Tera-Pass

Creating an Intelligent Optical Layer

Introduction to OTN

By Yossi Moshe

Table of Contents

Table of Contents

What is OTN/OTH

- OTH - Optical Transport Hierarchy
- OTN – Optical Transport Network
- OTH is an optical transport technology for optical transport networks
  - It is based on network architectures that are defined in ITU-T G.872
- OTN Functionality
  - Transport layer
  - Aggregation
  - Supervision
  - Survivability

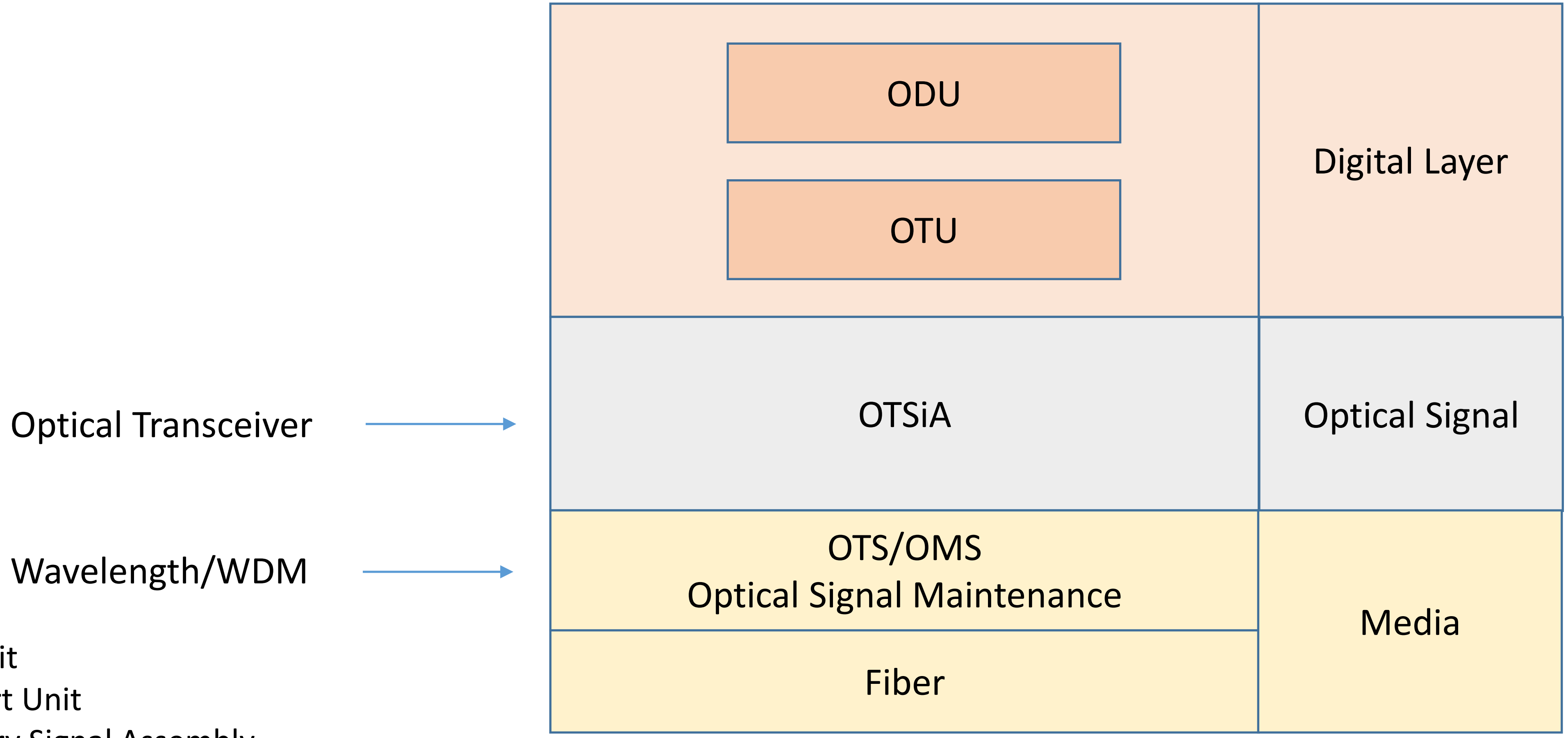
OTN Benefits (over SDH)

- Forward Error Correction (FEC)
- Optimized for higher bandwidth client signals – Bandwidth granularity
- Client signal transparency
- Switching scalability
- Multiple levels of Tandem Connection Monitoring (TCM)
  - End to end service management (OTN standard)

OTN Main Standards

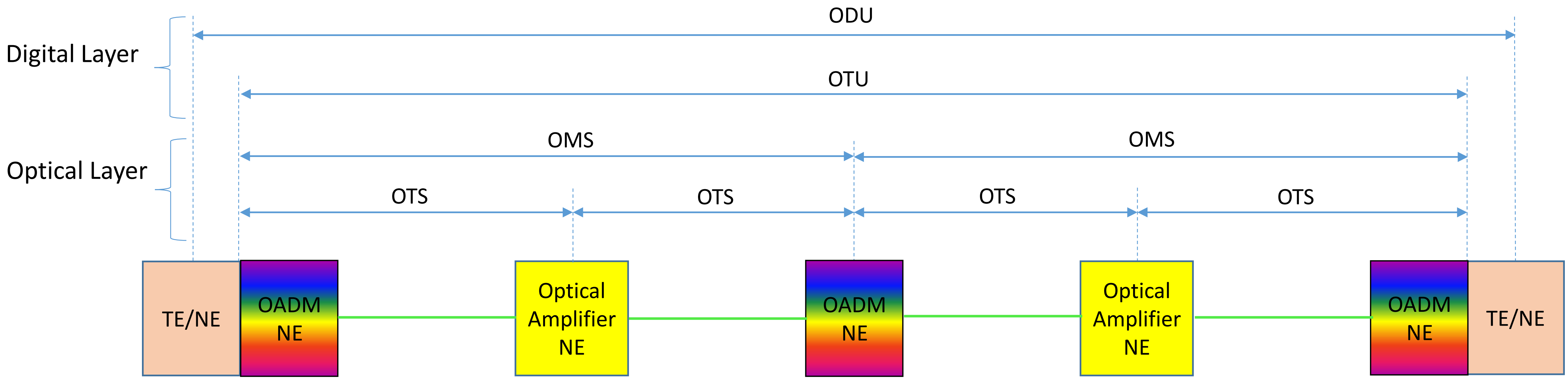
OTN		
Network Structure	G.872	Architecture of optical transport networks
	G.8080	Architecture for the automatically switched optical network
Physical Layer	G.959.1	Optical transport network physical layer interfaces
	G.693	Optical interfaces for intra-office systems
	G.664	Optical safety procedures and requirements for optical transmission systems
Mapping and Formats	G.709	Interfaces for the optical transport network
	G.709.1	Flexible OTN short-reach interfaces
	G.709.2	OTU4 long-reach interface
	G.709.3	Flexible OTN long-reach interfaces
	G.7041	Generic framing procedure
Equipment and Functions	G.798	Characteristics of optical transport network hierarchy equipment functional blocks
	G.806	Characteristics of transport equipment - Description methodology and generic functionality
Network Protection	G.873.1	Optical transport network: Linear protection
	G.873.2	ODUk shared ring protection
	G.873.3	Optical transport network - Shared mesh protection
Performance and Jitter	G.8201	Error performance parameters and objectives for multi-operator international paths within optical transport networks
	G.8251	The control of jitter and wander within the optical transport network (OTN)
Management	G.874	Management aspects of optical transport network elements
	G.874.1	Optical transport network: Protocol-neutral management information model for the network element view

OTN Layers



ODU – Optical Data Unit
OTU – Optical Transport Unit
OTSiA - Optical Tributary Signal Assembly
OTS - Optical Transmission Section
OMS - Optical Multiplex Section

