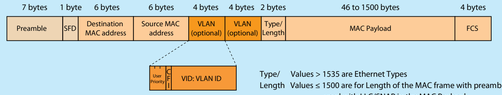
World of 100 Gb/s – The Lower Layers

100 Gigabit Ethernet

MAC

802.3 MAC Frame Structure

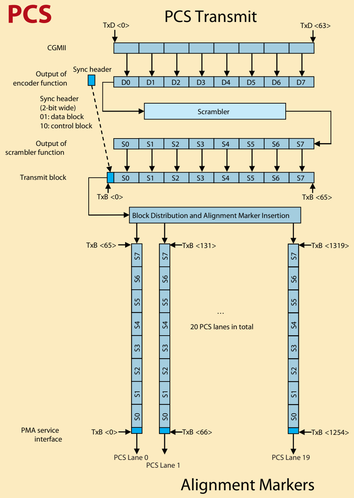


Type/ Length: Values > 1535 are Ethernet Types; Values ≤ 1500 are for Length of the MAC frame with preamble/SFP and typically used with LLC/SNAP in the MAC Payload

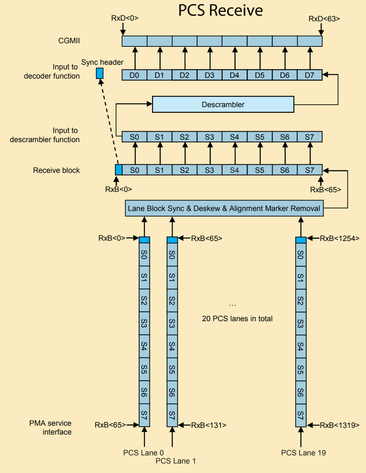
CAUI	100 Gb/s Attachment Unit Interface
CGMII	100 Gigabit Media Independent Interface
CFI	Canonical Format Indicator
CPPI	100 Gb/s Parallel Physical Interface
FCS	Frame Check Sequence
LLC	Logical Link Control
LWDM	LAN Wave Division Multiplexing
MAC	Media Access Control
MDI	Media Dependent Interface
PCS	Physical Coding Sublayer
PMA	Physical Media Attachment
PMD	Physical Media Dependent
RS	Reconciliation Sublayer
SFD	Start Frame Delimiter
SP	Skew Point
VLAN	Virtual Local Area Network

PCS

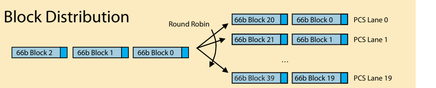
PCS Transmit



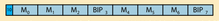
PCS Receive



PCS Block Distribution



Alignment Markers



Alignment markers are inserted after every 16383 66-bit blocks on each PCS lane

PCS Lane	Encoding	PCS Lane	Encoding
0	0xC1, 0x68, 0x21, BIP_0, 0x3E, 0x97, 0xDE, BIP_7	10	0xFD, 0x6C, 0x99, BIP_0, 0x02, 0x93, 0x66, BIP_7
1	0x9D, 0x71, 0xBE, BIP_1, 0x62, 0x8E, 0x71, BIP_7	11	0x89, 0x91, 0x55, BIP_1, 0x46, 0x6E, 0xAA, BIP_7
2	0x59, 0x4B, 0x68, BIP_2, 0xA6, 0x84, 0x17, BIP_7	12	0x5C, 0x89, 0xB2, BIP_2, 0xA3, 0x46, 0x4D, BIP_7
3	0x4D, 0x95, 0x7B, BIP_3, 0xB2, 0x6A, 0x84, BIP_7	13	0x1A, 0xF8, 0x8D, BIP_3, 0xE5, 0x07, 0x42, BIP_7
4	0xF5, 0x07, 0x09, BIP_4, 0x0A, 0xF8, 0xF6, BIP_7	14	0x83, 0xC7, 0xCA, BIP_4, 0x7C, 0x38, 0x35, BIP_7
5	0xDD, 0x14, 0xC2, BIP_5, 0x22, 0xEB, 0x3D, BIP_7	15	0x35, 0x36, 0xCD, BIP_5, 0xCA, 0xC9, 0x32, BIP_7
6	0x9A, 0x4A, 0x26, BIP_6, 0x65, 0x85, 0xD9, BIP_7	16	0xC4, 0x31, 0x4C, BIP_6, 0x38, 0xCE, 0xB3, BIP_7
7	0x7B, 0x45, 0x66, BIP_7, 0x84, 0xBA, 0x99, BIP_7	17	0xAD, 0xD6, 0xB7, BIP_7, 0x52, 0x29, 0x48, BIP_7
8	0xA0, 0x24, 0x76, BIP_8, 0x5F, 0xDB, 0x89, BIP_7	18	0x5F, 0x66, 0x2A, BIP_8, 0xA0, 0x99, 0xD5, BIP_7
9	0x68, 0xC9, 0xFB, BIP_9, 0x97, 0x36, 0x04, BIP_7	19	0xC0, 0xF0, 0xE5, BIP_9, 0x3F, 0x0F, 0x1A, BIP_7

