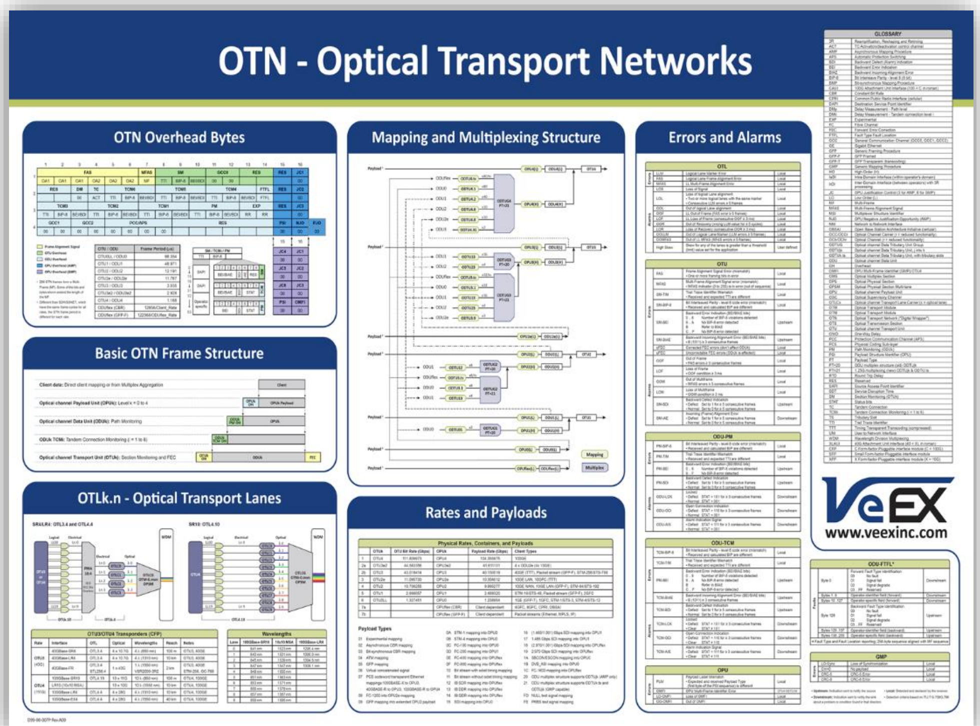
APPLICATION NOTE

OTN Reference Guide

Quick Terminology, Structure, Layers, Errors & Alarms Definitions

Dec 2021 | Rev. B01



P/N: D08-00-026

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Optical Transport Networks (OTN) Reference Guide

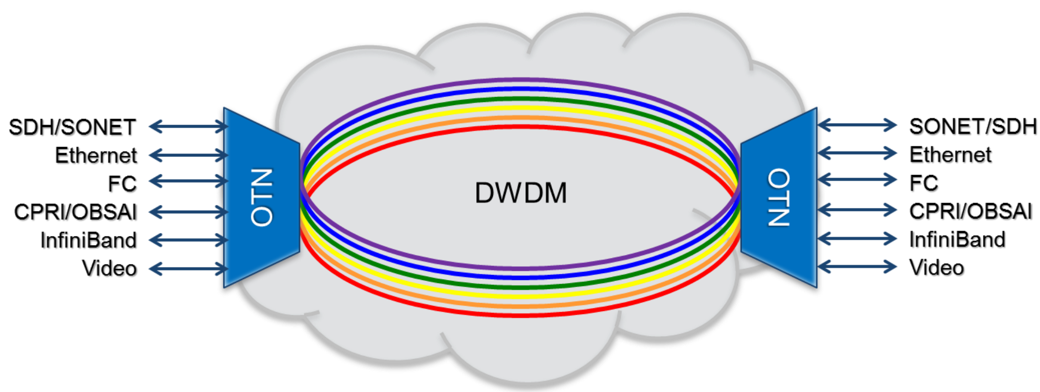
Quick Terminology, Structure, Layers, Errors & Alarms Definitions

Certain users may not be very familiar with OTN, since the transition to DWDM and OTN may have happened in the background. The end result may look totally transparent to them as they may still be dealing with the same traditional interfaces, in access and aggregation points, while all the OTN "magic" happens in the backbone (core).

This abbreviated OTN guide is based on VeEX's "OTN – Optical Transport Network" wall poster and it is intended to be used as a quick reference.

Basic OTN Definitions

- OTN = Optical Transport Networks (a.k.a. "digital wrapper technology" or "optical channel wrapper").
- Defined by ITU-T Recommendation G.709 and applicable worldwide.
- Usually associated with FEC (Forward Error Correction) and sometimes referred as GFEC (Generic FEC).
- OTN is a Core Technology defined to provide end-to-end "pipes" to efficiently transport common access/transport client technologies, data rates and manage DWDM layers.
- The OTUk (k = 0 to 4) nomenclature is used to identify physical interfaces (ports).
- The ODUk (k = 1 to 4) nomenclature is commonly used to identify the corresponding logical container or channel used to transport a payload.
- Line Side refers to the transport/core side of the network. These are usually interfaces ≥40 Gbit/s using complex optical modulation schemes to transmit 40 or 100 Gbit/s in a single wavelength to be carried by the DWDM network. Line Side interfaces are seldom accessible for testing as they may be built into the DWDM multiplexer. Access to the DWDM layer may also be restricted as any mistake could impact thousands of customers.
- Client Side refers to the aggregation or access points. They are usually single wavelength NRZ (serial) optical interfaces for rates ≤ 10.7 Gbit/s and single-fiber multi-wavelength for ≥40 Gbit/s (4x10G, 10x10G, 4x28G). An OTL layer (Optical channel Transport Lane) is added to manage the multiple wavelengths.
- Payloads (Clients) are still the traditional SONET/SDH, Ethernet, Fibre Channel, etc.