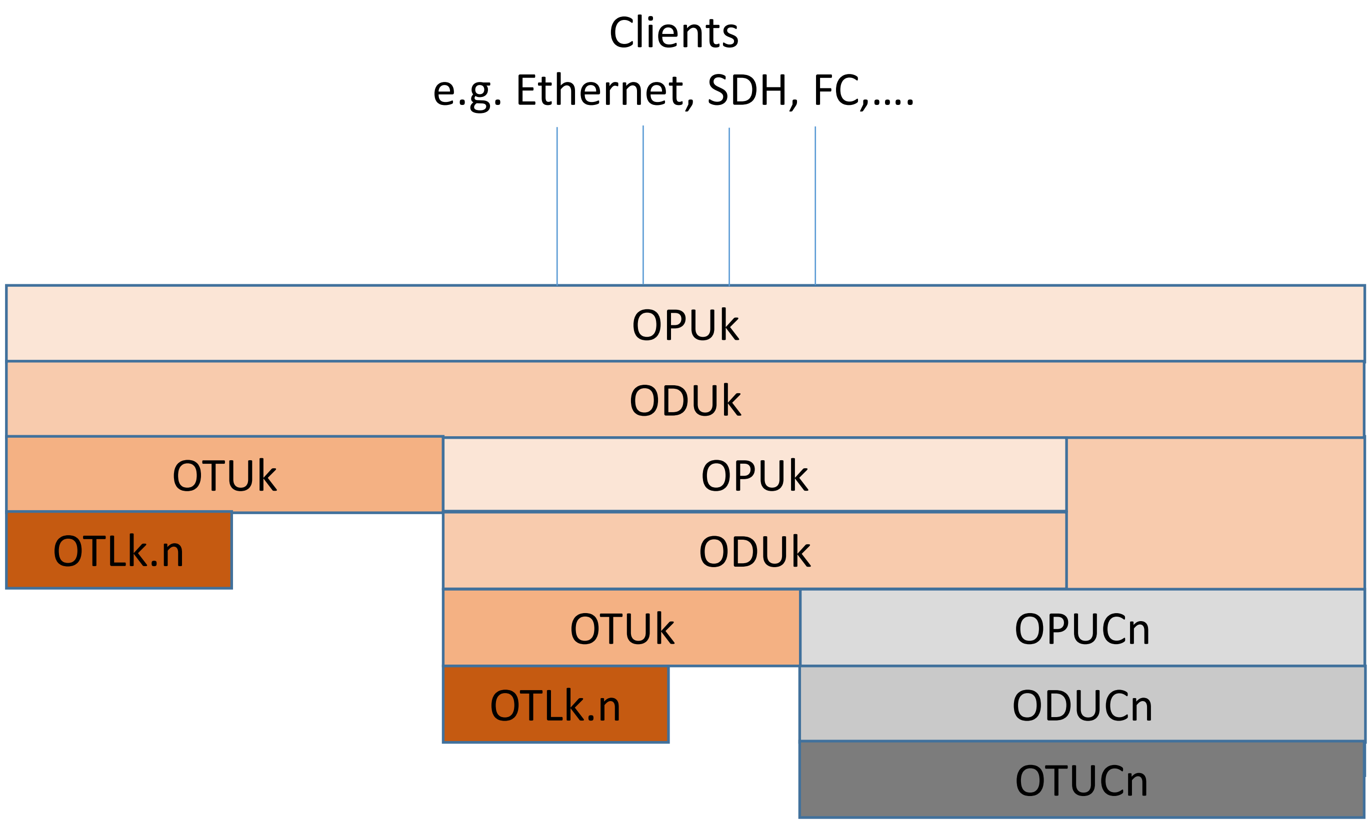
OTN Layers



- OTS Monitors optical span section between NEs
- OMS Terminates and monitors optical multiplexing (WDM)
- OTU Monitors electrical span between NEs
- ODU Monitors end to end path

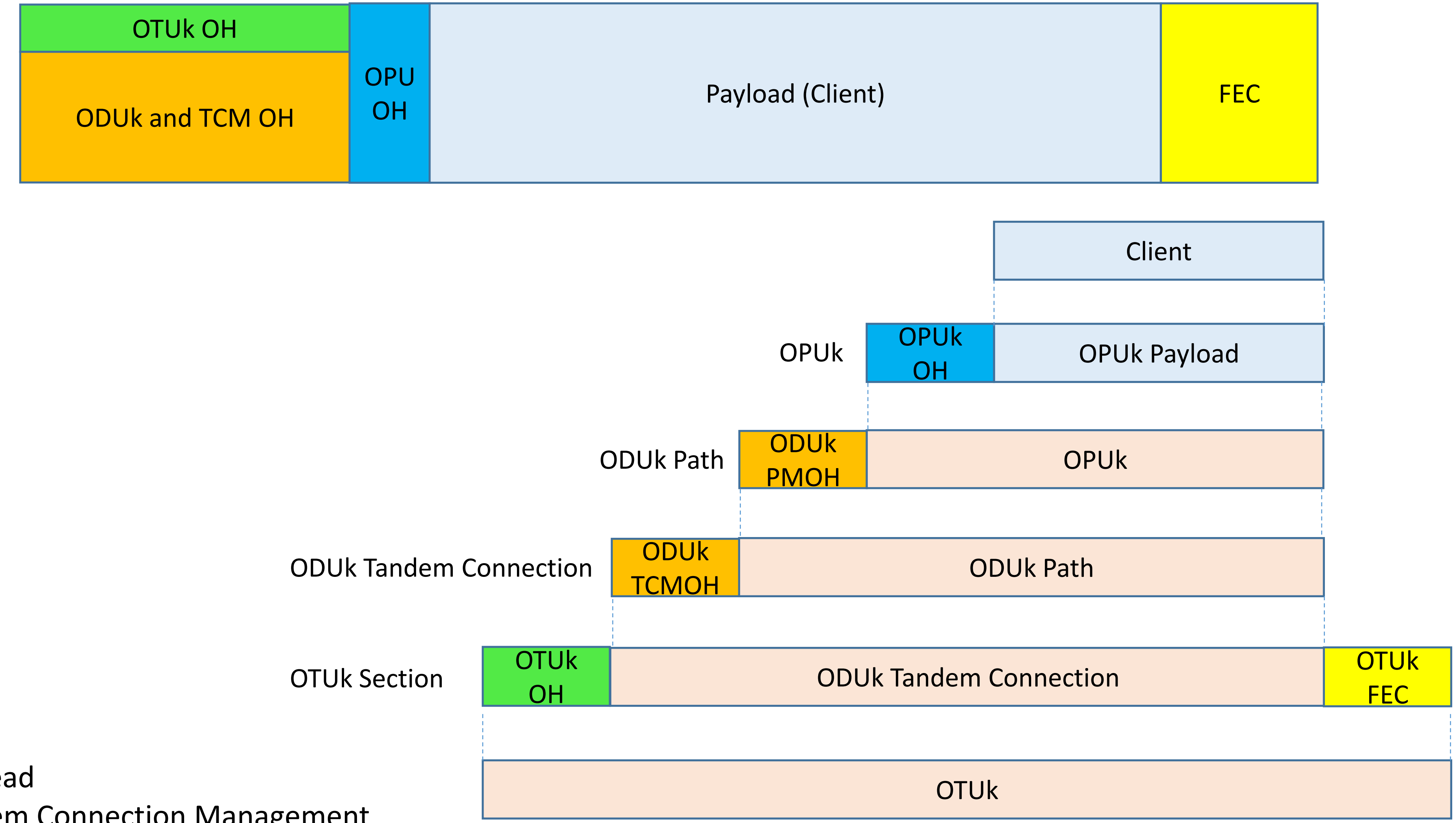
Table of Contents

OTN Digital Layers



OPU – Optical Payload Unit
OTL – Optical Transport Lane

OTN Digital Layers



OH – Overhead
TCM – Tandem Connection Management
FEC – Forward Error Correction

OTU and OTL Types and Bit Rates

OTU Types	OTU Nominal Bit Rate (±20 ppm)	
OTU1	2,666,957.143 Kbps	255/238 x 2,488,320 Kbps
OTU2	10,709,225.316 Kbps	255/237 x 9,953,280 Kbps
OTU3	43,018,413.550 Kbps	255/236 x 39,813,120 Kbps
OTU4	111,809,973.568 Kbps	255/227 x 99,532,800 Kbps
OTUCn	n x 105,258,138.053 Kbps	n x 239/226 x 99,532,800 Kbps

OTL Types	OTL Nominal Bit Rate (±20 ppm)	
OTL3.4	10,754,603.390 Kbps	255/236 x 9,953,280 Kbps
OTL4.4	27,952,493.392 Kbps	255/227 x 24,883,200 Kbps

