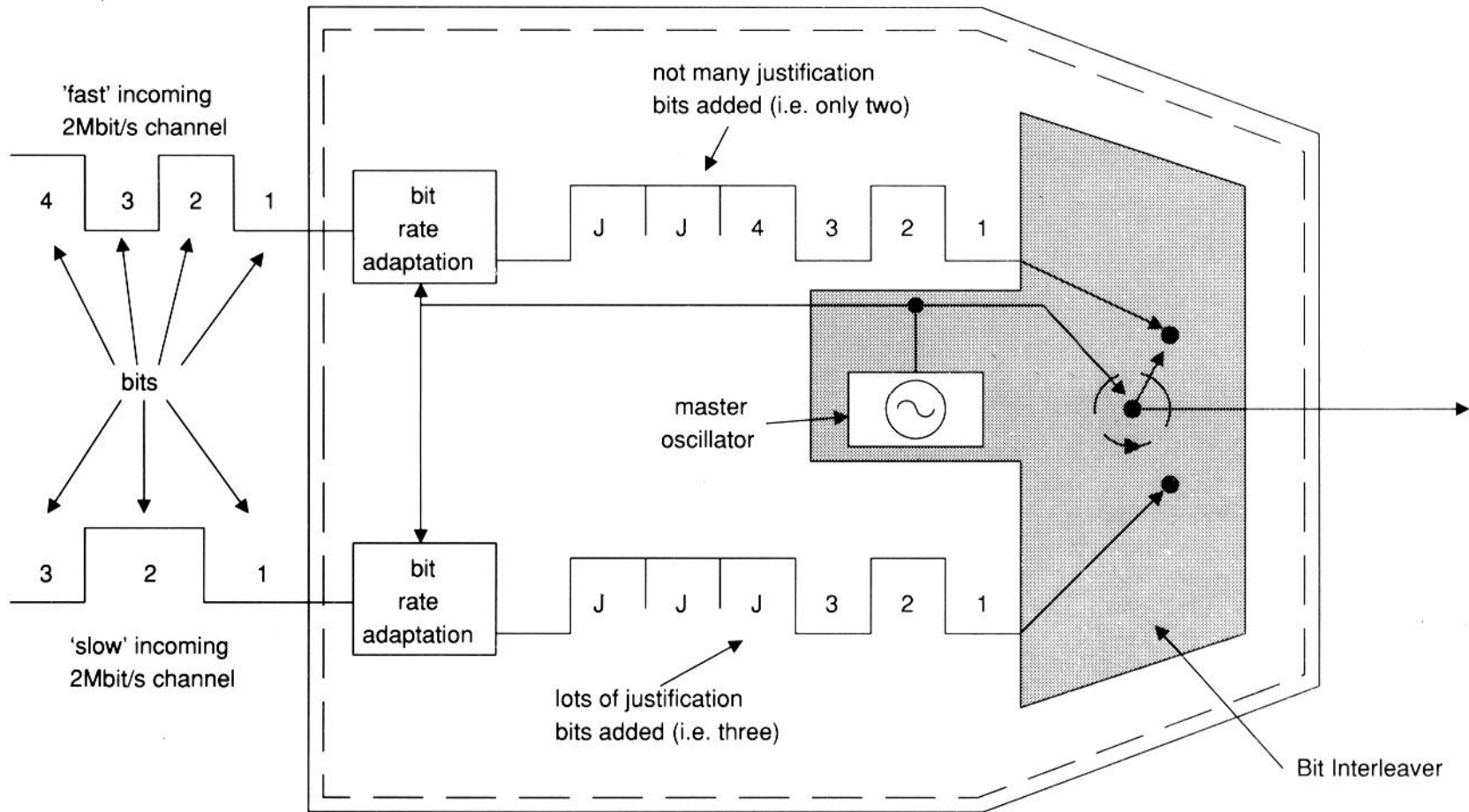


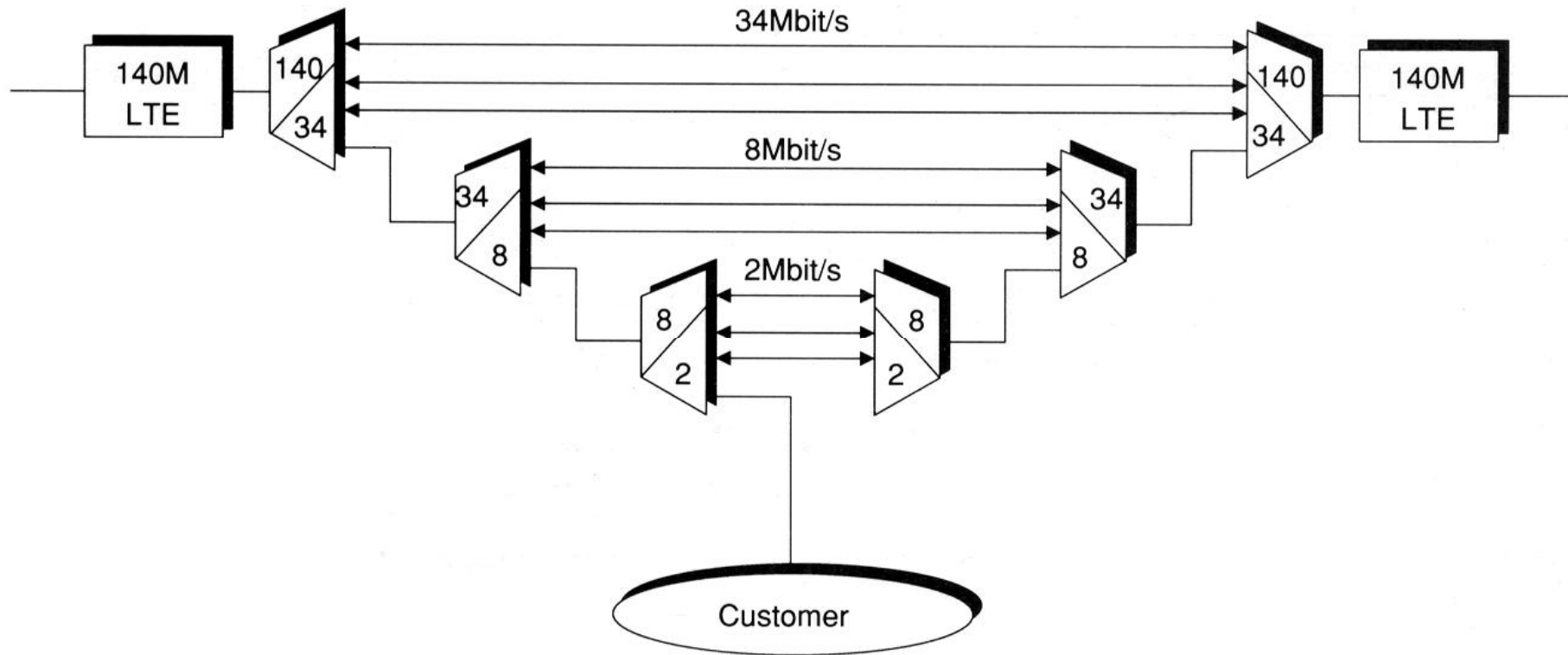
μ

μ



Bit-Stuffing







SONET/SDH

- **SONET - Synchronous Optical NETWORK**
 - 1985
 - Bellcore
 - Synchronous Optical Network (SONET).
 - ANSI

- **SDH - Synchronous Digital Hierarchy**
 - ITU

- **SONET vs SDH**
 - μ
 - μ



SONET/SDH

□ 1984-

μ

□ 1985-

, ANSI

□ 1986- ITU-T

SONET, SDH

□ 1987-

μ μ

□ 1988-

– SONET standard

□ 1989 SDH standard



to-point trunking)

μ - - μ (Point-



PDH



(synchronous) μ



μ μ SONET/SDH
μ video,



μ μ μ μ μ μ μ μ



SONET/SDH



μ

o

o

o

Broadband

o **Internet**

o

μ

$\mu\mu$

o

o



μ

SONET/SDH;