Besides being used as an end-to-end long reach transport technology, for its error-correction performance, OTN provides direct support for optical networks using DWDM at the Core

- Adds OAM capabilities to manage DWDM networks.
- Adds FEC to each frame to improve OSNR requirements by 4 to 6 dB, resulting in longer spans and fewer regeneration requirements.

Basic OTN Frame Structure

Client Data
- Direct client mapping or from Multiplex Aggregation

Optical channel Payload Unit (OPUk)
- Level k = 0 to 4

Optical channel Data Unit (ODUk)
- Path Monitoring

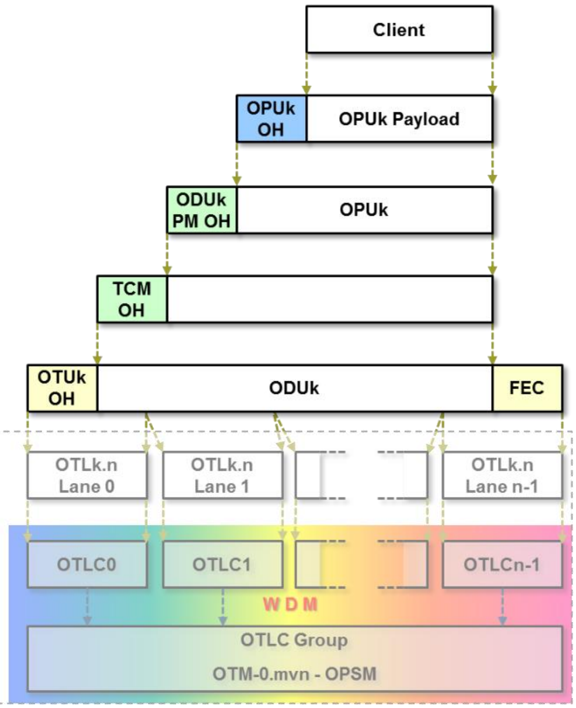
ODUk TCMi
- Tandem Connection Monitoring (i = 1 to 6)

Optical channel Transport Unit (OTUk)
- Section Monitoring and Forward Error Correction

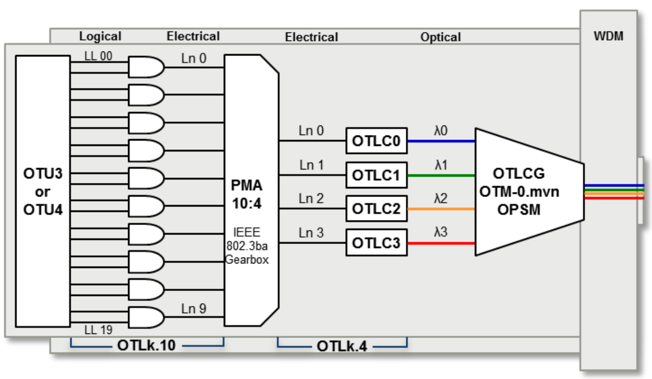
Optical channel Transport Lane (OTLk.n)
- OTU3 (OTL3.4) and OTU4 (OTL4.4, OTL4.10)

Optical channel Transport Lane Carrier (OTLCx)
- Optical lanes x = 0 to n-1

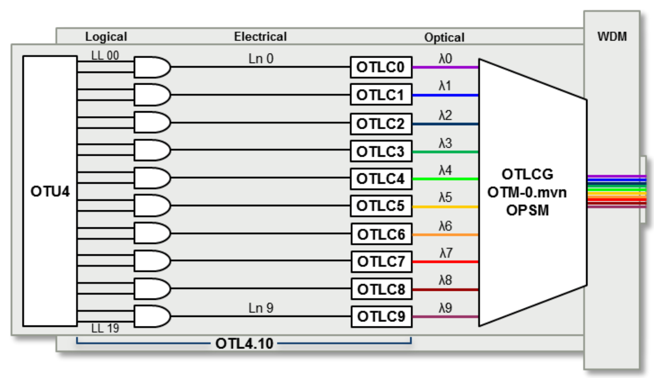
Optical Transport Module (OTM-0.mvn)
- OTM-0.3v4 (OTU3), OTM-0.4v4 (OTU4)



40G and 100G OTLk.n Sub-layer (Client Side) and Common Interface Types



OTL3.4 and OTL4.4 (n=4 lanes)



OTL4.10 (n=10 lanes)

