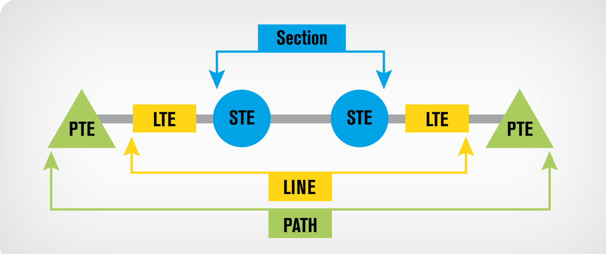
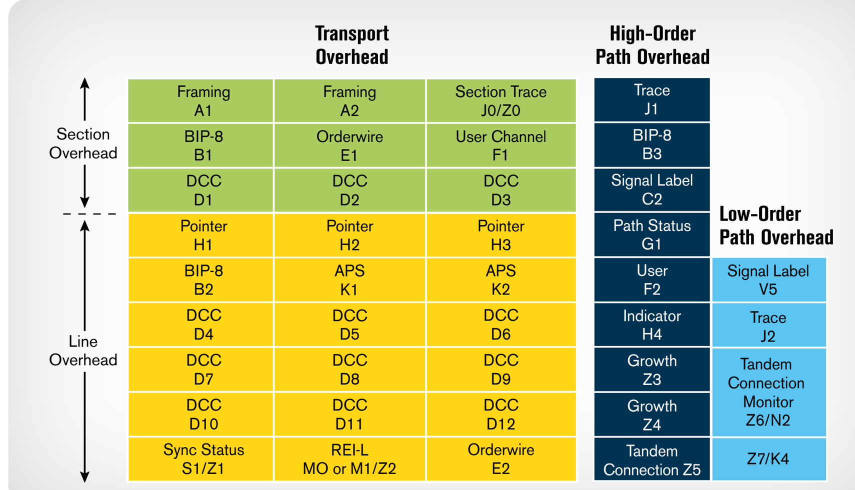
40G/43G Technical Poster