ODU Types and Bit Rates

ODU Types	ODU Nominal Bit Rate		Bit Rate Tolerance
ODU0	1,244,160 Kbps	1,244,160 Kbps	±20 ppm
ODU1	2,498,75.126 Kbps	239/238 x 2,488,320 Kbps	±20 ppm
ODU2	10,037,273.924 Kbps	239/237 x 9,953,280 Kbps	±20 ppm
ODU3	40,319,218.983 Kbps	239/236 x 39,813,120 Kbps	±20 ppm
ODU4	104,794,445.815 Kbps	239/227 x 99,532,800 Kbps	±20 ppm
ODUCn	n x 105,258,138.053 Kbps	n x 239/226 x 99,532,800 Kbps	±20 ppm
ODU2e	10,399,525.316 Kbps	239/237 x 10,312,500 Kbps	±100 ppm
ODUflex CBR	239/238 x Client signal bit rate	239/238 x Client signal bit rate	±100 ppm
ODUflex GFP-F	ODU2: n x 1,249,177.230 Kbps ODU3: n x 1,254,470.354 Kbps ODU4: n x 1,301,467.133 Kbps	ODU2: n x ODU2.ts (1,249,177.230 Kbps, 1≤n≤8) ODU3: n x ODU3.ts (1,254,470.354 Kbps, 9≤n≤32) ODU4: n x ODU4.ts (1,301,467.133 Kbps, 33≤n≤80)	±100 ppm
ODUflex IMP	Per G.709 Para. 12.2.6	s x 239/238 x 5,156,250 Kbps s = 2,8,n x 5 with n≥1	±100 ppm
ODUflex FlexE Aware		240/238 x 103,125,000 x n/20 Kbps ($n = n_1+n_2+....+n_p$)	±100 ppm

OPU Types and Bit Rates

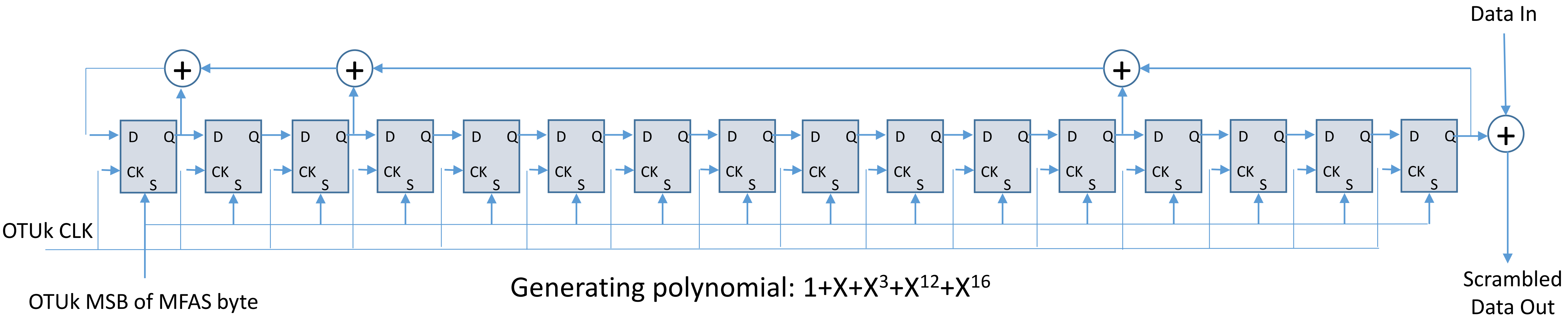
OPU Types	OPU Nominal Bit Rate		Bit Rate Tolerance
OPU0	1,238,954.310 Kbps	238/239 x 1,244,160 Kbps	±20 ppm
OPU1	2,488,320 Kbps	2,488,320 Kbps	±20 ppm
OPU2	9,995,276.962 Kbps	237/238 x 9,953,280 Kbps	±20 ppm
OPU3	40,150,519.322 Kbps	238/236 x 39,813,120 Kbps	±20 ppm
OPU4	104,355,975.330 Kbps	238/227 x 99,532,800 Kbps	±20 ppm
OPUCn	n x 104,817,727.434 Kbps	n x 238/226 x 99,532,800 Kbps	±20 ppm
OPU2e	10,356,012.658 Kbps	238/237 x 10,312,500 Kbps	±100 ppm
OPUflex CBR	Client signal bit rate	Client signal bit rate	±100 ppm
OPUflex GFP-F	238/239 ODUflex signal rate	238/239 ODUflex signal rate	±100 ppm
OPUflex IMP	Per G.709 Para. 12.2.6	s x 5,156,250 Kbps s = 2,8,n x 5 with n≥1	±100 ppm
OPUflex FlexE Aware		240/239 x 103,125,000 x n/20 Kbps $(n = n_1+n_2+....+n_p)$	±100 ppm

Non-Standard Bit Rates

k	OTUk	ODUk	OPUk	Bit Rate Tolerance	Signal
1e	11,049,107.143 Kbps	10,355,829.832 Kbps	10,312,500.000 Kbps	±100 ppm	10GE
2e	11,095,727.850 Kbps	10,399,525.316 Kbps	10,356,012.658 Kbps	±100 ppm	10GE
1f	11,270,089.286 Kbps	10,562,946.429 Kbps	10,518,750.000 Kbps	±100 ppm	10GFC
2f	11,317,642.405 Kbps	10,607,515.823 Kbps	10,563,132.911 Kbps	±100 ppm	10GFC
3e1	44,570,974.576 Kbps	41,774,364.407 Kbps	41,599,576.271 Kbps	±20 ppm	4xODU2e AMP
3e2	44,583,355.576 Kbps	41,785,968.560 Kbps	41,611,131.871 Kbps	±20 ppm	4xODU2e GMP

Scrambling

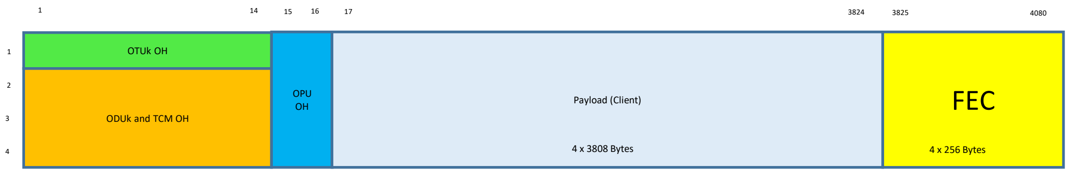
- OTUk signal must have sufficient bit timing content
  - A suitable bit pattern, which prevents a long sequence of "1"s or "0"s, is provided by using a scrambler
- The framing bytes (FAS) of the OTUk overhead shall not be scrambled
- Scrambling is performed after FEC computation and insertion into the OTUk signal



Generating polynomial: $1+X+X^3+X^{12}+X^{16}$

Forward Error Correction

- OTUk (k=1,2,3) FEC is a Reed Solomon RS(255,239) algorithm
  - Defined in ITU-T G.709
  - Non-binary code operating on byte symbols
  - Coding gain 6.2db @ BER 10^{-15}
  - FEC overhead: 7%
  - Latency ~ Time period of an OTN frame row

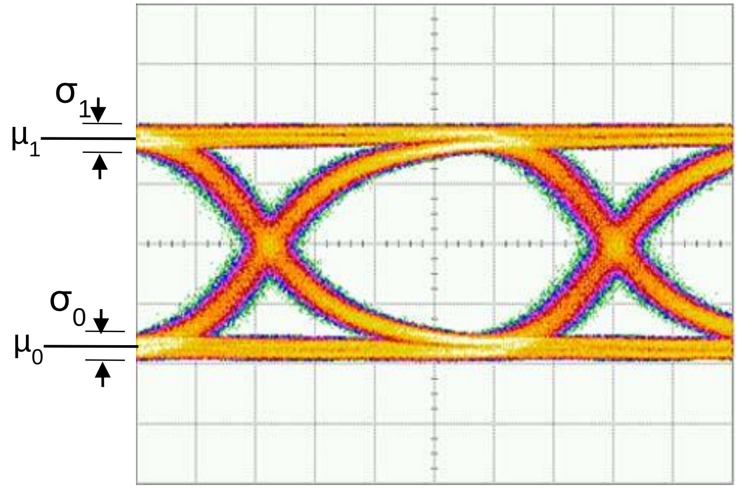


- OTU4 FEC is Staircase FEC defined in ITU-T G.709.2
- Other FEC algorithms (non-standard) are defined in ITU-T G.975.1
  - Popular FEC algorithms (Mainly for OTU2):
    - I.4 Super FEC: RS(1023,1007)/BCH(2047,1952)
    - I.7 Super FEC: Two orthogonally concatenated BCH and Super FEC
  - Higher coding gain: ~ 8.5db
  - Higher latency
- There are stronger FEC algorithms that use 11% and 25% FEC overhead
- Low latency FEC algorithm