Rate	Optical Interface	OTL	Optical	Wavelengths	Reach	Supports (typical)
OTU3 (43G)	40GBase-SR4	OTL3.4	4 x 10.7G	4 λ (850 nm)	100, 300 m	OTU3, 40GE
	40GBase-LR4	OTL3.4 STL256.4	4 x 10.7G	4 λ (1310 nm)	10 km	OTU3, 40GE STM-256, OC-768
	40GBase-FR	OTL3.4 STL256.4	1 x 43G	1 λ (1550 nm) VSR2000-3R2	2 km	OTU3, 40GE STM-256, OC-768
OTU4 (111G)	100GBase-SR10	OTL4.10	10 x 11G	10 λ (850 nm)	100 m	OTU4, 100GE
	LR10 (10X10 MSA)		10 x 10G	10 λ (1550 nm)	10 km	OTU4, 100GE
	100GBase-LR4	OTL4.4	4 x 28G	4 λ (1310 nm)	10 km	OTU4, 100GE
	100GBase-ER4	OTL4.4	4 x 28G	4 λ (1310 nm)	40 km	OTU4, 100GE
	100GBase-EX4	OTL4.4	4 x 28G	4 λ (1550nm)	40 km	OTU4, 100GE

Lanes and Skew

In OTU4 and 100GE implementations, the transmit data stream is split into 10 electrical lanes and 20 logical lanes, which are scrambled to ensure sufficient transition density (pulses) for clock recovery. The OTL/PCS layer is responsible for inserting Lane Alignment Markers into each of the logical lanes in the transmit direction, so the original 100G data stream can be reconstructed at the far end. The receiver's OTL/PCS layer is responsible of detecting the lane alignment markers and aligning recovered data in the receive direction. The alignment process ensures properly formatted data. Skew accumulation occurs downstream from the OTL/PCS and it is the responsibility of the receiver's OTL/PCS layer to remove skew and re-align the receive data.

Fixed Skew: Fixed or static skew represents the constant difference in arrival time for two signals generated from the same source. It is generated by physical lane-to-lane differences in the time a signal reaches a destination relative to the data on any other lane. This usually related to implementation factors, such as differences in electrical trace lengths (0.5 UI/cm), fiber optics dispersion and lane-dependent clock recovery circuits (CDR).

Dynamic (Variable) Skew: Lane-to-lane skew can change, or wander, over time due to many physical and environmental factors, including uneven temperature, data rate and supply voltage fluctuations.

Standard OTN Interfaces, Rates and Payloads

OTUk	Bit Rate (Gbit/s)	OPUk Payload	Payload Rate (Gbit/s)	Client Types
OTUCn[1]	N x 115.2	OPUCn/FlexO	N x 105.258138	100G, 200G, 400GE,… (M x 5G clients)
OTU4	111.809973	OPU4	104.355975	100GE
OTU50[2]	53.125827	OPU50	49.7664	50GE (lower FEC overhead, shot reach)
OTU3e2	44.583356	OPU3e2	41.611131	4 x ODU2e (4x 10GE)
OTU3	43.018414	OPU3	40.150519	40GE (TTT), Packets (GFP-F), STM-256/STS-768
OTU25[2]	27.252493	OPU25	24.8832	25GE (lower FEC overhead, short reach)
OTU2e	11.095730	OPU2e	10.356012	10GE LAN, 10GFC (TTT)
OTU2	10.709255	OPU2	9.995277	10GE WAN, 10GE LAN (GFP-F), STM-64/STS-192
OTU1	2.666057	OPU1	2.488320	STM-16/STS-48, Packets (GFP-F), 2GFC
OTU0LL[3]	1.327451	OPU0	1.238954	1GE (GFP-T), 1GFC, STM-1/STS-3, STM-4/STS-12
		OPUflex (CBR)	Client dependent	4GFC, 8GFC, CPRI, OBSAI
		OPUflex (GFP-F)	Client dependent	Packet streams (Ethernet, MPLS, IP)

ODU0 – More Efficient Transport of 1GE and SDH/SONET Payloads

ODU0 is the smallest container defined for OTN. Originally OTN channels started in increments of 2.5G, then in 2009 ODU0 was added to offer a better fit to transport Gigabit Ethernet and lower rate payloads.

- 1.25G container size (1.244160 Gbit/s ± 20ppm).
- Increases bandwidth efficiency and sized to fit the original OTN hierarchy.
- 2x 1.25G ODU0 tributaries fit into an ODU1, 8 into ODU2, 32 into ODU3, 80 into ODU4.
- An ODU0 can carry 1000Base-X (1GbE), OC3/STM-1, OC12/STM-4, 1G FC.

A newer OTU0LL[1] edge physical interface has been defined for ODU0 but not yet adopted by the industry.

[1] Later added to ITU-T G.709. FlexO defined by G.709.3
[2] Defined by G.709.4: OTU25 and OTU50 short-reach interfaces
[3] Originally ODU0 did not have a related physical interface. The OTU0LL (Low Latency) Edge Interface was later introduced in G.709 Amendment 2, Annex G (Oct. 2013). Not commonly used.

ODUflex – Brings Flexibility to the Otherwise Rigid OTN Structures

The ODUflex container was also added at the end of 2009 to accommodate other traditional clients (rates), using a more flexible Nx1.25G to provide a tighter fit for other data rates (e.g. 4G and 8G Fibre Channel) and make more efficient use of the available bandwidth. It avoids differential delay problems by constraining the entire ODUflex to be carried over the same higher order ODUk(H). There are two types of ODUflex:

Circuit ODUflex

- Supports any possible client bit rate as a service in circuit-based transport networks.
- CBR clients use a bit-sync mapping into ODUflex (239/238x the client rate).