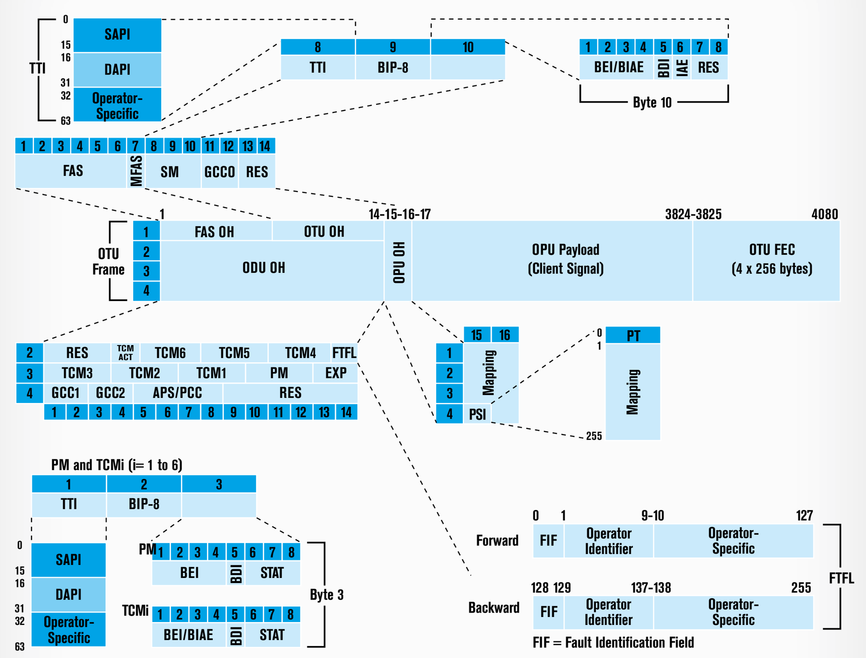
Overhead Byte Definition and Usage	Section Overhead						Line Overhead							High-Order Path Overhead						Low-Order Path Overhead			
	A1-A2 Framing Bytes	B1 Section Parity	J0/Z0 Section Trace	D1-D3 Section DCC	E1 Local Orderwire	F1 Section User Channel	B2 Line Parity	D4-D12 Line DCC	E2 Express Orderwire	H1-H2 Payload Pointer	K1-K2 APS	S1/Z1 Growth/Sync	M0 or M1/Z2 REI-L	B3 Path Error Monitoring	C2 Signal Label	F2 Path User Channel	G1 Path Status	H4 Multiframe Indicator	J1 Path Trace	J2 Path Trace Identifier	V5 Signal Label	Z6/N2 Tandem Connection Monitor	Z7/K4
SONET	Pattern identical to SDH. Begins each STS-1.	BIP-8, bit interleaved parity even. Computed from previous STS-n after scrambling. Placed in STS-1 no. 1 only.	Section trace. J0 is section trace in STS-1 no. 1 of an STS-n. Z0 is growth for all other STSs of an STS-n.	Section DCC 7 layer OSI stack using CMISE message format. Used for control, monitor, alarm and communicate between section terminating equipment.	Local voice channel defined only for STS-1 no. 1 of an STS-n. Signaling is undefined.	Optional for SONET defined only for STS-1 no. 1 of an STS-n.	Line BIP-8. Line error monitoring in each STS-1 of an STS-n. Calculated from all line overhead bytes and payload bytes.	Line DCC 7 layer OSI stack using CMISE message format for OAM&P between line terminating equipment. Defined only for STS-1 no. 1 of an STS-n.	Optional express orderwire between line equipment. Defined only for STS-1 no. 1 of an STS-n.	H1 and H2 point to the start of the SPE. H3 used for pointer justification, ss bits (5-6) in H1 no. 1 are undefined and H1 no. 3 are set to "00" in STS-3c.	Provides automatic protection switching (APS) signaling between line level entities. Defined only for STS-1 no. 1 of an STS-n.	S1 is used for synchronization status messages (bits 5-8) in STS-1 no. 1 of an STS-n. Z1 is growth for all other STS-1s of an STS-n.	M0 is defined only for OC-1 or STS-1 electrical, bits 5-8 used for REI-L. M1 is defined only for STS-3 or higher, located in STS-1 no. 3, used for REI-L. The other STS-1s are for growth (Z2).	BIP-8 even parity. Entire SPE including VT stuff bytes are calculated.	One byte used to identify the construction of the SPE. Any value other than "0" indicates an equipped condition.	User communication channel between path elements.	One byte used to indicate the status of the far-end terminating equipment. Allows the full-duplex path to be monitored at either end or at any point along the path. Contains RDI-P and REI-P.	Multiframe payload indicator.	64-byte fixed length string to verify connection between path transmitting equipment and path receiving equipment.		This byte provides the same functions for the VT paths as the B3, C2 and G1 bytes provide for STS paths, including error checking, signal labeling and path status indication.	This byte provides support for low-order tandem-connection monitoring.	This byte is used to enable APS signaling and extended RDI (ERDI) capability.
SDH	Begins each STM-1. Pattern identical to SONET.	BIP-8 calculated from previous STM-n after scrambling.	Regenerator section trace.	Regenerator section DCC 7 layer OSI stack using CMISE message format. Used for control, monitor, alarm and communicate between section terminating equipment.	Voice orderwire used between section regenerators.	Reserved for user purposes.	Multiplex section BIP-24xN. Error monitoring for a multiplex section. Calculated over line, overhead and payload bytes.	7 layer OSI stack CMISE message format for OAM&P between NEs and the OS/NMD.	Part of multiplexer section overhead (MSOH). This byte may be accessed at the multiplex section terminating equipment.	H1 and H2 point to the start of the AU. H3 used for pointer justification, ss bits (5-6) in H1 no. 1 are set to "10" and H1 no. 3 are undefined for AU4.	Provides APS signaling between multiplex section elements.		The byte is called M2 in SDH and provides a count for the BIP-24xN errors detected in B2.	BIP-8 even parity. SPE is calculated but VC stuff bytes are excluded.	One byte used to identify the construction of the SPE. Any value other than "0" indicates an equipped condition.	User communication channel between path elements.	One byte used to indicate the status of the far-end terminating equipment. Allows the full-duplex path to be monitored at either end or at any point along the path.	Multiframe payload indicator can be payload specific.	First byte in the VC either a 64-byte free format or a 16-byte E.164 format. E.164 is mandatory at international boundaries.	Used to identify lower-order (LO) VCs.	VT path overhead byte.	Allocated for tandem connection monitoring for the VC2, VC-12 and VC-11 level.	Bit 1 is used for multiframe alignment signals and extended signal labels, whereas bit 2 is used for virtual concatenation.
Notes	A1 = 11110110 A2 = 00101000 Hex A1 = F6 A2 = 28		SDH usage not currently defined. The E.164 is the likely format.	Considered as one 192 kbit/s message-based channel.	SDH: A-law to μ-law conversion per ITU G.802.	Available for use by the network provider.		Considered as one 576 kbit/s message-based channel.	SDH A-law to μ-law conversion per ITU G.802.	The setting of the ss bits differentiates an STS-3c from an STM-1.				There is compatibility because the byte is duplicated in SDH.			RFI-P is a failure indication derived from RDI-P defect.						



SONET	EQUIVALENTS	SDH
OC-1	51.84 Mbit/s	N/A
OC-3	155.52 Mbit/s	STM-1
OC-12	622.08 Mbit/s	STM-4
OC-48	2488.32 Mbit/s	STM-16
OC-192	9.953 Gbit/s	STM-64
OC-768	39.813 Gbit/s	STM256



OTN Frame Structure



Frame Rates

OTN Interface	Line Rate	Corresponding Service
OTU3	43.018 Gbit/s	OC-768/STM-256 40 GigE
OTU3e1	44.57 Gbit/s	4 x ODU2e (uses 2.5 Gig TS; total of 16)
OTU3e2	44.58 Gbit/s	4 x ODU2e (uses 1.25 Gig (ODU0) TS; total of 32)
OTU4	111.81 Gbit/s	100 GigE

OPU Overhead Bytes

Field	Definition
Payload structure identifier (PSI)	Defined to transport a 256-byte message aligned with MFAS.
Payload type (PT)	Contains the PT identifier that reports the type of payload being carried in the OPU payload to the receiving equipment field; it is currently undefined in the standard.
Multiplex structure identifier (MSI)	Located in the mapping-specific area of the PSI signal (PSI[2] to PSI[17]); it is used to encode the ODU multiplex structure in the OPU.
Justification control (JC)	JC, negative justification opportunity (NJO) and positive justification opportunity (PJO) signals are used in the ODU multiplexing process to make the justification decision in the mapping/demapping process of the client signal.