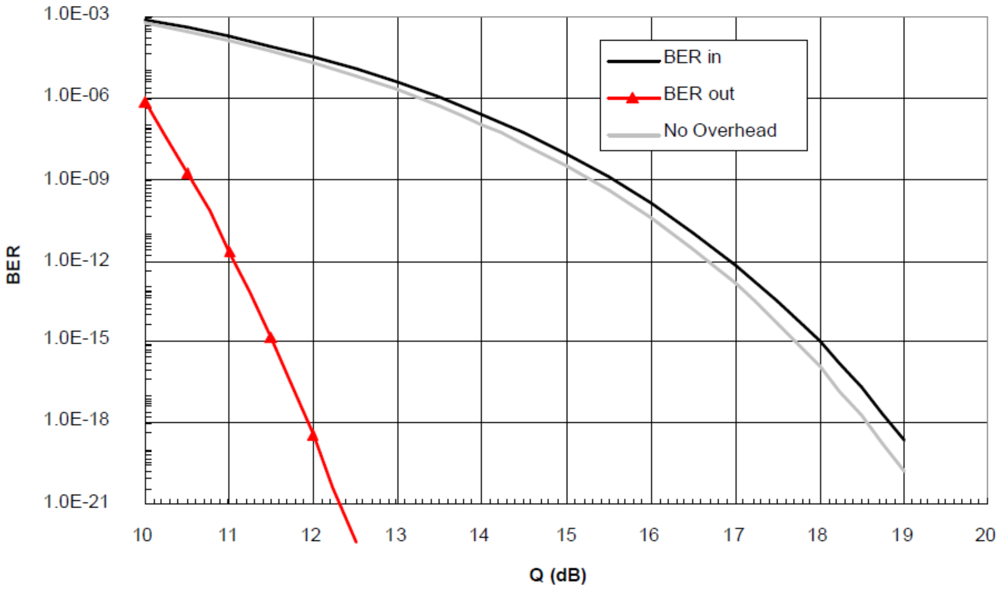
Q Factor

$$Q = (\mu_1 - \mu_0)/(\sigma_1 + \sigma_0)$$

- Q factor is the signal-to-noise ratio at the decision circuit in voltage or current units
- Q limit is the minimum required Q factor at the input signal in order to achieve a reference BER

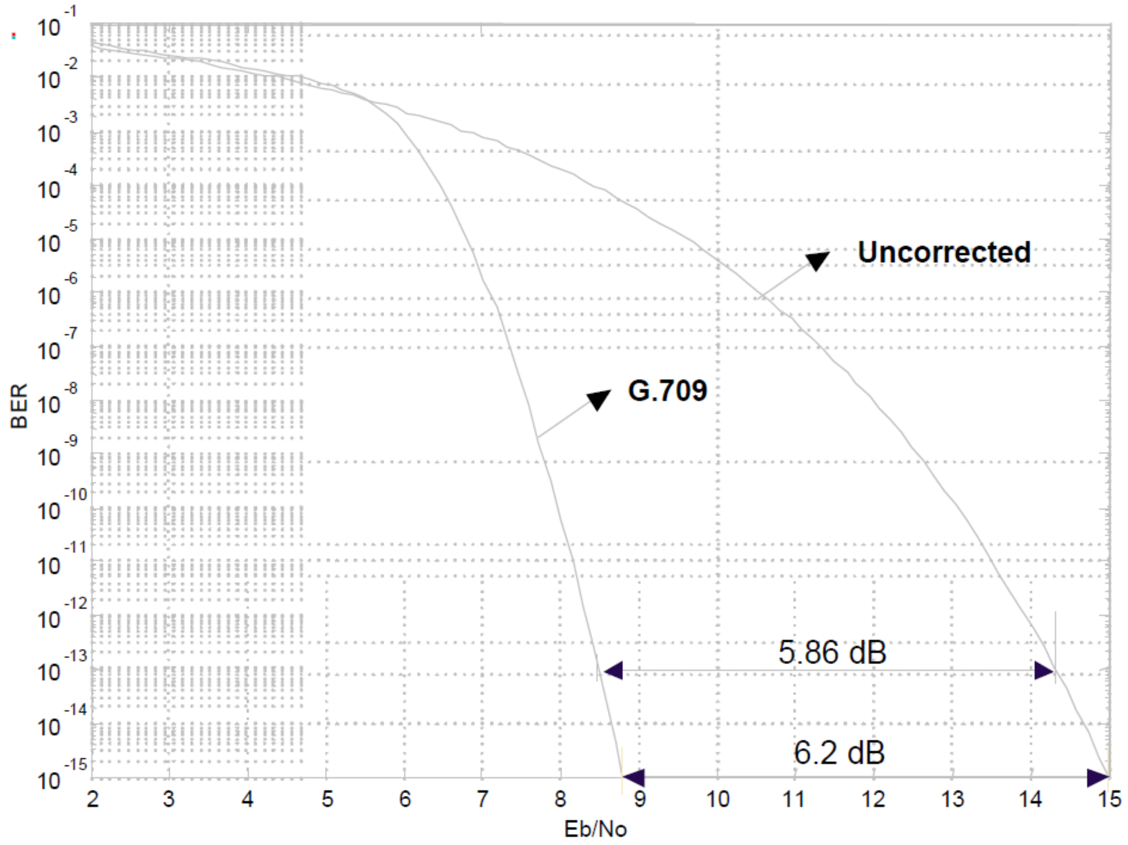


Eye Pattern Diagram



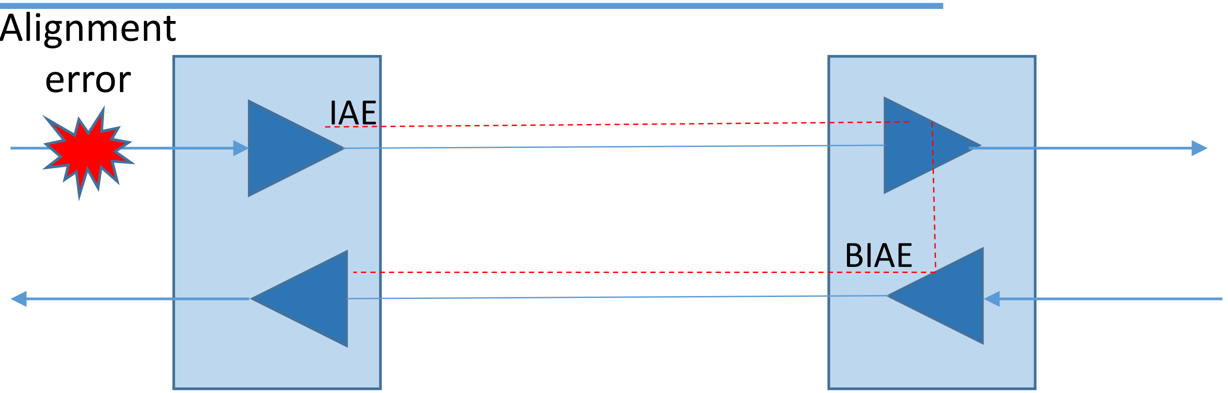
- A system that requires an operating BER of 10-15 has a Q-factor measurement of 18 dB without FEC.
- If RS(255, 239) FEC is employed, the Q-factor measurement decreases to 11.8 dB, yielding 6.2 dB of coding gain.

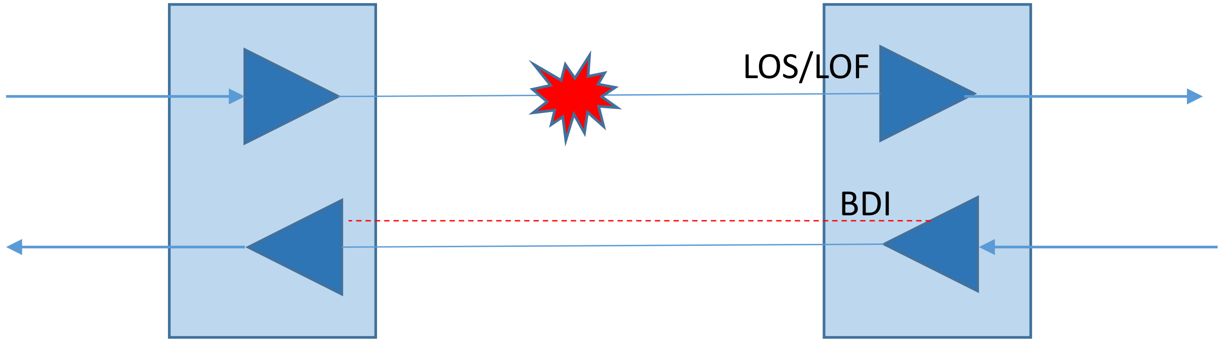
Forward Error Correction (FEC)