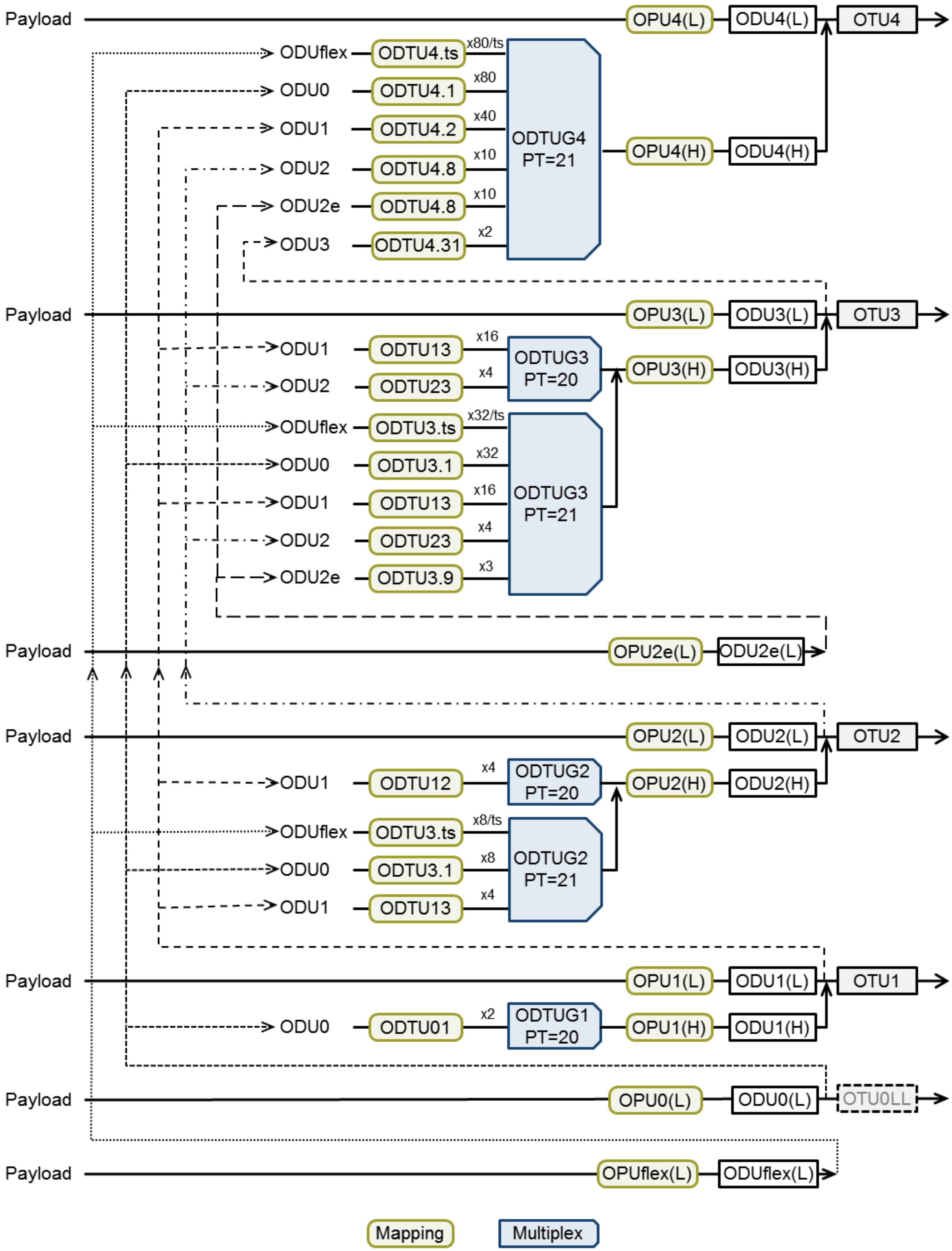
Packet ODUflex

- Creates variable size packet trunk to transport packet flows using Layer 1 switching.
- Uses GFP-F to map packet data.

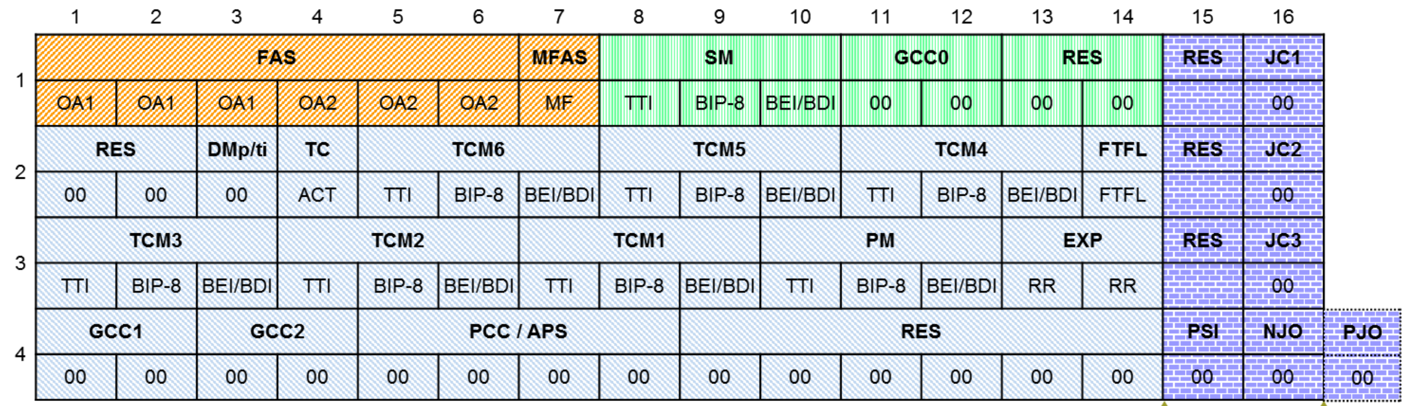
FlexO – Added Flexibility to OTN, Beyond 100G