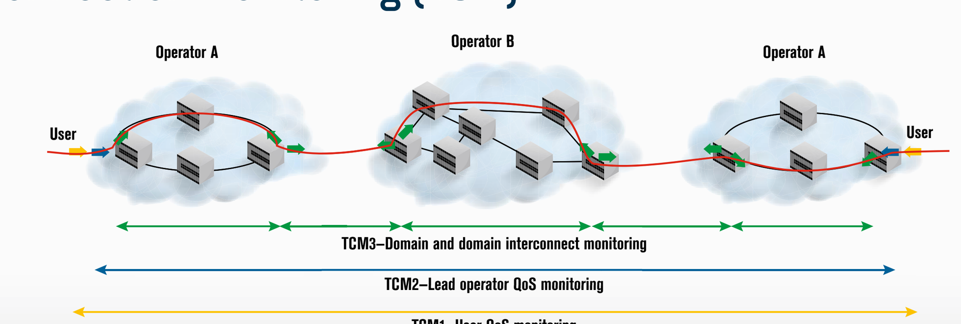
Payload Type (PT) Defined Values

Payload Type Codes	HEX Values	Payload Type Codes	HEX Values
Experimental mapping	01	FC-400 into ODUflex	0E
Asynchronous CBR mapping	02	FC-800 into ODUflex	0F
Bit synchronous CBR mapping	03	Bit stream with octet timing mapping	10
ATM mapping	04	Bit stream without octet timing mapping	11
GFP mapping	05	ODU multiplex with ODTUjk	20
Virtual concatenated signal	06	ODU multiplex with ODTUk.ts/ODTUjk	21
1000BASE-X into ODU0	07	Not available	55
FC-1200 into ODU2e	08	Not available	66
GFP mapping into extended OPU2	09	Reserved codes for proprietary use	80-8F
OC-3/STM-1 into ODU0	0A	NULL test signal mapping	FD
OC-12/STM-4 into ODU0	0B	PRBS test signal mapping	FE
FC-100 into ODU0	0C	Not available	FF
FC-200 into ODU1	0D		

ODU Overhead Bytes

Field	Definition	
Path Monitoring	PM consists of the following bytes: TTI, BIP-8, BEI, BIAE, BDI and IAE.	
	Trail trace identifier (TTI)	The 64-byte multiframe TTI signal is similar to the J0 byte in SONET/SDH.
	Bit interleaved parity (BIP-8)	The ODU PM contains a BIP-8 field that covers the OPU and customer payload of the G.709 frame. The BIP-8 values are inserted in the BIP-8 field of the frame following calculation.
	Backward defect indication (BDI)	The AIS–forwarded signal in the downstream direction–is sent as a response to a signal fail indication, such as in the FTFL or the incoming ODU-AIS. In the upstream direction, the response to continuity, connectivity and maintenance signals is a backward defect indication (BDI) signal indicated by a bit found in the PM and TCMi. BDI is raised as an alarm when it has been received for five consecutive frames.
	Backward error indication (BEI) and backward incoming alignment error (BIAE)	The AIS–forwarded signal in the downstream direction–is usually sent as a response to a signal fail indication, such as in the FTFL or the incoming ODU-AIS. In the upstream direction the response to continuity, connectivity and maintenance signals is a BDI signal indicated by a bit found in the PM and TCMi. BDI is raised as an alarm when it has been received for five consecutive frames.
	STAT	These three bits indicate the presence of maintenance signals (AIS, OCI, TCMi, IAE).
Tandem connection monitoring (TCM)	Six TCM sublayers are defined in the ODU overhead. Each TCM sublayer contains TTI, BIP-8, BEI/BIAE, BDI and STAT subfields.	
Tandem connection monitoring activation/deactivation (TCM ACT)	One-byte field used for the activation and deactivation of the TCM fields. This field is currently undefined in the standard.	
Fault type and fault location (FTFL)	Reporting communication channel field that is used to create a message for sending forward and backward path-level fault indications.	
Experimental (EXP)	This field is not subject to standards and is available for network operator applications.	
General communication channel 1 and 2 (GCC1/GCC2)	Clear channels used for transmission of information at the ODU layer; similar to the GCC0.	
Automatic protection switching and protection communication channel (APS/PCC)	This field supports up to eight levels of nested APS/PCC signals, which are associated to a dedicated-connection monitoring level.	
RES	Reserved bytes that are currently undefined in the standard.	

Tandem Connection Monitoring (TCM)



OTU Overhead Bytes

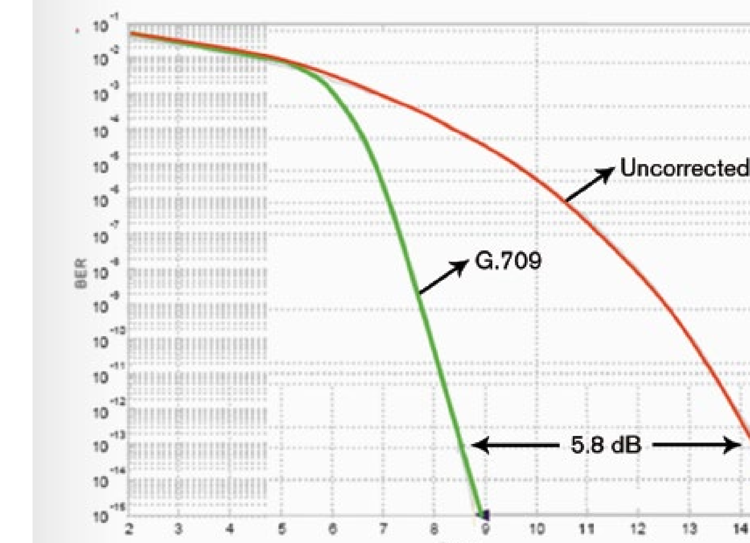
Field	Definition	
Section monitoring (SM)	SM consists of the following bytes: TTI, BIP-8, BEI, BIAE, BDI and IAE.	
	Trail trace identifier (TTI)	The 64-byte multiframe TTI signal is similar to the J0 byte in SONET/SDH.
	Bit-interleaved parity (BIP-8)	The BIP-8 value covers the OPU and client payload of the G.709 frame and its value is inserted in the BIP-8 field of the second frame following calculation.
	Backward defect indication (BDI)	When an AIS is sent in the downstream direction as a response to a signal fail indication (such as in the FTFL), the upstream direction response to continuity, connectivity and maintenance signals is a backward defect indication (BDI) signal. BDI is raised as an alarm when it has been received for five consecutive frames.
	Backward error indication (BEI) and backward incoming alignment error (BIAE)	The detection of a frame slip, which can occur at the OTU, generates an alignment error (IAE) in the downstream direction. The three-bit value of "010" in the status (STAT) field indicates IAE. A corresponding BIAE is inserted in the upstream direction by specifying bits "1011" in the BEI/BIAE SM field.
	STAT	These three bits indicate the presence of maintenance signals (AIS, OCI, TCMi, IAE).
General communication channel 0 (GCC0)	A clear channel used for transmission of information between OTU termination points.	
RES	Reserved bytes that are currently undefined in the standard.	

