OIF FlexE 2.1 – Flexible Use of Ethernet

VIAVI Solutions

WHAT IS FlexE?

OIF

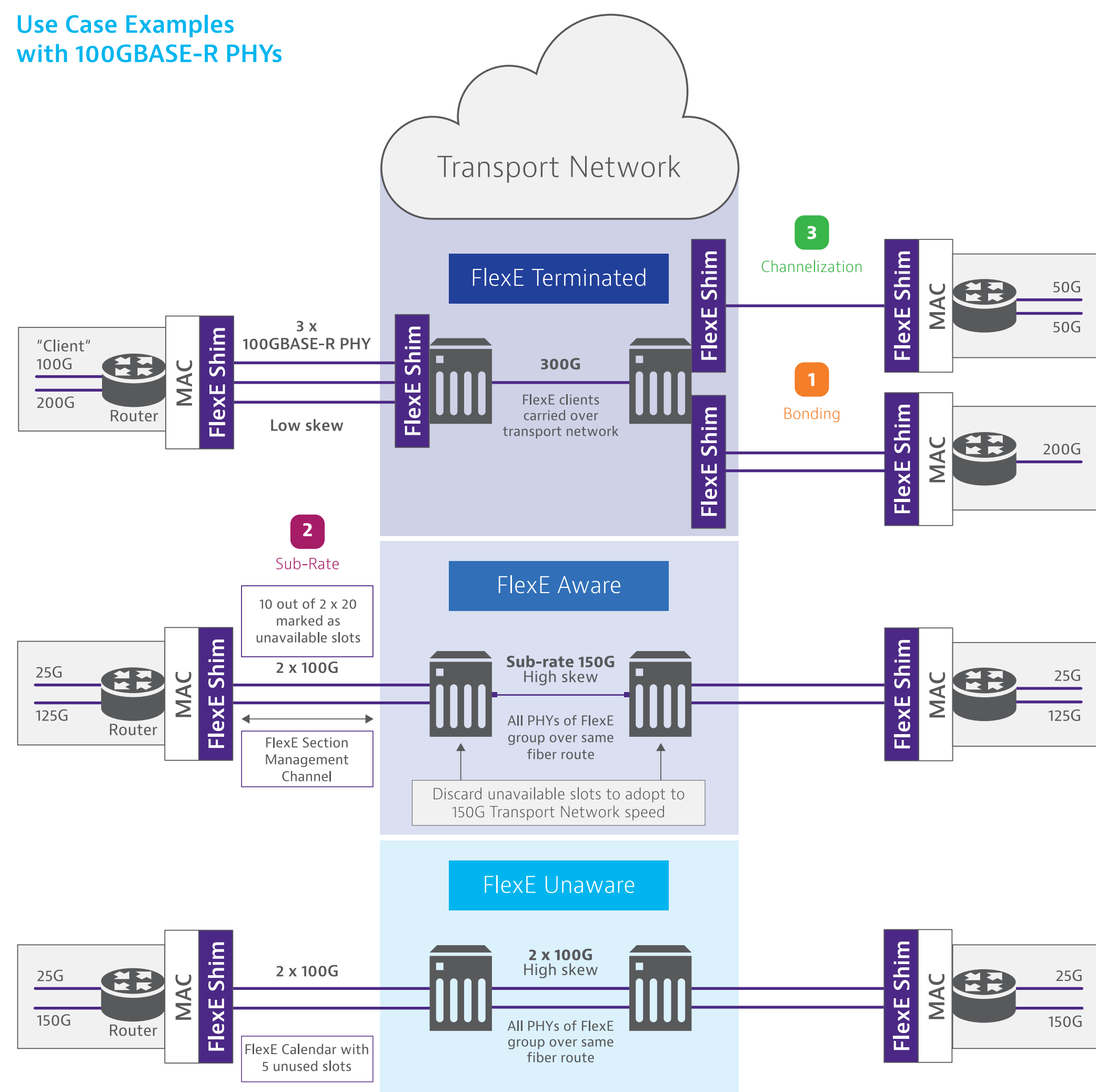### FlexE is a Homogeneous Way to Deliver Flexible Bandwidth

OIF FlexE Implementation Agreement provides flexible use of network bandwidth. It supports channelization, bonding and subrating features to connect one or more Ethernet MACs using standard Ethernet PMDs between routers either directly or through transport gear.