64B/66B PCS Block Format

Input Data	S Y N C	Block Payload							
Bit Position	0 1	2							65
Data Block Format	01	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7
Control Block Formats		Block Type Field							
$C_0C_1C_2C_3C_4C_5C_6C_7$	10	0x1E	C_0	C_1	C_2	C_3	C_4	C_5	C_6	C_7
$S_4D_5D_6D_7D_4D_5D_6D_7$	10	0x78	D_1	D_2	D_3	D_4	D_5	D_6	D_7
$O_4D_5D_6D_7Z_4Z_5Z_6Z_7$	10	0x4B	D_1	D_2	D_3	O_5	0x000_0000		
$T_4C_5C_6C_7C_4C_5C_6C_7$	10	0x87			C_1	C_2	C_3	C_4	C_5	C_6	C_7
$D_4T_5C_6C_7C_4C_5C_6C_7$	10	0x99			D_1	C_2	C_3	C_4	C_5	C_6	C_7
$D_4D_5T_6C_7C_4C_5C_6C_7$	10	0xAA			D_1	D_2	C_3	C_4	C_5	C_6	C_7
$D_4D_5D_6T_7C_4C_5C_6C_7$	10	0xB4			D_1	D_2	D_3	C_4	C_5	C_6	C_7
$D_4D_5D_6D_7T_4C_5C_6C_7$	10	0xCC			D_1	D_2	D_3	D_4	C_5	C_6	C_7
$D_4D_5D_6D_7D_4T_5C_6C_7$	10	0xD2			D_1	D_2	D_3	D_4	C_6	C_7
$D_4D_5D_6D_7D_4D_5T_6C_7$	10	0xE1			D_1	D_2	D_3	D_4	D_5	C_7
$D_4D_5D_6D_7D_4D_5D_6T_7$	10	0xFF			D_1	D_2	D_3	D_4	D_5	D_6

Add optical power from tables 86-6/86-7 launch power & Rx power per lane
Add optical power from tables 88-7/86-8 launch power & Rx power per lane

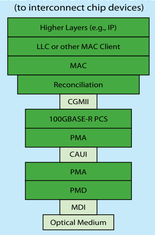
Skew Tolerance

Skew Point	Maximum Skew	Maximum Skew Variation
SP1	29 ns (~150 UI)	0.2 ns
SP2	43 ns (~222 UI)	0.4 ns (~10 UI)
SP3	54 ns (~278 UI)	0.6 ns (~15 UI)
SP4	134 ns (~691 UI)	3.4 ns (~88 UI)
SP5	145 ns (~748 UI)	3.6 ns (~93 UI)
SP6	160 ns (~824 UI)	3.8 ns (~39 UI)
At PCS Rx	180 ns (~928 UI ~928 bits)	4 ns (~21 bits)

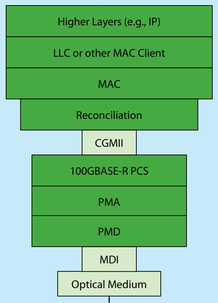
SP Points shown in Multilane Model

Signal Structure

IEEE Model with CAUI
(to interconnect chip devices)

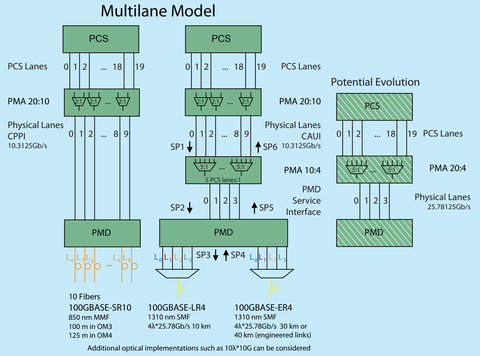


IEEE Layer Model



100 Gigabit Ethernet
103.125 Gb/s ± 100 ppm

Multilane Model



Additional optical implementations such as 10λ*10G can be considered

Optical

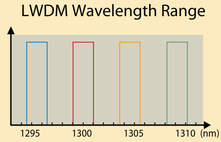
Average Optical Power

Parameter	100GBASE-SR10	100GBASE-LR4	100GBASE-ER4
Max Launch Power/lane	2.4 dBm	4.5 dBm	2.9 dBm
Min Launch Power/lane	-8 dBm	-4.3 dBm	-2.9 dBm
Max Avg Rx Power/lane	2.4 dBm	4.5 dBm	4.5 dBm
Min Avg Rx Power/lane	-9.9 dBm	-10.6 dBm	-20.9 dBm