Frame and Frame Alignment Bytes

The frame alignment overhead is applicable for both the OTUk and ODUk signals and is divided into two portions: FAS and MFAS.

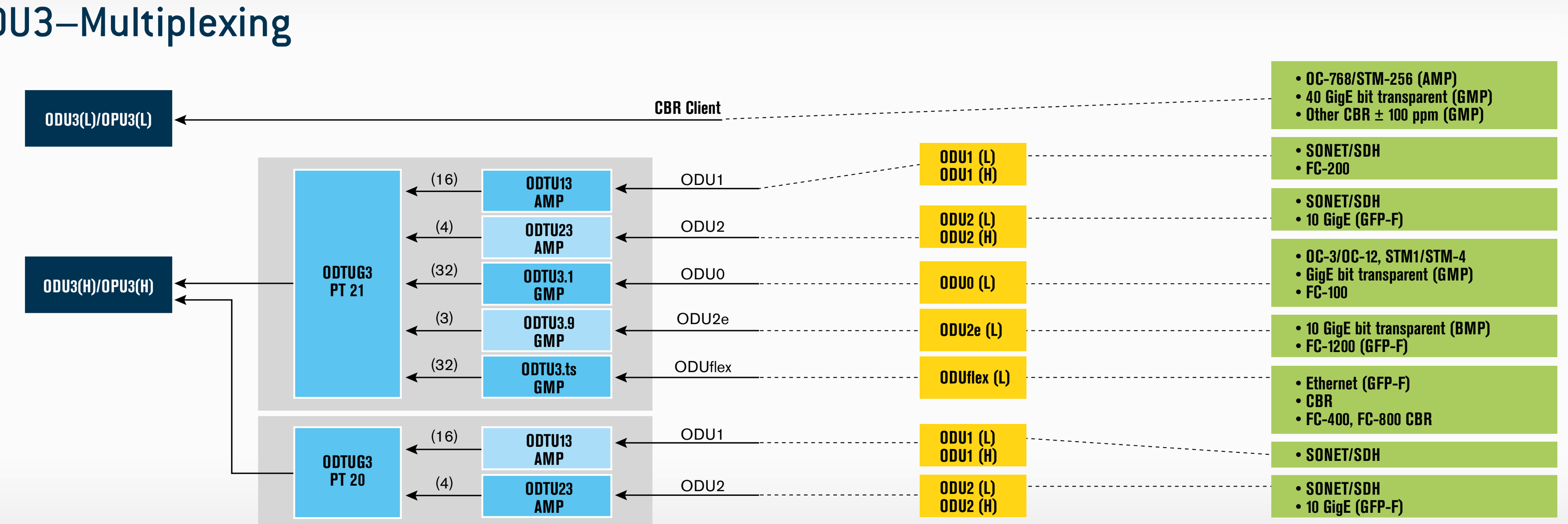
Frame alignment signal (FAS)	Framing bytes are used in the transmission systems to determine where frames start and end.
Multiframe alignment signal (MFAS)	In the case of multiframe structure (i.e., TTI and TCM-ACT signals), multiframe alignment processing is required using MFAS. The MFAS byte will be incremented each OTUk/ODUk from 0 to 256.

Reed Solomon (255,239) FEC Algorithm

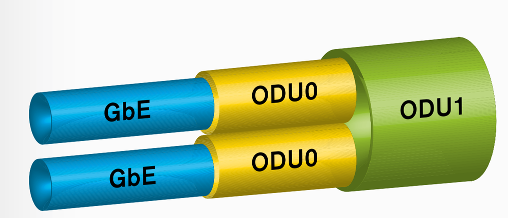


- FEC is a signal coding/decoding technique adding redundancy data to a signal to identify and correct corrupted data, thus reducing the bit error rate (BER).
- OTN uses the Reed Solomon (RS 255,239) error correction code, which improves the coding gain by 5.8 dB, allowing for optical-link expansion of approximately 18 km without repeaters.