FlexE Provides Flexible Ethernet Use Cases

Segment	Use Case	Benefit
Operators	Flexible Ethernet Services	Enables SDN with lower cost per bit and new attractive Services and efficient restoration capabilities
DCI	Ethernet Router to high-speed Optical Transport Network	Full rate utilization of existing transport network
Intra-Data Center	"Large pipes"	Cost efficiency. For example using available 100GE PMDs. Standardization independent
Mobile 5G	Network slicing in 5G Midhaul / Backhaul	Discrete channelization in Ethernet

Use Case Examples with 100GBASE-R PHYs

Transport Network

FlexE Terminated

"Client" 100G / 200G — Router — MAC — FlexE Shim — 3 x 100GBASE-R PHY — Low skew — 300G — FlexE clients carried over transport network

FlexE Aware

25G / 125G — Router — MAC — FlexE Shim — 2 x 100G — 10 out of 2 x 20 marked as unavailable slots — Sub-rate 150G High skew — All PHYs of FlexE group over same fiber route — FlexE Section Management Channel — Discard unavailable slots to adopt to 150G Transport Network speed

FlexE Unaware

25G / 150G — Router — MAC — FlexE Shim — 2 x 100G — FlexE Calendar with 5 unused slots — 2 x 100G High skew — All PHYs of FlexE group over same fiber route

50G / 50G — MAC — FlexE Shim — **3** Channelization

200G — MAC — FlexE Shim — **1** Bonding

25G / 125G — MAC — FlexE Shim

25G / 150G — MAC — FlexE Shim

VIAVI ONT with FlexE

FlexE Applications

1 Bonding

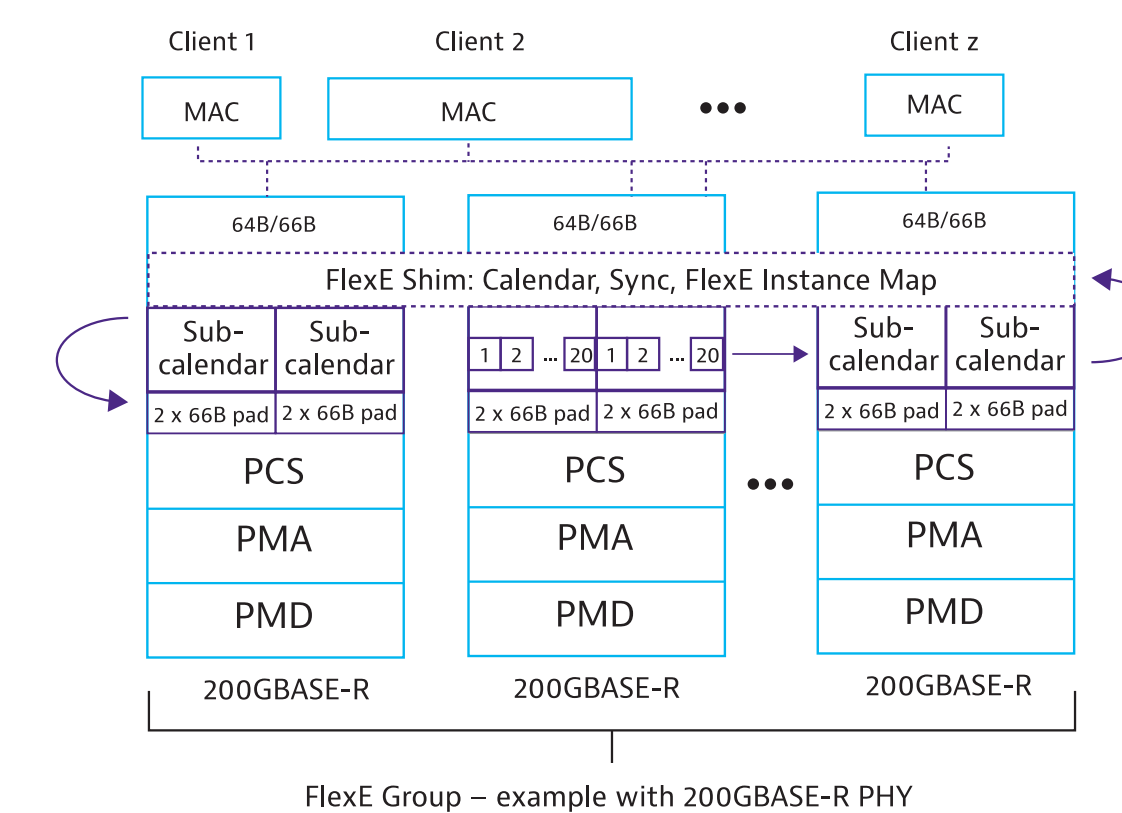|	
Definition	Bonding of Ethernet PHYs
Typical Use Cases	"Big Fat Pipe" (e.g. Intra-Data Center) – enhanced LAG
Examples	Bonding 2 x 100GBASE-R PHYs to a 200G MAC