100GBASE-LR4 and ER4
LWDM Lane Assignments

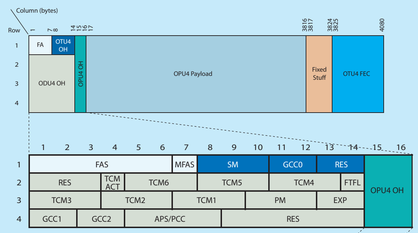
Lane	Center λ	λ Range
L_0	1295.56 nm	1294.53 to 1296.59 nm
L_1	1300.05 nm	1299.02 to 1301.09 nm
L_2	1304.58 nm	1303.54 to 1305.63 nm
L_3	1309.14 nm	1308.09 to 1310.19 nm

LWDM Wavelength Range

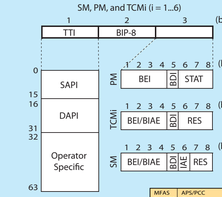


OTU4

Frame Structure



SM, PM, and TCMi (i = 1...6)



JC1	C1	C2	C3	C4	C5	C6	C7	CB
JC2	C9	C10	C11	C12	C13	C14	II	DI
JC3	CRC-8							
JC4	RES		D1	D2	D3	D4	D5	
JC5	RES		D6	D7	D8	D9	D10	
JC6	RES	CRC-5						

Justification via GMP

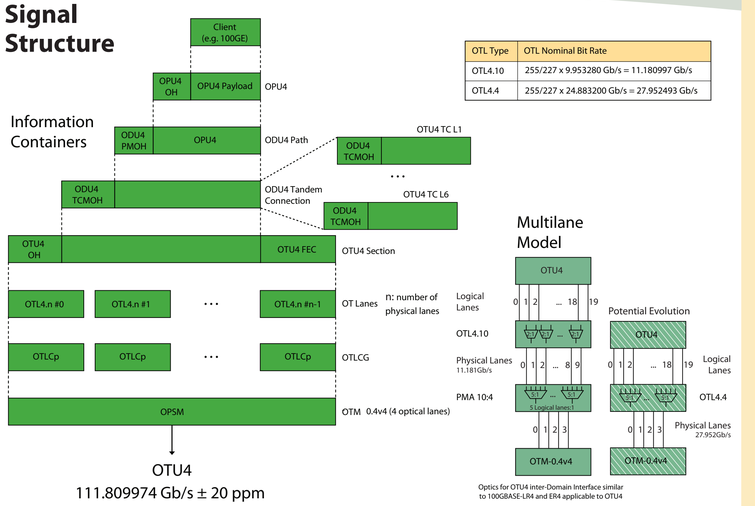
GMP provides a generic mapping method for the justification of CBR client signals into OPU
CI Relative change indication
II Increment Indicator
DI Decrement Indicator
Di C-derived cumulative value

TSOH	OMFI Bits								
1.25G TS	1	2	3	4	5	6	7	8	Decimal
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	1	1
3	0	0	0	0	0	0	1	0	2
4	0	0	0	0	0	0	1	1	3
5	0	0	0	0	0	1	0	0	4
...									
79	0	1	0	0	1	1	1	0	78
80	0	1	0	0	1	1	1	1	79
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	1	1

MFAS Bits 678	APS/PCC Channel	Protection Scheme using the APS/PCC Channel
000	ODU4 Path	ODU4 SNC/N
001	ODU4 TCM1	ODU4 SNC/S, ODU4 SNC/N
010	ODU4 TCM2	ODU4 SNC/S, ODU4 SNC/N
011	ODU4 TCM3	ODU4 SNC/S, ODU4 SNC/N
100	ODU4 TCM4	ODU4 SNC/S, ODU4 SNC/N
101	ODU4 TCM5	ODU4 SNC/S, ODU4 SNC/N
110	ODU4 TCM6	ODU4 SNC/S, ODU4 SNC/N
111	ODU4 server layer trail	ODU4 SNC/I

