μ

μ

NG- SDH/SONET

❑   **(traffic)**

  –   μ -

  –   μ   μ

      μ

❑   μ   **?**

        μ   « μ ».

❑   **SDH/SONET**   μ   μ

  ❑   « »   ,   **TDM**

          μ   μ   .

  ❑   μ « »   μ

     μ   μ   .

  ❑   μ

    μ   μ   μ   .

❑ μ μ μ
μ bandwidth taxation

❑ HDLC
μ μ μ QoS
byte stuffing μ
.

❑ NG-SDH/SONET μ .
:
– μ
payload.
– (μ framing)
– μ

– μ μ SONET

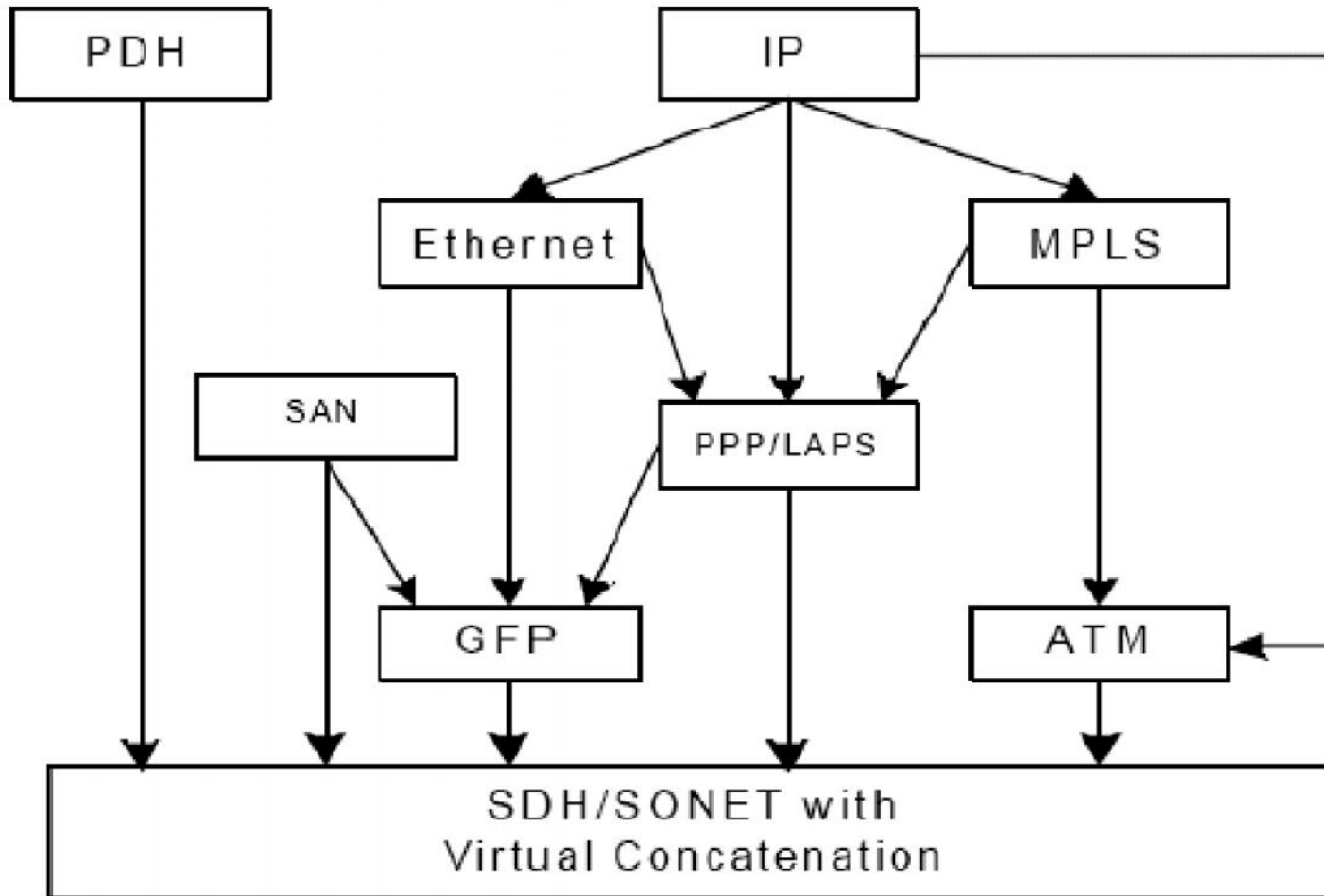❑   :
  – Generic Framing Procedure (GFP)
❑   μ   μ   :
  – Virtual Concatenation (VCAT)
    • **Virtual concatenation   μ   μ**
         μ   payload
                  SPE (Synchronous Payload
      Envelop)   μ   μ
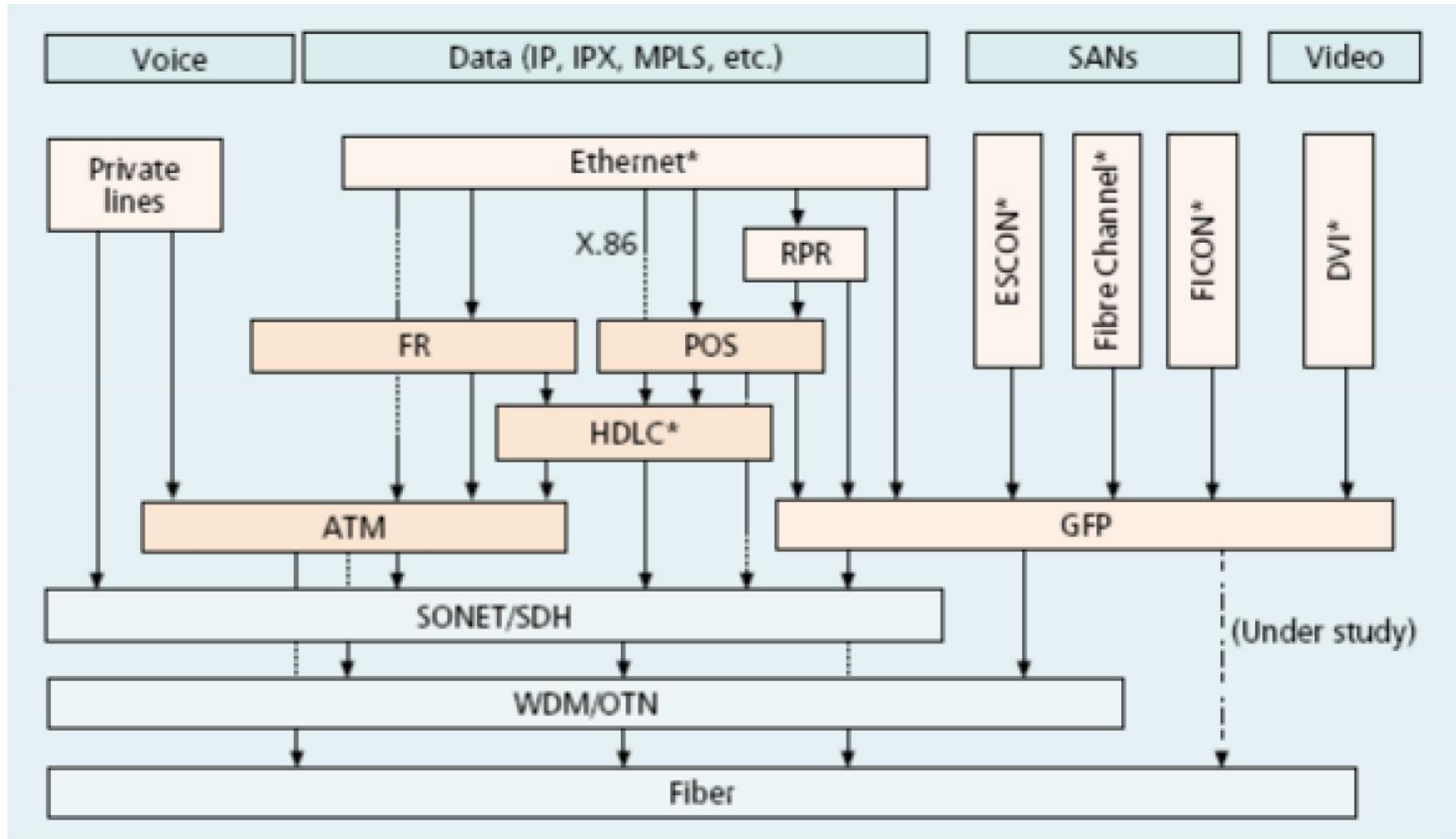   **.**
  – Link Capacity Adjustment Scheme (LCAS)
    •   **μ   μ   μ**
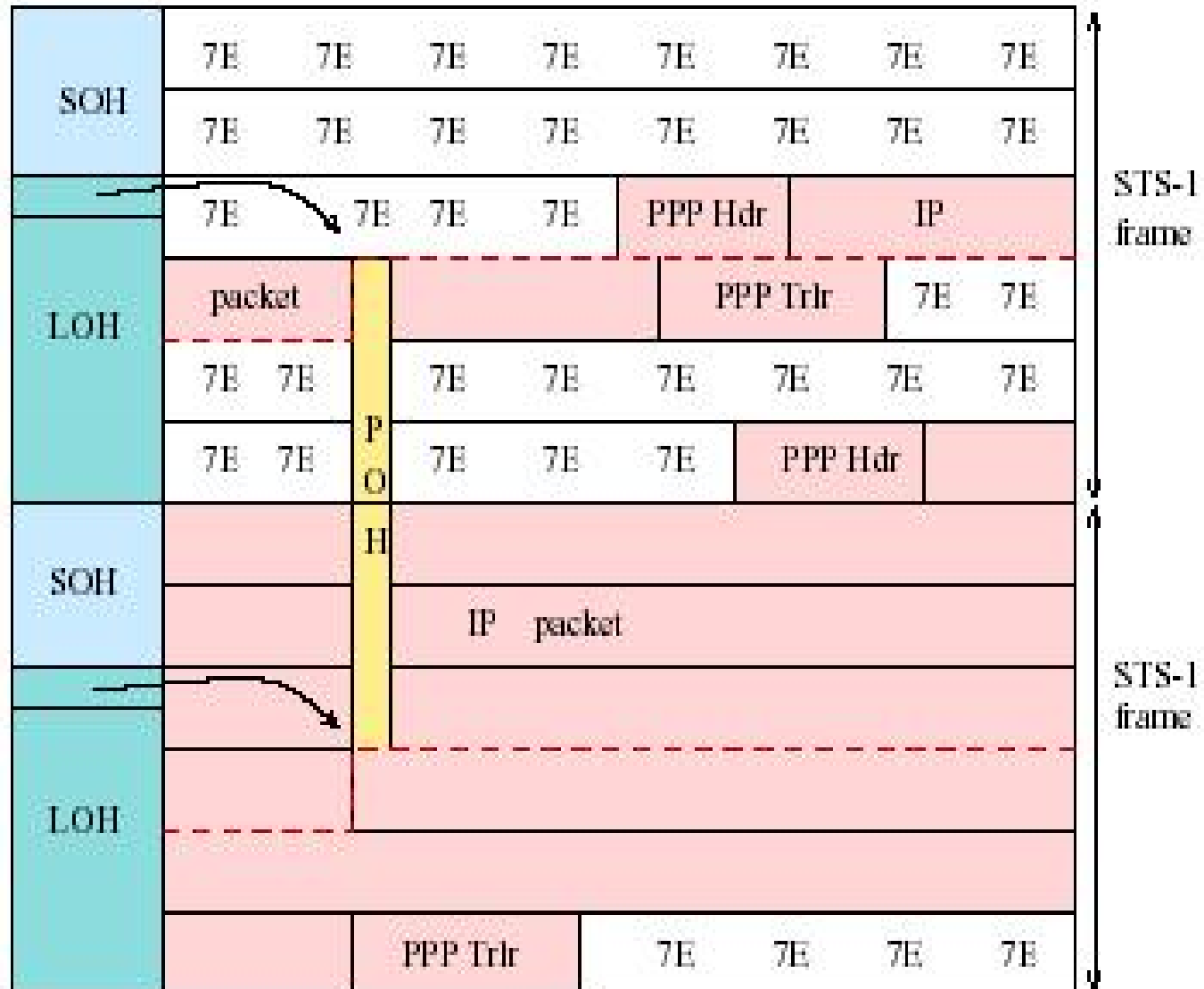   **μ   virtual concatenation**

Encapsulation Hierarchy-II

Generic Framing Procedure (GFP)

GFP

- ❑   ,   μ   μ
  μ   μ   μ
  μ .
- ❑   SONET/SDH,   μ   μ
  μ   ,   μ   .
  - o   μ ,   Packet over SONET (PoS),   μ
    PPP   SPE   SONET.
- ❑   GFP   μ   :
  μ
  clients.
- ❑   GFP   ,   .
  μ   μ   μ
  μ   -   .
- ❑   GFP   ITU-T: G.7041 (12/2003).