2 Sub-Rate

Definition	Sub-rates of Ethernet PHYs
Typical Use Cases	Transport rate < Ethernet PHY Rate (e.g. DCI)
Examples	Subrating towards Transport Network 150G capacity. Channelize 25G and 125G MACs over Bonding 2 x 100GBASE-R PHYs.

3 Channelization

|	
Definition	Channelization within a PHY or a group of bonded PHYs
Typical Use Cases	Multiple services / clients – generalized MLG
Examples	Channelize 2 x 50G MACs over one 100GBASE-R PHY

HOW DOES IT WORK?

FlexE 2.1 Protocol Stack

Client 1 — MAC — 64B/66B
Client 2 — MAC — 64B/66B
Client z — MAC — 64B/66B

FlexE Shim: Calendar, Sync, FlexE Instance Map

Sub-calendar | Sub-calendar — 2 x 66B pad x 66B pad — PCS — PMA — PMD — 200GBASE-R
Sub-calendar | Sub-calendar — PCS — PMA — PMD — 200GBASE-R
Sub-calendar | Sub-calendar — PCS — PMA — PMD — 200GBASE-R

FlexE Group – example with 200GBASE-R PHY

FlexE 2.1 Functions

FlexE Definition	Function
FlexE PHYs	50GBASE-R, 100GBASE-R, 200GBASE-R, 400GBASE-R are defined by OIF IA FlexE-02.1 • 50GBASE-R PHY uses bulk of PCS functions defined by IEEE802.3cd clause 133 • 100GBASE-R PHY uses bulk of PCS functions defined by IEEE802.3 clause 82 • 200GBASE-R PHY and 400GBASE-R PHY uses bulk of PCS functions defined by IEEE802.3 clause 119 • To compensate for alignment marker spacing, each 50GBASE-R PHY carries 2x66B pad blocks, or 200GBASE-R PHY carries 4x66B and each 400GBASE-R PHY carries 8x66B pad blocks
FlexE Group	• A group of 1 to n bonded 50GBASE-R PHYs, 100GBASE-R, 200GBASE-R or 400GBASE-R Ethernet PHYs. • All PHYs in the group operate at the same rate and use a common clock. • All 100G FlexE Instances of a PHY must be part of same FlexE Group
FlexE Instance	Information structure carried across each PHY of the FlexE Group. Each with its own FlexE Overhead. FlexE Instance numbers are unique within a FlexE Group • 1x50G FlexE Instance in a 50G BASE-R PHY • 1x100G FlexE Instance in a 100G BASE-R PHY • 2x100G FlexE Instance in a 200G BASE-R PHY • 4x100G FlexE Instance in a 400G BASE-R PHY
Unequipped 100G FlexE Instances • At least one equipped 100G FlexE Instance on every PHY • Unequipped 100G FlexE Instances must always be the highest numbered instance(s) on a PHY of the FlexE Group
FlexE Client	The "Service Rate" of FlexE. Possible client rates include 10GE, 40GE and n x 25GE. Each client is a 64B/66B encoded bit stream.
FlexE Shim	The logic layer that maps/demaps set of FlexE Clients carried over a FlexE Group and is transparent to traffic.
FlexE Map	Entire list of all FlexE Instances in the FlexE Group. Common information in all Overhead frames for the different FlexE Instances within the group.
FlexE Calendar	Client allocation through sub-calendar per 50G FlexE Instance or 100G FlexE Instance. • A 50G FlexE Instance carries 10x5G calendar slots • A 100G FlexE Instance carries 20x5G or 4x25G calendar slots • Calendar A and Calendar B option allows for reconfiguration • 5 consecutive 5G calendar slots build one 25G calendar slot across PHYs • 25G slots within one 100G FlexE Instance – calendar slot positions 0-4, 5-9, 10-14 and 15-19
FlexE Overhead Frame	Each 50G FlexE Instance or 100G FlexE Instance carries an 8 blocks long, 66B block-encoded FlexE Overhead Frame. The first block synchronizes each 50G FlexE Instance or 100G FlexE Instance to the FlexE Group.
Flex Overhead Multiframe	• 32 FlexE Overhead Frames build the FlexE Overhead Multiframe for a 100G FlexE Instance. • 16 FlexE Overhead Frames build the Overhead Multiframe for a 50G FlexE Instance.
FlexE Management Channels	• Each PHY of the FlexE Group can carry its own Management Channels – in the first 50G FlexE Instance or 100G FlexE Instance per PHY • Optional Synchronization Messaging Channel is enabled through the Synchronization Configuration (SC) bit in the FlexE Overhead