ODU3–Multiplexing

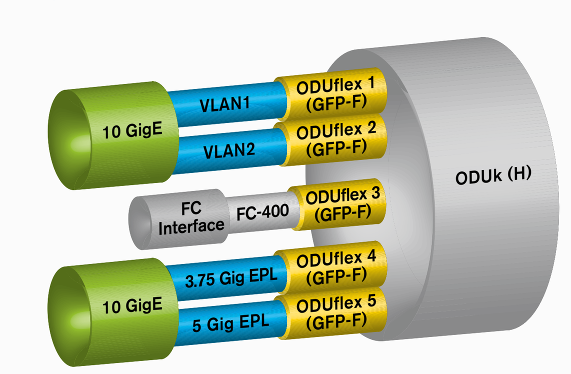


OTN–ODU0



Size	• Newly defined OTN container in G.709 of 1.25 Gig • Virtual container that does not have a physical instance
Client	• Perfectly fits GigE , OC-3/STM-1 and OC-12/STM-4 services
Benefits	• Removes dependency on SONET/SDH for carrying GigE services • Provides OTN OAM capabilities

OTN–ODUflex



Definition	• ODUflex as defined in ITU-T G.709 allows traffic grooming • Addresses incremental bandwidth growth in steps of 1.25 Gbit/s
Benefits	• Fit existing OTN rates; x 32 ≥ ODU3 and x 80 ≥ ODU4 • Facilitates virtual channeling similar to VCAT • Enables bandwidth increase without allocating full ODU container • Supports OTN OAM and fault management

Over-Clocked OTU3–OTU3e1/OTU3e2

OTU3e1 OH	OPU3e1 = 41.56 Gbit/s	FEC

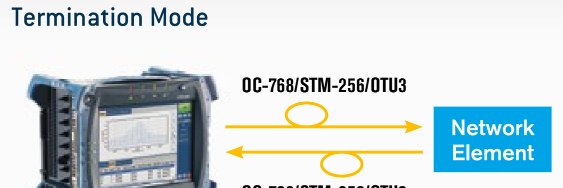
- Defined in ITU-T G.709 Sup43 Sec9.1
- OTU3e1 supports nominal bit rate of 44.57 Gbit/s ± 20 ppm
- The OPU3e1 is divided into 16 x 2.5 Gig tributary slots (TSs) interleaved within the OPU3e1 payload area
- OTU3e1 is key for asynchronous bit-transparent mapping of 4 x ODU2e signals

OTU3e2 OH	OPU3e2 = 41.61 Gbit/s	FEC

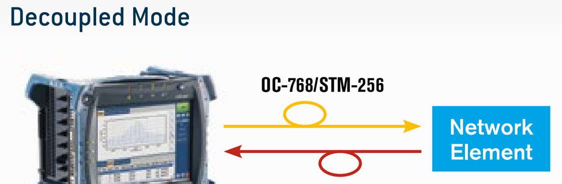
- Defined in ITU-T G.709 Sup43 Sec9.2
- OTU3e2 supports nominal bit rate of 44.58 Gbit/s ± 20 ppm
- The OPU3e2 is divided into 32 tributary slots (TS) of approximately 1.25 Gbit/s interleaved within the payload area
- OTU3e2 uses generic mapping procedure (GMP) for mapping 4 x ODU2e signals into OPU3e2 payload area

Testing Configurations

Termination Mode



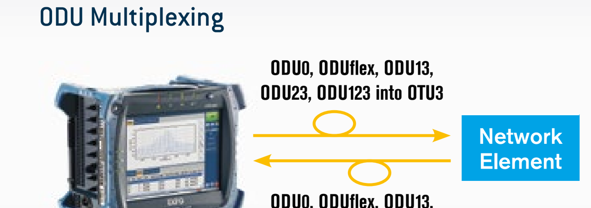
Decoupled Mode



Unframed Mode

Intrusive Through Mode

ODU Multiplexing



Transparent FEC

Line Side Testing

Assessing Next-Gen Networks

40G/43G
TECHNICAL POSTER

EXFO Assessing Next-Gen Networks

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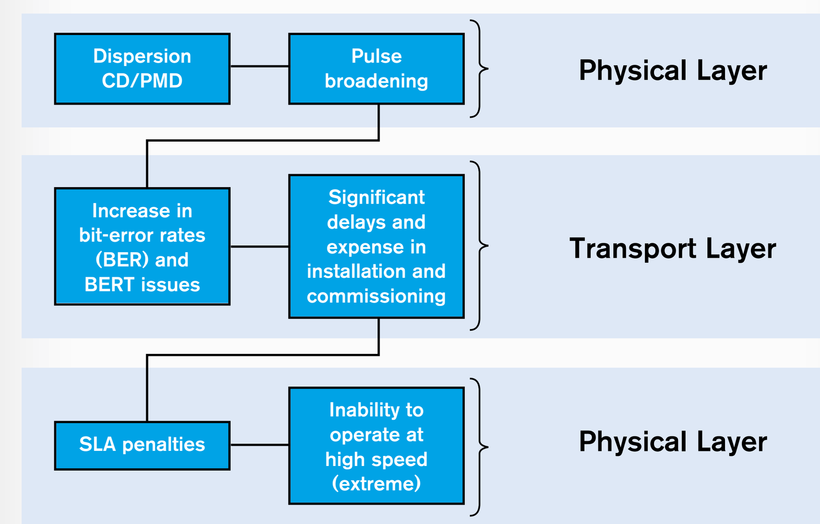
Advanced Fiber Characterization