μ

μ



μ

μ



-

μ

μ

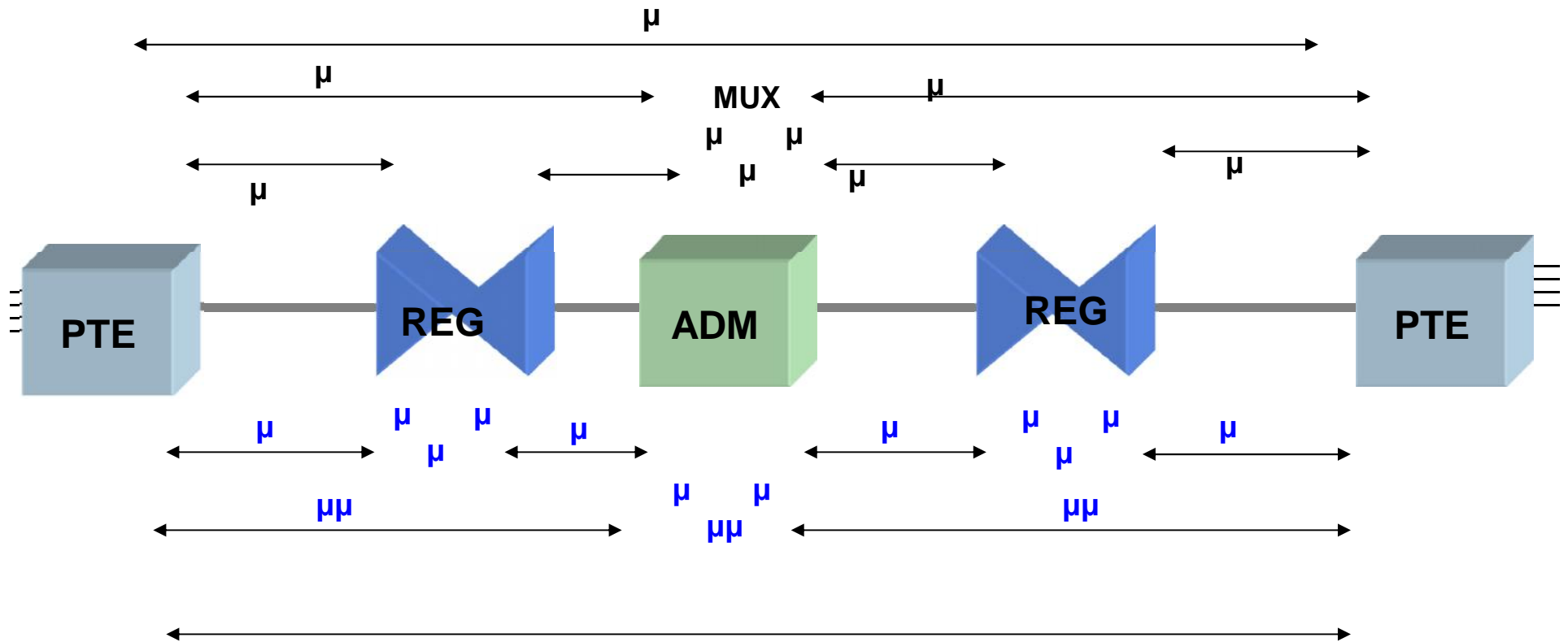
μ





SONET/SDH

SDH



SONET



SONET/SDH

μ μ

μ

Add/Drop

Digital cross-connect system (DCS DXC)



μ

μ



SONET/ SDH

μ



SDH

μ

μ

.

μ

clients

μ

SONET/

SDH

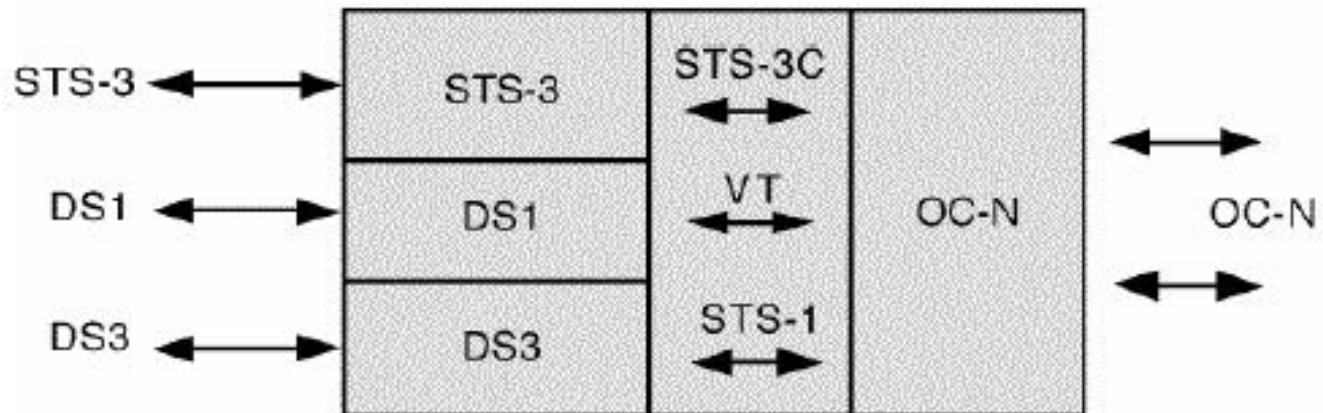
μ

μ

μ

**SONET/
SONET/ SDH**

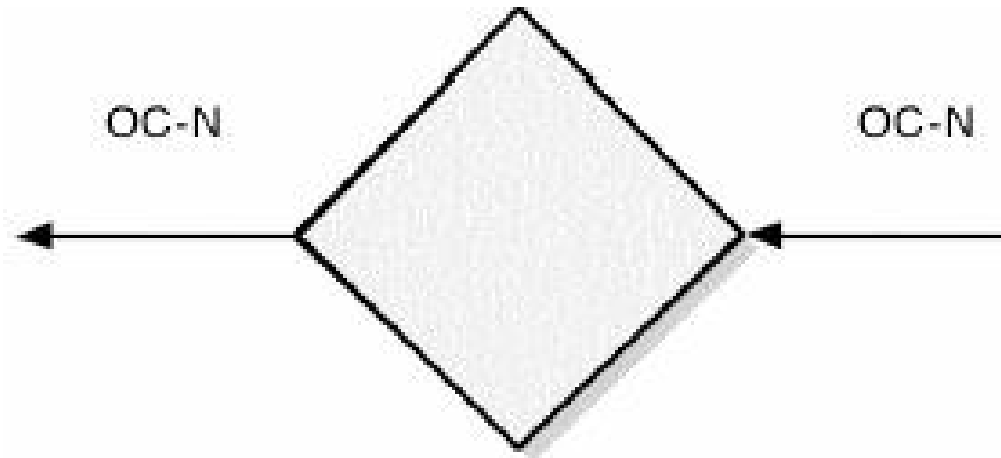
μ .





μ

μ , μ μ μ .





Digital cross-connect system (DCS DXC)



Add / Drop

μ

μ

μ

,

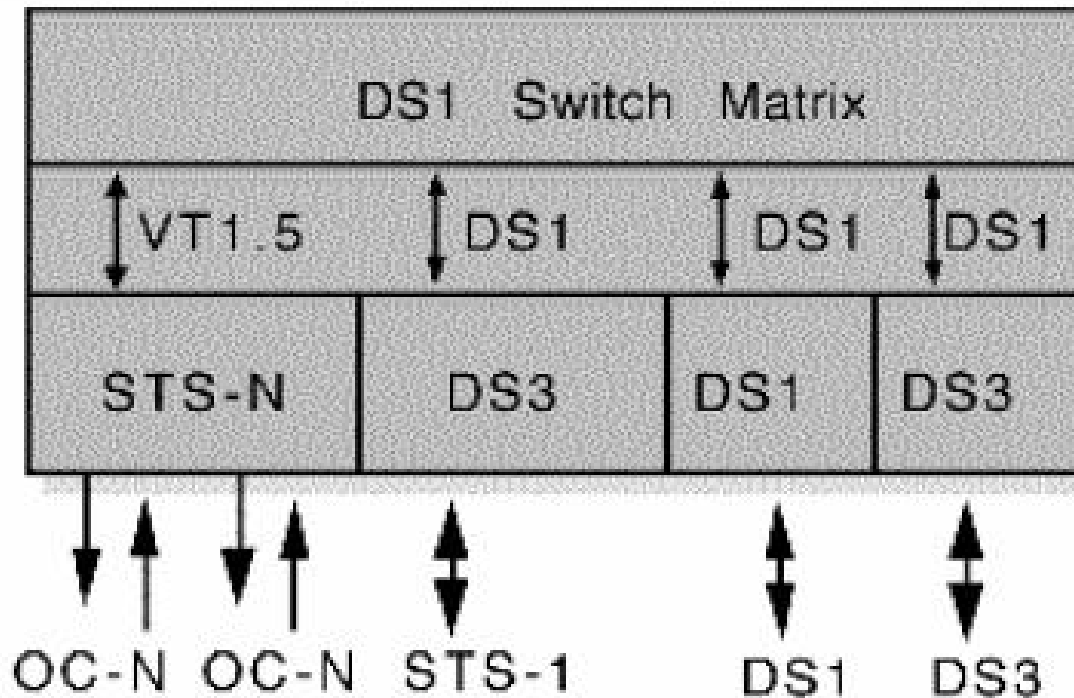
μ

,

μ

μ

.





Point-to-point

- μ μ μ

Point-to-multipoint

- μ μ + ADM μ
 μ

Hub

- Digital Cross Connect (DCS)