- Coding Gain – E_b/N_0
  - E_b – Energy of a bit (Bit Power * Bit Time)
  - N_0 – Noise energy (Noise Power / Bandwidth)
  - E_b/N_0 = SNR
- G.709 FEC – RS(255,239) increase the coding gain by 6.2db @ BER 10-^{15}

BDI, IAE, BIAE





BIP-8 Violation	BEI/BIAE	BIAE
0	0000	false
1	0001	false
2	0010	false
3	0011	false
4	0100	false
5	0101	false
6	0110	false
7	0111	false
8	1000	false
0	1001, 1010	false
0	1011	true
0	1100 to 1111	false

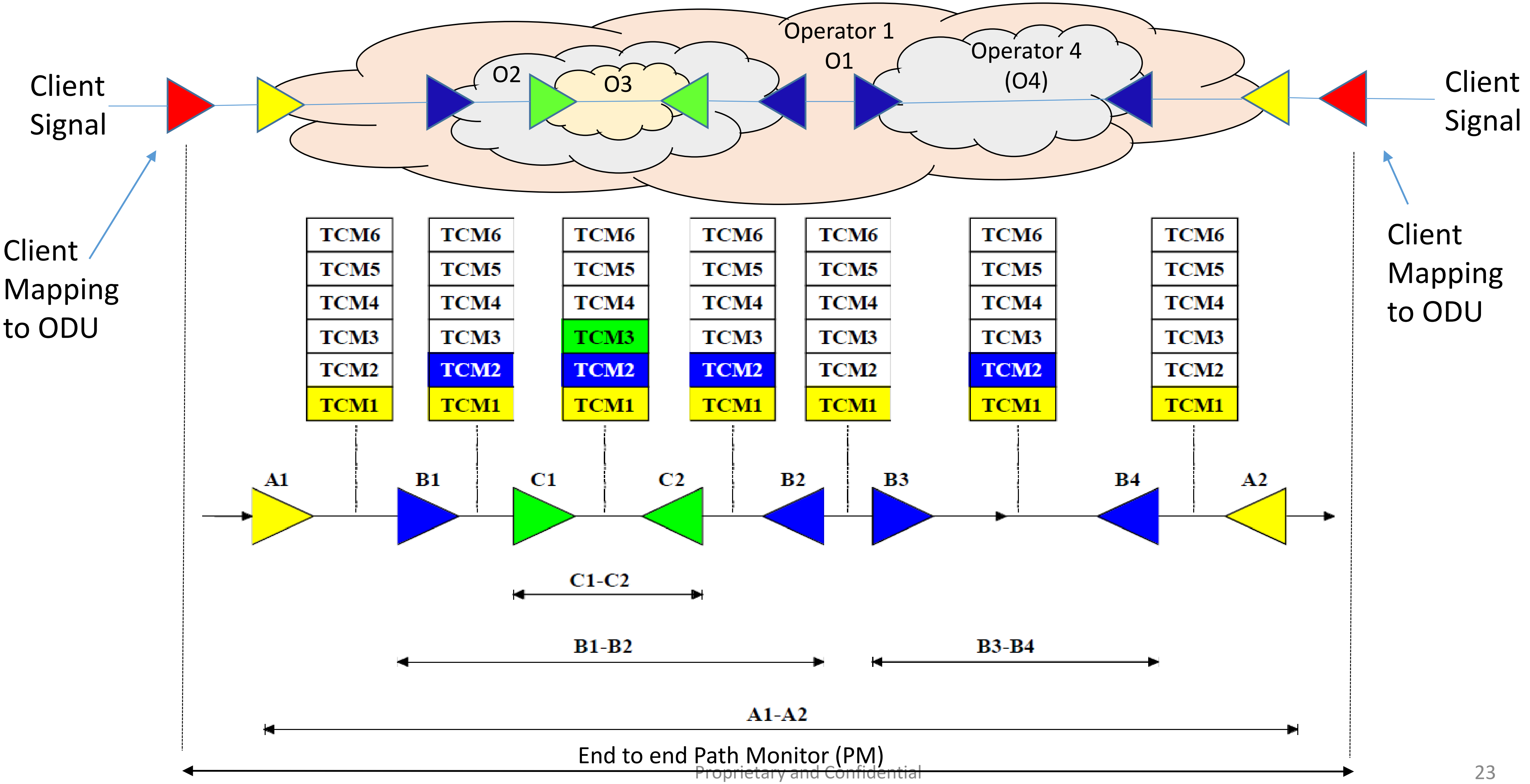
IAE – Incoming Alignment Error
BIAE – Backward Incoming Alignment Error
BDI - Backward Defect Indication

OSMC – OTN Synchronization Message Channel

- One byte is defined in the OTU overhead as an OTN synchronization message channel to transport SSM, eSSM and PTP messages
- The SSM, eSSM and PTP messages are encapsulated into GFP-F frames
- PTP event messages are timestamped and after encapsulation into GFP-F frames inserted into the OSMC
- GFP-F encapsulated SSM and eSSM messages (and PTP non-event messages) are inserted into the OSMC at the earliest opportunity
- GFP idle frames may be inserted between successive GFP frames

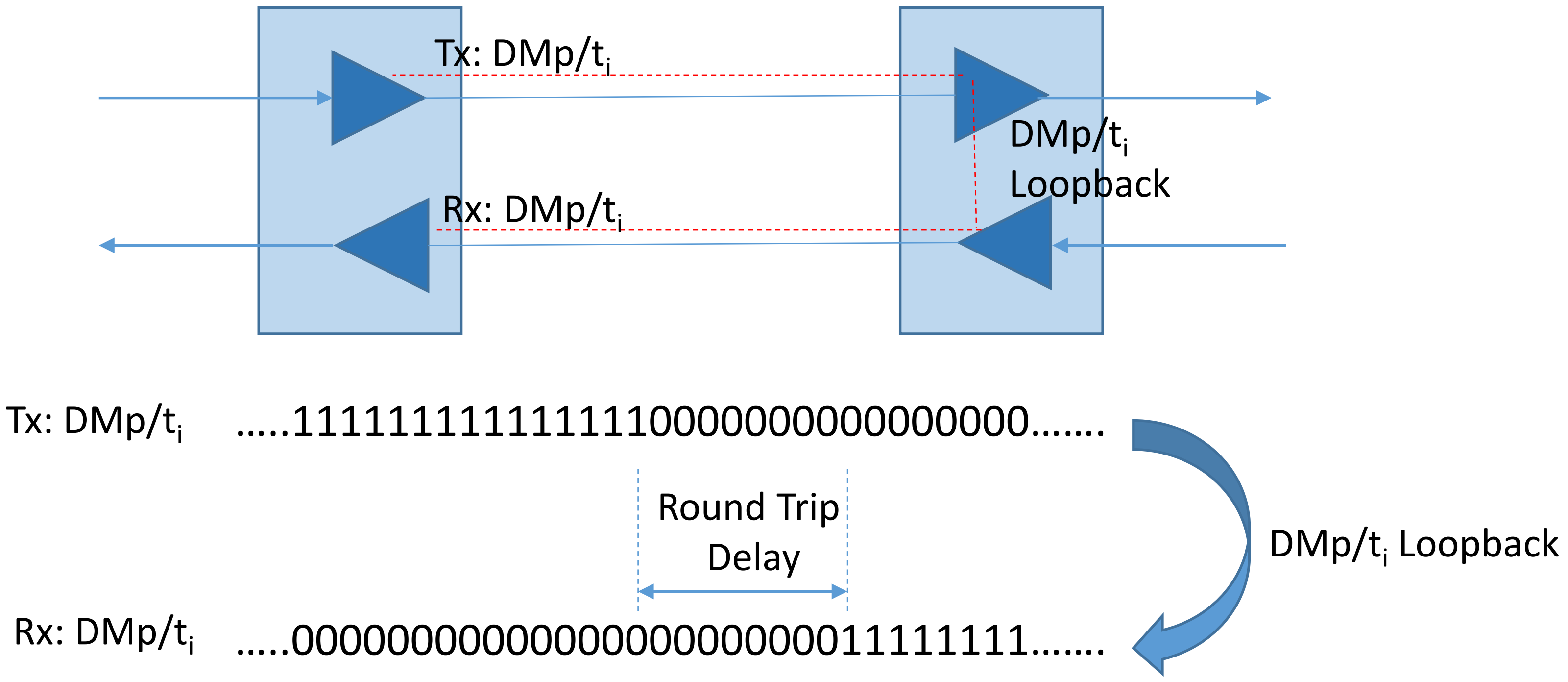
SSM - Synchronization Status Message
eSSM - enhanced Synchronization Status Message
PTP - Precision Time Protocol