FlexE 2.1 Overhead for Each 100G FlexE Instance
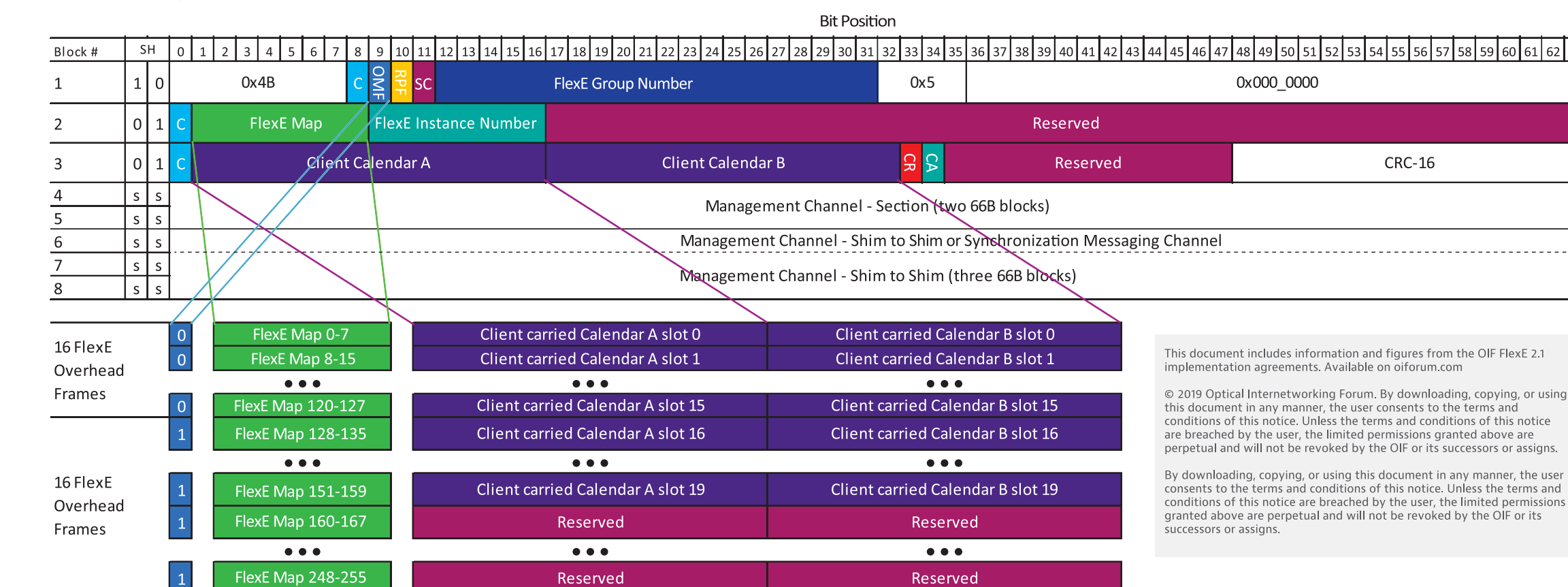
C = Calendar configuration in use
OMF = Overhead Multiframe Indicator
RPF = Remote PHY Fault
SC = Synchronization Configuration
CR = Calendar Switch Request
CA = Calendar Switch Acknowledge
s s = Valid sync header bits (01 or 10)
FlexE Map = Control of which 100G FlexE Instances are members of this group
FlexE Instance Number = Identity of this 100G FlexE Instance within the group
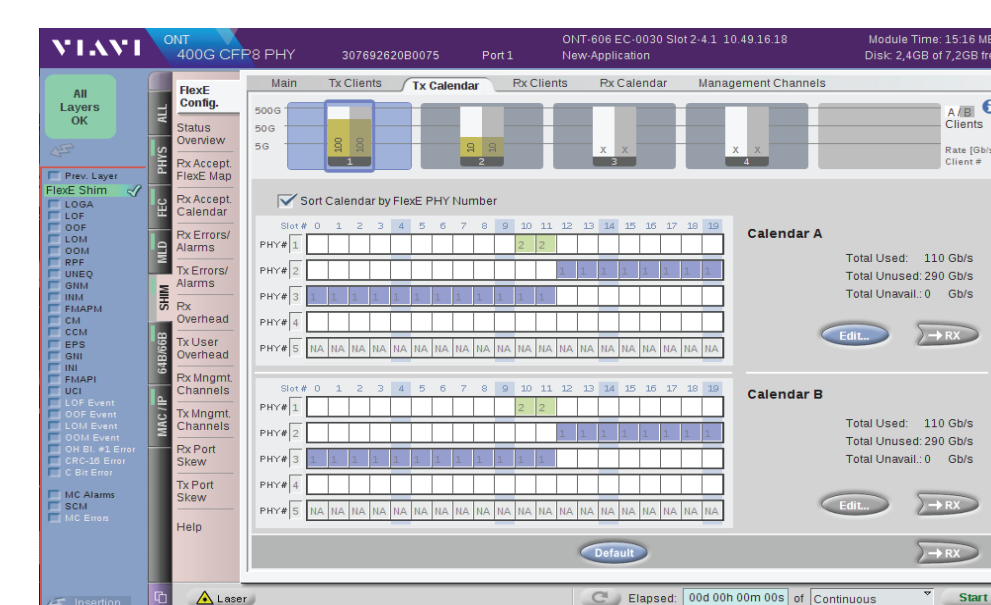FlexE Group Number