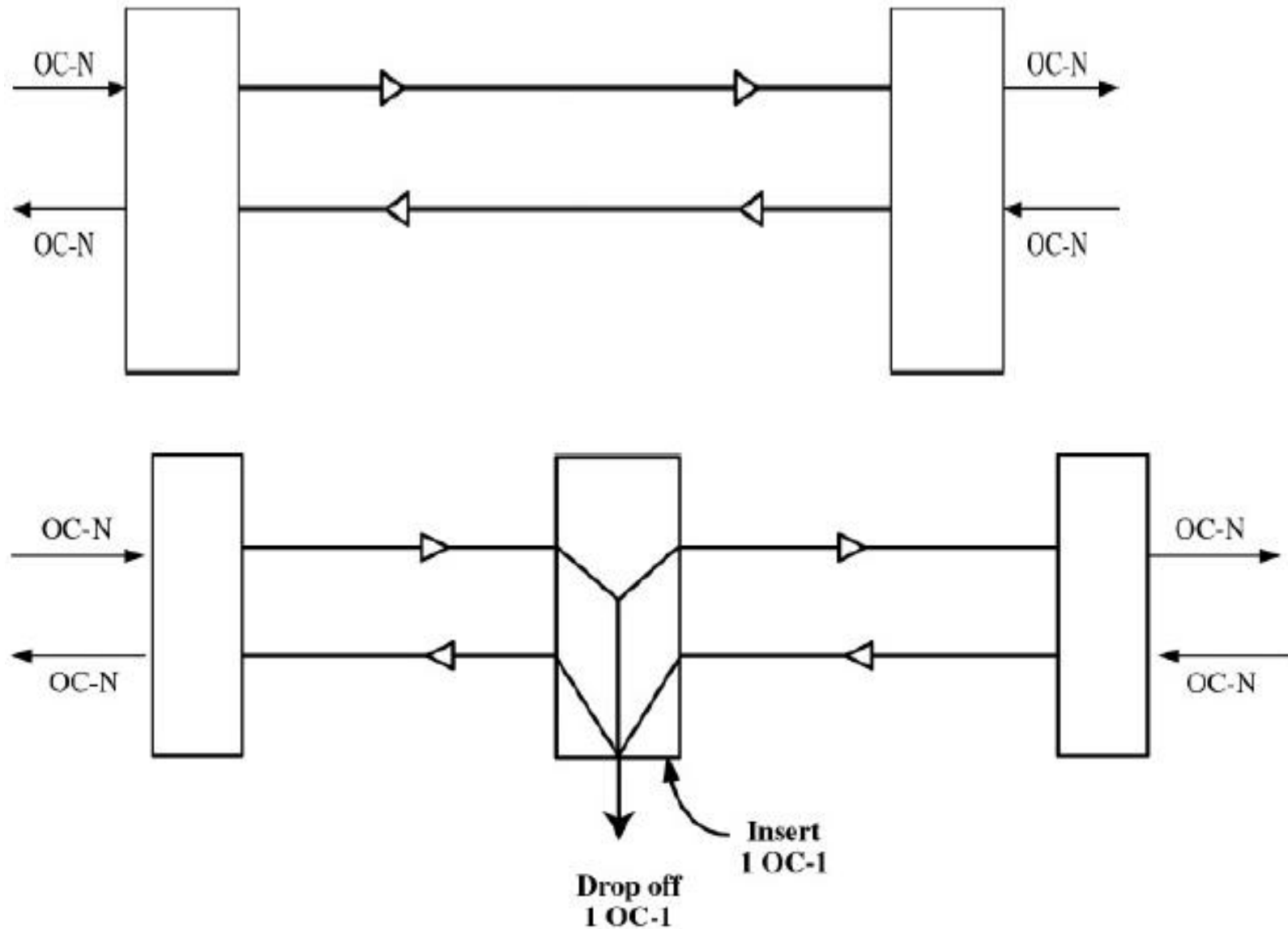
Ring ()

-

- μ

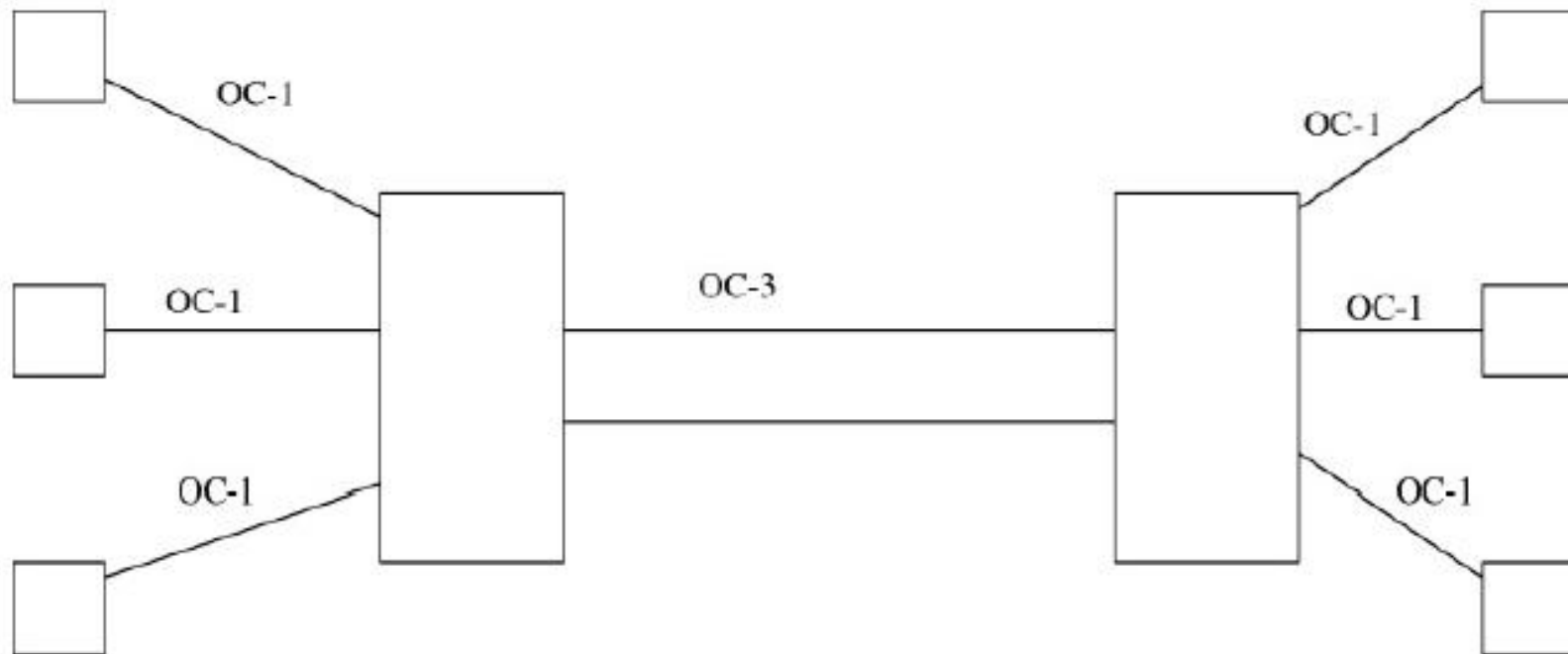


Point-to-point. Point-to-multipoint



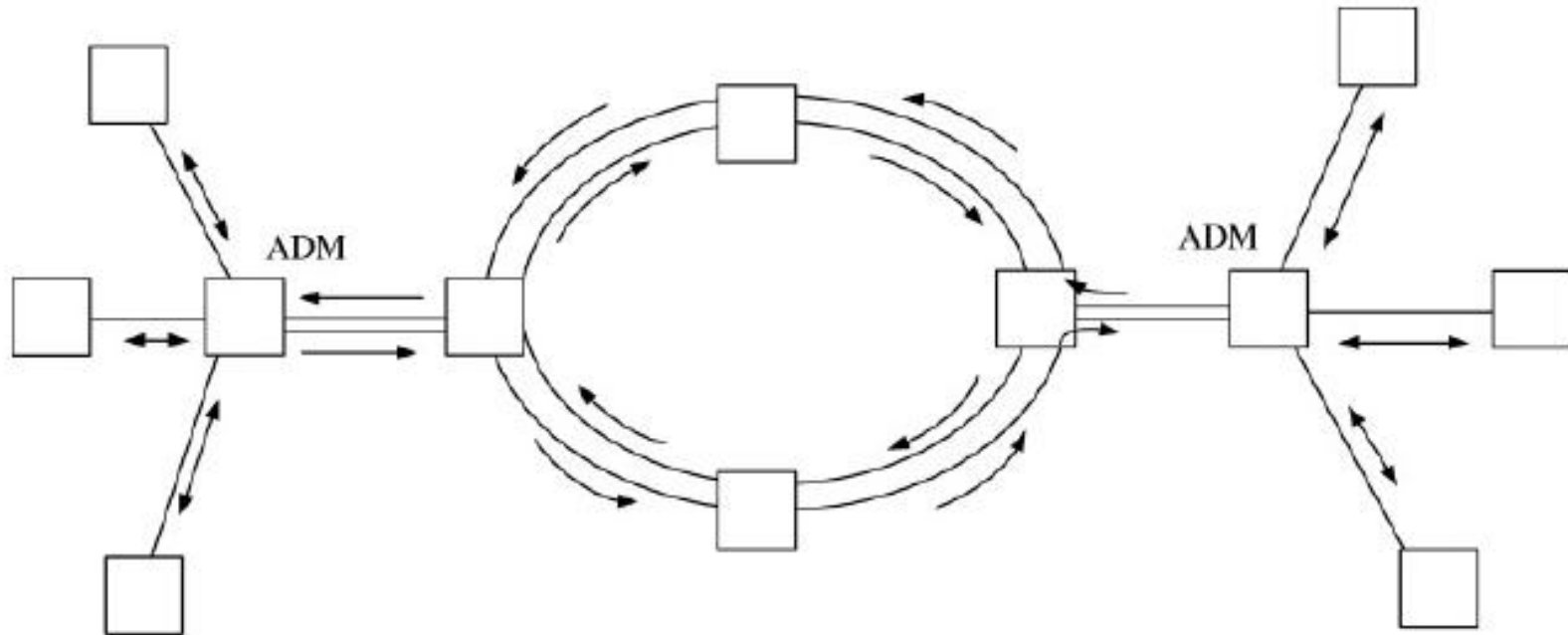


Hub





Ring ()