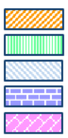
Flexible OTN borrows concepts from Flexible Ethernet (FlexE) to create a client interface for OTUCn, over n bonded 100GE modules, using RS(544,514) FEC. It provides an interoperable interface for OTUCn transport signals. FlexO Group interfaces provide modularity by bonding standard-rate interfaces. It also provides frame, alignment, deskew, group management, management communication channel, and other functions that are not associated with the OTUCn transport signal.

OTN Mapping and Multiplexing Structures (Direct, Single and multi-stage Map/Mux)



OTN Overhead (OTU, ODU and OPU Overhead Bytes)

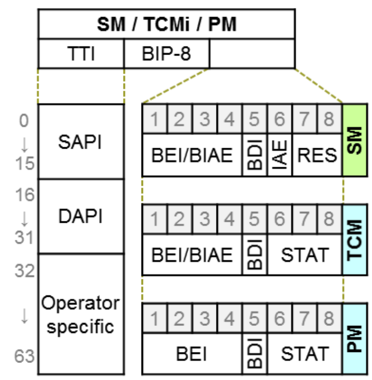


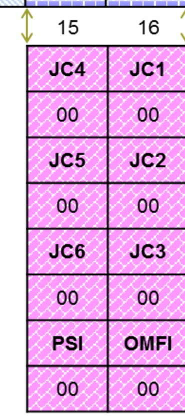


256 OTN frames form a Multi-Frame (MF). Some of the bits and bytes shown are actually a sequence that extend the length of the MF.

Different than SDH/SONET, which have the same frame cycles for all rates, the OTN the frame period is different for each rate.

OTU / ODU	Frame Period (µs)
OTU0LL / ODU0	98.354
OTU1 / ODU1	48.971
OTU2 / ODU2	12.191
OTU2e / ODU2e	11.767
OTU3 / ODU3	3.035
OTU3e2 / ODU3e2	2.928
OTU4 / ODU4	1.168
ODUflex (CBR)	12856/Client_Rate
ODUflex (GFP-F)	122368/ODUflex_Rate





Payload Types (PT=XX)

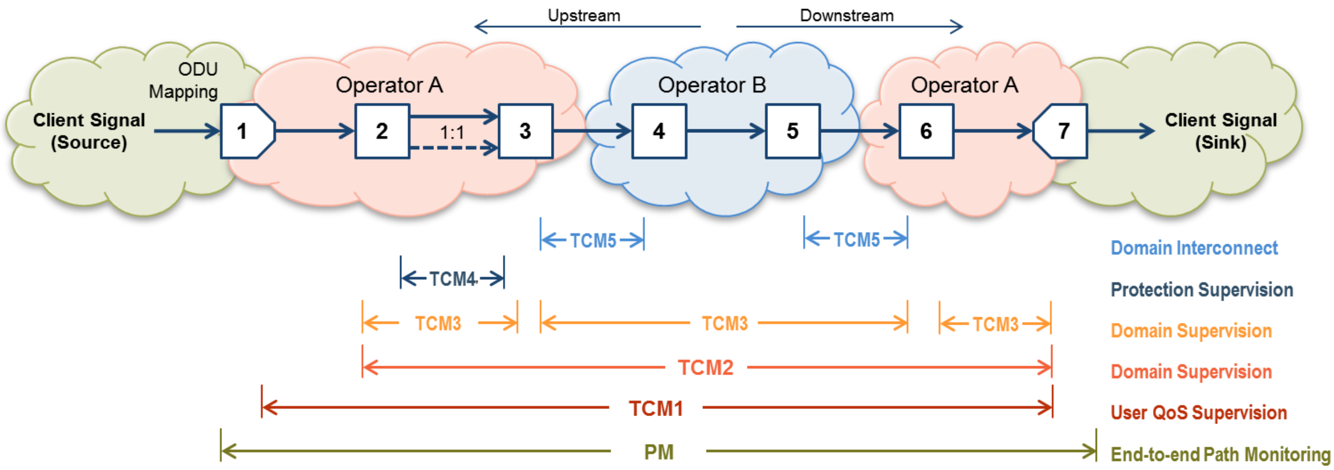
The payload type indicator, Payload Identifier or PT, is carried by the first byte of the PSI field (col 15, row 4) in the OTN overhead. As its name suggests, it indicates what kind of client is being carried in the payload.