The Importance of Testing Chromatic and Polarization-Mode Dispersion

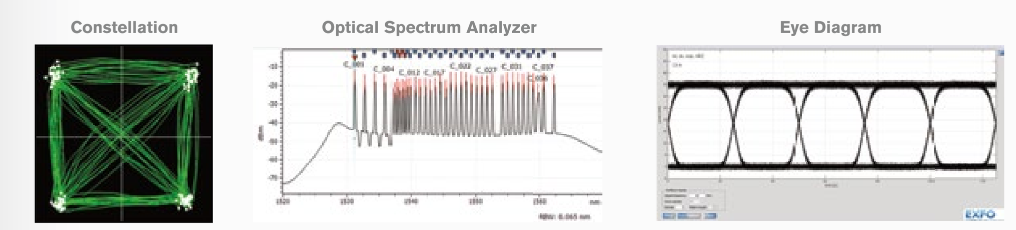


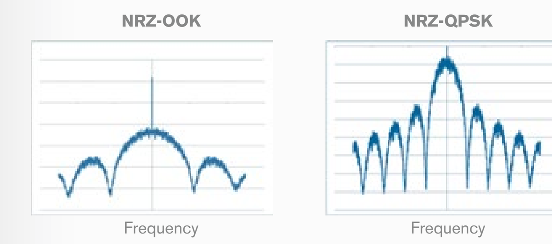
Why Test Dispersion?

Dispersion can affect the entire cycle. Precise measurement of CD and PMD on all the available fiber segments (metro, regional and core networks) differentiates between the bad segments, allowing the highest line-rate transmission on the longest distance possible.

Evolution of 10G to 40G

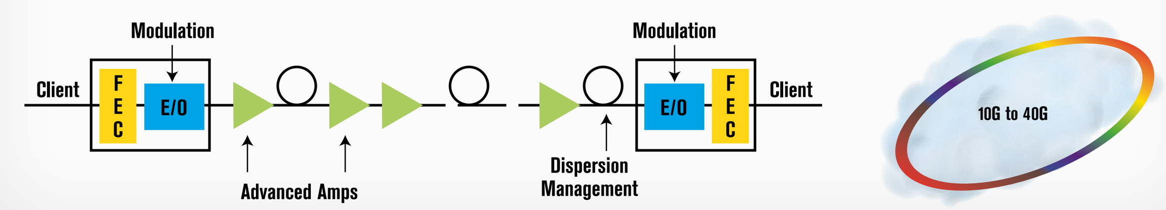
Key Modulation Format Challenges





- 40G to be transported on the existing 10G network and meet 10G design rules
- New advanced and complex modulation formats like DPSK, QPSK and DP-QPSK

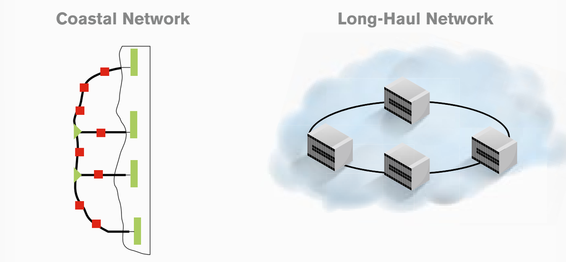
Requires:
- Advanced modulation formats
- Dispersion characterization



Two Network Topologies:

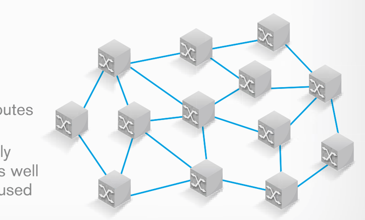
Ring Network

Ring testing objective:
- Know end-to-end CD and PMD limits
- Apply proper compensation when applicable

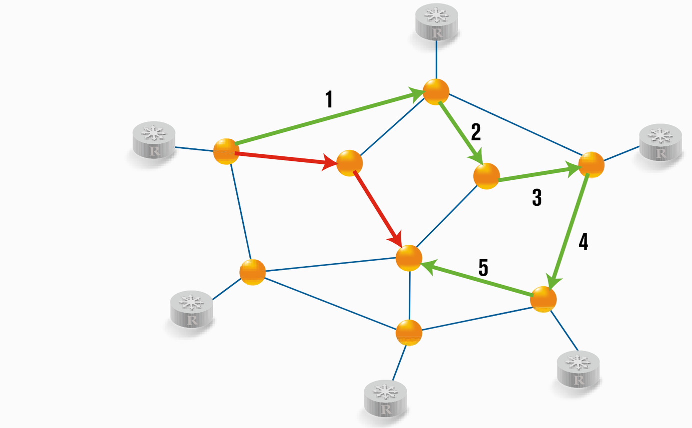


Mesh Network

Mesh testing objective:
- All the transmitting information does not propagate using the same path: many routes are used to reach destination.
- Have a complete dispersion map to apply adequate compensation at each node as well as to know which combinations can be used for which transmission speed



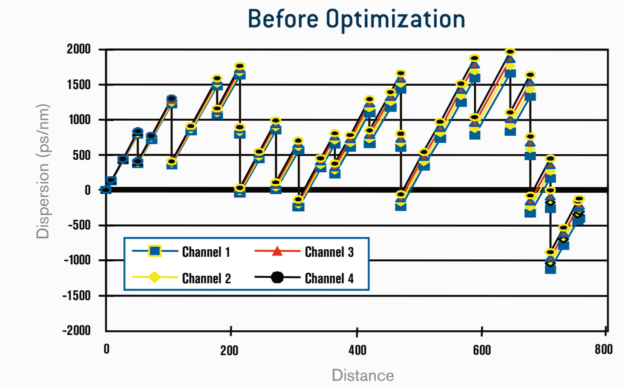
Short Links—Long Traveling Distances

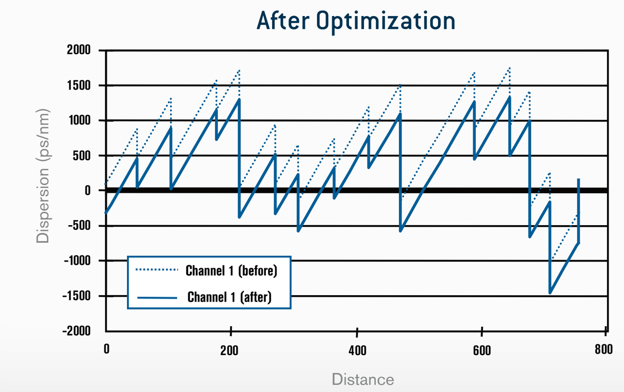


Same transmitting station, two different route examples.