TDM/PCM

SONET

□ PCM

μ

8000

μ

4 kHz μ

μ

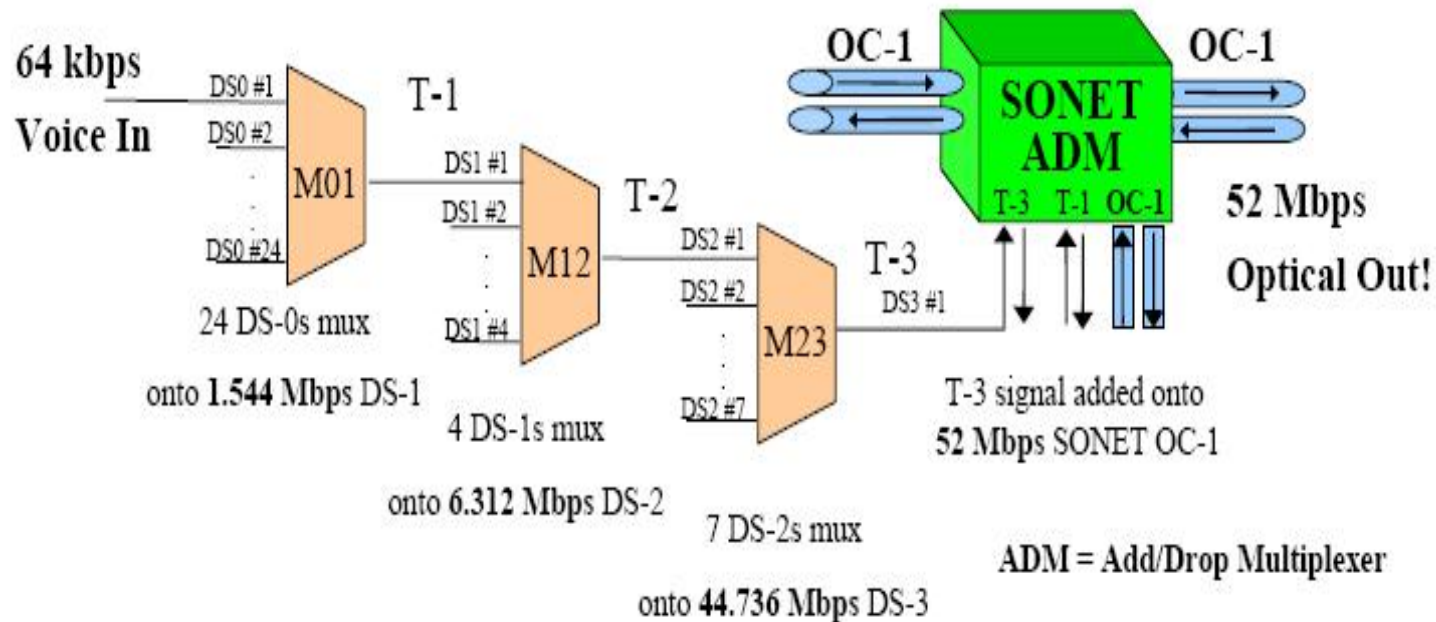
□

μ

μ 8 bits

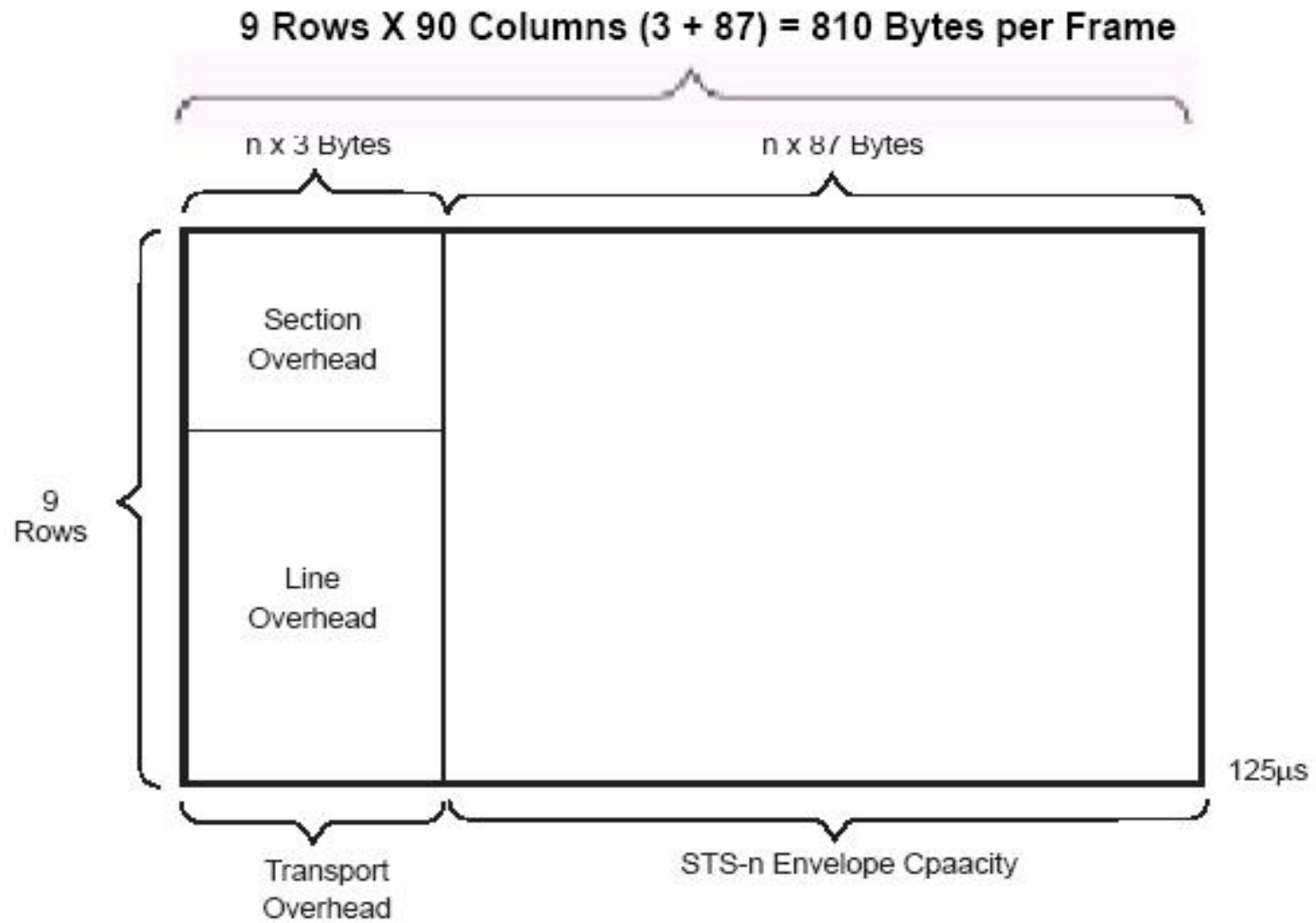
□

64 kbps (8*8000)





