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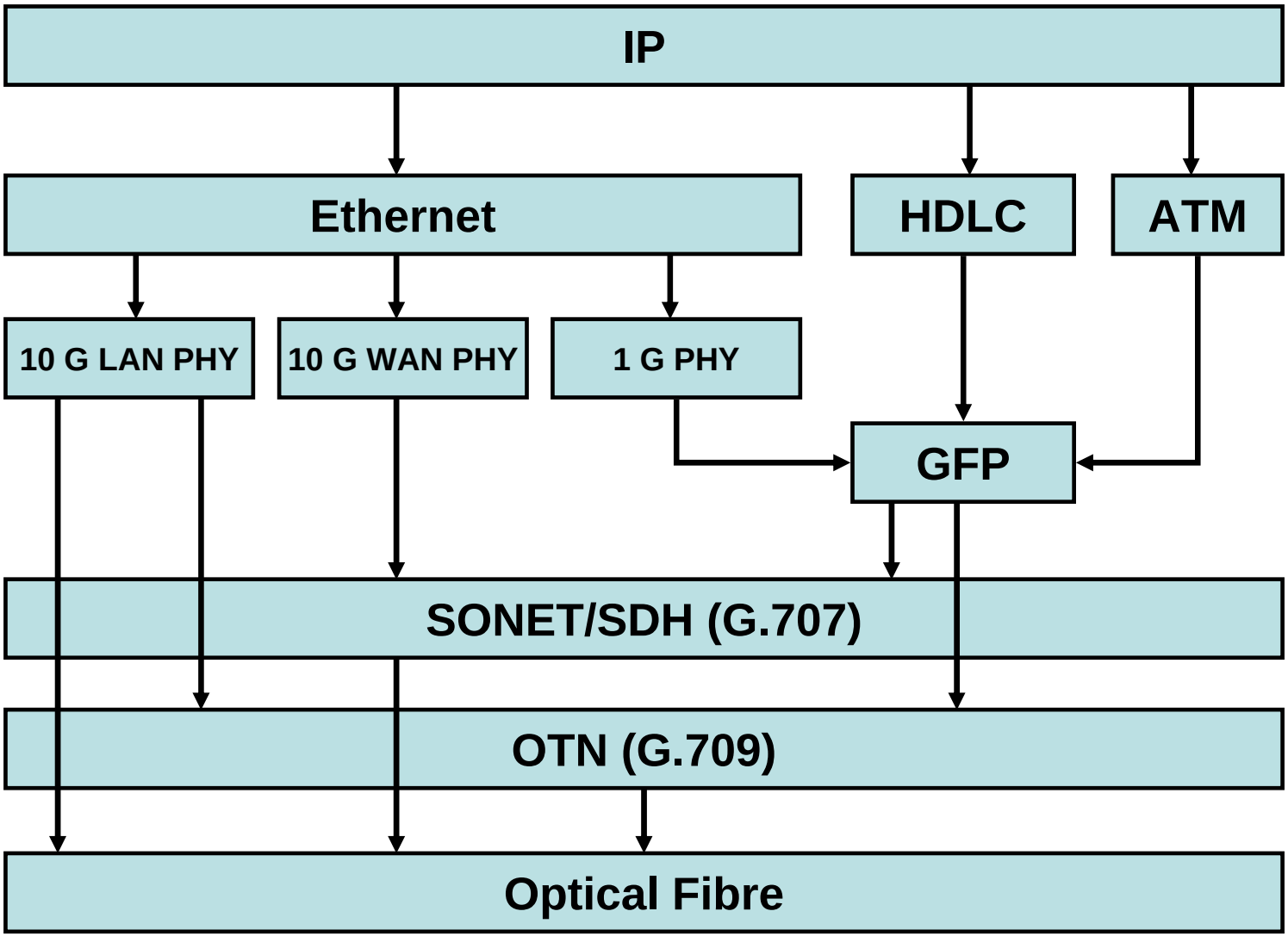
Developments in Transcontinental Ethernet

Dr. John S. Graham
UKLight

Hybrid Optical/Packet Networks



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Wide-Area Ethernet

- Ethernet Through IP WAN
  - MPLS Tunnels
  - L2TPv3
- Ethernet Through Circuit-Switched WAN
  - Deprecated Techniques
    - ATM, POS, LAPS
  - New ANSI and ITU-T Standards
    - GFP with VCAT and LCAS
  - 10 Gigabit Ethernet

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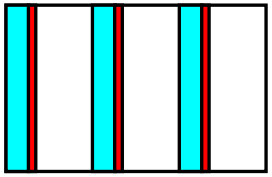
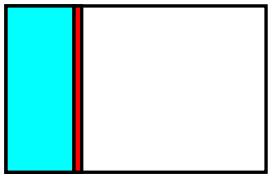
Ethernet *vs* SDH

Feature	Ethernet	SDH
Guaranteed Delivery	No (Packet Switched)	Yes (Circuit Switched)
Guaranteed BW	No	Yes
Performance Monitoring	CRC Count	BER
Protection	None (STP?)	APS
Fault Location	None	AIS
Access Costs	Low	High