PPP over SONET (P-over-SONET)

❑ μ GFP SONET.

❑ , μ GFP-F.

❑ GFP

, μ μ   μ   μ

μ   SONET/SDH.

❑   GFP,   μ   PoS, μ

μ   μ   μ   (
PoS μ   μ   μ
μ   μ   . . IP μ
PPP).

❑   **:**
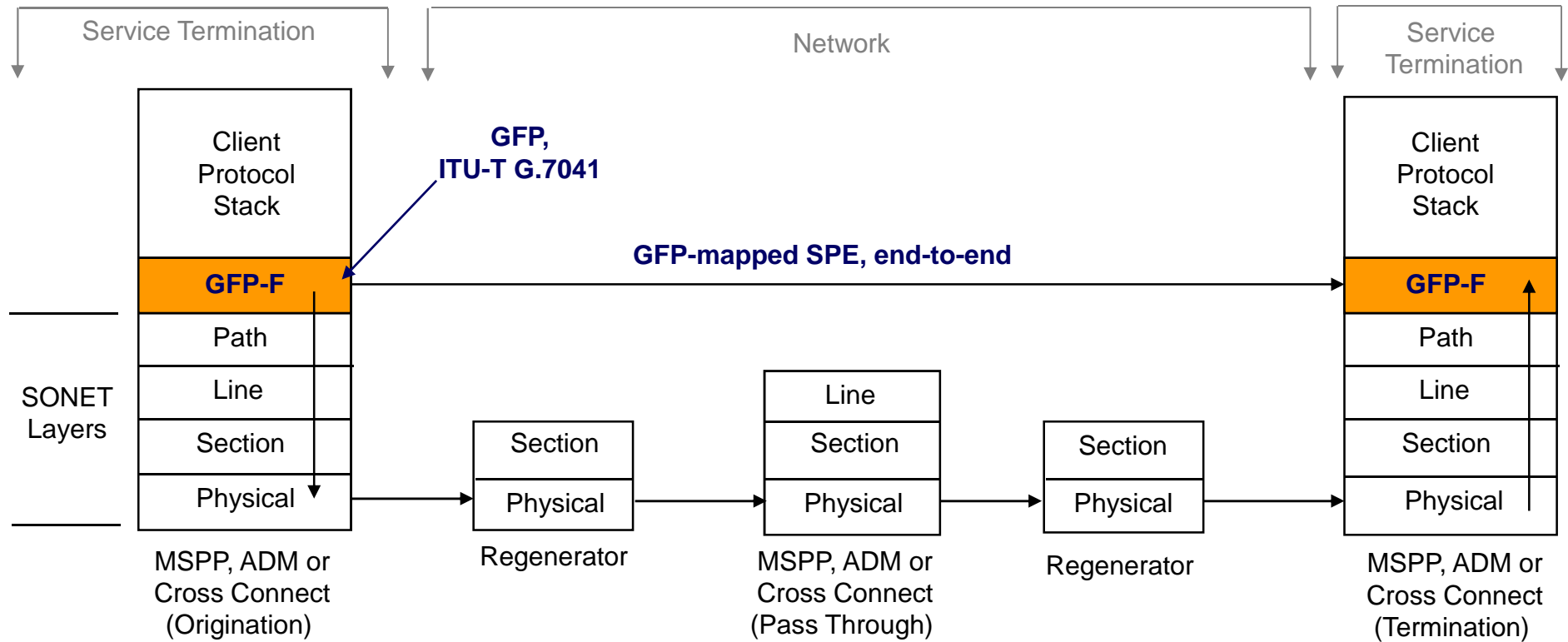
    o **GFP-T (transparent GFP)**

    o **GFP-F (frame mapped GFP)**

❑   **GFP**   **μ**   **μ**

  ❑   **μ**   **μ μ**   **,**

  ❑   **μ**   **.**

❑   **GFP μ**

           4   **65535 byte,**   **μ**

        μ   **μ**

      clients.

❑   **GFP**

  Channel ID,   **μ 256**

               .

```
                    GFP

        GFP                    GFP
       Framed               Transparent
```

❑   client
    μ   «   »
                    .
❑   μ
   client   GFP
❑   μ   μ
❑   MAC
❑   hardware
❑   μ   μ
    ❑
❑   (idle)

        μ

❑   μ
            .
❑   μ   .
❑   MAC
❑   μ   hardware
                  μ
       SONET/SDH
❑   μ   μ
    ❑
           low latency.
❑

❑ GFP μ μ
layers.

❑ μ , μ
byte-synchronous (bit!) μ .

❑ μ
byte-aligned.

❑ GFP
(core header) μ (payload).

❑ GFP μ .

Client data frames

Core header

Payload area

Byte transmission order

Bit transmission order

Payload length MSB
Payload length LSB
Core HEC MSB
Core HEC LSB

Payload header

Payload information N [536,520] or variable length packets

Payload FCS

Payload type MSB
Payload type LSB
Type HEC MSB
Type HEC LSB
0–60 bytes of extension headers (optional)

PTI | PFI | EXI
UPI

CID
Spare
Extension HEC MSB
Extension HEC LSB

Linear extension header shown (others may apply)

Payload FCS MSB
Payload FCS
Payload FCS
Payload FCS LSB

Client control frames

0x00 (0xB6)
0x00 (0xAB)
0x00 (0x31)
0x00 (0xE)

Idle frame (scrambled)

Type Field Format

15 14 13	12	11 10 9 8	7 6 5 4 3 2 1 0
PTI	PFI	EXI	UPI

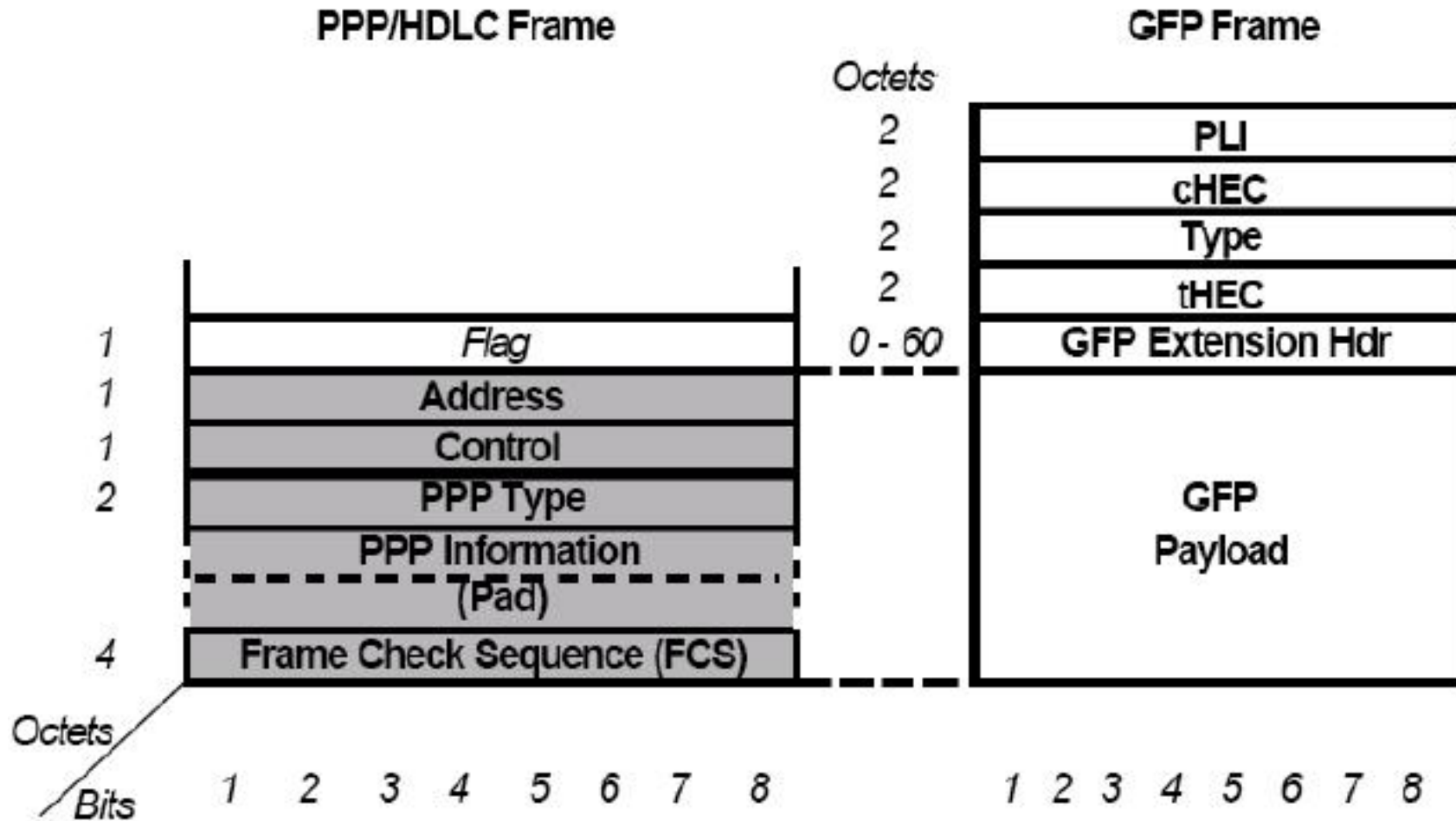# Ethernet and GFP Frame Relationship
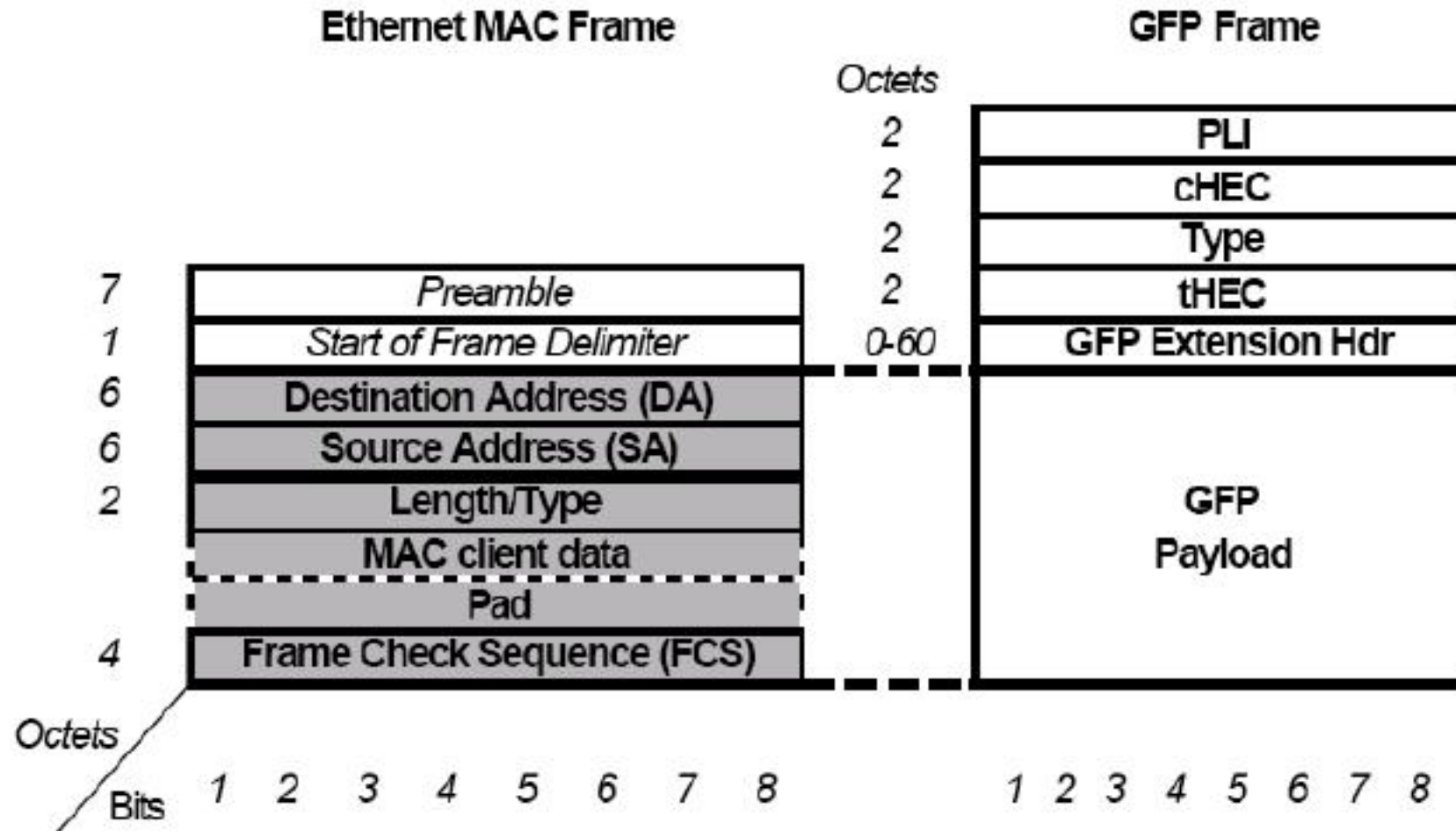
PPP/HDLC and GFP Frame Relationships

- ❑   μ   μ   μ
  μ   .