SONET





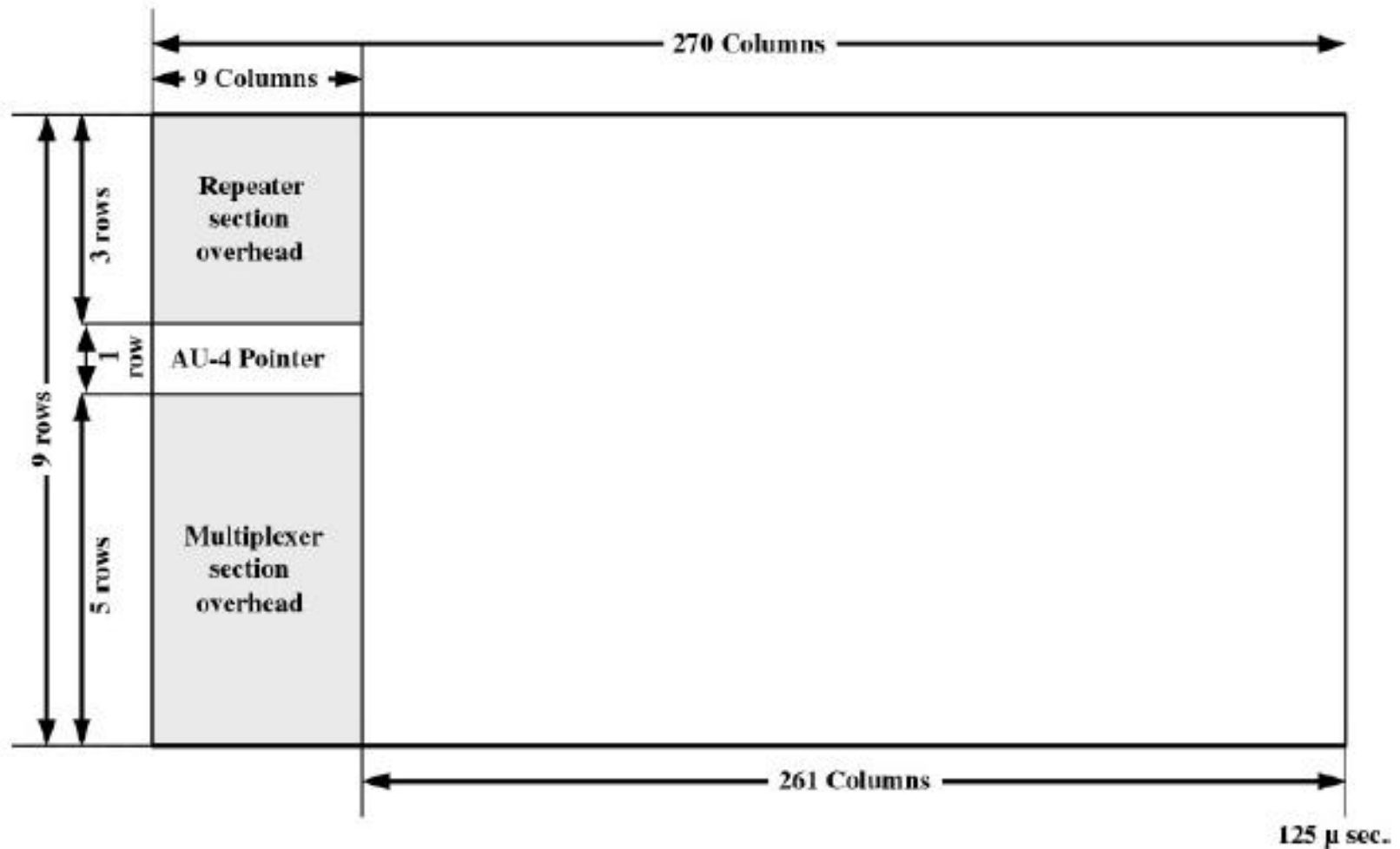
μ SONET

		SONET	
μ	μ		
STS-1	OC-1	51.84 Mbps	28 DS-1 1 DS-3
STS-3	OC-3	155.520 Mbps	84 DS-1 3 DS-3
STS-12	OC-12	622.08 Mbps	336 DS-1 12 DS-3
STS-24	OC-24	1.244 Gbps	672 DS-1 24 DS-3
STS-48	OC-48	2.488 Gbps	1344 DS-1 48 DS-3
STS-192	OC-192	9.95 Gbps	5376 DS-1 192 DS-3
STS-768	OC-768	40 Gbps	21504 DS-1 768 DS-3



SDH (Synchronous Digital Hierarchy)

STM-1





μ μ

SDH

μ μ **SDH**

155.52 Mb/s STM-1

- μ **139.264 Mbps**

PDH E4

- μ μ **SONET STS-3**

μ μ μ μ
STM-1

STM-4 622 Mb/s μ μ **STS-12**

STM-16 2.5 Gb/s μ μ **STS-48**

STM-64 10 Gb/s μ μ **STS-192**



□ Synchronous Transport Signal N (STS-N):

– μ SONET μ N-

– SONET (
, μ ,
)

□ Optical Carrier N (OC-N):

– μ μ N-

– μ -

– μ SONET

□ Synchronous Transport Module (STM):

SDH



μ

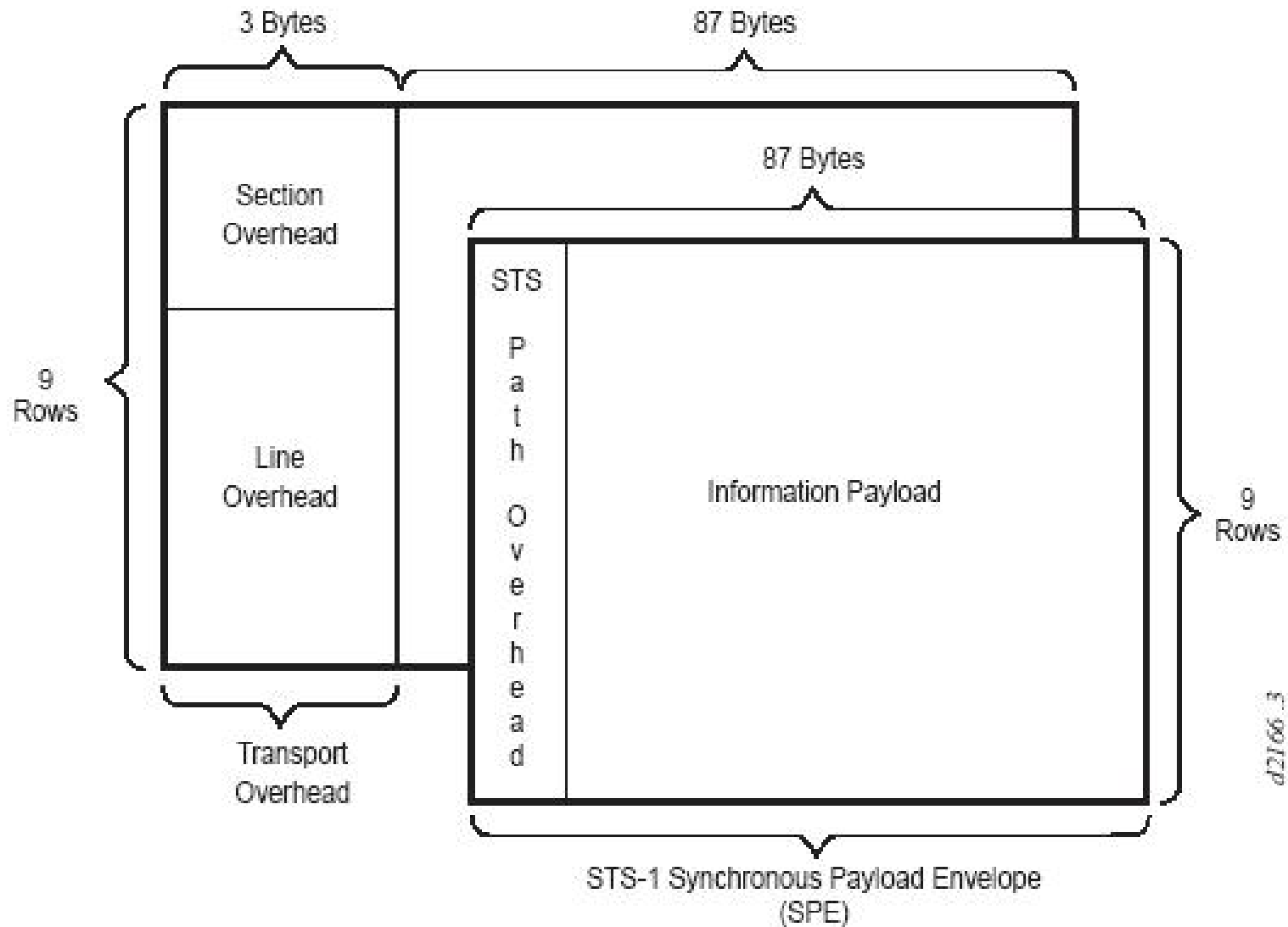
STS-1 (I)

- 810 bytes, () μ 9 $\mu\mu$
90 bytes
- (frame) 125 μsec
- 8*810 bits/frame 8000 frames/sec = 51.84 Mb/s
- μ 45 Mb/s DS-3
- Transport Overhead (TOH): 27 bytes (3)
- 9 bytes section overhead (SOH) (3 $\mu\mu$)
- 18 bytes line overhead (SOH) (6 $\mu\mu$)
- 9 bytes path overhead (POH) ()
- Synchronous Payload Envelop (SPE): 783 bytes
(87)
- 774 bytes user data (86)



μ

STS-1 (II)





STS-N

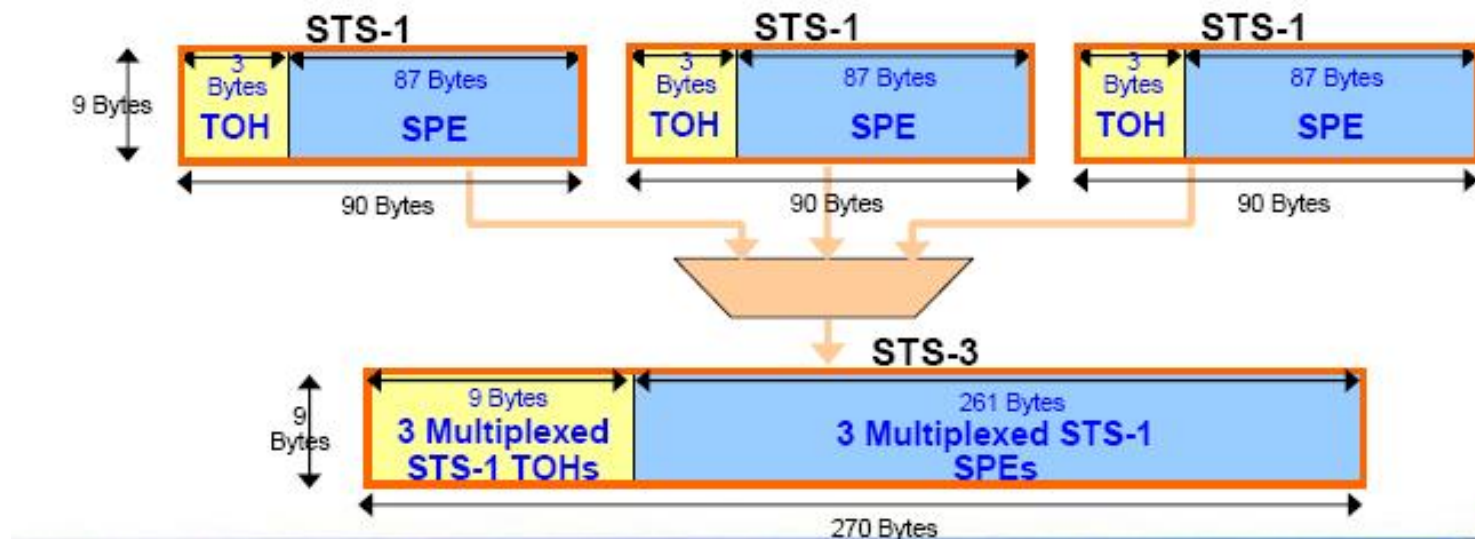
- **STS-N frame**
frames
 - N overhead bytes
 - N payloads