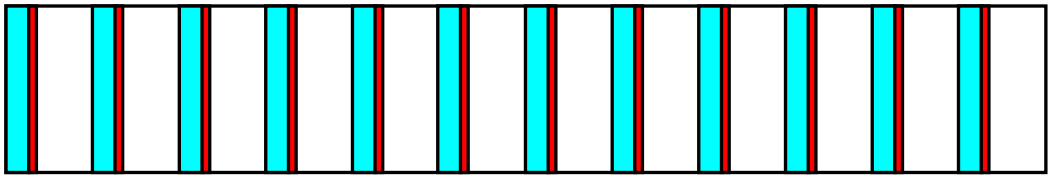
SONET Concatenation



STS-3 155 Mb/s
145.152 Mb/s



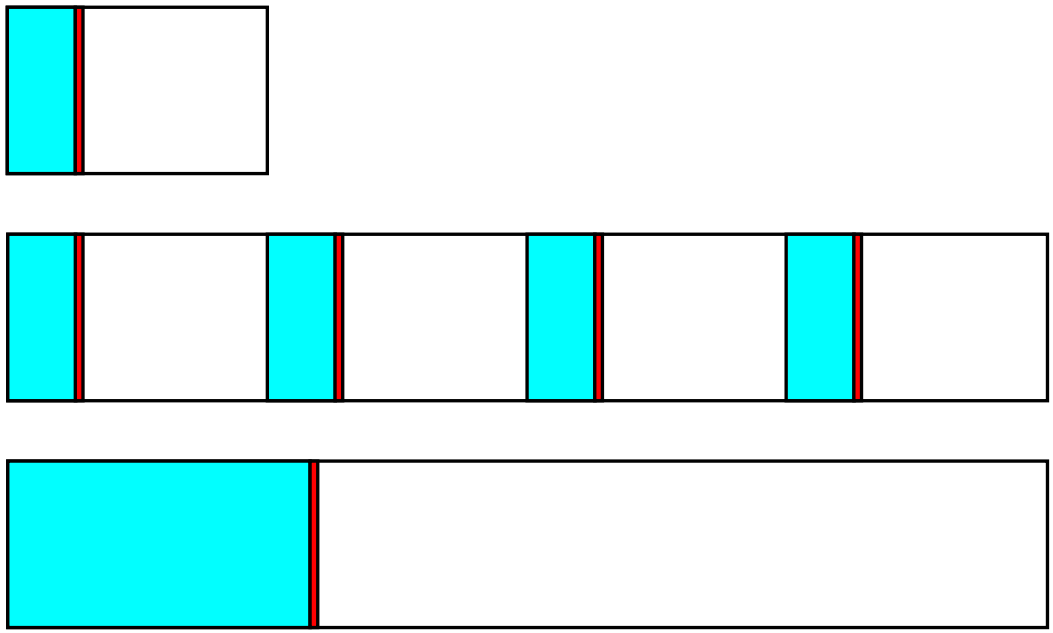
STS-3c (=VC-4) 155 Mb/s
149.76 Mb/s



STS-12 622 Mb/s
580.608 Mb/s

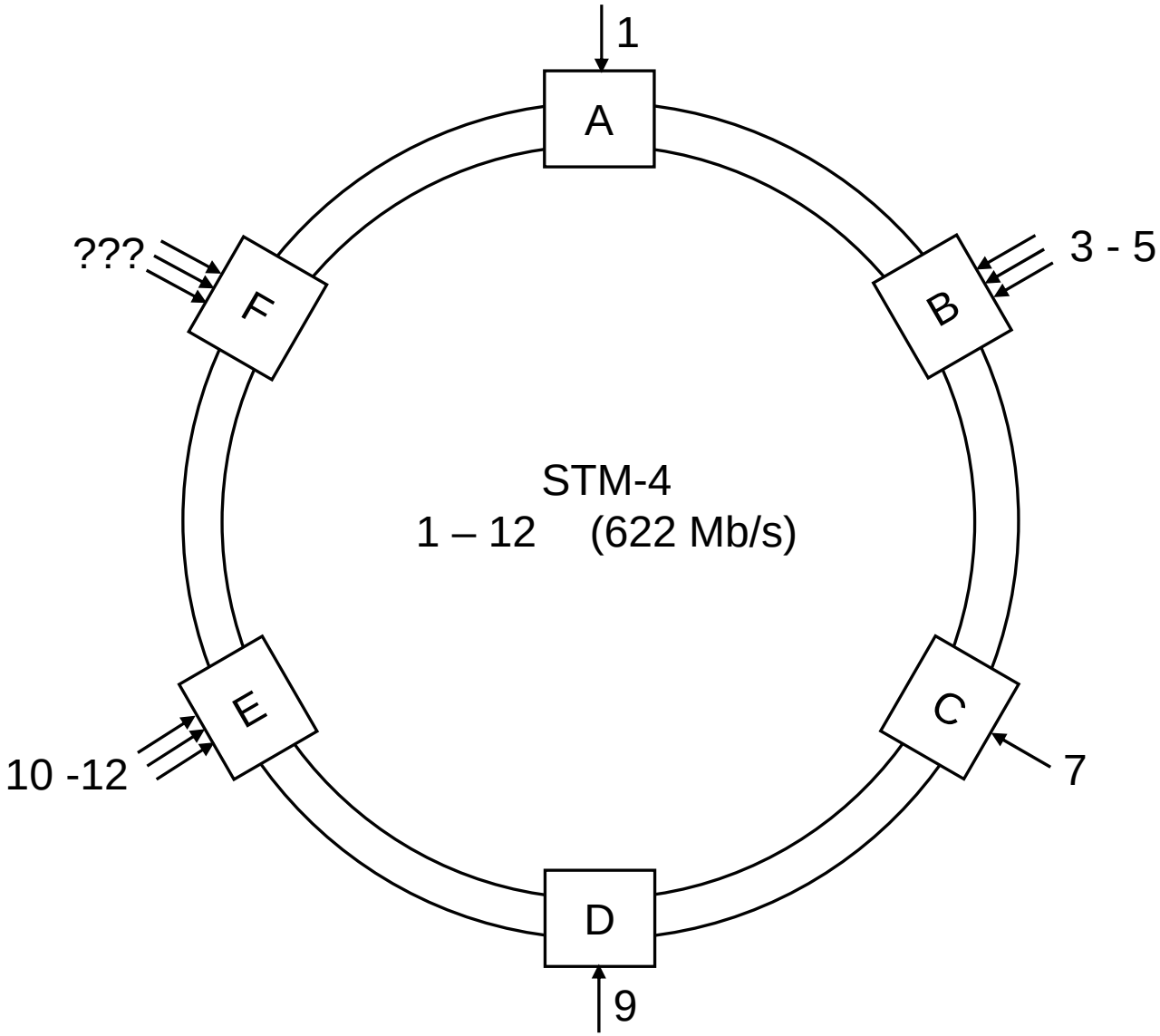
STS-12c 622 Mb/s
599.04 Mb/s

SDH Concatenation

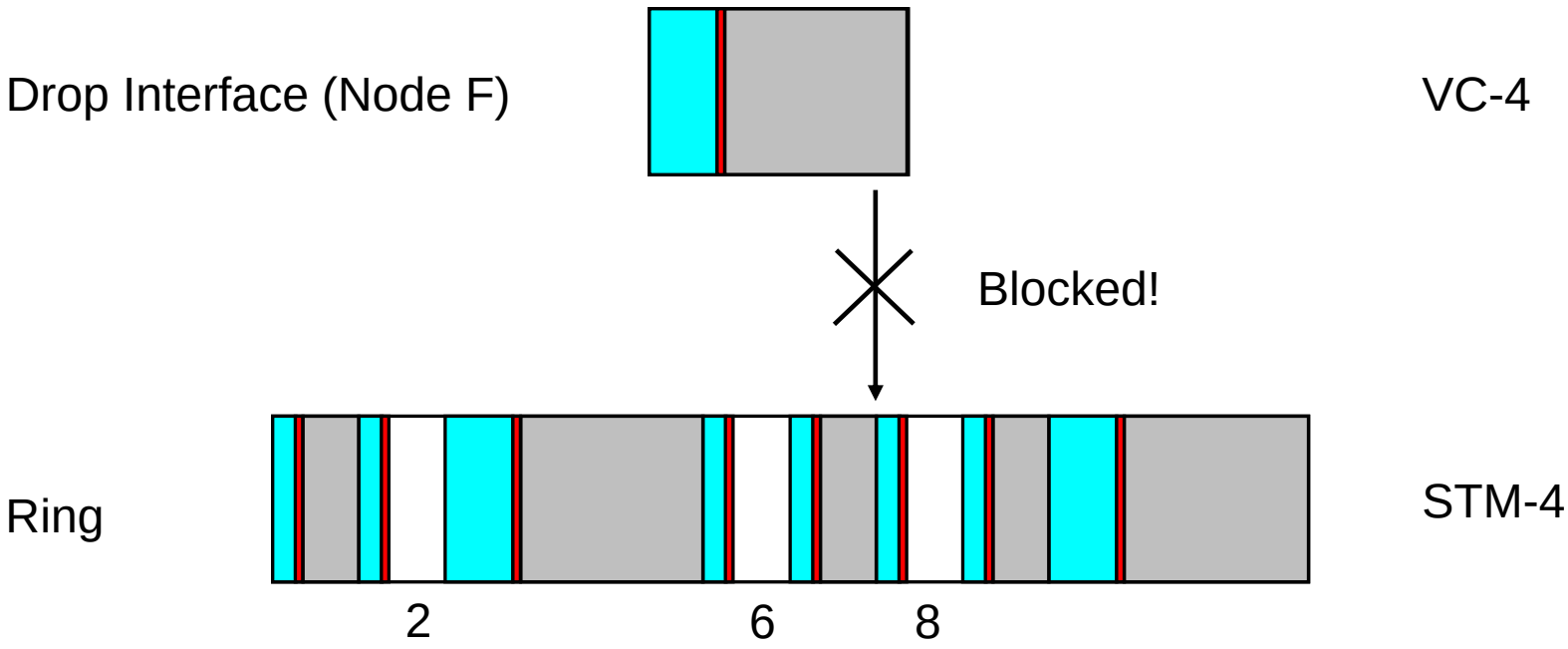


VC-4	155 Mb/s 149.76 Mb/s
VC-4-4	622 Mb/s 599 Mb/s
VC-4-4c	622 Mb/s 600.768 Mb/s

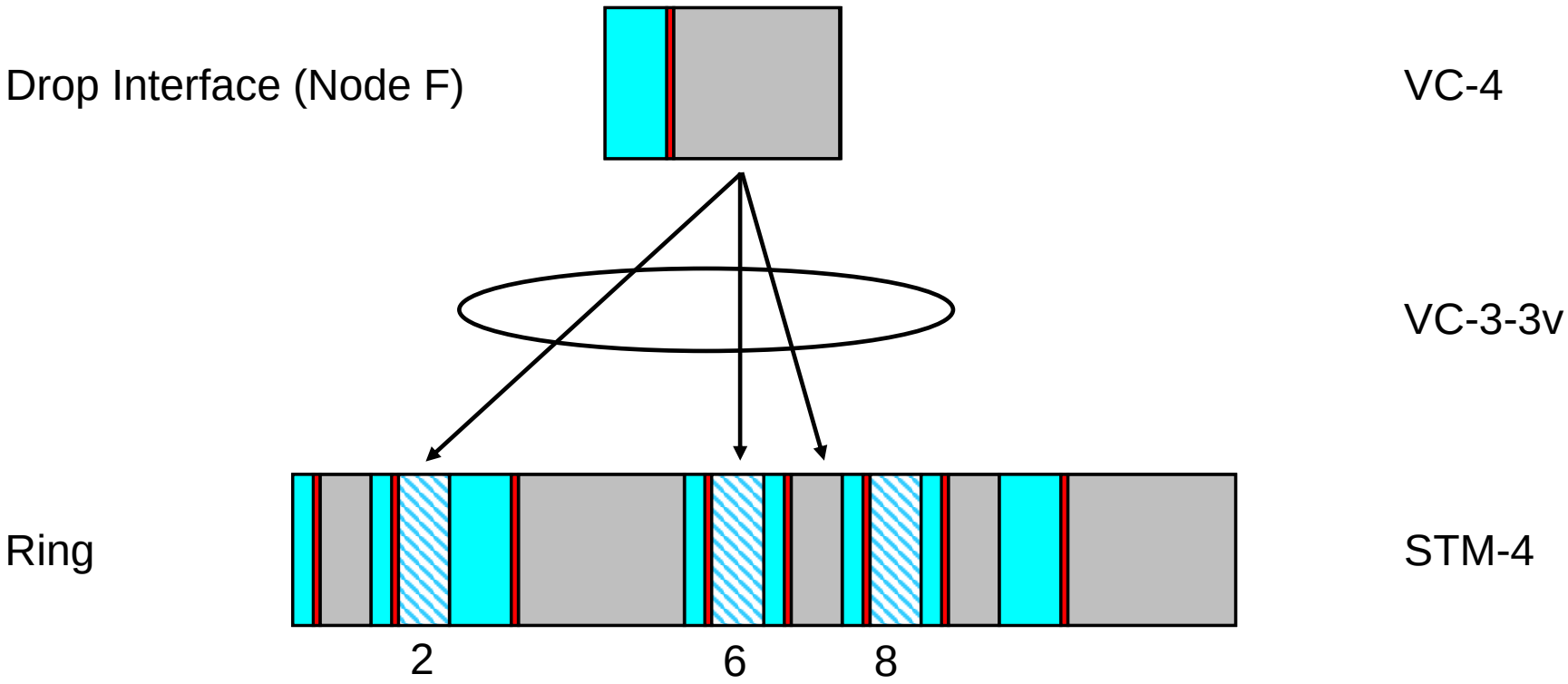
Provisioning Example



Bandwidth Fragmentation



Virtual Concatenation (G.707)



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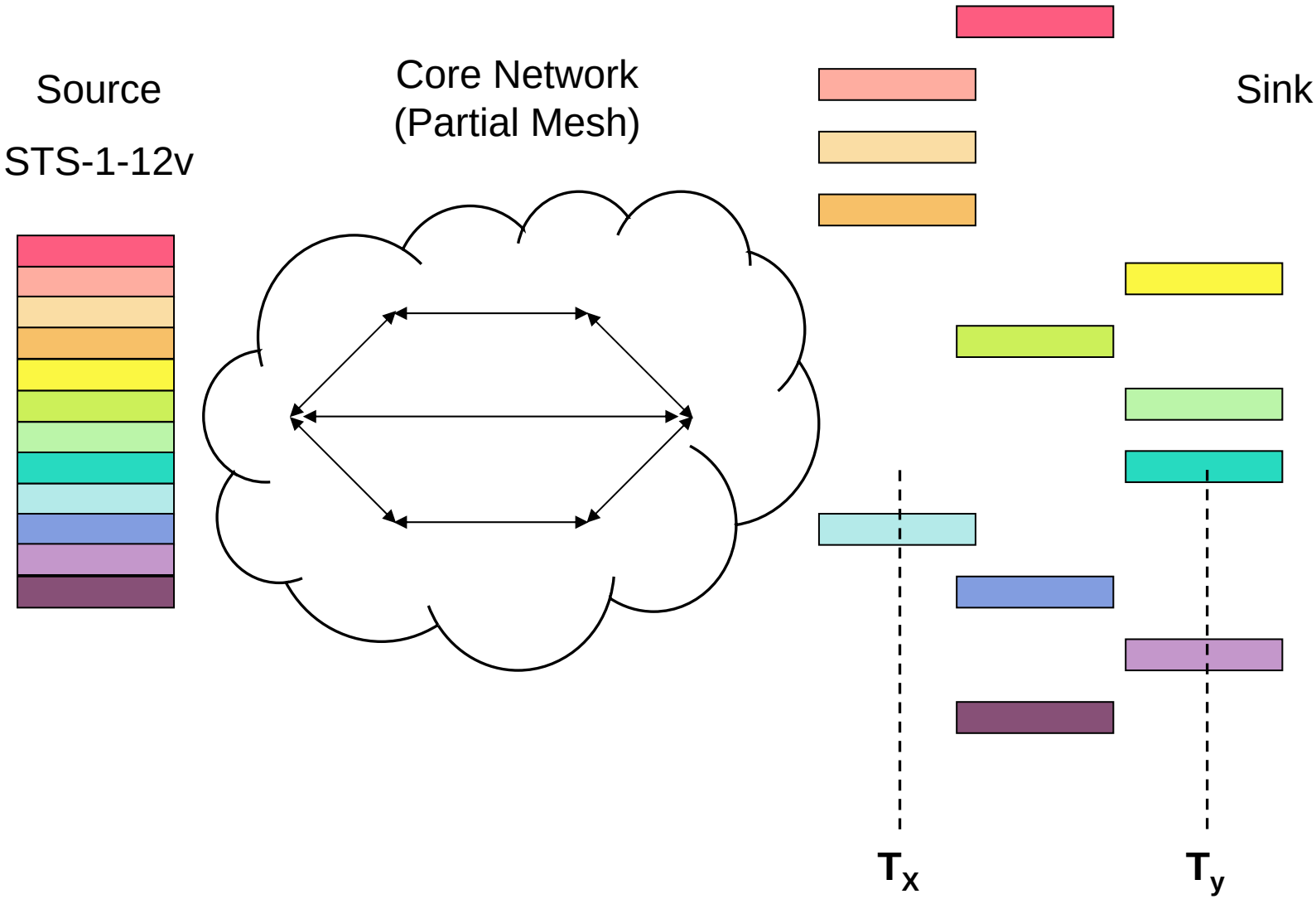
The Magic of VCAT