This document includes information and figures from the OIF FlexE 2.1 implementation agreements. Available on oifforum.com

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FlexE Muxing (example 400GBASE-R PHY)

FlexE Demuxing (example 400GBASE-R PHY)

HOW IS IT TESTED?

FlexE Test Challenges Addressed

FlexE Test Case	What Needs to be Tested?
Calendar Client Setup	Setup of multiple clients with different client sizes to support applications for bonding, channelization and sub-rating.
RX FlexE Map and Accepted Calendar	FlexE Map for entire FlexE Overhead Multi-frame and Sub-calendar per slot with associated client number
FlexE Alarms and Errors	VIAVI ONT test set provides unique FlexE Shim Alarm and Error tests that help analyze FlexE Overhead logic and interoperability between network elements
FlexE Overhead Manipulation	User manipulation of any bit in the FlexE Overhead and Overhead Multi-frame to provoke unusual configuration, device and network conditions
FlexE Management Channel	Flex Management Transparency test and user defined bit loading in the Section-to-Section, Shim-to-Shim and optional Synchronization Messaging Channel
Port Skew	Skew between PHYs because too-high PHY skew might cause payload not to be reconstructable
64B/66B Reconciliation	64B/66B Block analysis per FlexE client. Including Local and Remote Fault
MAC / IP	FlexE MAC client rate, utilization, QoS, Errors