STS-1

- μ **Byte-interleaving**
frames

STS-1

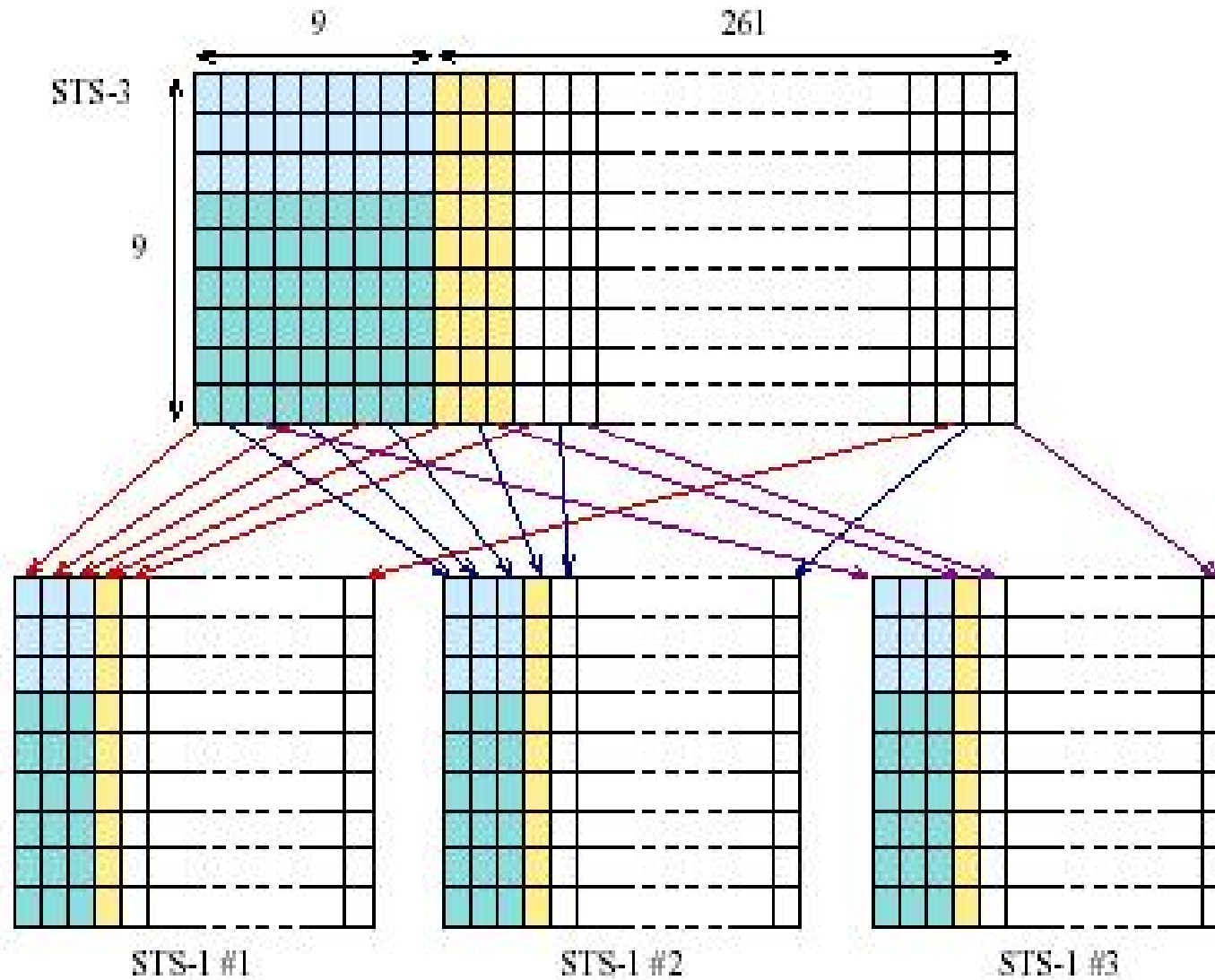
- direct add/drop multiplexing





μ

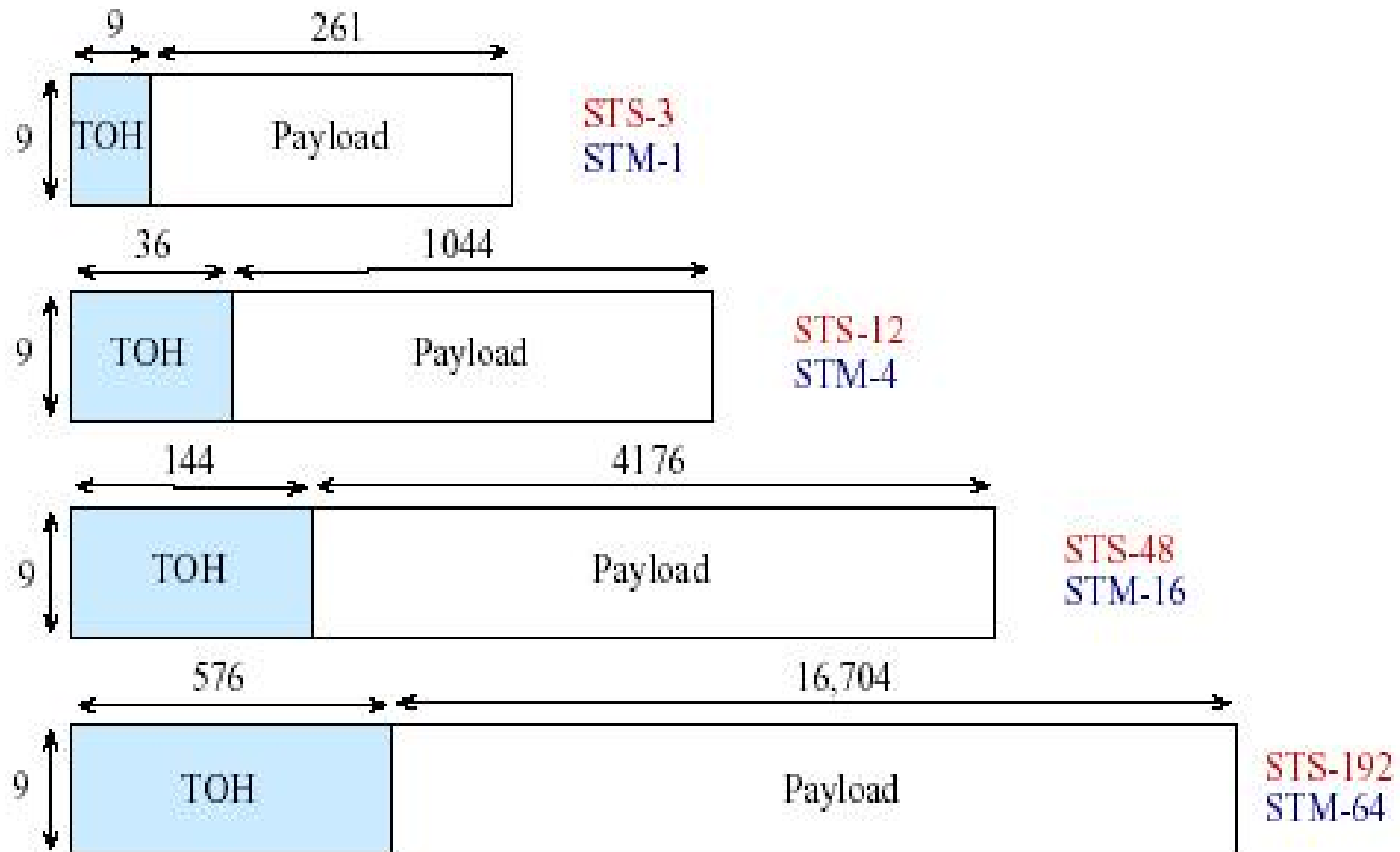
STS-3





μ

STS-N





μ STS-1N

□ μ STS-N μ
STS-1 frames

□ “Concatenation” STS-3c (OC-3c), STS-12c (OC-12c),
. . . : STS-3c

- 9 TOH
- μ
- SPE 10-270
- μ POH

□ μ μ μ μ μ μ
 μ μ 52 Mb/s



STS-3 μ STS-3c

STS-1 STS-1 STS-1 STS-1

STS-3 STS-1 STS-1 STS-1

STS-1 STS-1 STS-1 ...

STS-1 STS-1 STS-1 ...