Protocol	Client Rate	Contiguous Concatenation		Virtual Concatenation	
Ethernet	10	VC-3	20%	VC-11-7v	89%
Fast Ethernet	100	VC-4	67%	VC-3-2v	99%
Gigabit Ethernet	1000	VC-4-16c	42%	VC-4-7v	95%
ESCON	160	VC-4-4c	26%	VC-3-4v	83%
Fibre Channel 2	1700	VC-4-16c	71%	VC-4-12v	95%
ATM	25	VC-3	50%	VC-11-16c	98%

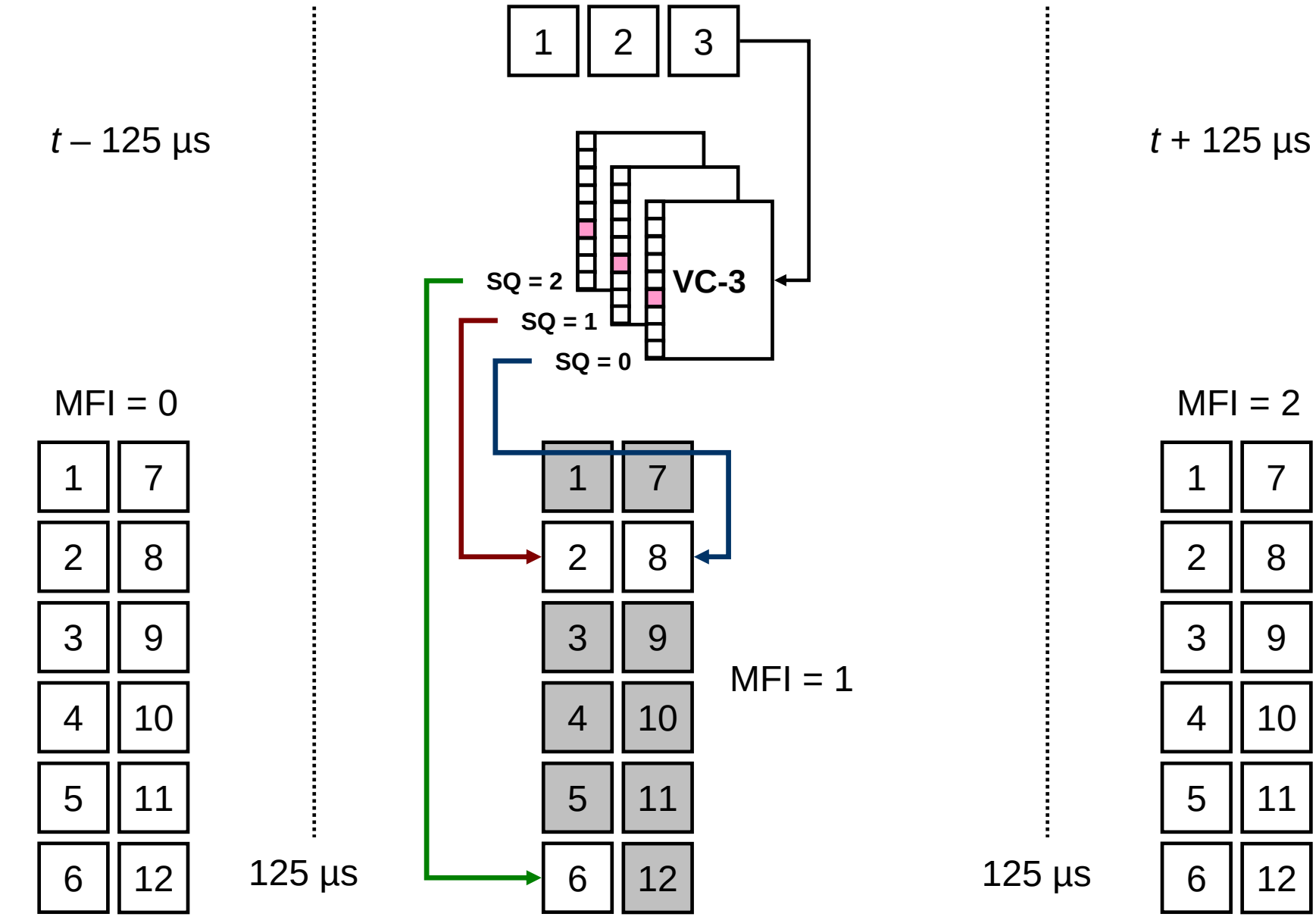
Differential Delay



Multiframe Indicator

Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
MFI2 MSBs (bits 1 - 4)				0	0	0	0
MFI2 LSBs (bits 5 – 8)				0	0	0	1
CTRL				0	0	1	0
GID				0	0	1	1
				0	1	0	0
				0	1	0	1
CRC-8				0	1	1	0
CRC-8				0	1	1	1
MST				1	0	0	0
MST				1	0	0	1
				1	0	1	0
				1	0	1	1
				1	1	0	0
				1	1	0	1
SQ MSBs (bits 1 – 4)				1	1	1	0
SQ LSBs (bits 5 – 8)				1	1	1	1

Signalling in VCAT



VCAT Puzzle

- An STS-1-2v between Chicago and London
- One STS-1 sent via geostationary satellite
- The other STS-1 sent via transatlantic fibre
- Will it work? ;-)

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VCAT: Buffer Requirements

VC Path Type	Transport Signal	Number Paths	Buffer Size
STS-1 VC-3	STS-12 STM-4	12	18 MB
STS-1 VC-3	STS-48 STM-16	48	71 MB
STS-3c VC-4	STS-12 STM-4	4	18 MB
STS-3c VC-4	STS-48 STM-16	12	55 MB

Link Capacity Adjustment Scheme

- Modify membership of a VCG
- On-demand and hitless bandwidth changes
- Automatic removal of failed VCG members
- Interworking of LCAS-enabled VCG with non-LCAS VCG
- Old-style ‘bridge and roll’ requires double bandwidth

LCAS Messaging

- Source → Sink
  - Control (CTRL)
    - Fixed
    - Add
    - Norm
    - EOS
    - Idle
    - DNU
- Sink → Source
  - MST
  - RS-Ack

LCAS Signalling Flows (1/3)

	CTRL = NORM SQ = 0	CTRL = EOS SQ = 1	
	CTRL = NORM SQ = 0	CTRL = EOS SQ = 1	CTRL = IDLE SQ = 255
MST = FAIL (#2)	CTRL = NORM SQ = 0	CTRL = EOS SQ = 1	CTRL = ADD SQ = 2
MST = OK (#2)	CTRL = NORM SQ = 0	CTRL = NORM SQ = 1	CTRL = EOS SQ = 2
RS-ACK	CTRL = NORM SQ = 0	CTRL = NORM SQ = 1	CTRL = EOS SQ = 2
Source	**Sink (N-1)**	**Sink (N)**	**Sink (N+1)**

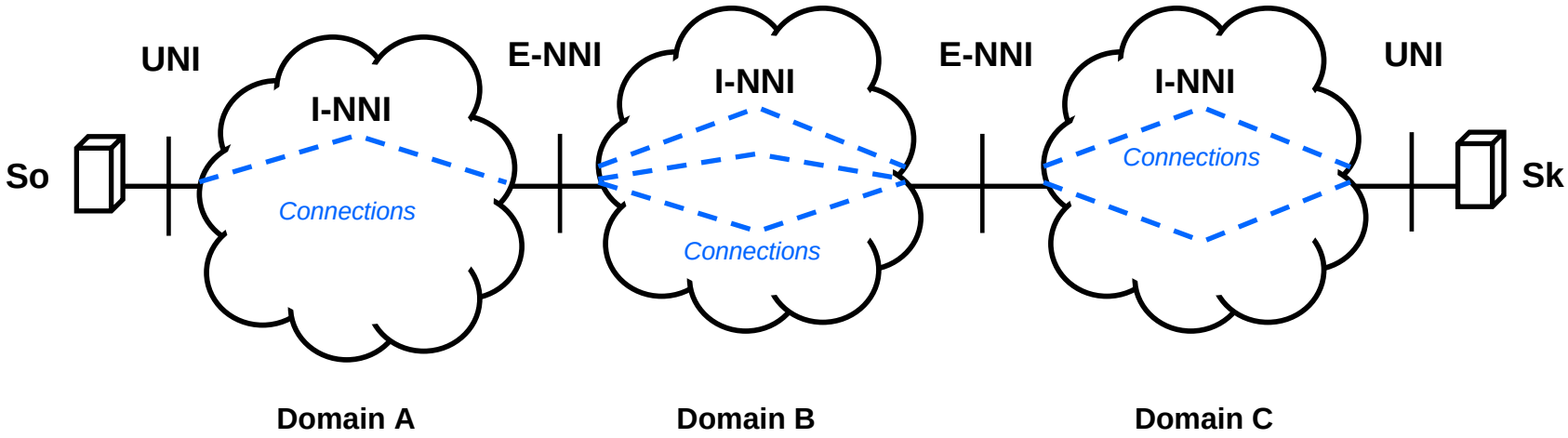
LCAS Signalling Flows (2/3)