- ❑   μμ   μ
        64 /65   .

- ❑   GbE, FC, ESCON

❑   -standardized

❑

❑

❑

❑

❑   μ

SONET Virtual Concatenation (VCAT)

STS-3

STS-3c
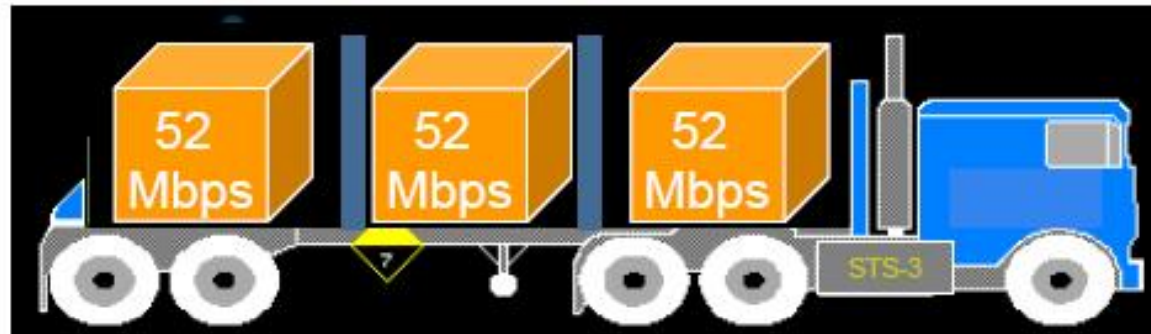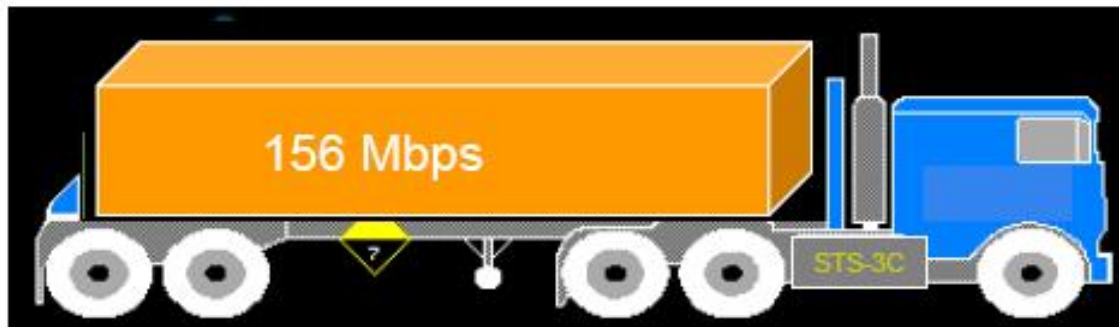
❑ **SONET** μ

– **Channelized:** STS-1 VT.

 • STS-1 51.840 Mb/s, μ 50.112 Mb/s 1.728
   .

 • VT 4 μ : VT1.5 (1.728 Mb/s), VT2 (2.304 Mb/s),
   VT3 (3.456 Mb/s), VT6.0 (6.912 Mb/s).

 • channelized SONET TDM
   .

– **Contiguously Concatenated** (CCAT) STS-1

 • 5 μ μ (STS-3c, 12c, 48c, 192c,
   768c)

 • STS-1 μ .

 • STS-Nc μ μ STS.

– **Virtual Concatenation**

 • STS - VT μ
   μ .

 • μ STS μ μ
   192.

Contiguously Concatenated Payload

❑ STS-1 μ SPE.

❑ μ μ concatenation.

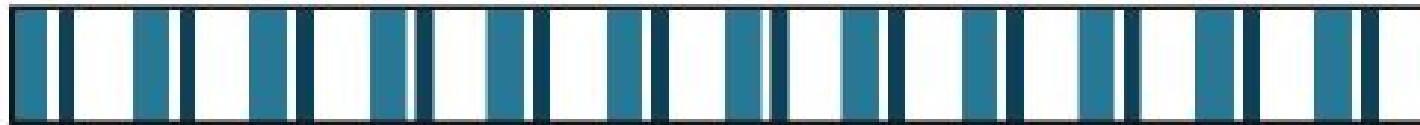❑ , μ H1 H2 line overhead .

❑ μ .

Contiguous Concatenation
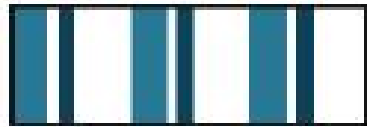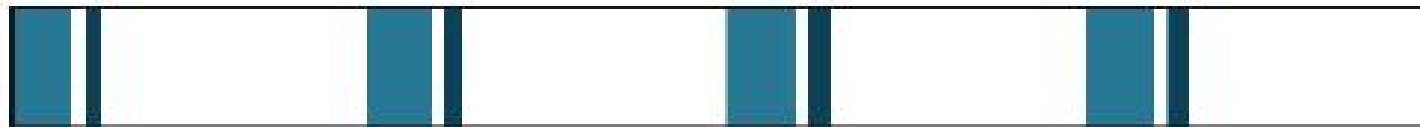

STS-3 (155 Mbps)

STS-3c/VC-4 (155 Mbps)

STS-12 (622 Mbps)

VC-4-4 (622 Mbps)

STS-12c, VC-4-4c (622 Mbps)

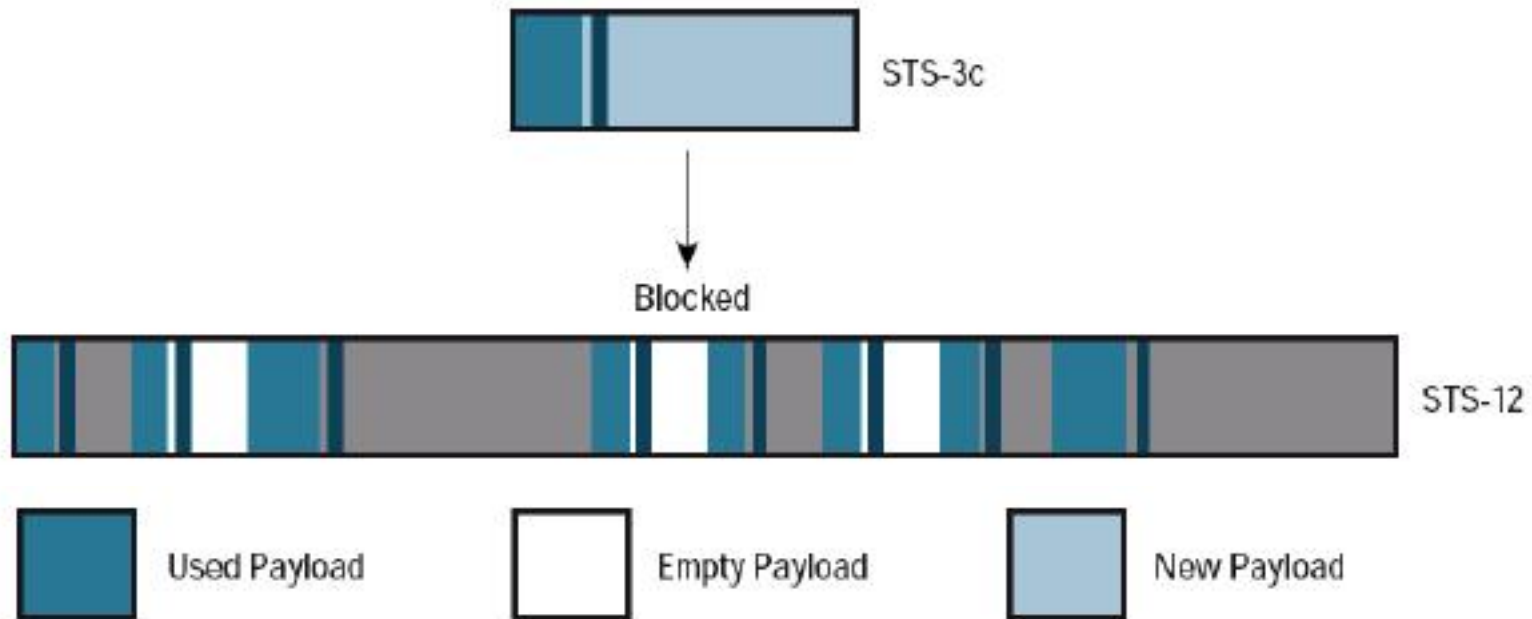Section/Line Overhead   Path Overhead   Payload

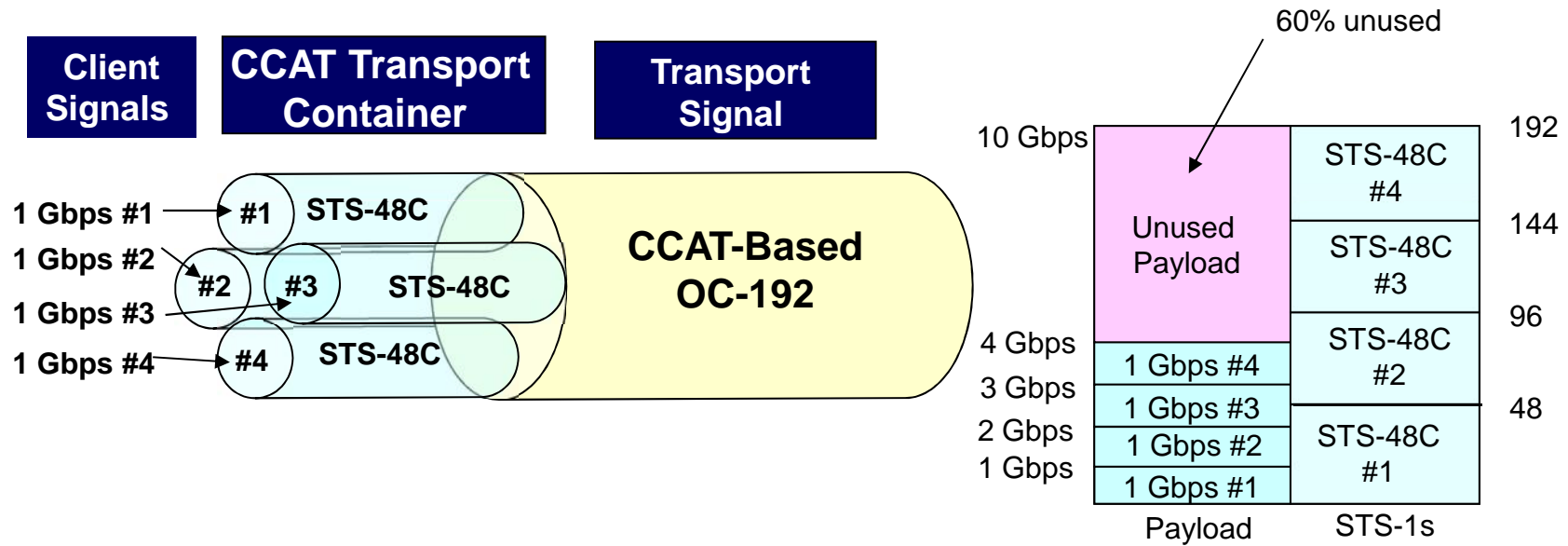| Service	Bit Rate	Utilization
Fast Ethernet	100 Mbit/s	STS-3c/VC-4 (67%)
Gigabit Ethernet	1000 Mbit/s	STS-48c/VC-4-16c (42%)
Fibre Channel	200 Mbit/s	STS-12c/VC-4-4c (33%)
Fibre Channel	1000 Mbit/s	STS-48c/VC-4-16c (42%)
ESCON	200 Mbit/s	STS-12cVC-4-4c (33%)