STS-3c STS-3c STS-3c STS-3c

\longleftrightarrow
125 μ s

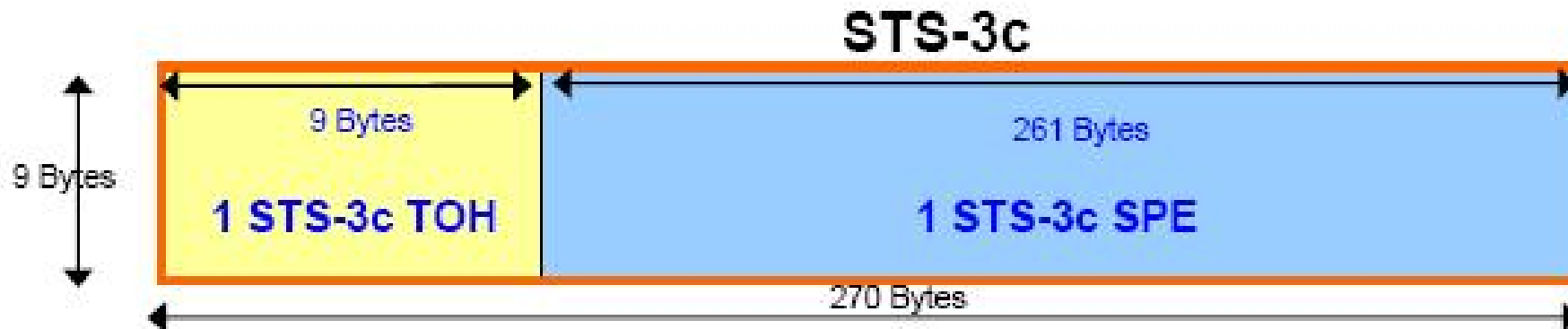


STS-3c

□ μ , STS-3c
 μ μ 156 Mb/s
52 Mb/s

- μ μ , E4 (139 Mb/s) μ
- TOH , SPE

□ μ μ STS-3c

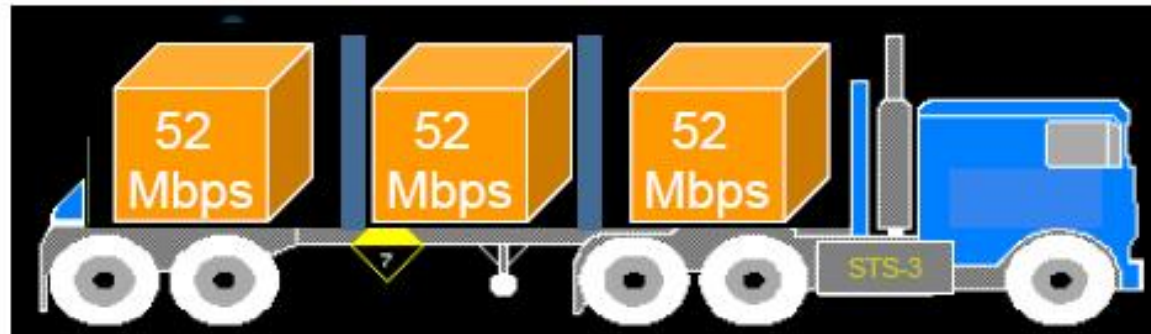




STS-3

STS-3c

STS-3



STS-3c





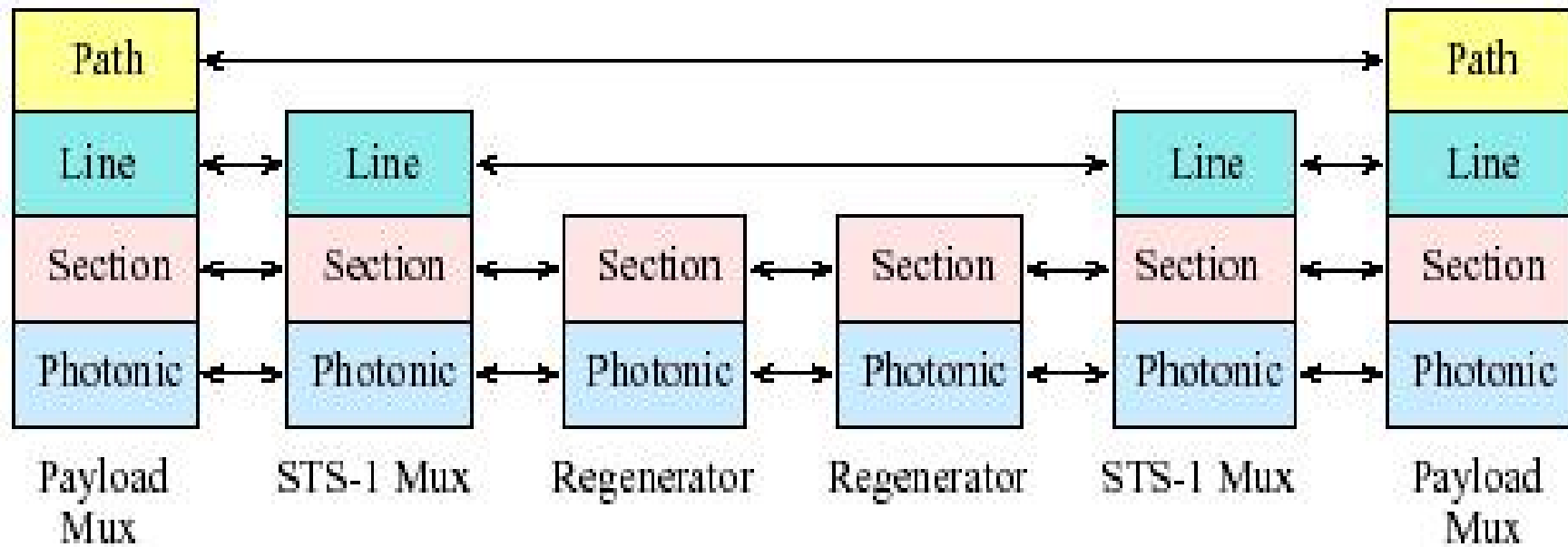
μ

SONET

SONET

μ

OSI





μ (Photonic Layer)

: bits μ

: μ STS frames
OC bit μ

μ
(overhead) μ 0 1



SONET



(Overhead)



3

– Path Overhead (POH)

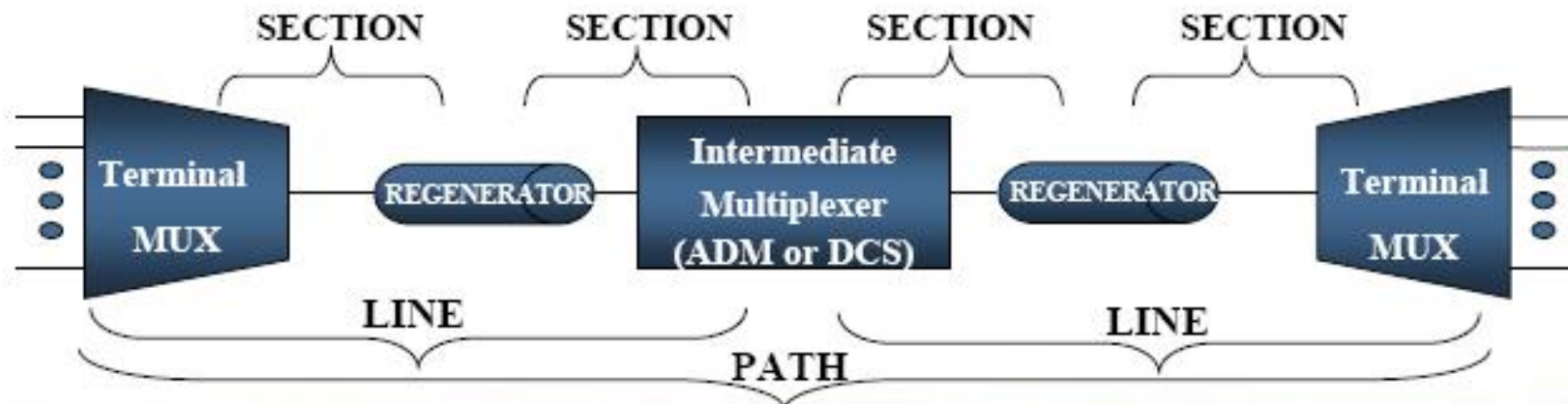
- μ μ

– Line Overhead (LOH)

-

– Section Overhead (SOH)

- μ



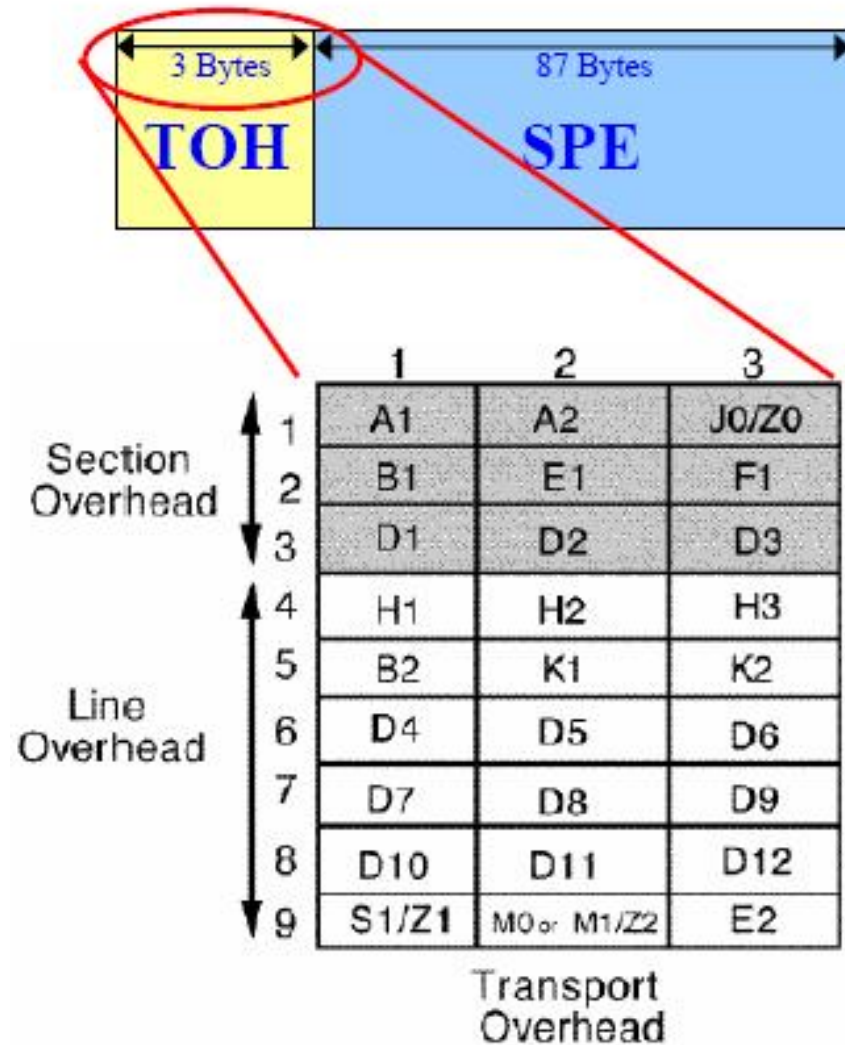


μ μ μ (Section Layer)