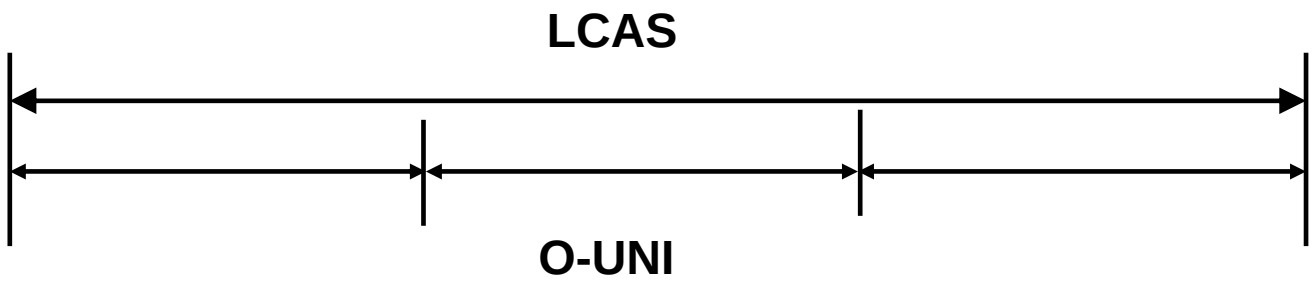
	CTRL = NORM SQ = 0	CTRL = NORM SQ = 1	CTRL = EOS SQ = 2
	CTRL = IDLE SQ = 255	CTRL = NORM SQ = 1	CTRL = EOS SQ = 2
MST = FAIL (#0)		CTRL = NORM SQ = 0	CTRL = EOS SQ = 1
RS-ACK		CTRL = NORM SQ = 0	CTRL = EOS SQ = 1
Source	Sink (N-2)	Sink (N-1)	Sink (N)

LCAS Signalling Flows (3/3)

	CTRL = NORM SQ = 0	CTRL = NORM SQ = 1	CTRL = EOS SQ = 2
	CTRL = NORM SQ = 0	CTRL = NORM SQ = 1	CTRL = IDLE SQ = 255
MST = FAIL (#2)	CTRL = NORM SQ = 0	CTRL = EOS SQ = 1	
RS-ACK	CTRL = NORM SQ = 0	CTRL = EOS SQ = 1	
Source	**Sink (N-2)**	**Sink (N-1)**	**Sink (N)**

LCAS as a UNI Client





Generic Framing Procedure

- ITU-T G.7041 and ANSI T1.105.02
- Defines mapping for many types of service onto SONET/SDH or OTN:
  - Ethernet, IP/PPP
  - GbE, Fibre Channel (inc. DVB), FICON etc
- Excellent bandwidth utilization; efficiency tailored to suit different client types
- Simple delineation and robust error control
- Extensible

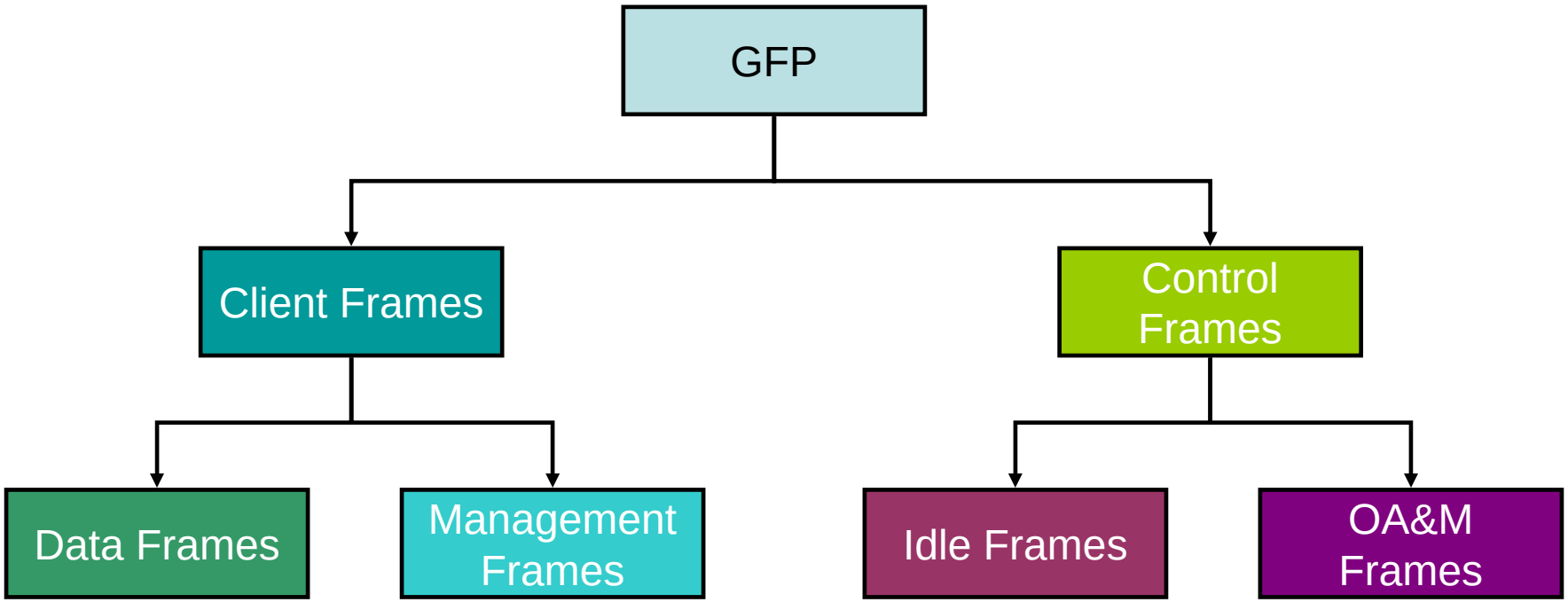
Motivation for GFP (1/2)

- ATM
  - Cell overhead causes 10% bandwidth inflation
  - Adaptation functions needlessly complex
- Packet over SONET (POS)
  - Requires all frames to be converted to PPP over HDLC
  - Byte stuffing causes non-deterministic bandwidth inflation
  - QoS hard to monitor or guarantee

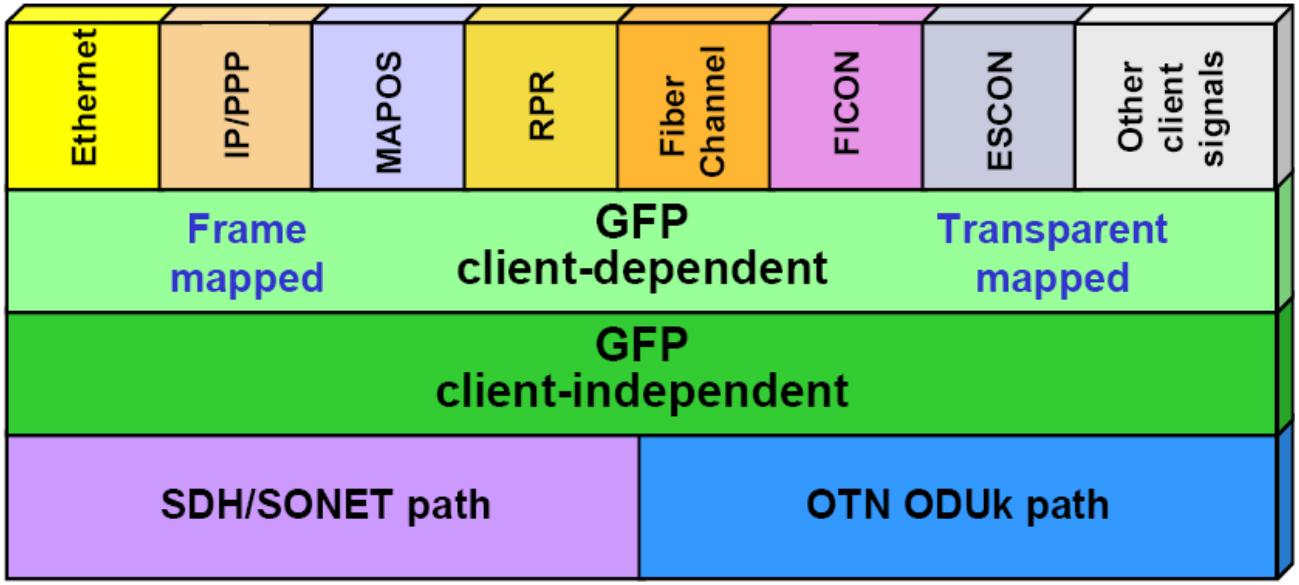
Motivation for GFP (2/2)

- Minimal overhead
- Transport of client PDUs in native format
- Designed for optimized processing
- Easy aggregation of frames from multiple client and multiple protocols into shared bandwidth channels
- Low latency capabilities for SAN and DVB