01 Experimental mapping
02 Asynchronous CBR mapping
03 Bit-synchronous CBR mapping
04 ATM mapping
05 GFP mapping
06 Virtual concatenated signal
07 PCS code-word transparent Ethernet mappings: 1000BASE-X to OPU0, 40GBASE-R to OPU3, 100GBASE-R to OPU4
08 FC-1200 into OPU2e mapping (10G Fibre Channel)
09 GFP mapping into extended OPU2 payload
0A STM-1 mapping into OPU0
0B STM-4 mapping into OPU0
0C FC-100 mapping into OPU0 (1G Fibre Channel)
0D FC-200 mapping into OPU1 (2G Fibre Channel)
0E FC-400 mapping into OPUflex (4G Fibre Channel)
0F FC-800 mapping into OPUflex (8G Fibre Channel)
10 Bit stream with octet timing mapping
11 Bit stream without octet timing mapping
12 IB SDR mapping into OPUflex
13 IB DDR mapping into OPUflex
14 IB QDR mapping into OPUflex
15 SDI mapping into OPU0
16 (1.485/1.001) Gbps SDI mapping into OPU1
17 1.485 Gbps SDI mapping into OPU1
18 (2.970/1.001) Gbps SDI mapping into OPUflex
19 2.970 Gbps SDI mapping into OPUflex
1A SBCON/ESCON mapping into OPU0
1B DVB_ASI mapping into OPU0
1C FC-1600 mapping into OPUflex (16G Fibre Channel)
20 ODU multiplex structure supporting ODTUjk only (AMP only)
21 ODU multiplex structure supporting ODTUk.ts and ODTUjk (GMP capable)
55-66 Not available
80-8F Reserved for proprietary use
FD NULL test signal mapping
FE PRBS test signal mapping
FF Not available

This field also carries the Multiplexer Structure Identifier (MSI) which indicates the ODUk tributary slots (T/S) used to build each individual port or channel.

TCM - Tandem Connection Monitoring

TCMi (i = 1 to 6) is used to monitor the status of the different segments that make an end-to-end path, allowing operators to monitor and pinpoint problematic segments during monitoring or troubleshooting. It becomes very useful when multiple carriers or service providers are involved in the delivery of a service.



OTN Alarms & Errors (based on ITU-T G.798 definitions)

OTN defects and anomalies can be categorized as:

- Local: Detected and declared by the network element at its receiver side.
- Upstream: Indication sent back to notify the source about a problem detected on its transmission.
- Downstream: Indication sent forward to notify the sink about a problem or condition found in that direction.

Physical Layer

	Physical	Description	Notes
	LOS	Loss of signal	Local

OTL - Optical channel Transport Lane

	OTL	Description	Notes
Errors	LLM	Logical Lane Marker Error	Local
	FAS	Logical Lane Frame Alignment Error	Local
	MFAS	LL Multi-Frame Alignment Error	Local
Alarms	LOL	Loss of logical Lane alignment • Two or more logical lanes with the same marker • Consecutive LLM errors for ≥ 5 frames	Local
	OOL	Out of logical Lane alignment	Local
	OOF	LL Out of Frame (FAS error for ≥ 5 frames)	Local
	LOF	LL Loss of Frame (consecutive OOF for ≥ 3ms)	Local
	OOR	Out of Recovery (wrong LLM value for ≥ 5 cycles)	Local
	LOR	Loss of Recovery (consecutive OOR for ≥ 3ms)	Local
	OOLLM	Out of Logical Lane Marker (LLM errors for ≥ 5 frames)	Local
	OOMFAS	Out of LL MFAS (MFAS errors for ≥ 5 frames)	Local
	High Skew	Skew for any of the lanes is greater than a threshold (limit) value set for the application	User defined

OTU – Optical Transport Unit

	OTU	Description	Notes
Errors	FAS	Frame Alignment Signal Error (mismatch) • One or more framing bits in error	Local
	MFAS	Multi-Frame Alignment Signal error (mismatch) • MFAS indicator (0 to 255) is in error (out of sequence)	Local
	SM-TIM	Trail Trace Identifier Mismatch • Received and expected TTI are different	Local
	SM-BIP-8	Bit Interleaved Parity - level 8 code error (mismatch) • Received and calculated BIP are different	Local
	SM-BEI	Backward Error Indication (BEI/BIAE bits) • 0 .. 8 Number of BIP-8 violations detected • 9 .. A No BIP-8 error detected • B Refer to BIAE • C .. F No BIP-8 error detected	Upstream
	SM-BIAE	Backward Incoming Alignment Error (BEI/BIAE bits) • B (1011) ≥ 3 consecutive frames	Upstream
	cFEC	Corrected FEC errors (don't affect ODUk)	Local
	uFEC	Uncorrectable FEC errors (ODUk is affected)	Local
Alarms	OOF	Out of Frame • FAS errors ≥ 5 consecutive frames	Local
	LOF	Loss of Frame • OOF condition for ≥ 3 ms	Local
	OOM	Out of Multiframe • MFAS errors for ≥ 5 consecutive frames	Local
	LOM	Loss of Multiframe • OOM condition for ≥ 3 ms	Local
	SM-BDI	Backward Defect Indication • Defect Set to 1 for ≥ 5 consecutive frames • Normal Set to 0 for ≥ 5 consecutive frames	Upstream
	SM-IAE	Incoming (Frame) Alignment Error • Defect Set to 1 for ≥ 5 consecutive frames • Normal Set to 0 for ≥ 5 consecutive frames	Downstream
	OTU-AIS	Alarm Indication Signal • Repetitive PN-11 sequence (2^{11}-1) completely filling OTUk frames	Downstream