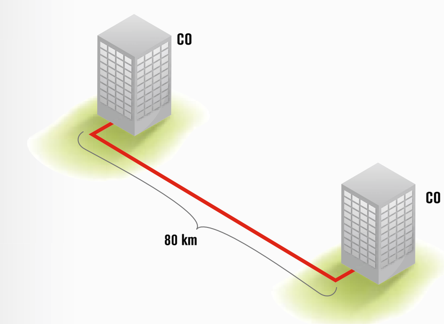
Green path example			
Network section	Length (km)	CD Value at 1550 nm (ps/nm)	PMD (ps)
1	53	890	6.49
2	37	632	0.39
3	29	484	8.93
4	45	765	5.21
5	42	726	0.88
Total	206	3497	12.24

Dispersion Map

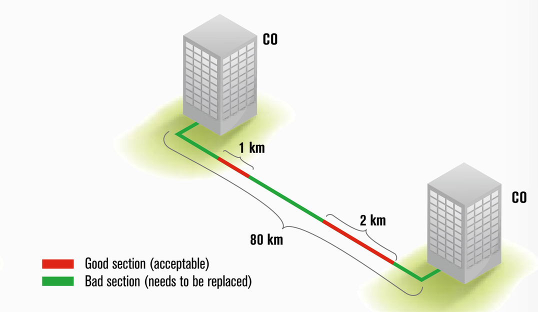




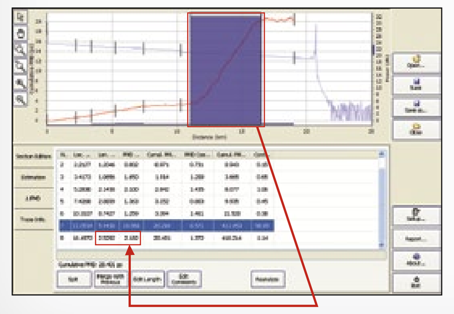
Mitigating PMD



Traditional PMD measurement techniques provide a total link PMD value but do not locate which spans are causing the link to fail the test.



Distributed PMD analysis breaks down the measurement results, effectively pinpointing the high-contributing sections of the link.

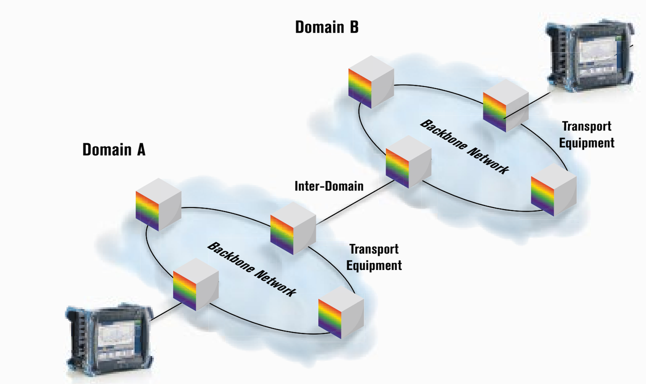


High-contributing PMD section

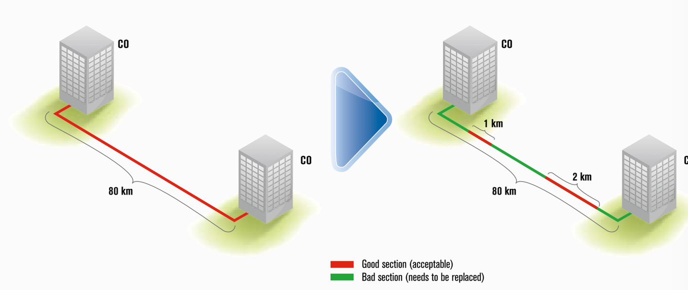
- Locates the fiber sections that are the main contributors of the total PMD of a link
- Enables to isolate and repair only the worst PMD sections of the fiber cable and allows the cost-effective upgrade of a fiber network

Dispersion Approaches

Using a single-ended instrument–a CD and PMD test tool that can characterize a section between two sites without having instruments at both ends–means that many sections can be characterized in a few minutes instead of a few hours from a single location. As a result, an entire network can be characterized in 66% less time than any other traditional test methods. This greatly reduces truck rolls and OPEX, while increasing speed to deliver new services and reducing time-to-cash.