GFP: Types of Frame



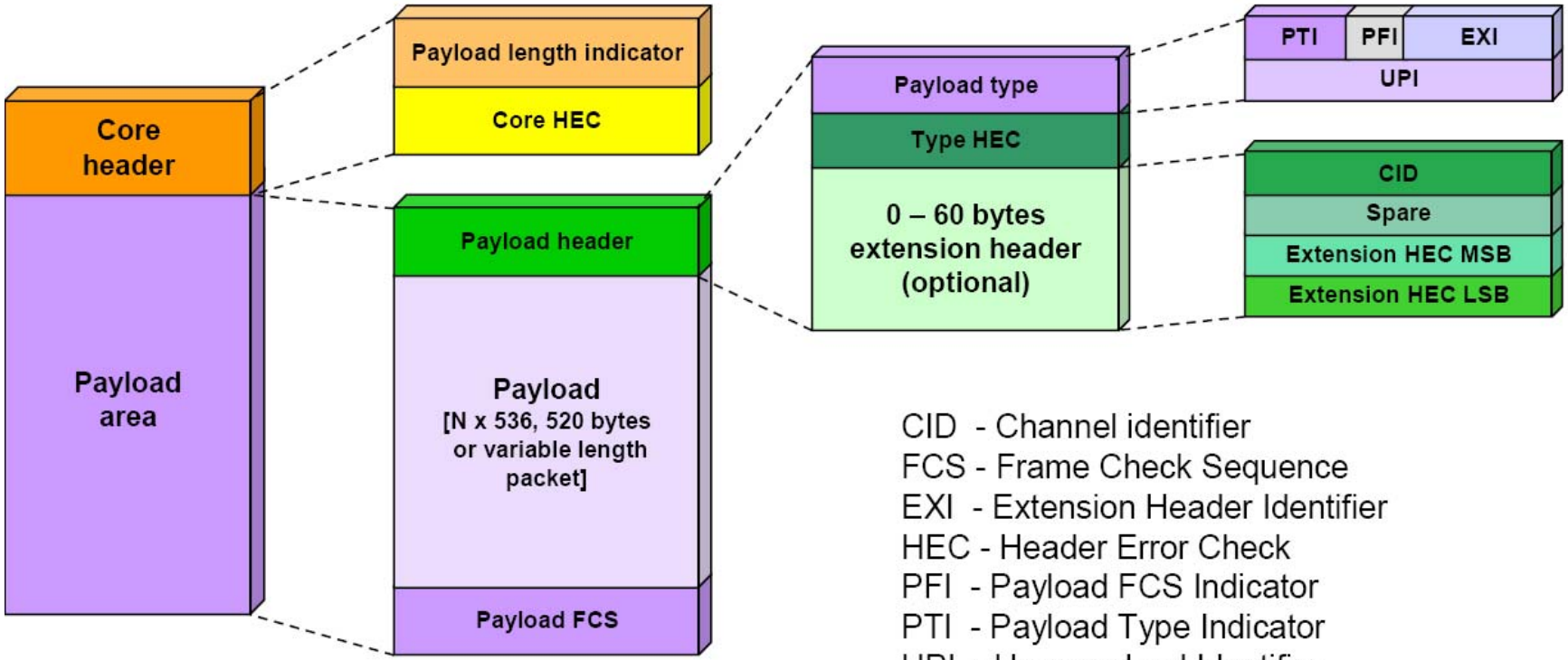
GFP: Functional Model



ESCON - Enterprise System CONnection
FICON - Fiber CONnection
IP/PPP - IP over Point-to-Point Protocol
MAPOS - Multiple Access Protocol over SONET/SDH
RPR - Resilient Packet Ring

Source = IEEE Communications Magazine, May 2002

GFP: Frame Structure



CID - Channel identifier
FCS - Frame Check Sequence
EXI - Extension Header Identifier
HEC - Header Error Check
PFI - Payload FCS Indicator
PTI - Payload Type Indicator
UPI - User payload Identifier

Source = IEEE Communications Magazine, May 2002

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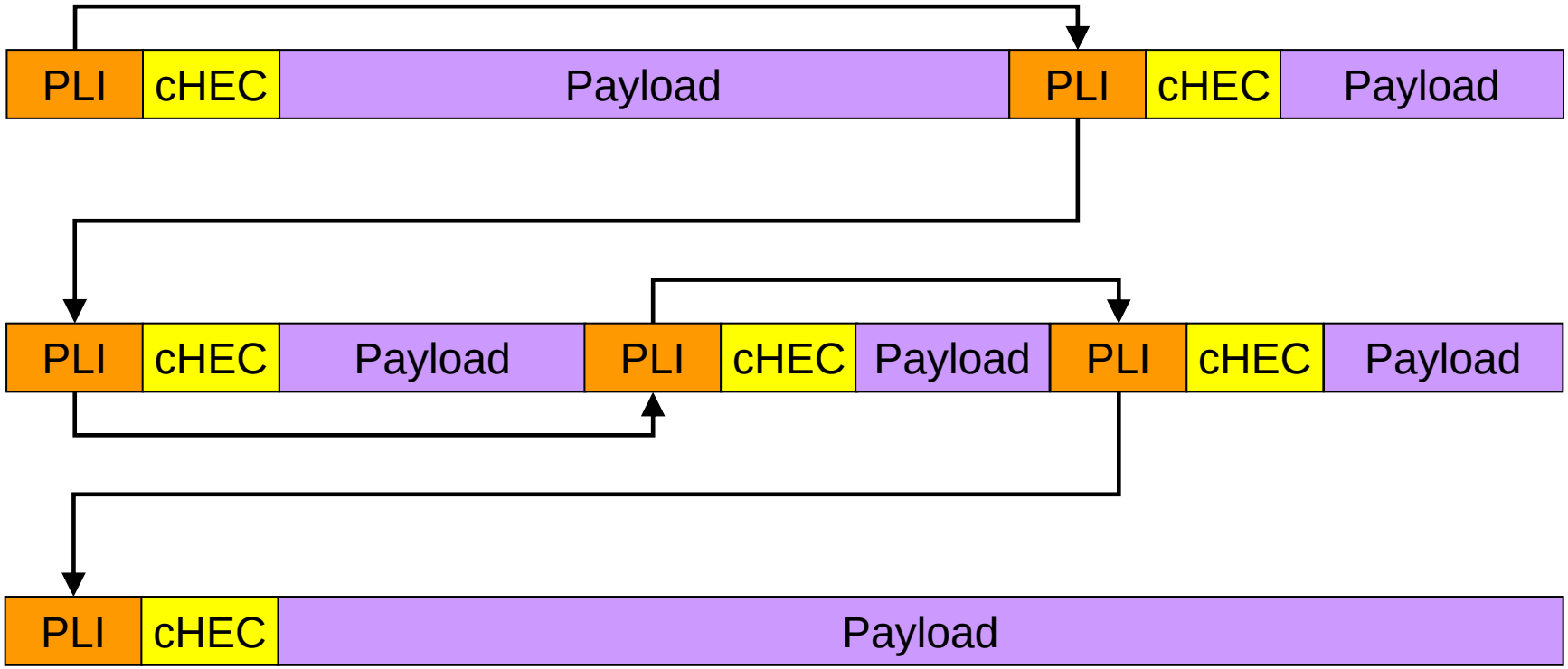
Payload Types

Value of UPI Field	Protocol	GFP Mode
0x01	Ethernet	F
0x02	PPP (IP & MPLS)	F
0x03	Fibre Channel	T
0x04	FICON	T
0x05	ESCON	T
0x06	GbE	T
0x07	reserved	
0x08	MAPOS	F
0x09 – 0xFE	reserved	
0x00 & 0xFF	unavailable	

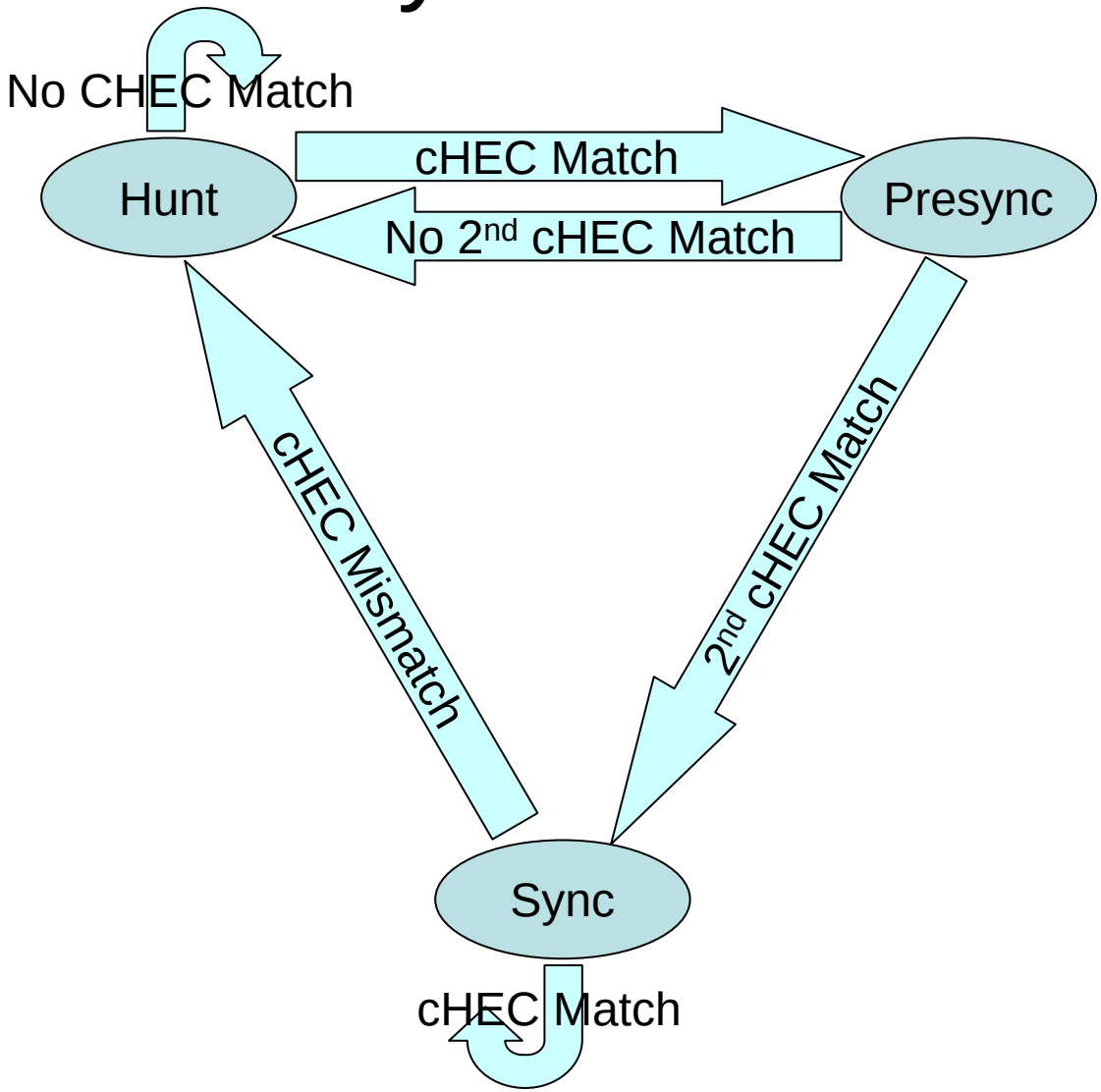
GFP: Client-Independent Processes

- Synchronization
  - Bit Level
  - Frame Delineation
- Scrambling
- Multiplexing
  - GFP Frame
  - Client PDU