Tandem Connection Monitoring

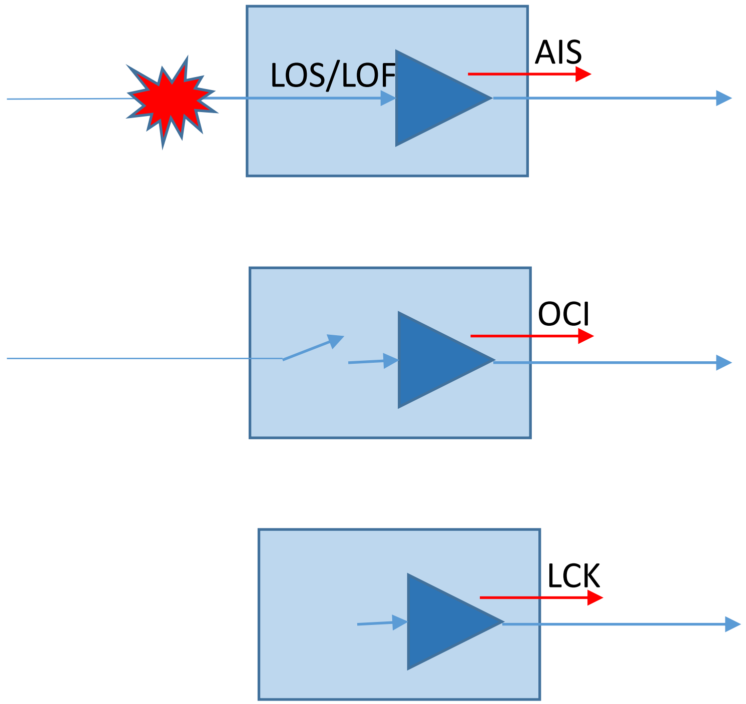


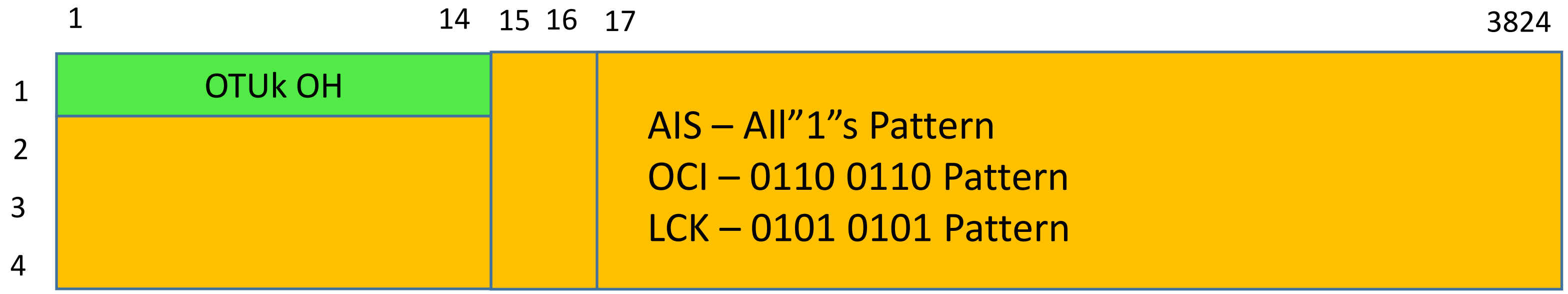
Delay Measurement

- Round Trip Delay Measurement
  - ODU level
  - TCM level
  - Delay Accuracy: OTN frame duration



ODU Maintenance Signals and STAT OH Field



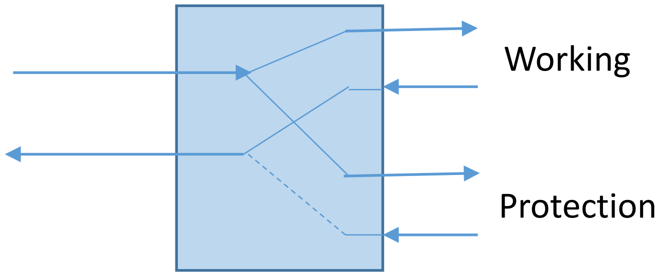


PM and TCM Byte 3, Bits 678	PM STAT	TCM STAT
000	Reserved	No source TC
001	Normal path signal	In use without IAE
010	Reserved	In use with IAE
011	Reserved	Reserved
100	Reserved	Reserved
101	ODU-LCK	ODU-LCK
110	ODU-OCI	ODU-OCI Reserved for ODUCn
111	ODU-AIS	ODU-AIS

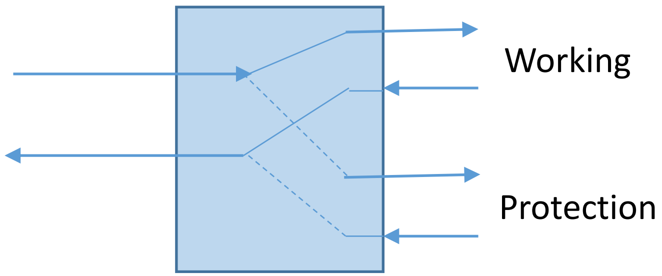
AIS – Alarm Indication Signal
OCI – Open Connection Indication
LCK – Locked Indication

APS/PCC OH Field

- APS/PCC – Four bytes are defined to enable 8 levels of nested APS/PCC signals
- For ODUCn, the APS/PCC signal is used to support coordination of the end points in linear and ring protection applications



1+1 Protection

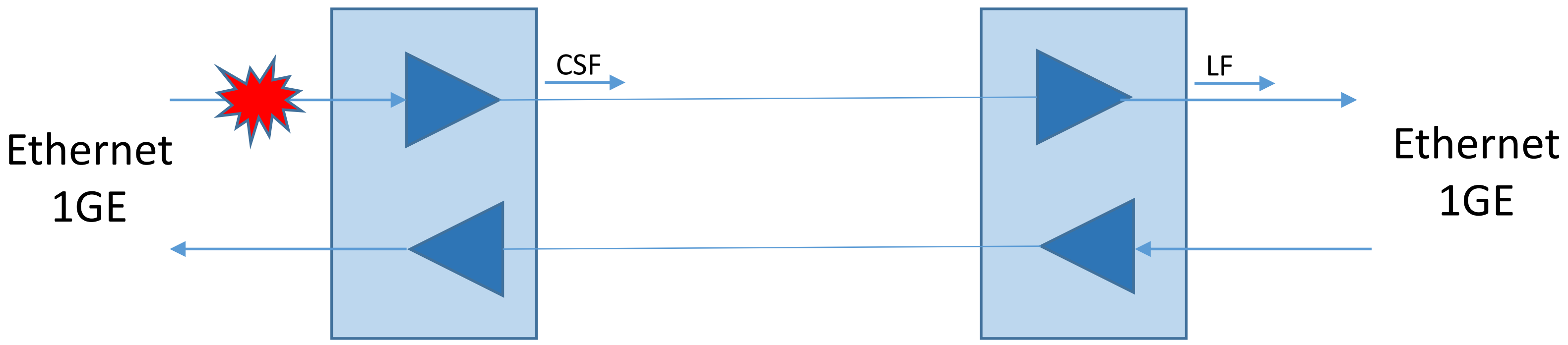


1:1 Protection

MFAS Bits 6,7,8	APS/PCC channel applies to connection monitoring level
000	ODUk path
001	ODUk TCM1
010	ODUk TCM2
011	ODUk TCM3
100	ODUk TCM4
101	ODUk TCM5
110	ODUk TCM6
111	ODUk Server (OTUk or higher order ODUk)

APS – Automatic Protection Switching coordination channel
PCC – Protection Communication Control channel

Example: Client Signal Fail (CSF)