☐ μ , μ Gigabit Ethernet μ STS-48c.

| Client Signals | CCAT Transport Container | Transport Signal |

1 Gbps #1 → #1 STS-48C
1 Gbps #2 → #2 #3 STS-48C
1 Gbps #3 →
1 Gbps #4 → #4 STS-48C

CCAT-Based OC-192

60% unused

10 Gbps — Unused Payload — STS-48C #4 — 192
— STS-48C #3 — 144
4 Gbps — 1 Gbps #4 — STS-48C #2 — 96
3 Gbps — 1 Gbps #3
2 Gbps — 1 Gbps #2 — STS-48C #1 — 48
1 Gbps — 1 Gbps #1

Payload   STS-1s

40%   OC-192   μ

❑ **Virtual concatenation** μ μ
2
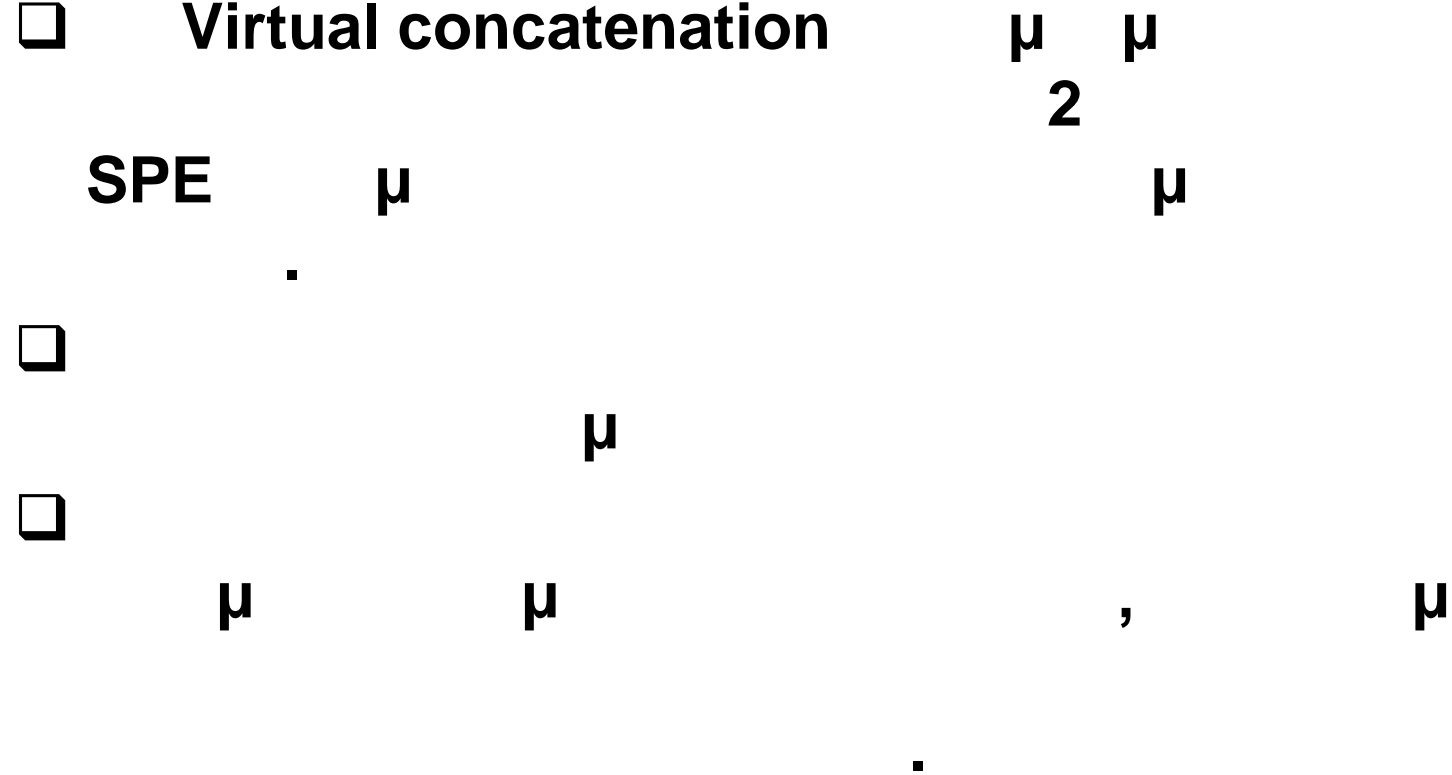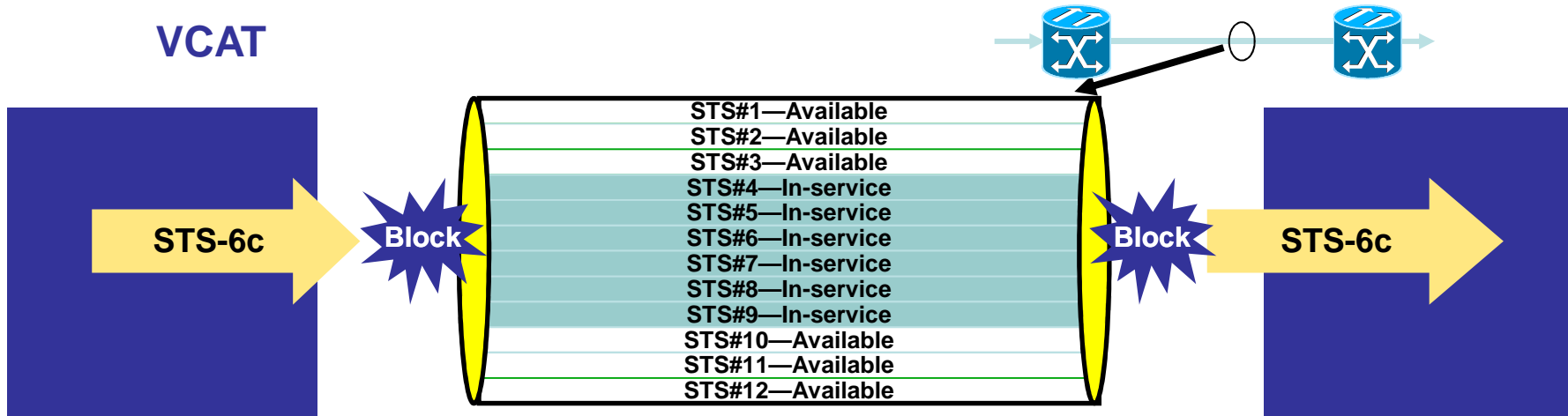
SPE μ μ
.

❑

μ

❑

μ μ , μ

.

OC192

STS3c

2xSTS1 VC

STS1

7xVT1.5 VC

100-Mbit/s Ethernet

10-Mbit/s Ethernet

❑   μ   μ   μ

Ethernet.

❑   μ

     μ   Sonet

     μ   .

❑   VCAT   SONET/SDH

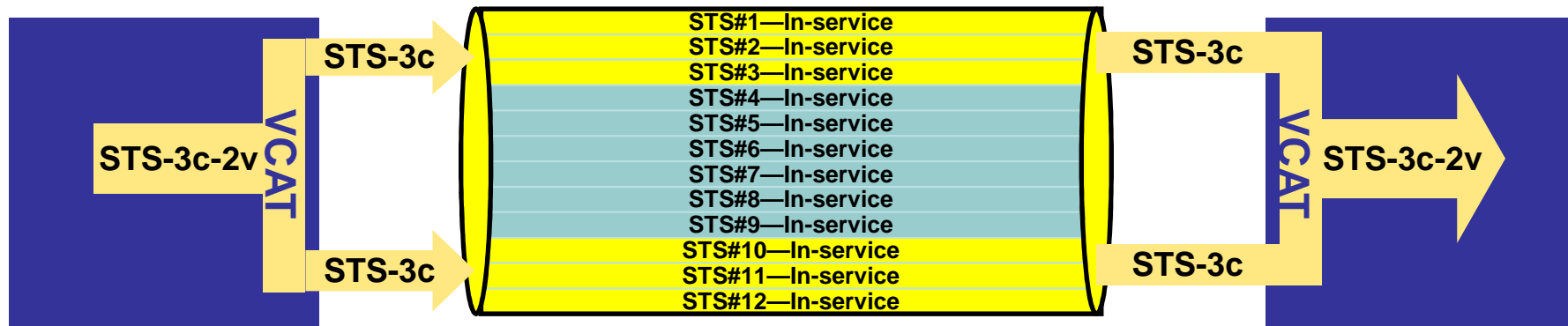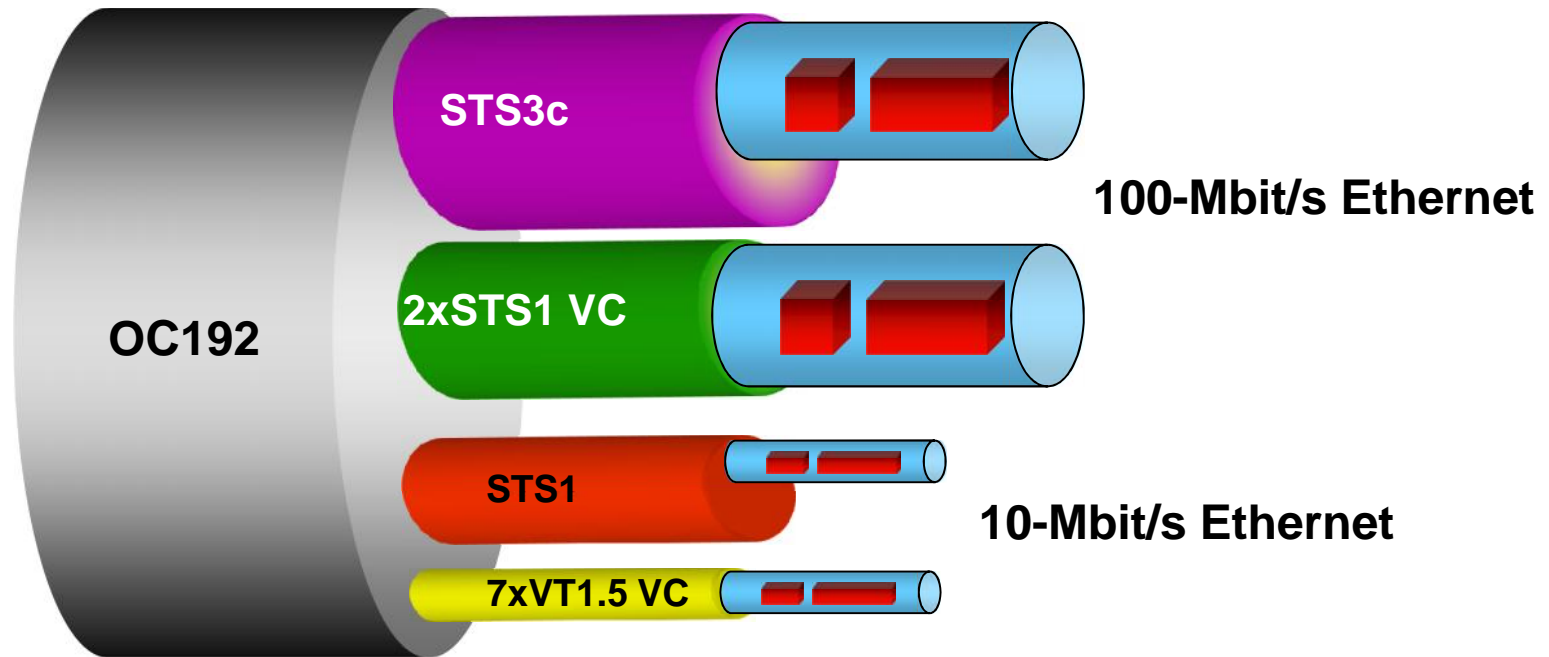   μ   μ

                                  .