GFP: Frame Delineation

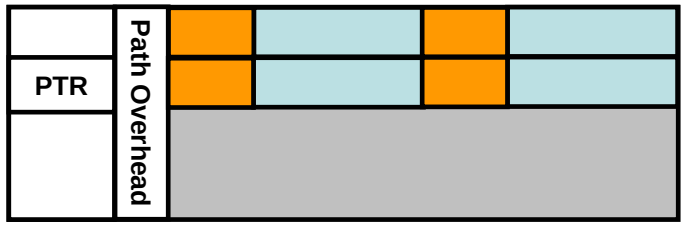


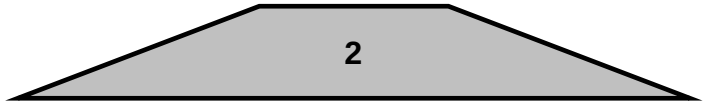
GFP: Synchronization



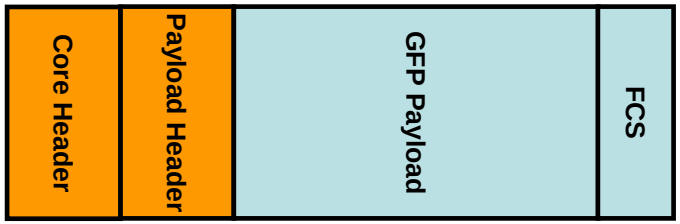
Ethernet → GFP → SDH

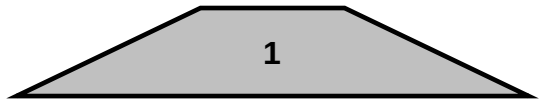
SONET/SDH Frame



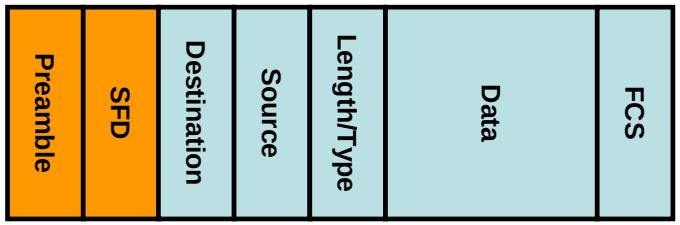


GFP Frame

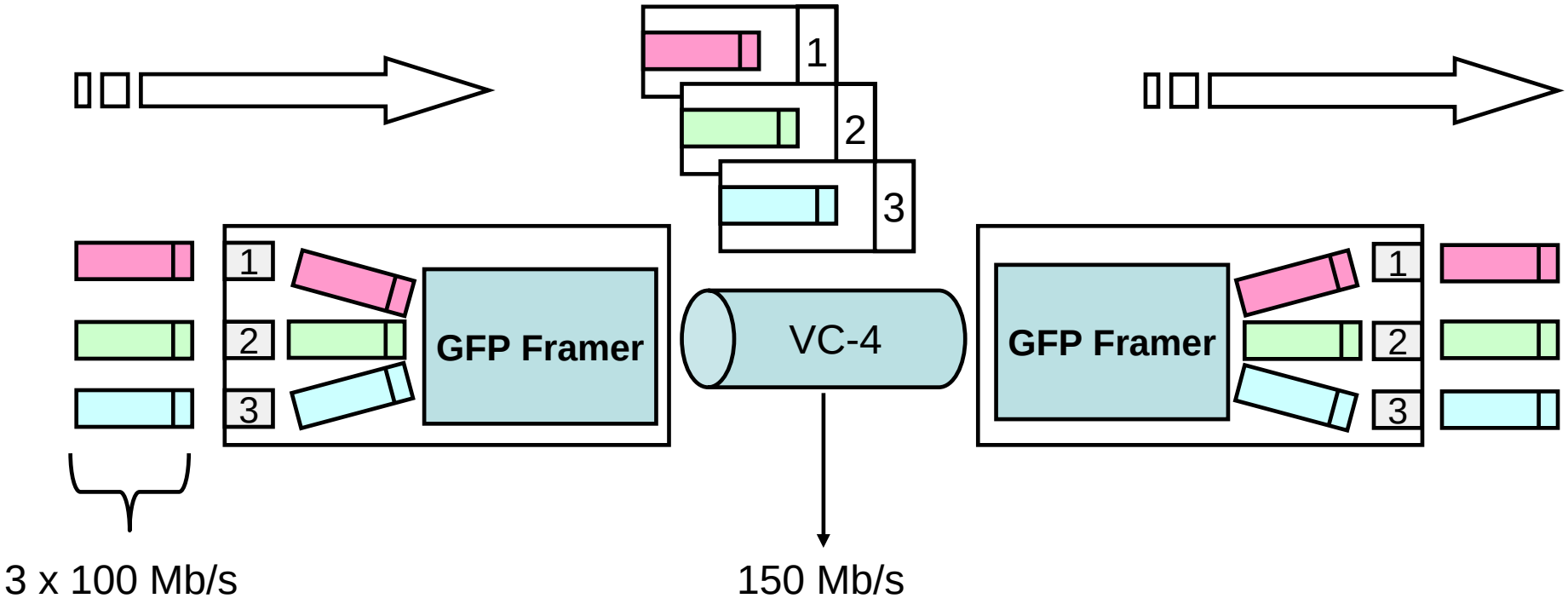




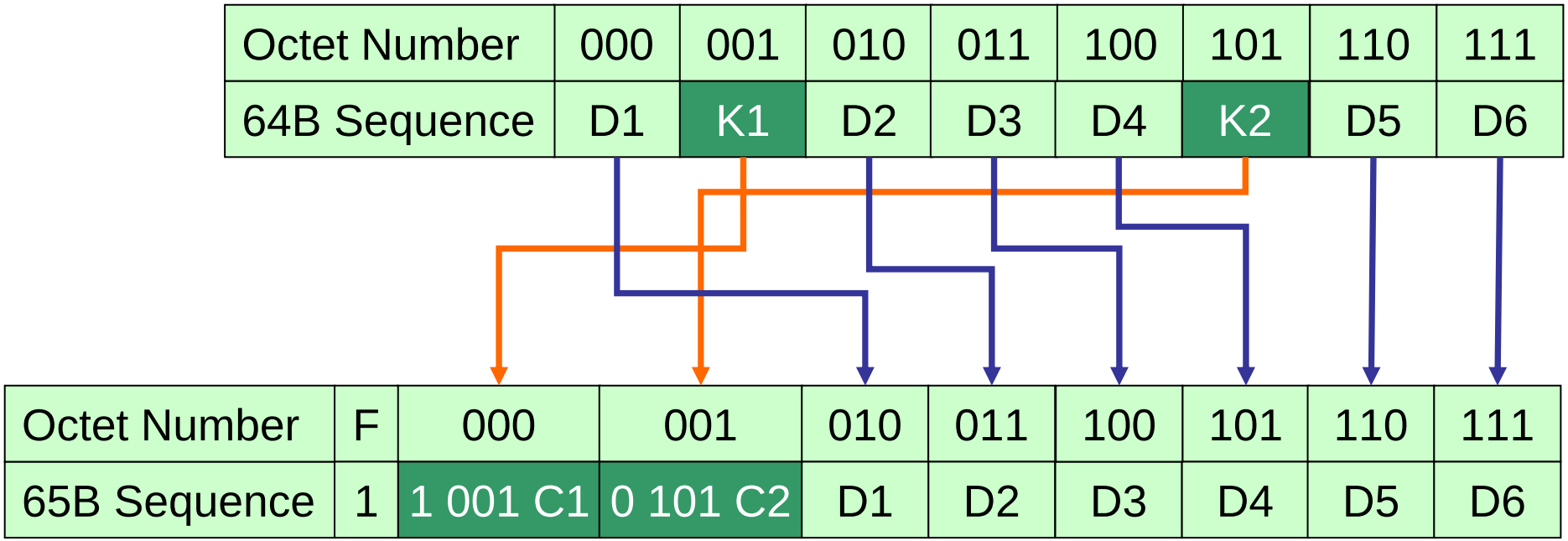
Ethernet Frame



Client PDU Statistical Multiplexing



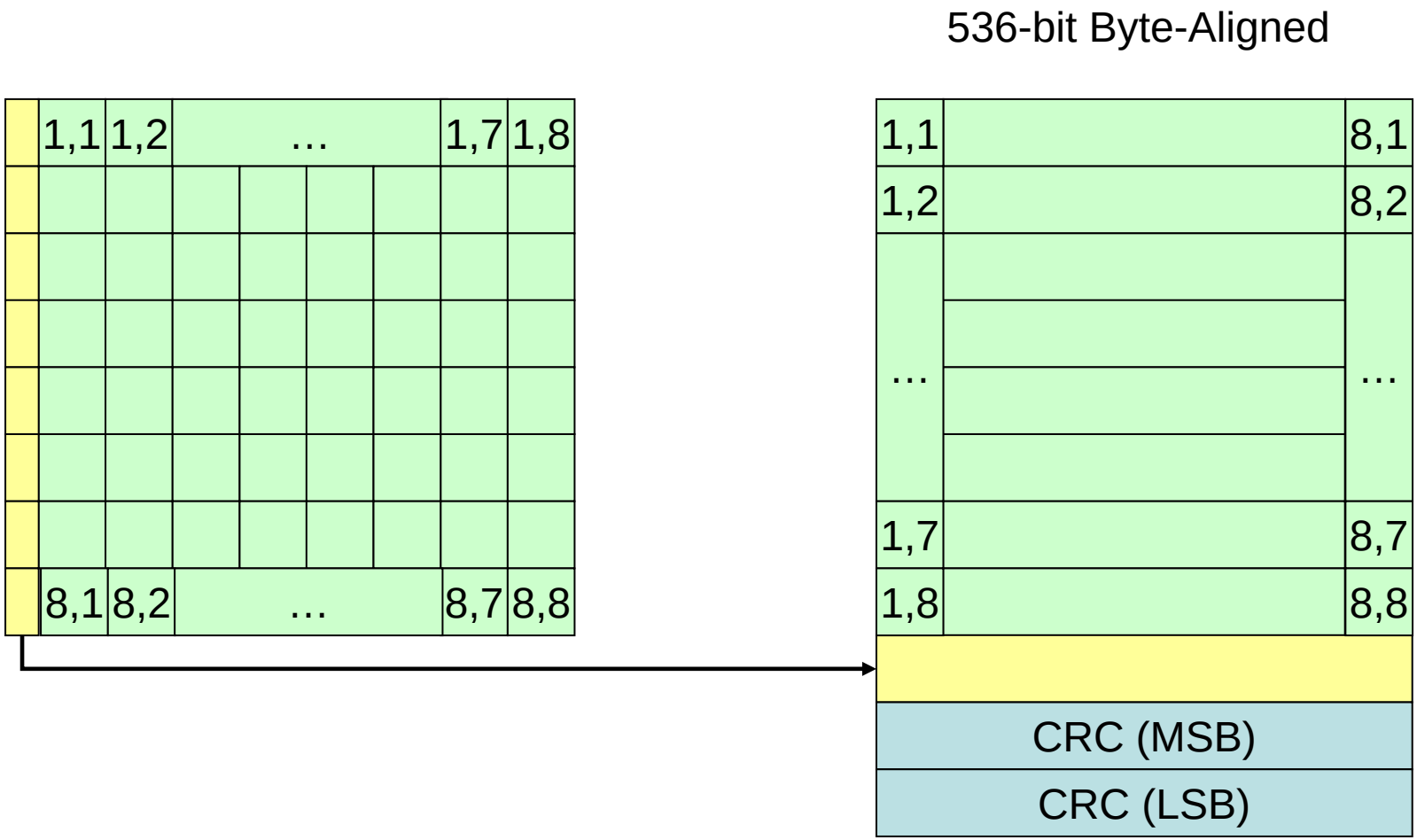
GFP-T: 64B/65B Payload



GFP-T Error Detection

- Leading flag bit is errored
- Error affects ‘Last control-code’ indicator
- Control-code location address received in error
- Error causes 4-bit control code to be modified