ODU-PM – Path Monitoring

	ODU-PM	Description	Notes
Errors	PM-BIP-8	Bit Interleaved Parity - level 8 code error (mismatch) • Received and calculated BIP are different	Local
	PM-TIM	Trail Trace Identifier Mismatch • Received and expected TTI are different	Local
	PM-BEI	Backward Error Indication (BEI/BIAE bits) • 0 .. 8 Number of BIP-8 violations detected • 9 .. F No BIP-8 error detected	Upstream

Alarms	PM-BDI	Backward Defect Indication • Defect Set to 1 for ≥ 5 consecutive frames • Normal Set to 0 for ≥ 5 consecutive frames	Upstream
	ODU-LCK	Locked • Defect STAT = 101 for ≥ 3 consecutive frames • Normal STAT = 001	Downstream + all PM bytes (except FTFL) and payload filled with 0101 0101
	ODU-OCI	Open Connection Indication • Defect STAT = 110 for ≥ 3 consecutive frames • Normal STAT = 001	Downstream + all PM bytes (except FTFL) and payload filled with 0110 0110
	ODU-AIS	Alarm Indication Signal • Defect STAT = 111 for ≥ 3 consecutive frames • Normal STAT = 001	Downstream + all PM bytes (except FTFL) and payload filled with 1111 1111

ODU TCMi – Tandem Connection Monitoring

	ODU-TCMi	Description	Notes
Errors	TCM-BIP-8	Bit Interleaved Parity - level 8 code error (mismatch) • Received and calculated BIP are different	Local
	TCM-TIM	Trail Trace Identifier Mismatch • Received and expected TTI are different	Local
	TCM-BEI	Backward Error Indication (BEI/BIAE bits) • 0 .. 8 Number of BIP-8 violations detected • 9 .. A No BIP-8 error detected • B Refer to BIAE • C .. F No BIP-8 error detected	Upstream
Alarms	TCM-BDI	Backward Defect Indication • Defect Set to 1 for ≥ 5 consecutive frames • Normal Set to 0 for ≥ 5 consecutive frames	Upstream
	TCM-LCK	Locked • Defect STAT = 101 for ≥ 3 consecutive frames • Clear STAT ≠ 101	Downstream
	TCM-LTC	Loss of Tandem Connection • Defect STAT = 000 for ≥ 3 consecutive frames • Clear STAT = 001	Downstream
	TCM-OCI	Open Connection Indication • Defect STAT = 110 for ≥ 3 consecutive frames • Clear STAT ≠ 110	Downstream
	TCM-BIAE	Backward Incoming Alignment Error (BEI/BIAE bits) • B (1011) ≥ 3 consecutive frames	Upstream
	TCM-IAE	Incoming Alignment Error • Defect STAT = 010 for ≥ 3 consecutive frames • Clear STAT ≠ 010	Downstream
	TCM-AIS	Alarm Indication Signal • Defect STAT = 111 for ≥ 3 consecutive frames • Clear STAT ≠ 111	Downstream

FTFL – ODU Fault Type and Fault Location Reporting

FTFL is a 256-byte string aligned to the multi-frame sequence

	FTFL	Description	Notes
ODU-FTFL	Byte 0	Forward Fault Type Identification • 00 No fault • 01 Signal fail • 02 Signal degrade • 03 .. FF Reserved	Downstream
	Bytes 1..9	Operator identifier field (forward)	Downstream
	Bytes 10..127	Operator-specific field (forward)	Downstream
	Byte 128	Backward Fault Type Identification • 00 No fault • 01 Signal fail • 02 Signal degrade • 03 .. FF Reserved	Upstream
	Bytes 129..137	Operator identifier field (backward)	Upstream
	Bytes 138..255	Operator-specific field (backward)	Upstream

OPU – Optical Payload Unit

	OPU	Description	Notes
Errors	PLM	Payload Label Mismatch • Expected and received Payload Type (first byte of the PSI sequence) are different	Local
	OMFI	OPU Multi-Frame Identifier Error	OTU4 ODTU.M only
	LO-OMFI	Loss of OMFI	Local
	OO-OMFI	Out of OMFI	Local

GMP – Generic Mapping Procedure

	GMP	Description	Notes
Errors	LO-Sync	Loss of Synchronization	Local
	Cm=0	No payload	Local
	CRC-5	CRC-5 Error	Local
	CRC-8	CRC-8 Error	Local

PRBS - Test Pattern in Payload

	BERT	Description	Notes
Errors	Bit (TSE)	Bit Error (Test Sequence Error)	Local
	LSS	Loss of test Sequence Synchronization (pattern loss)	Local