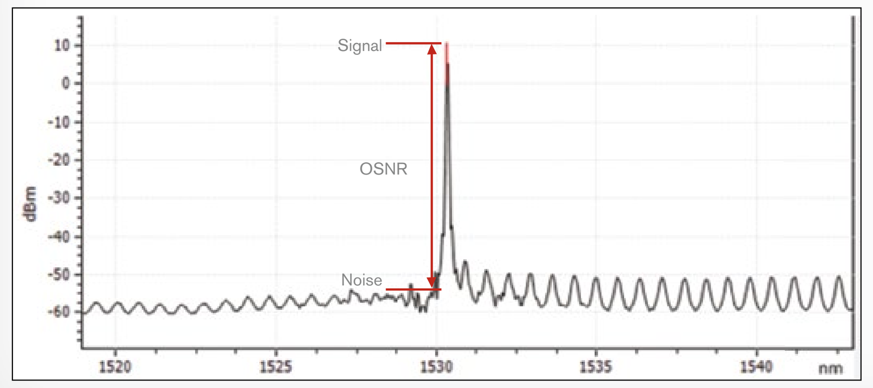
With data rates reaching 40 Gbit/s and beyond, fiber characterization is critical. When adding 40Gbit/s wavelengths to a DWDM route or ring, at that time, it will be nearly impossible to temporarily remove dozens of active wavelengths from service to characterize the optical fiber carrying them. It's important to fully characterize optical fiber links while it's possible: here ,in addition to being highly accurate, these future proof devices can be placed at several different positions, so a multitude of test points can be acquired, faster with high accuracy which together reduces test costs or the even greater cost of adding more fiber.



Distributed PMD analysis reduces CAPEX by revealing the worst segments on a high-PMD route. Replacing a few kilometers of fiber, instead of an entire route, puts it back in service for higher bit-rate services and substantially reduces CAPEX.

System Commissioning

Definition of OSNR



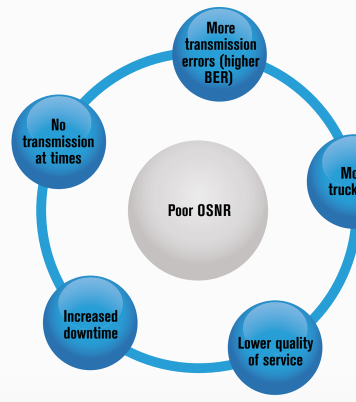
The simplest case for an OSNR measurement is a single channel, as there is no interference coming from adjacent channels.

Importance of OSNR

If the measured OSNR is higher than the required OSNR for a given bit error rate, one can:
- Increase the bit rate
- Increase the number of channels (wavelengths)
- Increase the distance between amplifiers, thereby reducing CAPEX

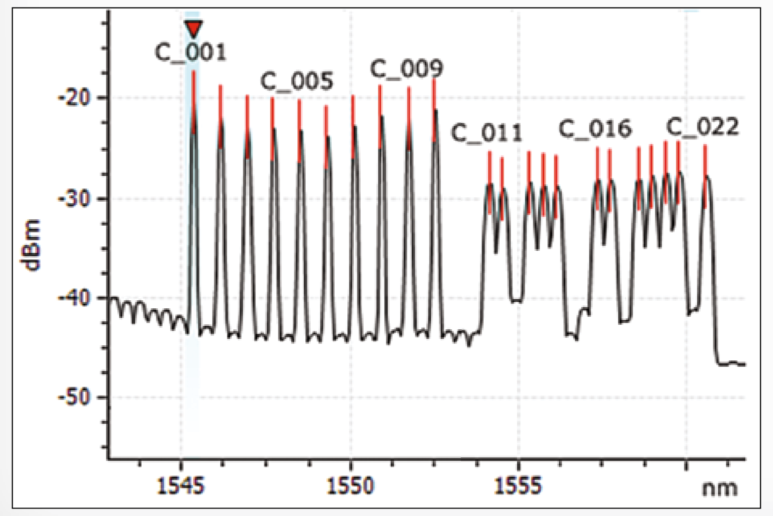
An accurate measurement of OSNR helps exploit the maximum capacity of a link.

Impact of Poor OSNR



Poor OSNR can significantly increase operational expenses (OPEX).

IEC and In-Band OSNR



The OSNR measurements were taken on this optical spectrum analyzer (OSA) using the IEC standard and EXFO's in-band OSNR method.

Result Differences Using IEC and In-Band OSNR Methods

The lines indicated in bold show the channels where the IEC approach would have resulted in a significant error. In-band OSNR is an approach to measure the OSNR directly at the channel wavelength that allows for accurate OSNR measurements in ROADM and 40G networks.

Channel Number	Channel Wavelength (nm)	Traditional IEC OSNR (dB)	EXFO's In-Band OSNR (dB)	Inaccuracy with Traditional IEC Method (dB)
7	1550.117	20.82	19.07	1.75
8	1550.923	21.42	19.90	1.52
9	1551.728	21.48	20.53	0.95
10	1552.519	22.26	20.54	1.72
11	**1554.135**	**13.33**	**17.68**	**4.35**
12	**1554.532**	**12.70**	**16.68**	**3.98**
13	**1555.341**	**12.79**	**17.90**	**5.11**
14	**1555.745**	**11.75**	**18.07**	**6.32**

Channel Number	Channel Wavelength (nm)	Traditional IEC OSNR (dB)	EXFO's In-Band OSNR (dB)	Inaccuracy with Traditional IEC Method (dB)
15	**1556.151**	**13.62**	**19.14**	**5.52**
16	**1557.352**	**12.94**	**17.99**	**5.05**
17	**1557.750**	**13.20**	**17.50**	**4.30**
18	**1558.580**	**12.90**	**18.52**	**5.62**
19	**1558.984**	**11.75**	**17.65**	**5.90**
20	**1559.392**	**11.98**	**17.80**	**5.82**
21	**1559.791**	**13.41**	**18.38**	**4.97**
22	**1560.608**	**16.04**	**20.38**	**4.34**

EXFO Assessing Next-Gen Networks