GFP-T: Superblocks



GFP-T: Bandwidth Requirements

Client Signal	Client Signal Bandwidth	Minimum Transport Channel Size	Nominal Transport Channel Bandwidth	Number Superblocks per GFP Frame
ESCON	160 Mb/s	STS-1-4v VC-3-4v	193.536 Mb/s	1
Fibre Channel	850 Mb/s	STS-3c-4v VC-4-6v	898.56 Mb/s	13
Gigabit Ethernet	1000 Mb/s	STS-3c-7v VC-4-7v	1.04832 Gb/s	95

Pros and Cons: GFP-F

- Higher bandwidth efficiency

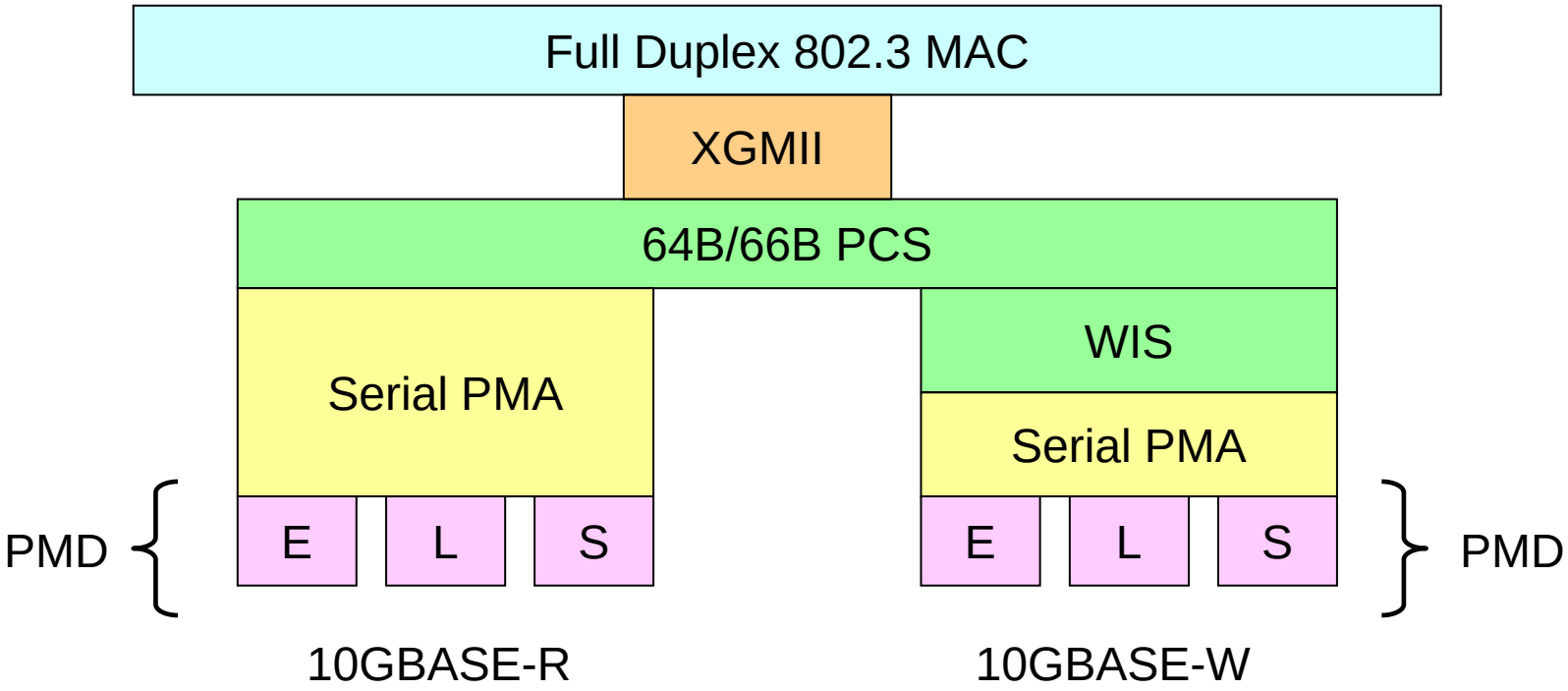
- Higher Latency
- More buffer memory required
- Core header fields must be calculated

Pros and Cons: GFP-T

- Supports many protocols
- Low latency
- Ingress core header fields need not be calculated