❑   μ

  μ   μ

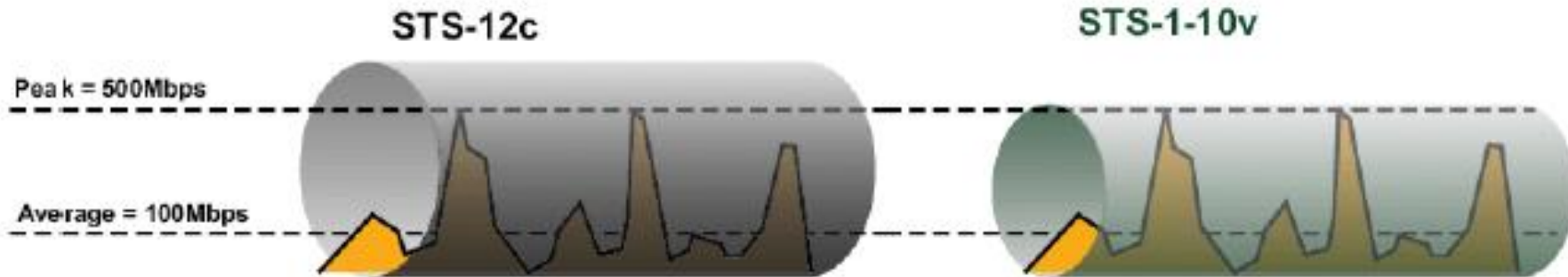   ❑ high order   STS
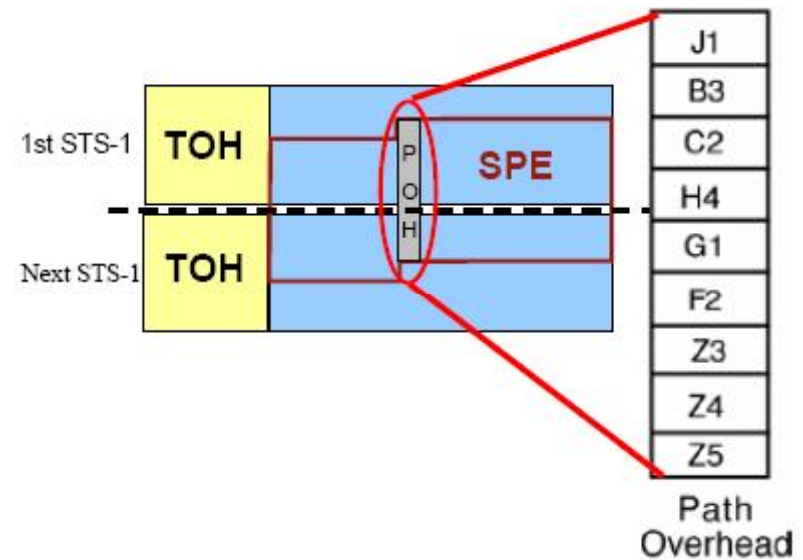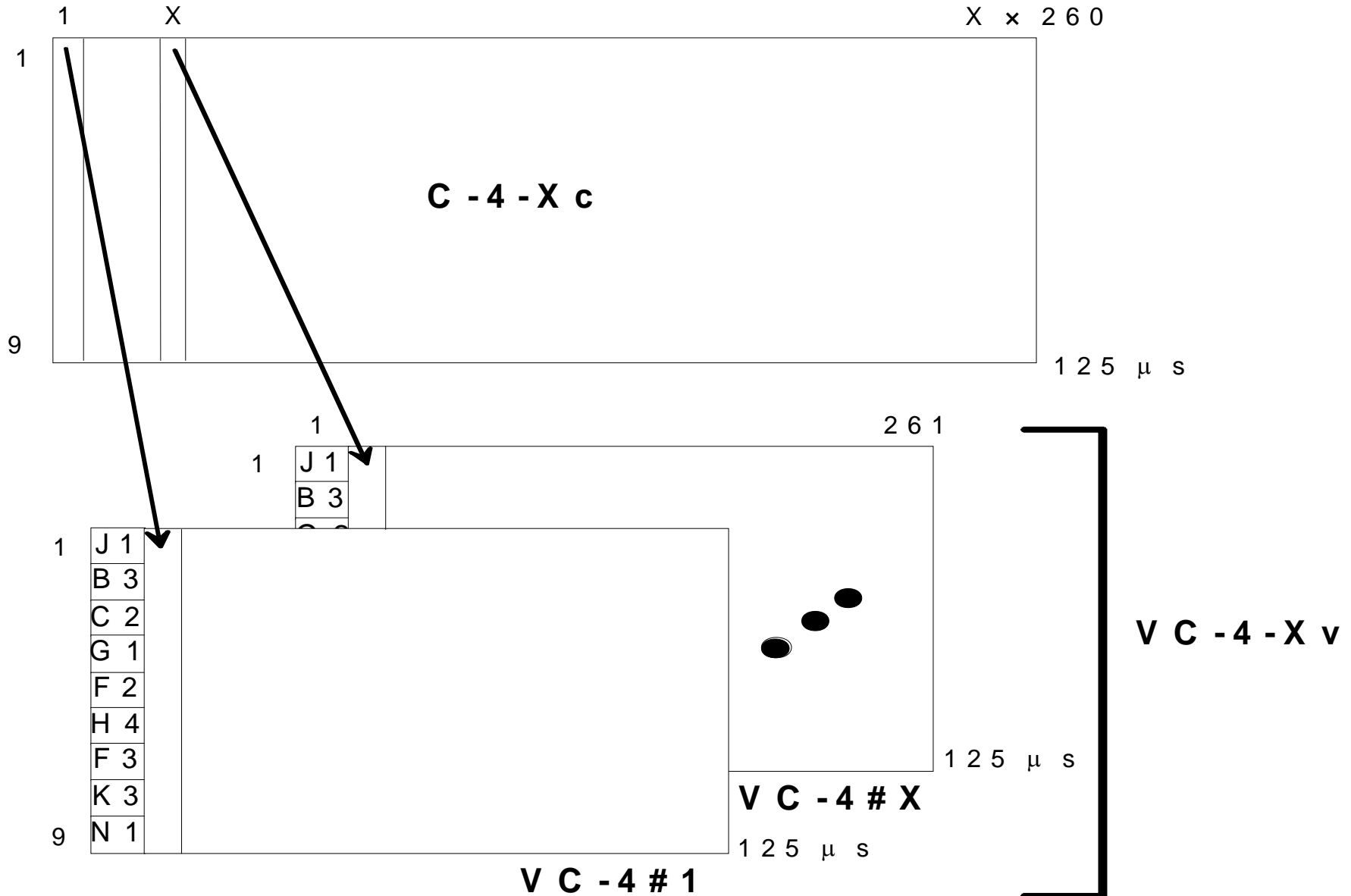   ❑ low order   VT

❑   μ

STS1   STS-3c (VC3 – VC4)

–   51 Mbit/s
(STS1/VC3)

–   155
Mbit/s (STS3c/VC4).

❑   μ

μ   H4 byte
path overhead.

❑ μ　　　　　　Virtual Tributaries

- 　　　　　　1.5 Mbit/s VT1.5 (VC11)

- 　　　　　　2 Mbit/s VT2 (VC12).

-

μ　　　　　VT

❑ 　　　　μ

μ　　　　　Z7 (K4) byte path overhead.

STS-12 Before

STS-3c

STS-12 After

Used Payload   Empty Payload   New Payload   VGC
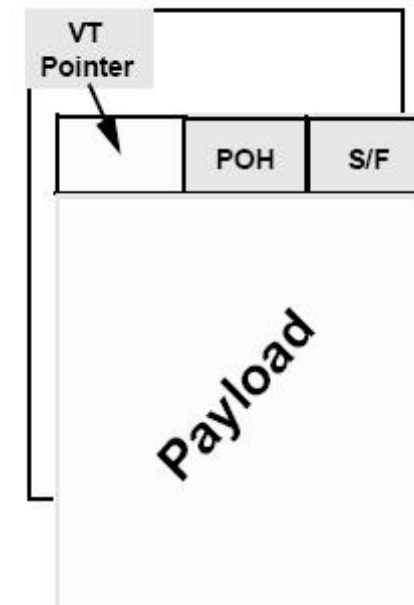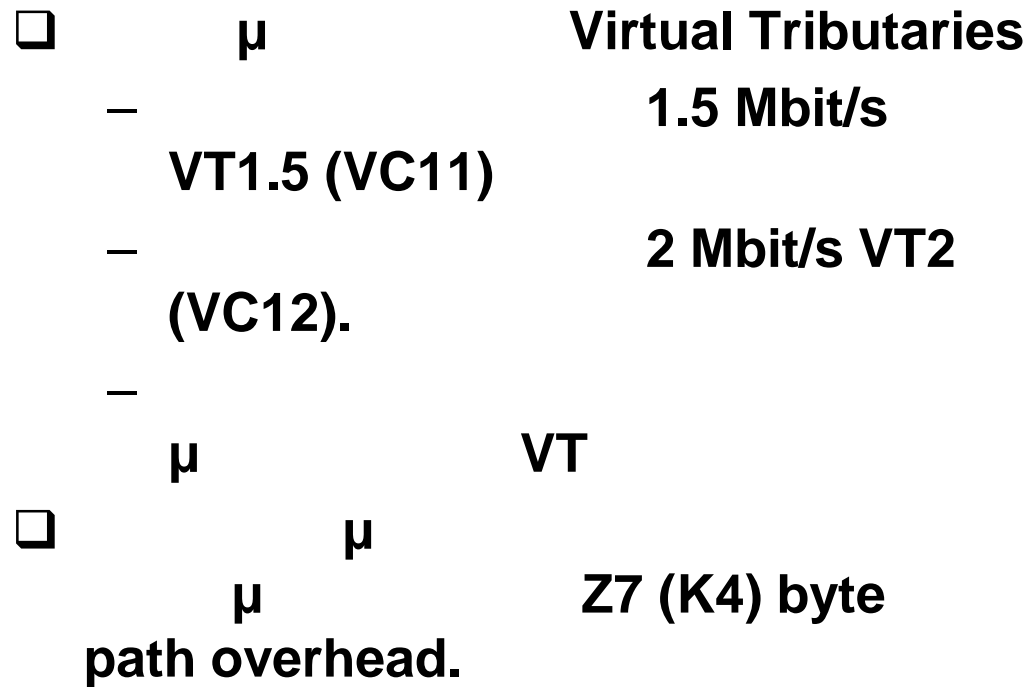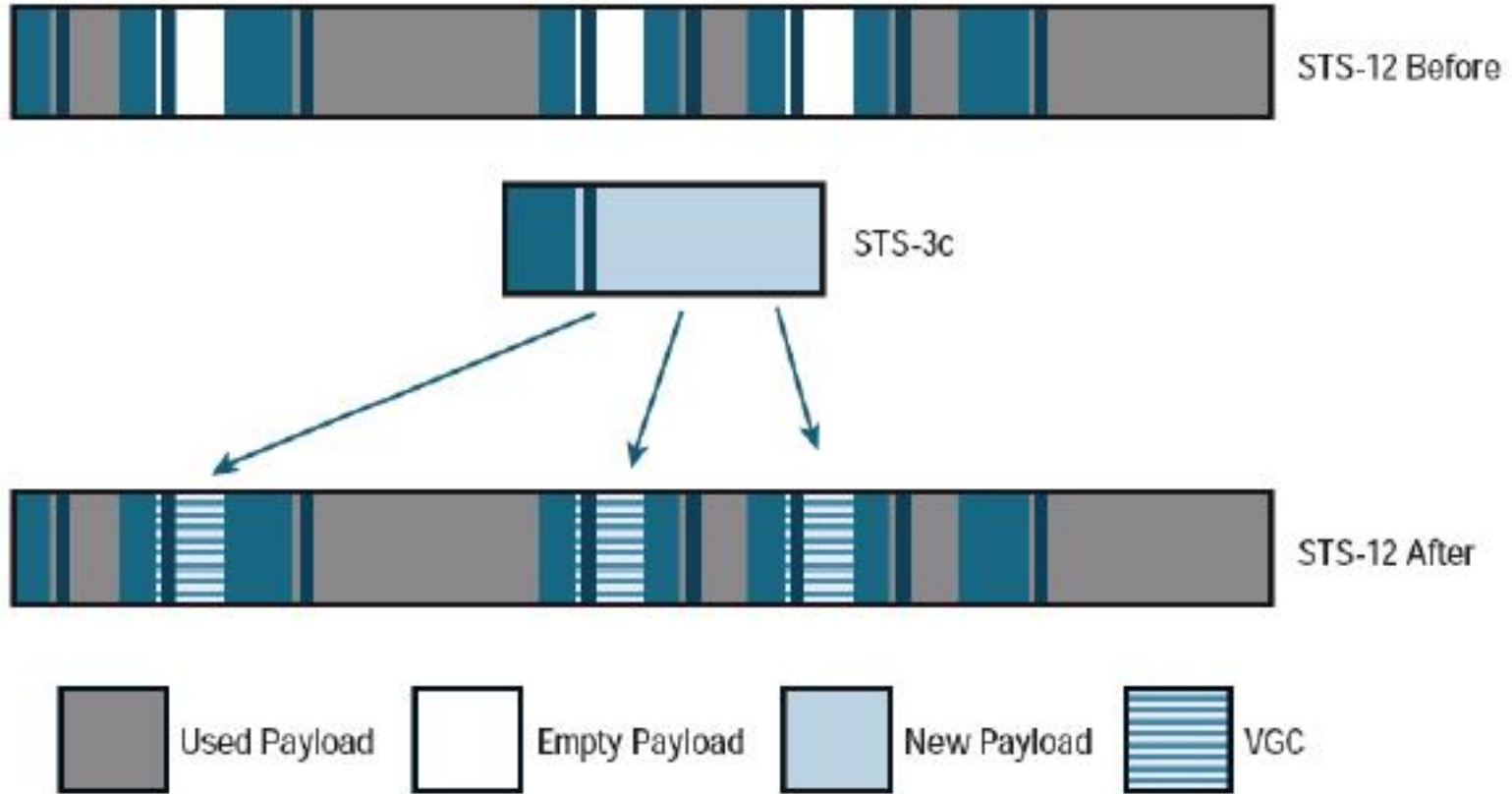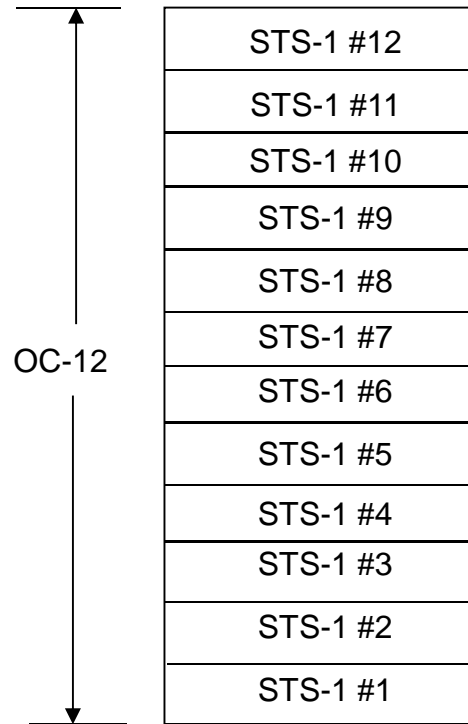
OC-12