OTN Glossary

3R	Re-amplification, Reshaping and Retiming
ACT	TC Activation/deactivation control channel
AM	Alignment Marker
AMP	Asynchronous Mapping Procedure
APS	Automatic Protection Switching
B100G	Beyond 100G
BDI	Backward Defect (Alarm) Indication
BEI	Backward Error Indication
BER	Bit Error Rate
BERT	Bit Error Rate Test
BIAE	Backward Incoming Alignment Error
BIP-8	Bit Interleave Parity - level 8 (8 bit)
BMP	Bit-synchronous Mapping Procedure
CAUI	100G Attachment Unit Interface (100 = C in roman numerals)
CBR	Constant Bit Rate
CFP	C Form-factor Pluggable interface module (C = 100G). Available in CFP, CFP2 and CFP4 sizes
CMx	Common Marker #x
CPx	Common Pad #x
CPRI	Common Public Radio Interface (cellular)
CWM	Code Word Marker
DAPI	Destination Service Point Identifier
DMp	Delay Measurement - Path level
DMti	Delay Measurement - TCM level i
EXP	Experimental
EFEC	Enhanced FEC
FC	Fibre Channel
FEC	Forward Error Correction
FlexE	Flexible Ethernet
FlexGrid	Flexible DWDM channel (ITU-T G.694.1)
FlexO	Flexible OTN (G.709.1. G.709.2, G.709.3)
FOIC	FlexO Interface
FTFL	Fault Type / Fault Location
GCC	General Communication Channels (GCC0, GCC1, GCC2)
GE	Gigabit Ethernet
GFEC	Generic FEC
GFP	Generic Framing Procedure
GFP-F	GFP Framed
GFP-T	GFP Transparent (transcoding)
GMP	Generic Mapping Procedure
HO	Higher Order (H)
IaDI	Intra-Domain Interface (within operator's domain)
IrDI	Inter-Domain Interface (between operators) with 3R processing
JC	OPU Justification Control (3 bytes for AMP and 6 for GMP)
LO	Lower Order (L)
LSS	Loss of test Sequence Sync (pattern loss)
MF	Multi-Frame
MFAS	Multi-Frame Alignment Signal
MSI	Multiplexer Structure Identifier (OPU)
NJO	OPU Negative Justification Opportunity (AMP)
NNI	Network to Network Interface
OBSAI	Open Base Station Architecture Initiative (cellular)
OCC/OCCr	Optical Channel Carrier (r = reduced functionality)
OCh/OChr	Optical Channel (r = reduced functionality)
ODTUG	Optical channel Data Tributary Unit Group
ODTUjk	Optical channel Data Tributary Unit, j into k
ODTUk.ts	Optical channel Data Tributary Unit, with tributary slots
ODUk	Optical channel Data Unit, level k (k = 1 to 4)
ODUk(H)	Higher order ODUk (Multiplexed clients)
ODUk(L)	Lower order ODUk (Direct client mapping)
OH	Overhead
OMFI	OPU Multi-Frame Identifier (GMP) OTU4
OMS	Optical Multiplex Section
OPS	Optical Physical Section
OPSM	Optical Physical Section Multi-lane
OPU	Optical channel Payload Unit
OSC	Optical Supervisory Channel
OSMC	OTN Synchronization Message Channel (carries an adaptation of 1588v2/PTP protocol)
OSU	Optical Service Unit, path layer network for sub 1 Gbit/s clients over ODUflex
OTLk.n	Optical channel Transport Lane
OTLCx	Optical channel Transport Lane Carrier (x = optical lane)
OTM	Optical Transport Module
OTN	Optical Transport Network ("Digital Wrapper")
OTS	Optical Transmission Section
OTSi	Optical Tributary Signal
OTUCn	n instances of 100G (OTUC) logically interleaved
OTUk	Optical channel Transport Unit, level k (1 to 4)
OWD	One-Way Delay (one-way latency)
PCC	Protection Communication Channel (APS)
PCS	Physical Coding Sub-layer
PM	Path Monitoring (ODUk)
PRBS	Pseudo Random Bit Sequence (test pattern)
PSI	Payload Structure Identifier (OPU)
PT	Payload Type
PT=20	2.5G ODU multiplex structure (old) ODTUjk
PT=21	1.25G multiplexing (new) ODTUjk & ODTU.ts
PTP	Precision Time Protocol
QSFP	Quad SFP transceiver
QSFP+	Enhanced QSFP transceiver (up to 4x10 Gbit/s)
QSFP28	Enhanced QSFP transceiver (up to 4x28 Gbit/s)
RS	Reed Solomon (FEC)
RTD	Round Trip Delay
RES	Reserved for future standardization
SAPI	Source Access Point Identifier
SDT	Service Disruption Time
SFP	Small Form-factor Pluggable transceiver
SFP+	Enhanced SFP transceiver (up to 16 Gbit/s)
SFP28	Enhanced SFP transceiver (25 Gbit/s)
SM	Section Monitoring (OTUk)
STAT	Status bits
TC	Tandem Connection
TCMi	Tandem Connection Monitoring (i = 1 to 6)
TS, T/S	Tributary Slot
TSE	Test Sequence Error (pattern error, bit error)
TTI	Trail Trace Identifier
TTT	Timing Transparent Transcoding (compressed)
UNI	User to Network Interface
WDM	Wavelength Division Multiplexing
xFP	x Form-factor Pluggable transceiver module (e.g., X=10G, C=100G, QS=Quad, etc.)
XLAUI	40G Attachment Unit Interface (40 = XL in roman numerals)

Notes

About VeEX Inc.

Founded in 2006 by test and measurement industry veterans and strategically headquartered in the heart of Silicon Valley, VeEX Inc. provides innovative Test and Measurement solutions for next generation networks, services and communication equipment.

With a blend of advanced technologies and vast technical expertise, VeEX's products diligently address all stages of network design, verification, deployment, maintenance, field service turn-up, troubleshooting and integrate legacy and modern service verification features across DSL, Fiber Optics, WDM, CATV/DOCSIS, Mobile backhaul and fronthaul/DAS (CPRI/OBSAI), next generation Core & Transport Network, Fibre Channel SAN, Carrier & Metro Ethernet technologies and Synchronization.

The VeEX team brings simplicity to verifying tomorrow's networks.

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