- Less bandwidth efficient
- More logic required

10 G Ethernet – 802.3ae

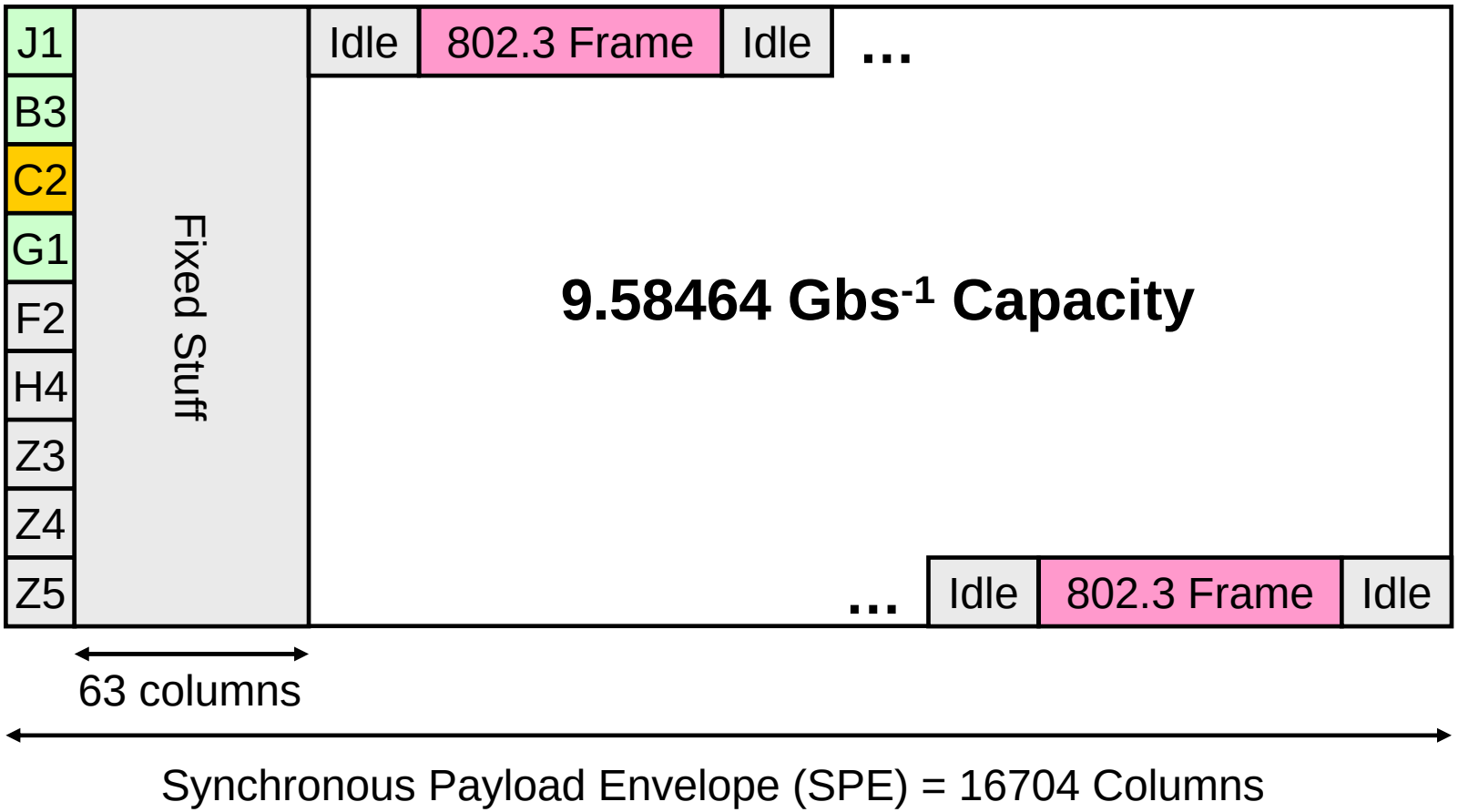


S = 850 nm	MM	300 m
L = 1310 nm	SM	10 km
E = 1550 nm	SM	40 km

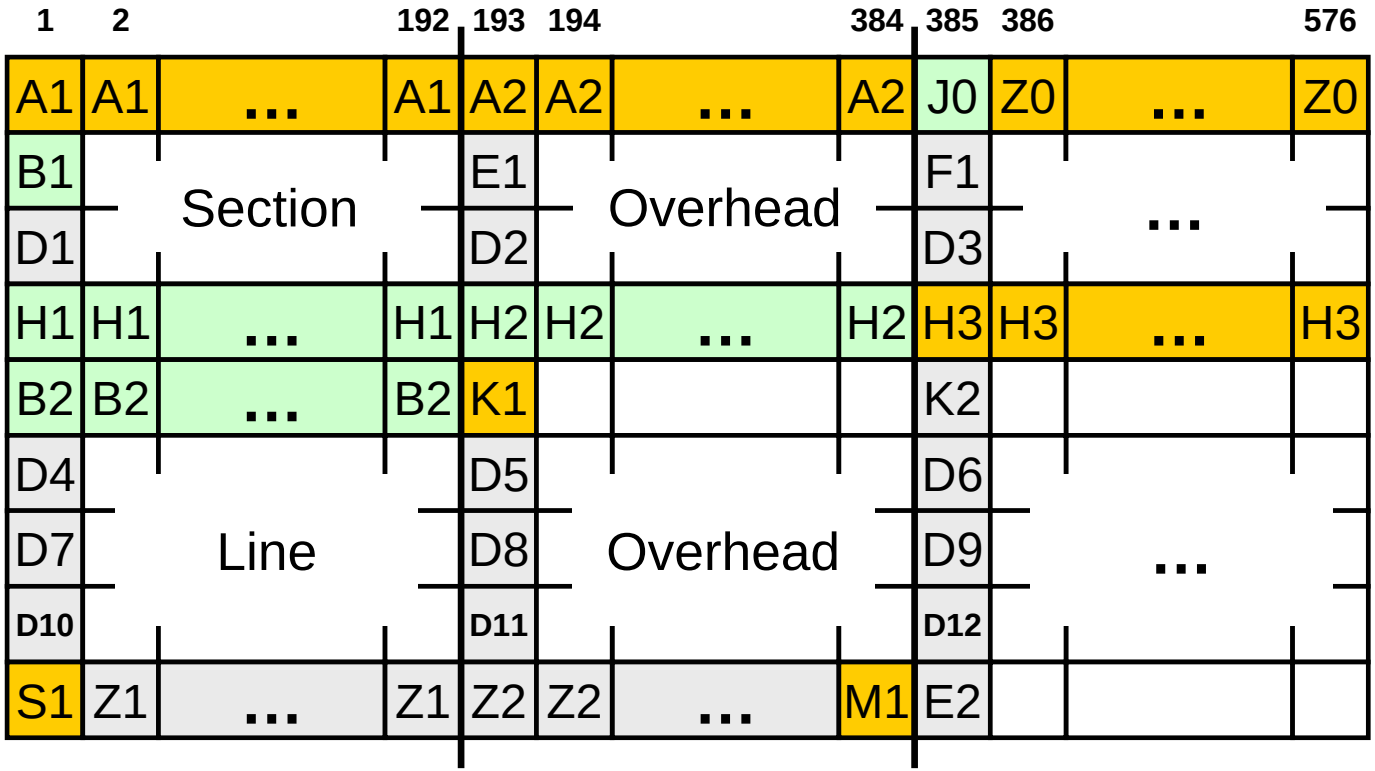
10 GbE Overview

- Usual 802.3 MAC and frame format
  - Jumbo frames *not* included in standard
- Full duplex only
  - No shared media
  - No CSMA/CD
- Only optical fibre
  - No copper interface
  - LAN-PHY or WAN-PHY at various reaches

The STS-192c WIS Frame



Section & Line Overhead



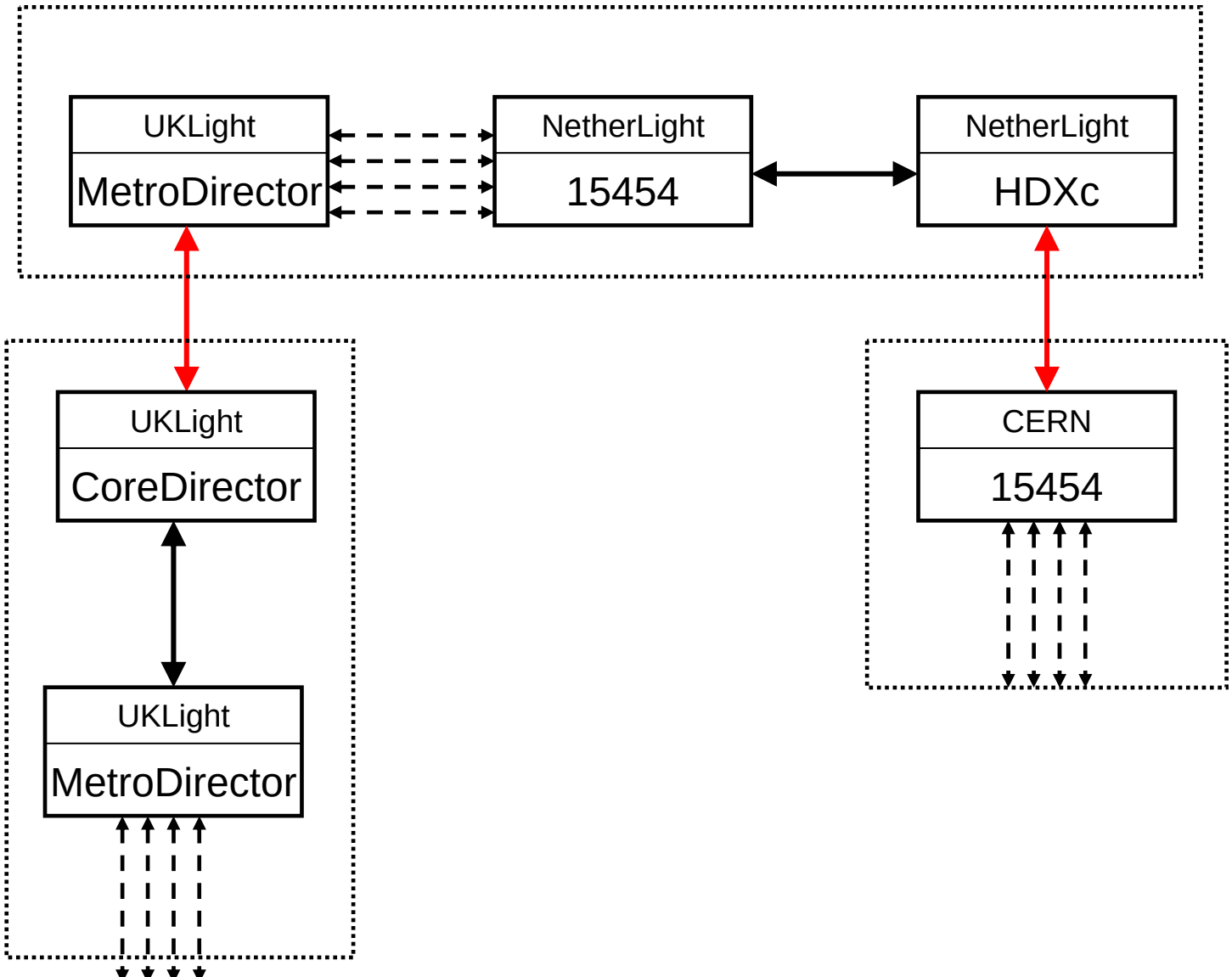
Supported by WAN PHY

Unused by WAN PHY
Optional for SONET/SDH

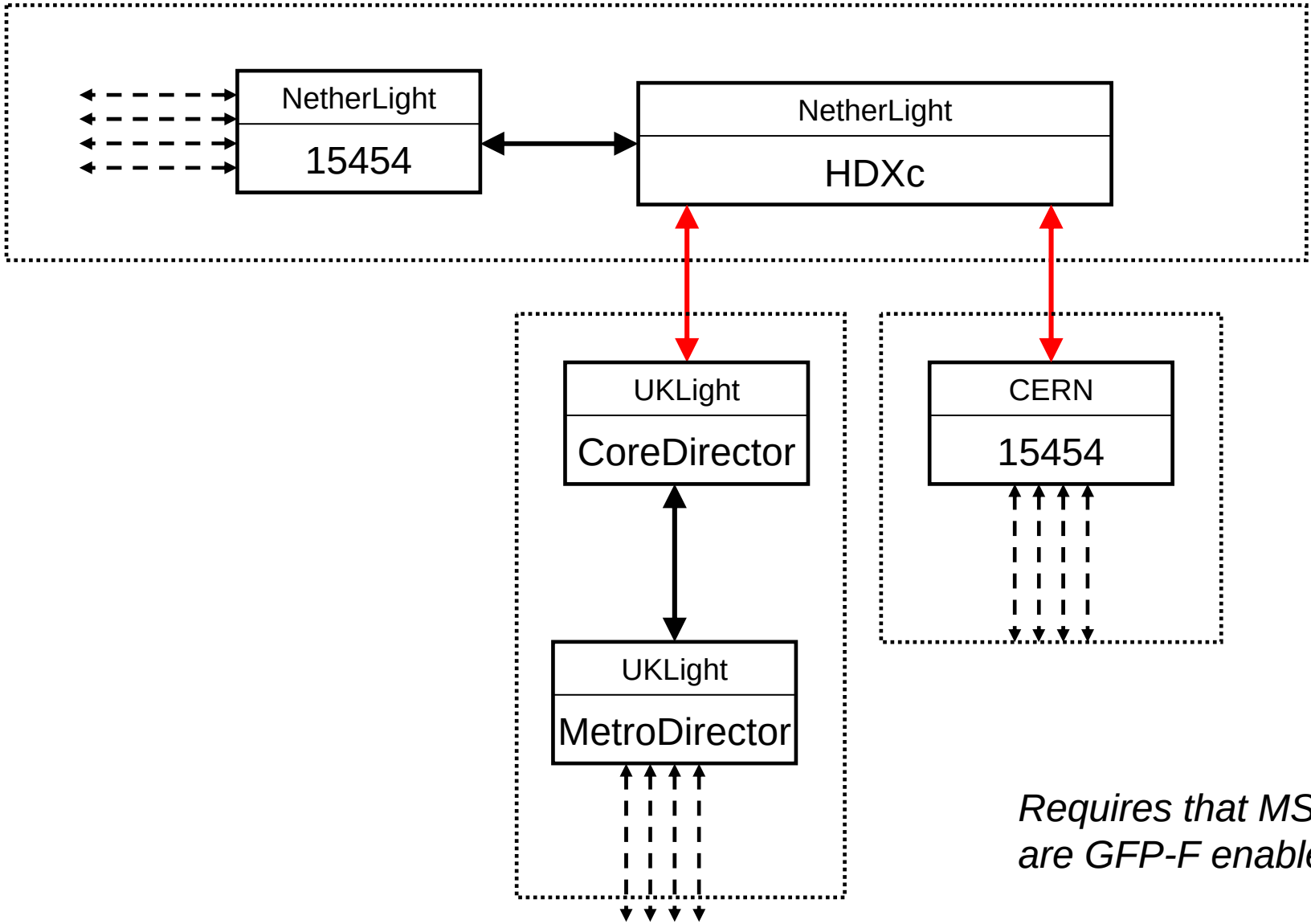
Defined by WAN PHY as Fixed Value

Unused by WAN PHY
Undefined for SONET/SDH

UKLight – NetherLight Today



UKLight – NetherLight Tomorrow?



Requires that MSPPs are GFP-F enabled