- μ μ μ μ μ μ μ μ (Regenerator section of transmission link)
- :
- μ μ μ μ μ μ μ μ (section error monitoring)
- (framing)
- (signal scrambling)
- 9-byte SOH:
- SOH μ μ μ μ μ μ μ μ / μ μ μ μ μ μ μ μ (section-terminating equipment -STE)



Section Overhead



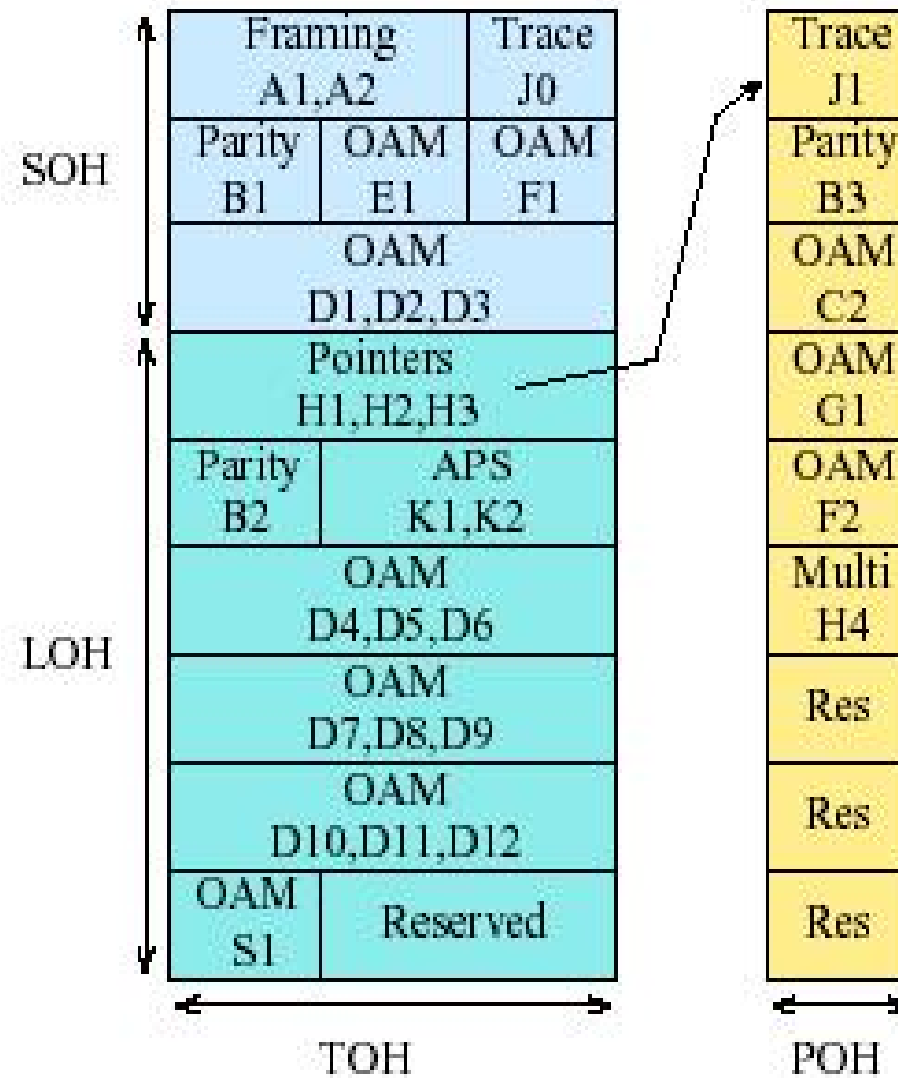
- $\mu\mu$
- TOH**
- 9 Bytes **STS-1**
-
-
- STS-N**
-
- OAM&P**
- μ



SONET



SONET (I)





SONET (II)

□ Framing: A1, A2 = 11110110 00101000

□ μ μ μ
 STS-1, (scrambled)
 □ A1, A2 bytes STS-1
 STS-N

□ Parity: B1 (SOH), B2 (LOH), B3 (POH) bytes

□ μ (even-parity check)
 STS-1, μ
 (scrambling)

□ bit interleaving: bit i

μ i-bit STS-1 byte



SONET (I I)

□ Pointers H1, H2, H3

□ H1, H2

(μ SPE
POH byte)

□ H3

μ
μμ

□

μ SPE μ
(dynamic alignment)

□ OAM: bytes D1-D3 (SOH), D4-D12 (LOH)

□

μ SONET

□

μ μ , ,
(alarms, maintenance, administration)

□

μ μ μ μ μ



SONET (IV)

□ APS: K1, K2

□ automatic protection switching protocol

□ μ μ

μ

□ μ

μ

μ

SONET

(SONET

rings)

□ μ : H4

μ

SPEs (. . AT cells, IP packets)



μμ

SONET μ



'

«

» μ

(SPE)

(frame synchronous) μ

μ

SONET



μ

μ



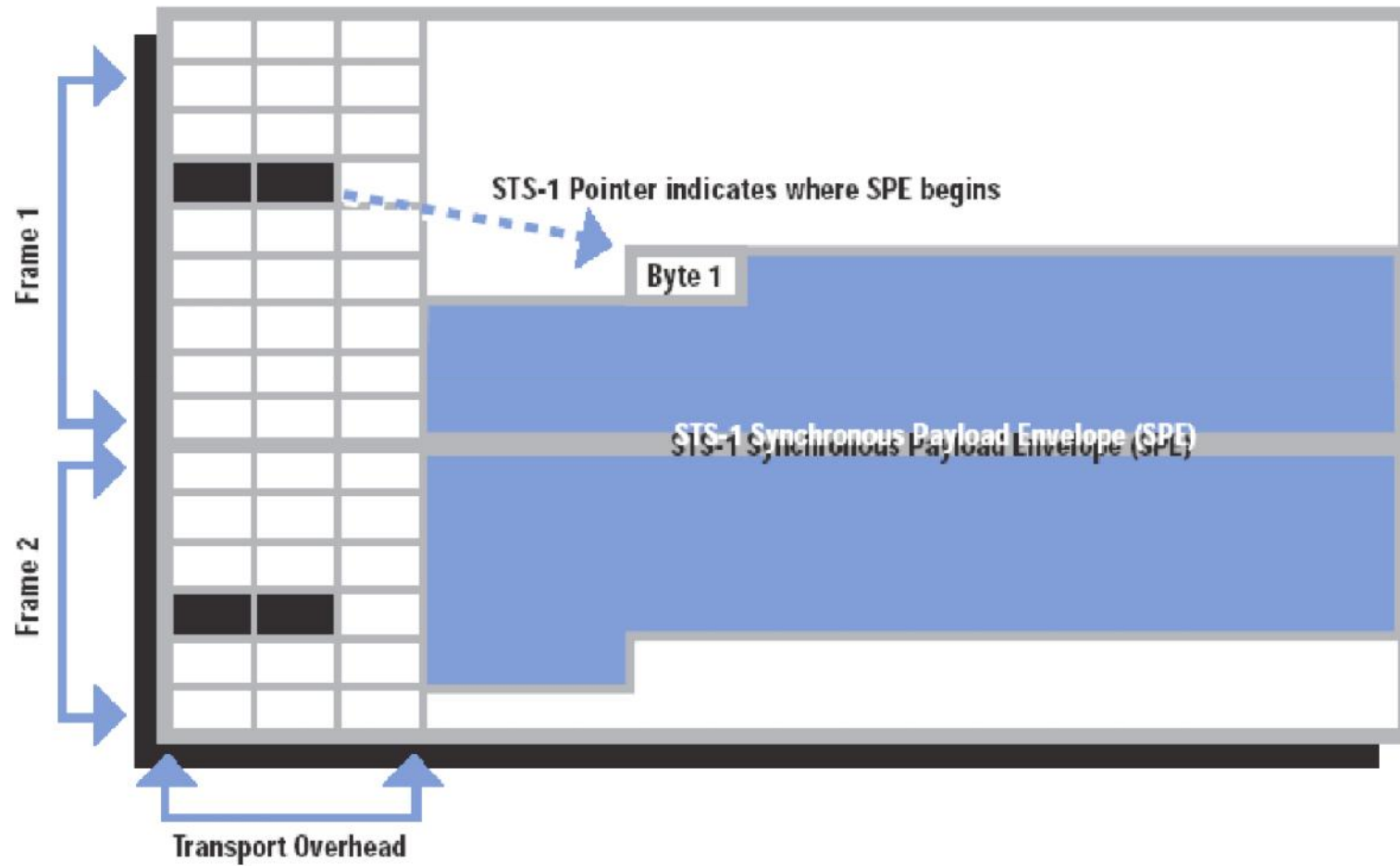
:

SPE

μμ

μ

SONET





μ

SONET

Virtual Tributaries (VTs): channelized 64 Kb/s DS-0s

DS-3: μ DS-3

ATM cells: SONET μ μ B-ISDN

**Packet over SONET (POS):
 μ 3 ()**



SONET