APS	Automatic Protection Switching
BDI	Backward Defect Indication
BEI	Backward Error Indication
BIAE	Backward Incoming Alignment Error
BIP-8	Bit Interleaved Parity-8
DAPI	Destination Access Point Identifier
EXP	Experimental
FAS	Frame Alignment Signal
FEC	Forward Error Correction
FTFL	Fault Type and Fault Location
GCC	General Communication Channel
GMP	Generic Mapping Procedure
IAE	Incoming Alignment Error
JC	Justification Control
JOH	Justification Overhead
LLM	Logical Lane Marker
MFAS	Multi-Frame Alignment Signal
ODTU	Optical channel Data Tributary Unit
ODTUG	Optical channel Data Tributary Unit Group
ODU	Optical channel Data Unit
OH	Overhead
OMFI	OPU Multi Frame Identifier
OPSM	Optical Physical Section Multilane
OPU	Optical channel Payload Unit
OTL	Optical channel Transport Lane
OTLCG	Optical Transport Lane Carrier Group
OTN	Optical Transport Network
OTU	Optical channel Transport Unit
PCC	Protection Communication Channel
PM	Path Monitoring
PMA	Physical Media Attachment
PMOH	Performance Monitoring Overhead
PSI	Payload Structure Identifier
PT	Payload Type
RES	Reserved
SAPI	Source Access Point Identifier
SM	Section Monitoring
SNC	SubNetwork Connection
SNC/I	SNC protection with Inherent monitoring
SNC/N	SNC protection with Non-intrusive monit.
SNC/S	SNC protection with Sublayer monitoring
STAT	Status
TC	Tandem Connection
TCM	Tandem Connection Monitoging
TCM ACT	TCM Activation
TCMOH	Tandem Connection Monitoring Overhead
TS	Tributary Slot
TTI	Trail Trace Identifier

Signal Structure



OTL Type	OTL Nominal Bit Rate
OTL4.10	255/227 x 9.953280 Gb/s = 11.180997 Gb/s
OTL4.4	255/227 x 24.883200 Gb/s = 27.952493 Gb/s

Multilane Model

Optics for OTU4 inter-Domain Interface similar to 100GBASE-LR4 and ER4 applicable to OTU4

Logical Lanes

Logical Lane Markers

Used for logical lane identification and skew

FAS Byte Values

OA1	OA1	OA1	OA2	OA2	OA2
F6	F6	F6	28	28	LLM

	OA2 LLM Bits							
LL	1	2	3	4	5	6	7	8	Decimal
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	1
2	0	0	0	0	0	0	1	0	2
3	0	0	0	0	0	0	1	1	3
...									
19	0	0	0	0	1	0	0	1	19
1	0	0	0	0	1	0	1	0	20
...									
18	1	1	1	0	1	1	1	0	238
19	1	1	1	0	1	1	1	1	239
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	1

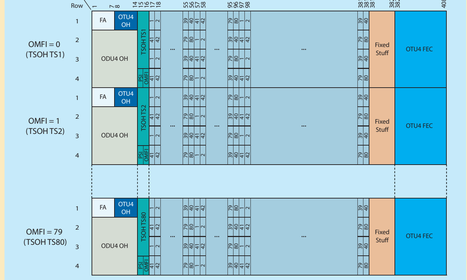
Byte Distribution from OTU4 to the 20 Logical Lanes

	Rotate			Rotate	Rotate		Rotate	
LL 0	1:16 (FAS)	321:336	...	16001:16016	305:320	...	16305:16320	17:32	...	16017:16032	1:16 (FAS)
LL 1	17:32	337:352	...	16017:16032	1:16 (FAS)	...	16001:16016	33:48	...	16033:16048	17:32
	...	...		...	...		...	...		...	...
LL 19	305:320	625:640	...	16305:16320	289:304	...	16289:16304	1:16 (FAS)	...	16001:16016	305:320

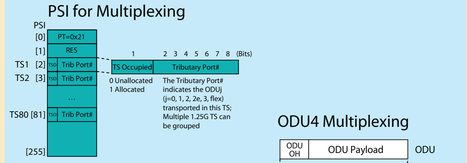
Multiple Rotations

ODU Multiplexing

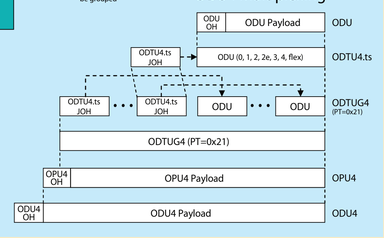
Tributary Slots (1.25G) for Multiplexing



PSI for Multiplexing



ODU4 Multiplexing



To learn more, www.jdsu.com/test

References:

100GE	IEEE 802.3ba, and 802.1Q
OTU4	ITU-T G.709, G.872, G.695, and G.959.1
Line I/F	OIF IA# OIF-SFI-S and IA# OIF2008.388.00

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