(A)
Fully
Channelized
OC-12

| STS-1 #12 |
| STS-1 #11 |
| STS-1 #10 |
| STS-1 #9 |
| STS-1 #8 |
| STS-1 #7 |
| STS-1 #6 |
| STS-1 #5 |
| STS-1 #4 |
| STS-1 #3 |
| STS-1 #2 |
| STS-1 #1 |

STS-3c must Start on specific STS boundaries (1, 4, 7, 10)

Within each STS-3c, STSs must be contiguous

STS-3c #4
STS-3c #3
STS-3c #2
STS-3c #1
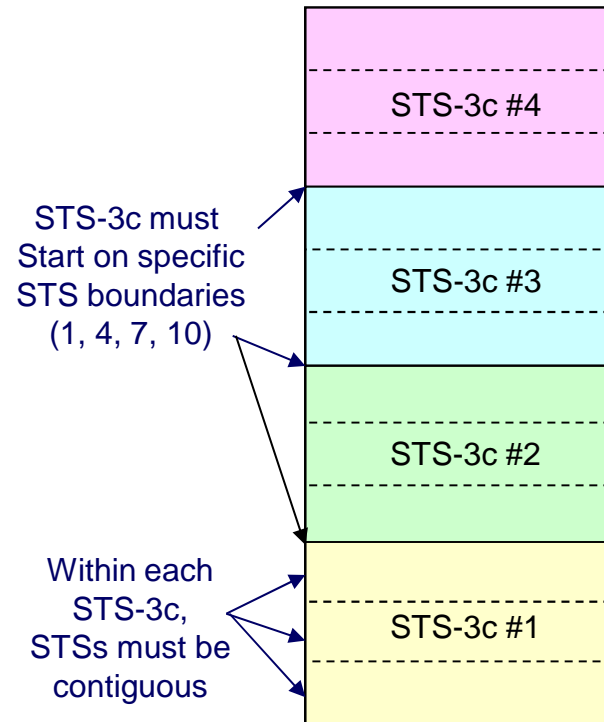
(B)
Contiguously
Concatenated
OC-12c

STS-1-5v

STS-1-4v
(1, 4, 6, 11)

STS-1-3v

| STS-1 #12 |
| STS-1 #11 |
| STS-1 #10 |
| STS-1 #9 |
| STS-1 #8 |
| STS-1 #7 |
| STS-1 #6 |
| STS-1 #5 |
| STS-1 #4 |
| STS-1 #3 |
| STS-1 #2 |
| STS-1 #1 |
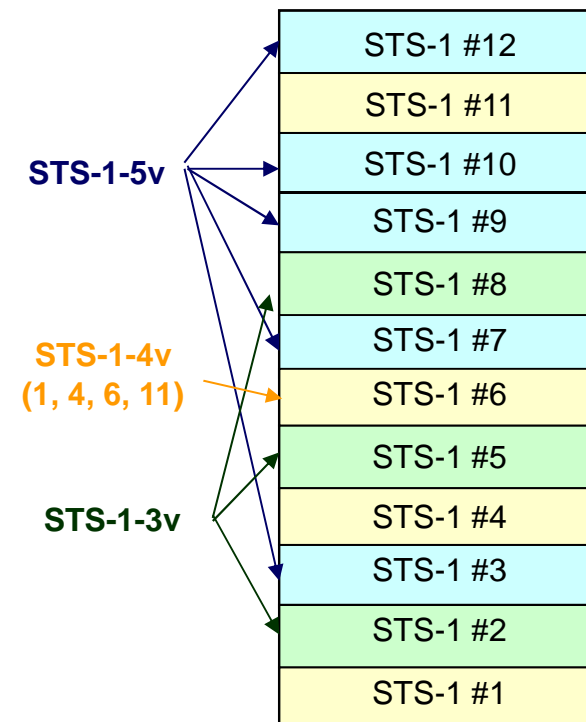
(C)
Virtual
Concatenated
(VCAT) OC-12
(example)

❑   VCAT   μ

              μ   μ

CCAT

Client Signal		Contiguously Concatenated			Virtually Concatenated		
Name	Rate	Best fit container	Container Rate	% Efficiency	Best fit container	Container Rate	% Efficiency
Fast Ethernet	100 Mbps	STS-3C	155 Mbps	64.5%	STS-1-2v	104 Mbps	96.2%
ESCON	200 Mbps	STS-12C	622 Mbps	32.1%	STS-1-4v	207 Mbps	96.6%
Fibre Channel							
New Format	274 Mbps	STS-12C	622 Mbps	44.1%	STS-3c-2v	311 Mbps	88.1%
New Format	500 Mbps	STS-12C	622 Mbps	80.4%	STS-1-10v	518 Mbps	96.5%
Fibre Channel	1 Gbps	STS-48C	2.488 Gbps	40.2%	STS-3c-7v	1.089 Gbps	91.8%
Gigabit Ethernet							
New Format	3 Gbps	STS-192C	9.953 Gbps	30.1%	STS-3c-20v	3.1 Gbps	96.8%
New Format	6 Gbps	STS-192C		60.3%	STS-3c-39v	6.1 Gbps	98.4%

% Transport Efficiency = client rate / container rate * 100

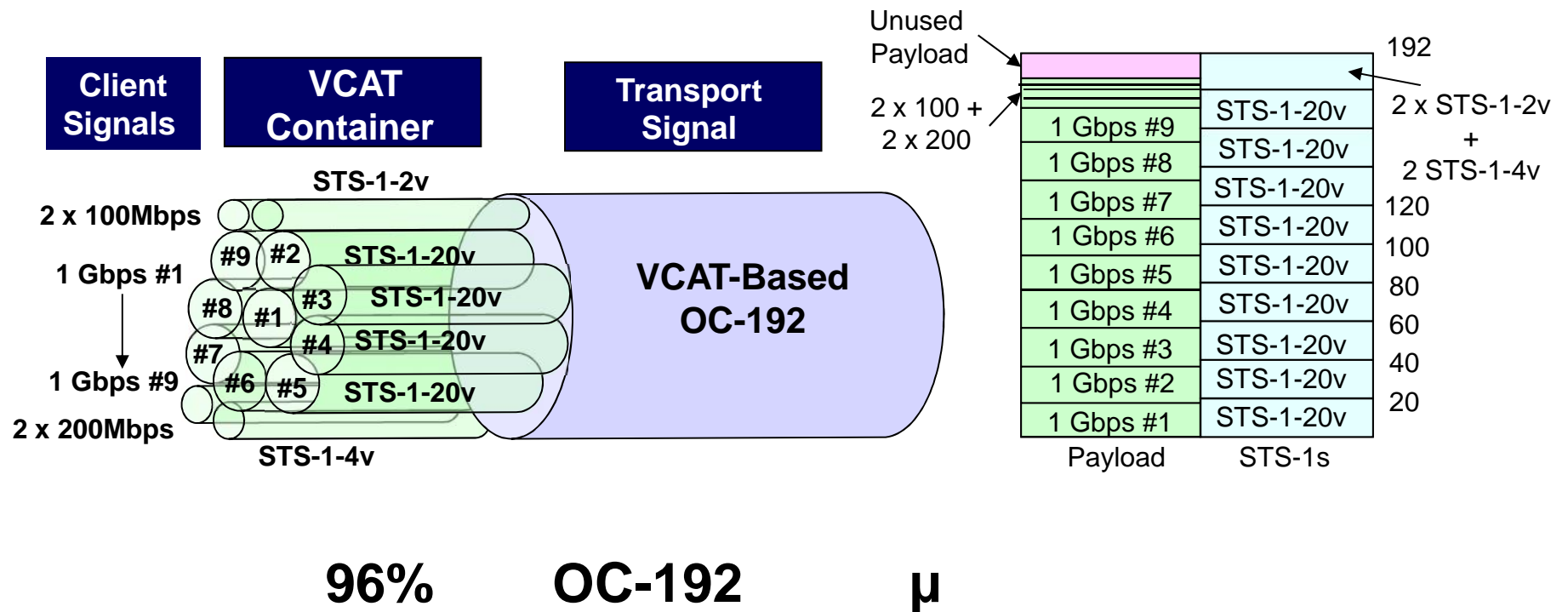**Compare how much More efficient VCAT is**

❏ μ μ μ μ **Gigabit Ethernet**

❏ μ **OC-192** μ μ
μ .