Payload Type (PT) Modes

Table 15-9 – Payload type code points

MSB 1 2 3 4	LSB 5 6 7 8	Hex code (Note 1)	Interpretation
0 0 0 0	0 0 0 1	01	Experimental mapping (Note 3)
0 0 0 0	0 0 1 0	02	Asynchronous CBR mapping, see clause 17.2
0 0 0 0	0 0 1 1	03	Bit-synchronous CBR mapping, see clause 17.2
0 0 0 0	0 1 0 0	04	Not available (Note 2)
0 0 0 0	0 1 0 1	05	GFP mapping, see clause 17.4
0 0 0 0	0 1 1 0	06	Not available (Note 2)
0 0 0 0	0 1 1 1	07	PCS codeword transparent Ethernet mapping: 1000BASE-X into OPU0, see clauses 17.7.1 and 17.7.1.1 40GBASE-R into OPU3, see clauses 17.7.4 and 17.7.4.1 100GBASE-R into OPU4, see clauses 17.7.5 and 17.7.5.1
0 0 0 0	1 0 0 0	08	FC-1200 into OPU2e mapping, see clause 17.8.2
0 0 0 0	1 0 0 1	09	GFP mapping into extended OPU2 payload, see clause 17.4.1 (Note 5)
0 0 0 0	1 0 1 0	0A	STM-1 mapping into OPU0, see clause 17.7.1
0 0 0 0	1 0 1 1	0B	STM-4 mapping into OPU0, see clause 17.7.1
0 0 0 0	1 1 0 0	0C	FC-100 mapping into OPU0, see clause 17.7.1
0 0 0 0	1 1 0 1	0D	FC-200 mapping into OPU1, see clause 17.7.2
0 0 0 0	1 1 1 0	0E	FC-400 mapping into OPUflex, see clause 17.9
0 0 0 0	1 1 1 1	0F	FC-800 mapping into OPUflex, see clause 17.9
0 0 0 1	0 0 0 0	10	Bit stream with octet timing mapping, see clause 17.6.1
0 0 0 1	0 0 0 1	11	Bit stream without octet timing mapping, see clause 17.6.2
0 0 0 1	0 0 1 0	12	IB SDR mapping into OPUflex, see clause 17.9
0 0 0 1	0 0 1 1	13	IB DDR mapping into OPUflex, see clause 17.9
0 0 0 1	0 1 0 0	14	IB QDR mapping into OPUflex, see clause 17.9
0 0 0 1	0 1 0 1	15	SDI mapping into OPU0, see clause 17.7.1
0 0 0 1	0 1 1 0	16	(1.485/1.001) Gbit/s SDI mapping into OPU1, see clause 17.7.2
0 0 0 1	0 1 1 1	17	1.485 Gbit/s SDI mapping into OPU1, see clause 17.7.2
0 0 0 1	1 0 0 0	18	(2.970/1.001) Gbit/s SDI mapping into OPUflex, see clause 17.9
0 0 0 1	1 0 0 1	19	2.970 Gbit/s SDI mapping into OPUflex, see clause 17.9
0 0 0 1	1 0 1 0	1A	SBCON/ESCON mapping into OPU0, see clause 17.7.1
0 0 0 1	1 0 1 1	1B	DVB_ASI mapping into OPU0, see clause 17.7.1
0 0 0 1	1 1 0 0	1C	FC-1600 mapping into OPUflex, see clause 17.9
0 0 0 1	1 1 0 1	1D	FlexE Client mapping into OPUflex, see clause 17.11
0 0 0 1	1 1 1 0	1E	FlexE aware (partial rate) mapping into OPUflex, see clause 17.12
0 0 0 1	1 1 1 1	1F	FC-3200 mapping into OPUflex, see clause 17.9
0 0 1 0	0 0 0 0	20	ODU multiplex structure supporting ODTUjk only, see clause 19 (AMP only)
0 0 1 0	0 0 0 1	21	ODU multiplex structure supporting ODTUk.ts or ODTUk.ts and ODTUjk, see clause 19 (GMP capable) (Note 6)
0 0 1 0	0 0 1 0	22	ODU multiplex structure supporting ODTUCn.ts, see clause 20 (GMP capable)
0 0 1 1	0 0 0 0	30	25GBASE-R mapping into OPUflex, see clause 17.13
0 0 1 1	0 0 0 1	31	200GBASE-R mapping into OPUflex, see clause 17.13
0 0 1 1	0 0 1 0	32	400GBASE-R mapping into OPUflex, see clause 17.13
0 1 0 1	0 1 0 1	55	Not available (Note 2)
0 1 1 0	0 1 1 0	66	Not available (Note 2)
1 0 0 0	x x x x	80-8F	Reserved codes for proprietary use (Note 4)
1 1 1 1	1 1 0 1	FD	NULL test signal mapping, see clause 17.5.1
1 1 1 1	1 1 1 0	FE	PRBS test signal mapping, see clause 17.5.2
1 1 1 1	1 1 1 1	FF	Not available (Note 2)

Multiplexing PT

NOTE 1 – There are 198 spare codes left for future international standardization. Refer to Annex A of [ITU-T G.806] for the procedure to obtain one of these codes for a new payload type.
NOTE 2 – These values are excluded from the set of available code points. These bit patterns are present in ODUk maintenance signals or were used to represent client types that are no longer supported.
NOTE 3 – Value "01" is only to be used for experimental activities in cases where a mapping code is not defined in this table. Refer to Annex A of [ITU-T G.806] for more information on the use of this code.
NOTE 4 – These 16 code values will not be subject to further standardization. Refer to Annex A of [ITU-T G.806] for more information on the use of these codes.
NOTE 5 – Supplement 43 (2008) to the ITU-T G-series of Recommendations indicated that this mapping recommended using payload type 87.
NOTE 6 – Equipment supporting ODTUk.ts for OPU2 or OPU3 must be backward compatible with equipment which supports only the ODTUjk. ODTUk.ts capable equipment transmitting PT=21 which receives PT=20 from the far end shall revert to PT=20 and operate in ODTUjk only mode. Refer to [ITU-T G.798] for the specification.

Table of Contents

Mapping and Multiplexing

- AMP – Asynchronous Mapping Procedure
- BMP – Bit synchronous Mapping Procedure
- GMP – Generic Mapping Procedure
- GFP – Generic Framing Procedure
- IMP – Idle Mapping Procedure

Timing Transparent Transcoding (TTT) Mapping

- 1GE - GFP-T
  - Transcode the incoming GE 8b/10b characters into 64B/65B code blocks
  - Group eight 64B/65B blocks into a 67-byte superblock
  - Map one superblock into a GFP frame without 65B_PAD or GFP Idles
  - Map the resulting CBR stream of GFP data frames into the OPU0 using GMP for rate adaptation
- FC1200
  - Transcode 64b/66b to 512b/513b in order to fit into an OPU2e
- 40GBASE-R
  - Transcode 64b/66b to 512b/513b in order to fit into an OPU3

Mapping (Multiplexing) ODUj signals into the ODTU signal and the ODTU into the OPUk tributary slots

- ODUj multiplexing into an OPUk is performed in two steps:
  - Asynchronous mapping of the ODUj into an Optical Data Tributary Unit (ODTU) using either AMP or GMP
  - Byte-synchronous mapping of the ODTU into one or more OPUk tributary slots

Mapping (Multiplexing) ODUk signals into an ODTUCn signal and the ODTUCn into OPUCn tributary slots

- ODUj multiplexing into an OPUk is performed in two steps:
  - Asynchronous mapping of ODUk into ODTUCn using GMP
  - Byte-synchronous mapping of ODTUCn into one or more OPUCn tributary slots

ODUj to ODUk and ODUk to ODUCn Mapping Types

	# 5G Tributary Slots	# 2.5G Tributary Slots		# 1.25G Tributary Slots			
	OPUCn (PT22)	OPU2 (PT20)	OPU3 (PT20)	OPU1 (PT20)	OPU2 (PT21)	OPU3 (PT21)	OPU4 (PT21)
ODU0	GMP			AMP	GMP	GMP	GMP
ODU1	GMP	AMP	AMP		AMP	AMP	GMP
ODU2	GMP		AMP			AMP	GMP
ODU2e	GMP					GMP	GMP
ODU3	GMP						GMP
ODU4	GMP						
ODUflex	GMP				GMP	GMP	GMP

ODU Multiplexing

Number of Tributary Slots Required for Multiplexing

	# 5G Tributary Slots	# 2.5G Tributary Slots		# 1.25G Tributary Slots			
	OPUCn	OPU2	OPU3	OPU1	OPU2	OPU3	OPU4
ODU0	1			1	1	1	1
ODU1	1	1	1		2	2	2
ODU2	2		4			8	8
ODU2e	2					9	8
ODU3	8						32
ODU4	20						
ODUflex CBR	n				n	n	n
ODUflex GFP	n				n	n	n

ODUflex

- ODUflex CBR
  - ODUflex CBR bit rate is derived from the client signal bit rate
    - ODUflex CBR bit rate = 239/238 x client CBR bit rate
  - ODUflex CBR bit rate tolerance: ±100 ppm
- ODUflex GFP
  - ODUflex GFP bit rate is derived from a local clock such as HO ODUk
    - ODUflex GFP bit rate tolerance: ±100 ppm
  - Hitless Adjustment ODUflex GFP (HAO), (ITU-T G.7044)
    - Hitless increase/decrease the number of ODUflex.ts
    - The resize protocol is activated between the 2 end points of the ODUflex path over 3 OPU overhead bytes - RCOH1/2/3 (Column 15, Rows 1, 2, 3,)

ODU Type	ODU Nominal Bit Rate	
ODUflex CBR	239/238 x Client signal bit rate	239/238 x Client signal bit rate
ODUflex GFP-F	ODU2: n x 1,249,177.230 Kbps ODU3: n x 1,254,470.354 Kbps ODU4: n x 1,301,467.133 Kbps	ODU2: n x ODU2.ts (1,249,177.230 Kbps, 1≤n≤8) ODU3: n x ODU3.ts (1,254,470.354 Kbps, 9≤n≤32) ODU4: n x ODU4.ts (1,301,467.133 Kbps, 33≤n≤80)

ODUflex may need a different number of time slots when it is carried in a different ODUk hierarchy

RCOH – Resize Control OverHead

Table of Contents

Why FlexO?