96% OC-192 μ
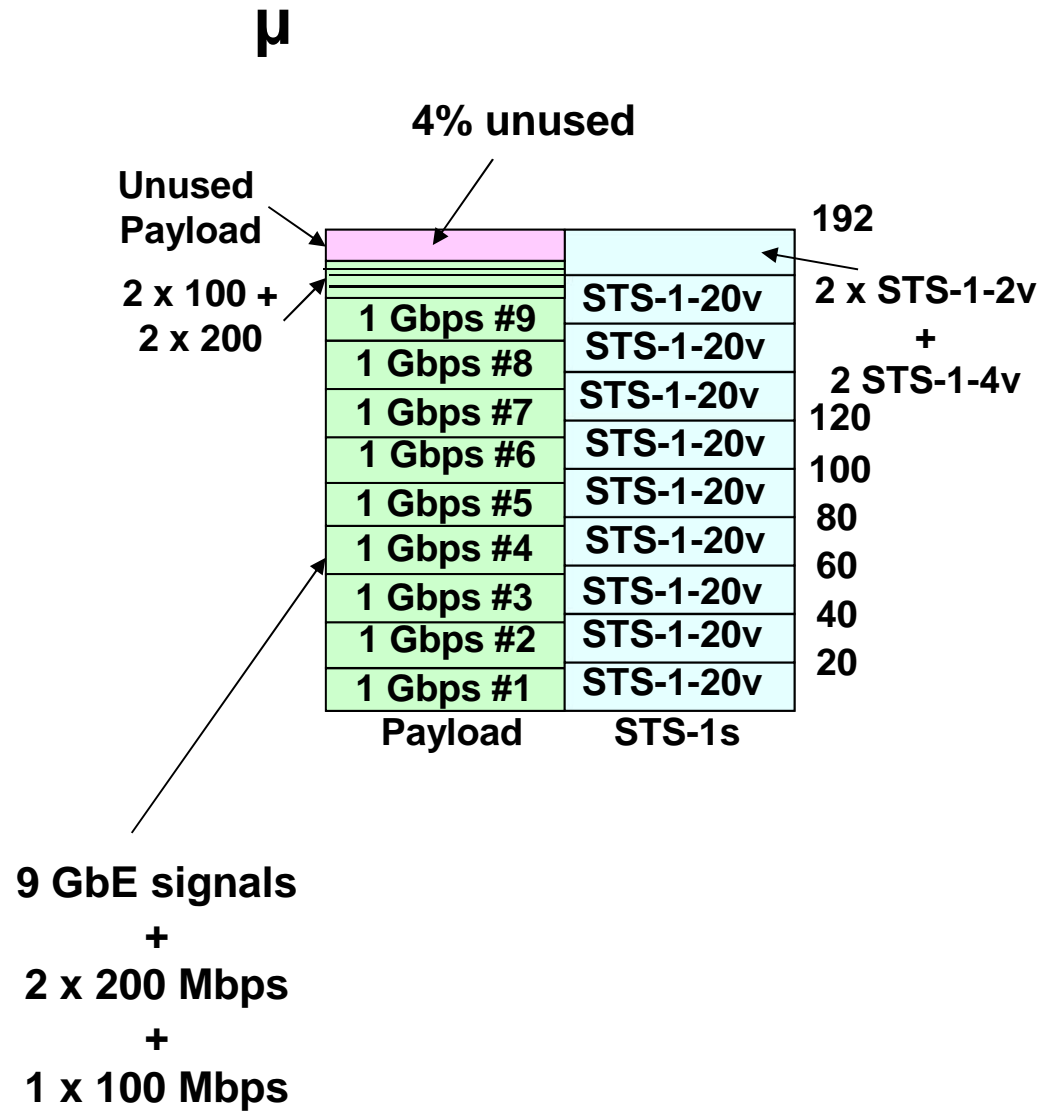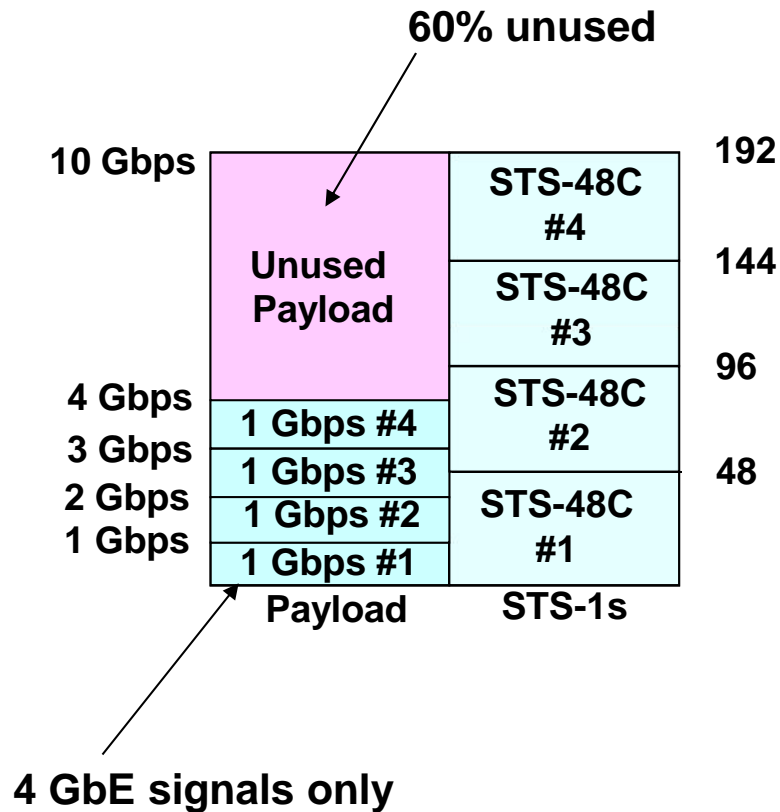
❑   µ

µ :

-   VCAT   µ   µ
-   VCAT   µ

Parameter	CCAT	VCAT
Gigabit Ethernets Transported	4	9
Total SPE bandwidth used by client signals	4 Gbps	9.6 Gbps
SPE bandwidth unused	6 Gbps	0.4 Gbps
Transport Efficiency	40%	96%
STS-1s Utilized	192	192

❑   **100 Mb/s Ethernet μ   μ**
VC-11-64v (102400 kbit/s) μ   μ
97%.

	Carried in	X	Capacity (kbit/s)	In steps of (kbit/s)
VC-11-Xv	VC-3	1 to 28	1600 to 44800	1600
VC-11-Xv	VC-4	1 to 64	1600 to 102400	1600
VC-11-Xv	Unspecified	1 to 64	1600 to 102400	1600
VC-12-Xv	VC-3	1 to 21	2176 to 45696	2176
VC-12-Xv	VC-4	1 to 63	2176 to 137088	2176
VC-12-Xv	Unspecified	1 to 64	2176 to 139264	2176
VC-2-Xv	VC-3	1 to 7	6784 to 47448	6784
VC-2-Xv	VC-4	1 to 21	6784 to 142464	6784
VC-2-Xv	Unspecified	1 to 64	6784 to 434176	6784

Traffic type	SONET		SDH	
	Contiguous	Virtual	Contiguous	Virtual
10 Mb/s Ethernet	STS-1 (20%)	VT-1.5-7v (89%)	VC-3 (20%)	VC-12-5v (92%)
100 Mb/s Fast Ethernet	STS-3c (67%)	STS-1-2v (100%)	VC-4 (67%)	VC-3-2v (100%) or VC-12-46v (100%)
200 Mb/s (ESCON)	STS-6c (66%)	STS-1-4v (100%)	VC-4-4c (33%)	VC-3-4v (100%) or VC-4-2v (66%)
1 Gb/s (FC/FICON)	STS-21c (85%)	STS-1-18v (95%)	VC-4-16c (35%)	VC-4-6v (95%)
1 Gb/s Ethernet	STS-24c (83%)	STS-1-21v (95%)	VC-4-16c (42%)	VC-4-7v (95%)

❑ CCAT μ

μ .
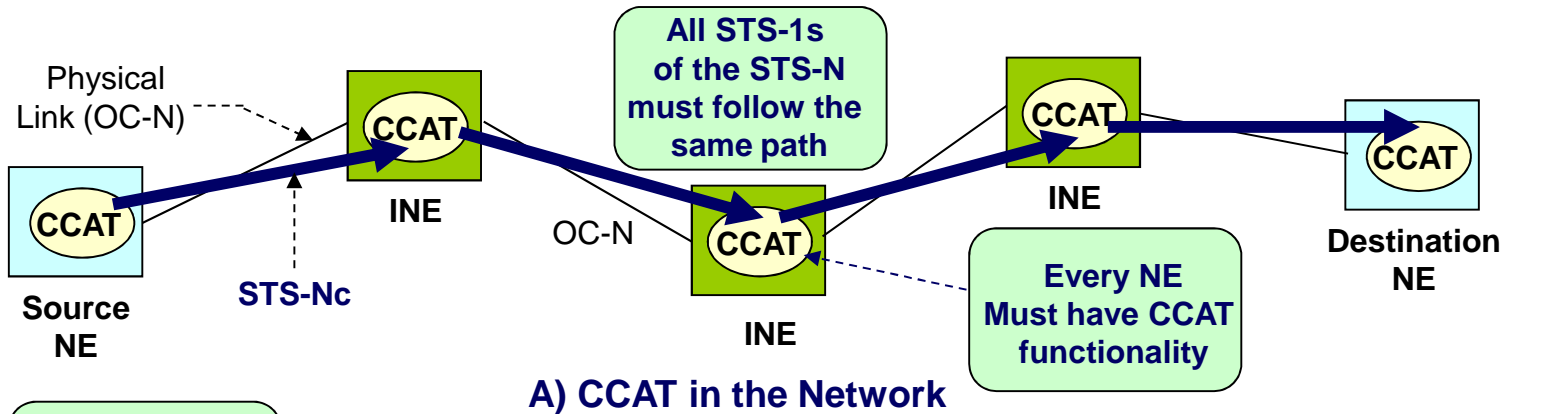
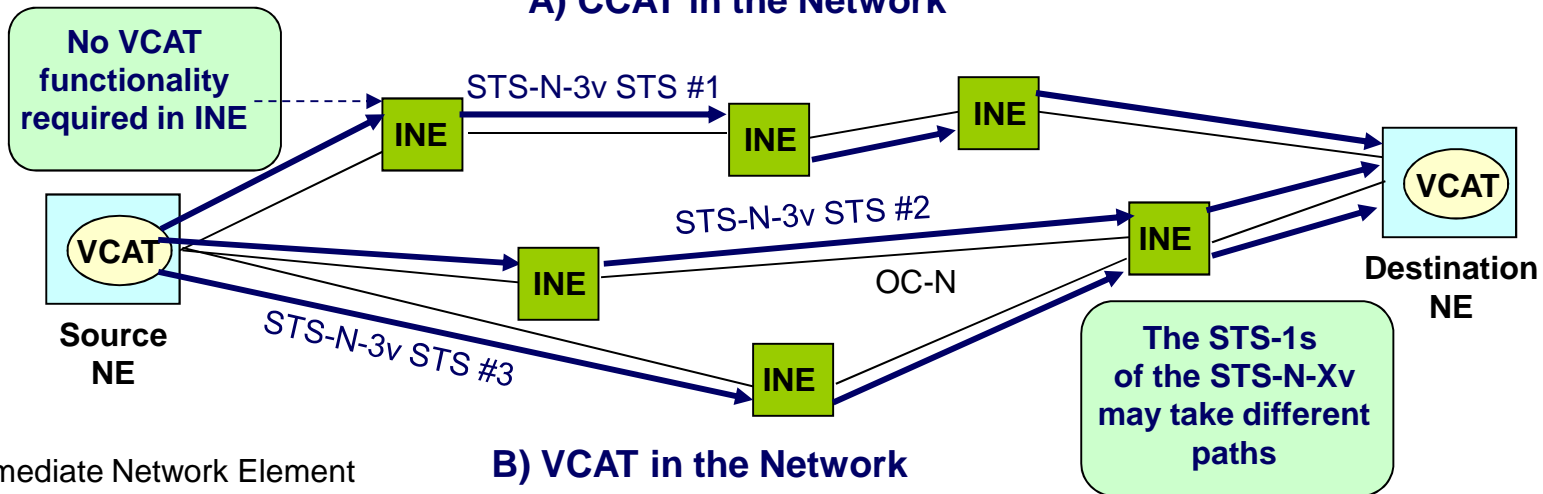❑ VCAT μ .

A) CCAT in the Network

B) VCAT in the Network

INE, Intermediate Network Element

❑   VCAT   μ   μ

❑   ,   VCAT μ

❑   μ   μ   μ

❑   μ
                μ   μ

Enterprise to WAN Box (GE)

200Mbps distributed over STS-1-4v

Two of the four STS-1 travel this way

The other two travel this way

- ☐   μ   μ   ,
  μ
    μ   μ μ

- ☐   **VCAT**
        μ   μ μ   μ

- ☐   **+/- 128 ms**   ,
                μ   μ .

- ☐   **128 µs**
       μ   μ μ ,
       μ   μ
      .

❑ µ

❑ VCAT µ µ
µ µ SONET
❑ VCAT (µ µ STS, µ
STS)

❑ TDM.

❑ µ µ

❑ µ

❑ , µ
µ µ µ .

❑ µ µ

µ µ µ .

Link Capacity Adjustment Scheme (LCAS)

- µ µ

µ µ µ VCAT

.

- µ TDM
bandwidth

µ

- µ

µ bandwidth

- µ

.

- high order (STS) low order (VT)

- ,

µµ

-

  μ

  μ   .
- LCAS   μ   μ
  μ
  - (on demand)
  - μ
-

  STS-1   ,   μ   μ   SLA
  .
- LCAS   μ   μ
  SONET

❑ LCAS μ

μ (source - So)

(sink - Sk)

**Sk NE for
VCG X
Member P**

**So NE for
VCG X
Member P**

VCG X Member P

NE

NE

VCG A Member N

**So NE for
VCG A
Member N**

**Sk NE for
VCG A
Member N**
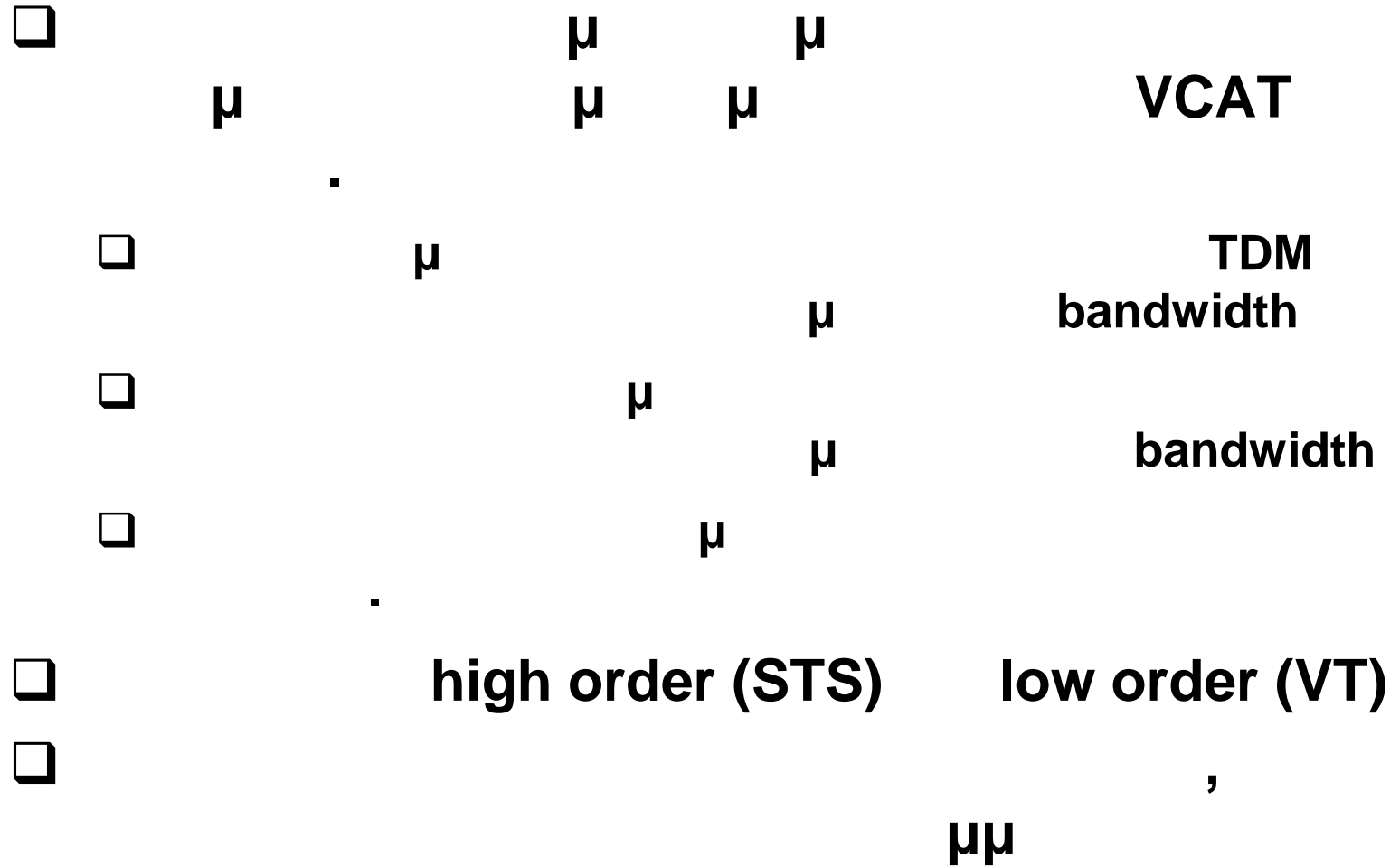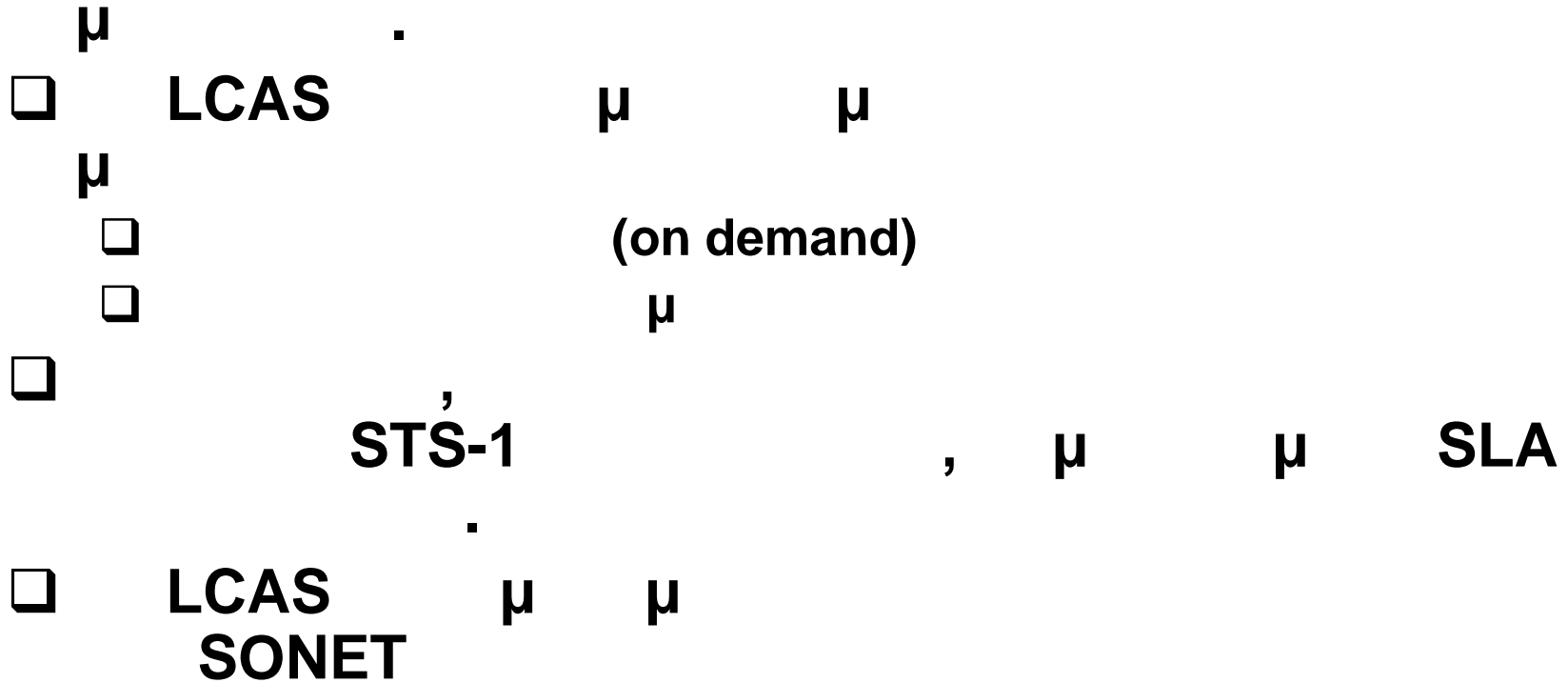
❑   high order VC,   μ

                    μ   bit 1–4
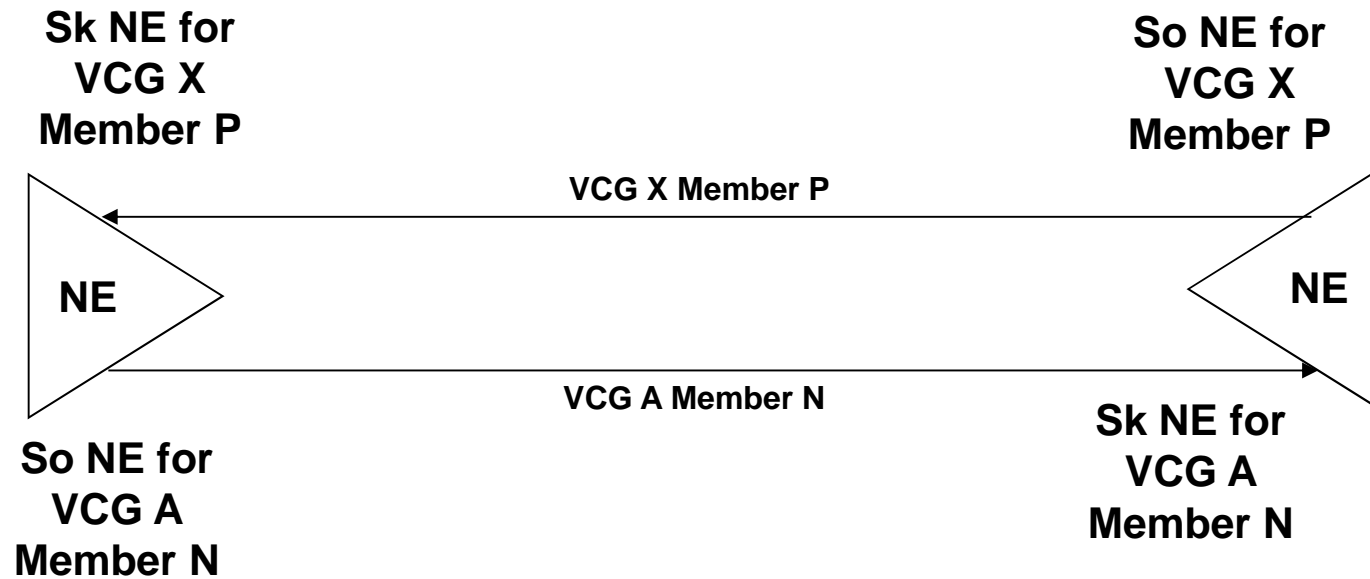   H4 byte   path overhead
     ❑   μ   16   multiframe

❑   low order VC,   μ

                    μ   bit 2   Z7
   (4) byte   path overhead
     ❑   μ   32   multiframe

❑

    ❑ **Multiframe Indicator field (MFI) – 8 bit**

    ❑ **Sequence Indicator filed (SQ) – 8 bit**

    ❑ **Control field (CTRL) – 4 bit**

    ❑ **Group Identification bit (GID) – 1 bit**

❑

    ❑ **Member Status field (MST) – 256 bit**

    ❑ **Re-Sequence Acknowledge bit (RS-Ack) – 1 bit**

❑

    ❑ **CRC field - (8 bit)**
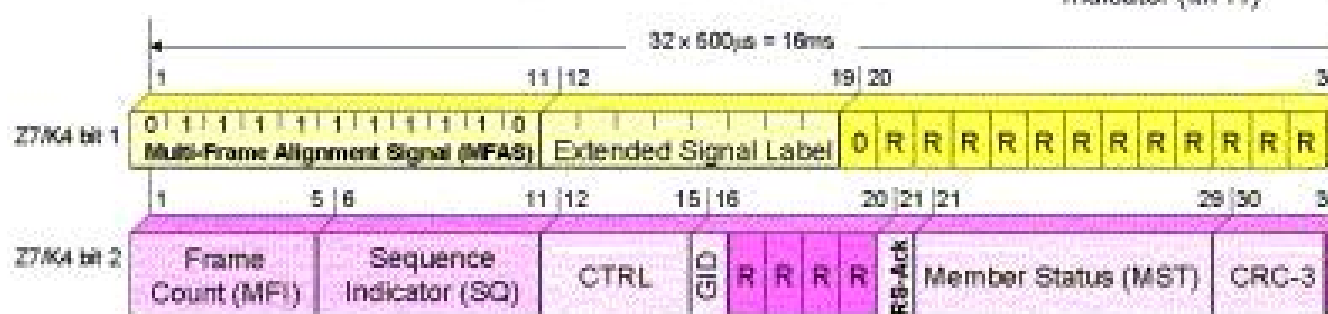
    ❑   μ   **bit**   μ **«0»**

STS-1/3c and VC-3/4

VT1.5/2 and VC-11/12

- ❑ **ADD**
    - ❑
- ❑ **NORM (normal)**
    - ❑
- ❑ **EOS (end of sequence)**
- ❑ **IDLE**
    - ❑
- ❑ **DNU (do not use)**

❑   LCAS   μ   μ
  VCG

  ❑   XMAX   μ   μ   μ   VCG
  (μ   μ   μ   ).

  ❑   XPROV   μ   μ   μ   VCG

      ❑   ADD   XPROV
      ❑   REMOVE μ   XPROV
      ❑0   XPROV   XMAX

  ❑   μ   X   μ   μ   μ
      VCG.
      ❑0   X   XPROV   XMAX

- LCAS μ μ μ (So)
  Sk

- , μ
  (Network Management System - NMS) :
  - μ VCG
  - μ μ XMAX VCG .
    - μ XMAX μ
      μ μ .
    - μ XMAX μ
      μ μ
      VCG.
  - μ VCG
    μ .