- FlexO interface group is defined for interoperable multi-vendor applications
    - It complements B100G (beyond 100G) [ITU-T G.709], by providing an interoperable interface for OTUCn transport signals
- FlexO interface group provides modularity by bonding standard-rate interfaces (e.g., m × 100G), over which the OTUCn ($n \geq 1$) signal is adapted
- FlexO group wraps OTUCn, abstracting the transport signal from the interface
- FlexO enables ODUflex services >100Gbit/s to be supported across multiple interfaces
- FlexO provides a frame, alignment, deskew, group management, management communication channel and such functions that are not associated with the OTUCn transport signal
- FlexO enables the reuse of optical modules (CFP2, QSFP28) by matching the OTU4 interface rate

FOICx.k – Parallel Lanes

	Number of Lanes	FOICx.k Nominal Bit Rate (±20 ppm)	
FOIC1.4-RS (100G)	4	27,952,368.611 Kbps	FlexO-1-RS bit rate/4
FOIC2.4-RS (200G)	4	55,904,734.223 Kbps	FlexO-2-RS bit rate/4
FOIC4.8-RS (400G)	8	55,904,734.223 Kbps	FlexO-4-RS bit rate/8
FOIC1.4-SC (100G)	4	28,183,592.249 Kbps	FlexO-1-SC bit rate/4
FOIC2.4-SC (200G)	4	56,367,184.498 Kbps	FlexO-2-SC bit rate/4
FOIC4.8-SC (400G)	8	56,367,184.498 Kbps	FlexO-4-SC bit rate/8

Table of Contents

Jitter (ITU-T G.8251)

Table A.5-2 – ODCp jitter generation requirements

Interface	Measurement bandwidth, –3 dB frequencies (Hz)	Peak-to-peak amplitude (UIpp) (Note 3)
CBR0G155	0.5 k to 1.3 M	0.3 UI 1.0
	65 k to 1.3 M	0.1
CBR0G622	1 k to 5 M	0.3 UI 1.0
	250 k to 5 M	0.1
1GE	2.52 k to 10 M	1.0
	0.673 M to f_4 (Note 1)	TP2, according to clause 38.5, Table 38-10 of [IEEE 802.3]
ODU0	2.5 k to 10 M	1.0
	0.673 M to 10 M	0.1
CBR2G5, ODU1	5 k to 20 M	0.3 UI 1.0
	1 M to 20 M	0.1
CBR10G, ODU2	20 k to 80 M	0.3 UI 1.0
	4 M to 80 M	0.1
10GE, ODU2e	20 k to 80 M	1.0
	4 M to f_4 (Note 2)	Transmit eye mask, defined in clause 52.7.1, Table 52-16 of [IEEE 802.3]
CBR40G, ODU3	80 k to 320 M	1.0
	16 M to 320 M	0.14
40GE, ODU3 Multilane	FFS	FFS
	4 M measured up to fourth-order Bessel-Thomson filter defined in clause 87.8.9 of [IEEE 802.3ba]	Each lane as defined in clause 87.7.1, Table 87-7, and clause 87.8.9 of [IEEE 802.3ba]

Table 6/G.813 – STM-N jitter generation for Option 1

Interface	Measuring filter	Peak-to-peak amplitude
STM-1	500 Hz to 1.3 MHz	0.50 UI
	65 kHz to 1.3 MHz	0.10 UI
STM-4	1000 Hz to 5 MHz	0.50 UI
	250 kHz to 5 MHz	0.10 UI
STM-16	5000 Hz to 20 MHz	0.50 UI
	1 MHz to 20 MHz	0.10 UI
STM-64	20 kHz to 80 MHz	0.50 UI
	4 MHz to 80 MHz	0.10 UI

Table 7/G.813 – STM-N jitter generation for Option 2

Interface	Measuring filter	Peak-to-peak amplitude
STM-1	12 kHz to 1.3 MHz	0.10 UI
STM-4	12 kHz to 5 MHz	0.10 UI
STM-16	12 kHz to 20 MHz	0.10 UI
STM-64	20kHz to 80 MHz	0.30 UI
STM-64	4 MHz to 80 MHz	0.10 UI

- Operators' requirements for SDH generated jitter can be much tighter than the ITU-T G.8251 specifications

Disclaimer

This Investor Presentation ("Presentation") is based upon information supplied by IP Light Inc. (the "Company"). Neither the Company, nor any of its employees, affiliates, or representatives makes any representation or warranty, express or implied, as to the accuracy or completeness of any of the information contained in this Presentation or any other written or oral communication transmitted or made available to a prospective acquirer or investor or any of its affiliates or representatives. Only those specific representations and warranties, if any, which may be made to the acquirer or investor in one or more definitive written agreements when, as and if executed, and subject to such limitations and restrictions as may be specified in such definitive written agreements, shall have any legal effect.

Any analyses or projections presented in or with this Presentation represent the personal and subjective views of management of the Company and management's current estimates or judgments of potential future performance based on assumptions which management believes are reasonable. However, there can be no assurance that management's perceptions are accurate or that management's projections can be realized or maintained. Other observers may disagree with management's assumptions and its views of the prospects of the Company. The sole purpose of this Presentation is to assist the recipient in deciding whether to proceed with further investigation of the Company. This Presentation does not purport to be all-inclusive or necessarily to contain all the information that an interested party might desire in investigating the Company. Any acquirer or investor should conduct its own independent analysis, evaluation and due diligence investigation. This Presentation shall not be construed to indicate that there has not been any change in the financial condition, business, operations, or other affairs of the Company since the date of preparation, and the Company does not expect to update or otherwise revise this Presentation. In addition, this Presentation is for informational purposes only and does not constitute an offer to sell or the solicitation of an offer to buy any securities. It is expected that any such offer would be made only after substantial due diligence investigations by the acquirer or investor and substantial negotiations among the Company, the acquirer or investor and their respective legal counsel and financial advisors.

Each recipient of this Presentation acknowledges and agrees that: (i) this Presentation and all of the information contained herein is confidential; (ii) the recipient will not disclose this Presentation or any information therein or the fact that a Presentation or any other information has been made available or that any discussions regarding the Company have occurred or may be occurring or the status of any such discussions, in whole or in part, to any person or entity other than representatives of the recipient who have likewise agreed not to disclose any information described above; (iii) the recipient and its representatives will not use any of the information described above for any purpose other than evaluating whether recipient desires to pursue an acquisition of the Company; (iv) if the recipient does not wish to pursue an acquisition of the Company, it will return the Presentation to the Company as soon as practicable, together with any other material relating to the Company which the recipient may have received from the Company; and (v) before engaging in any proposed actions which are inconsistent in any manner with the foregoing provisions, the recipient will obtain the prior written consent of the Company.

The Company reserves the right, in its sole discretion, to reject any and all proposals made by or on behalf of any prospective acquirer or investor with regard to an acquisition of or investment in the Company, to accept any such proposal, to negotiate with one or more prospective acquirers or investors at any time, and to enter into a definitive agreement for the sale of the Company or any of its securities, assets or properties without prior notice to other prospective acquirers or investors. The Company also reserves the right to terminate, at any time, further participation in the investigation and proposal process by, or discussions or negotiations with, any prospective acquirer or investor at any time in its sole discretion.

Tera-Pass

Creating an Intelligent Optical Layer

THANK YOU