ONT FlexE Alarms and Errors

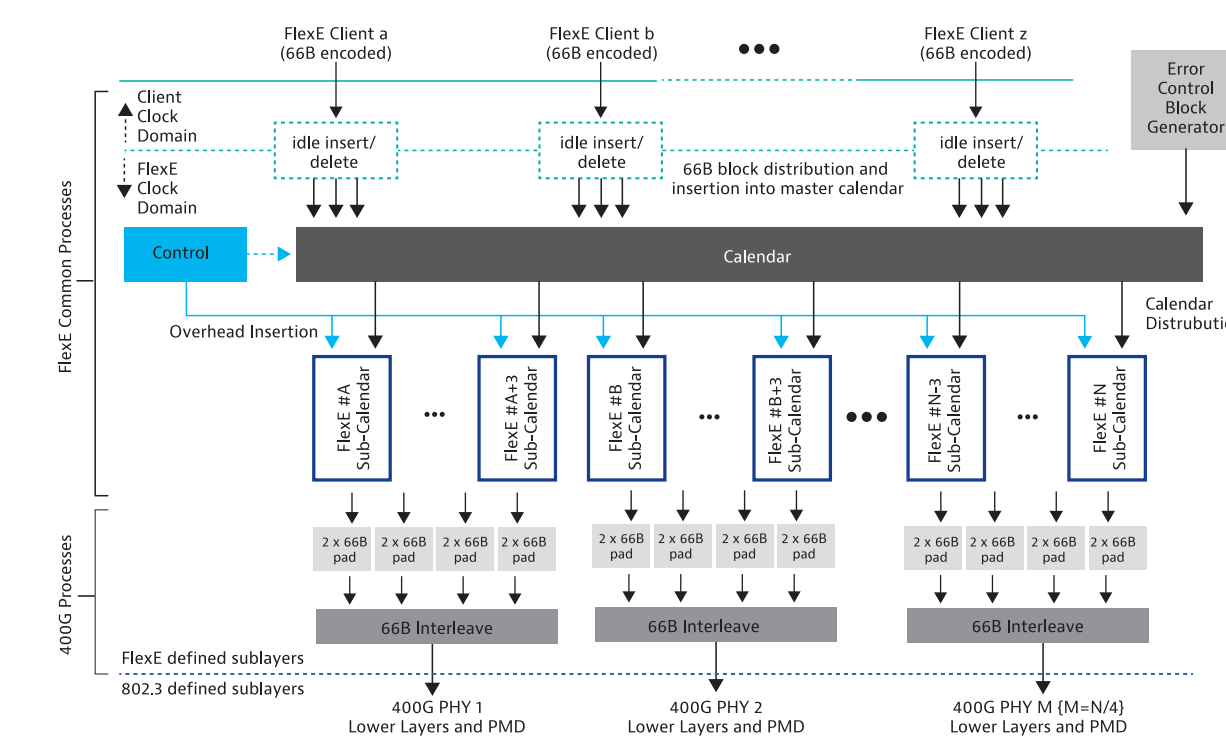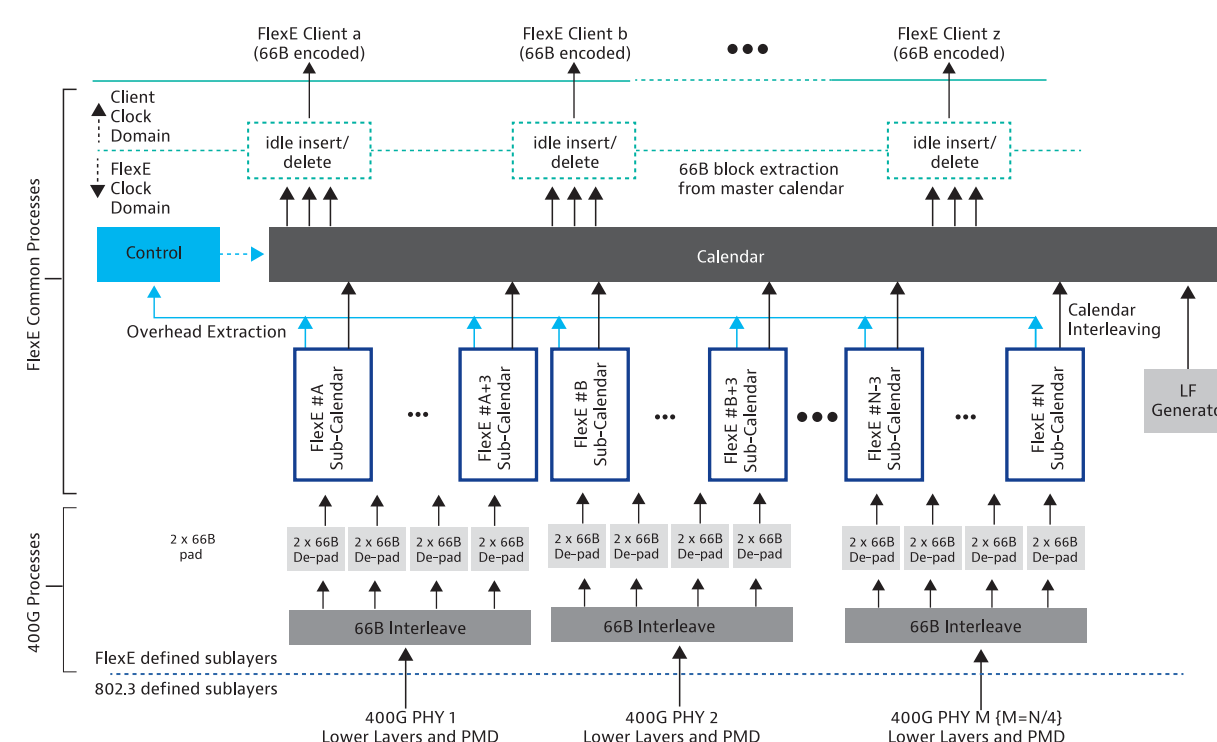| Test Metric	Type	Comments
LOGA (Loss of Group Alignment)	Alarm	Indication that payload cannot be reconstructed (multiple possible reasons)
Group Numbers Inconsistent	Alarm	Summary GNM (Group Number Mismatch) alarm. Asserted if any instance has GNM. GIDM (Group ID Mismatch) is in accordance with ITU-T G. 798 definition
Group Numbers Inconsistent	Alarm	Accepted FlexE group numbers are not identical across the group.
EPS (Excessive Port Skew)	Alarm	Skew between PHYs exceeding defined threshold
Instance Numbers Inconsistent	Alarm	Accepted FlexE Instance numbers do not match the accepted FlexE Map on one or more FlexE Instances
FlexE Maps Inconsistent	Alarm	Accepted FlexE Maps are not identical across the group.
Calendar in Use Inconsistent	Alarm	Accepted "Calendar in use" does not match across the group.
LOF (Loss of FlexE Overhead frame)	Alarm	Loss of FlexE Overhead frame. Definition acc. ITU-T G. 798 (3 ms timer)
LOM (Loss of Multiframe)	Alarm	Loss of FlexE Overhead Multi-frame. Definition acc. ITU-T G. 798 (10 ms timer)
RPF (Remote PHY Fault) – OIF	Alarm	Inform far-end shim of locally detected failure of a PHY
Unequipped Instance (PHY# for 100G)	Alarm	Enable/disable Unequipped Instance detection. Note: not relevant for 100GBASE-R PHYs
OOF (Out-of-Frame)	Alarm	FlexE Overhead Frame mismatches on the sync header, control block type or O code field for 5 occurrences
OOM (Out-of-Multiframe)	Alarm	Two consecutive FlexE Overhead Frames with failure to the expected OMF bit transition although good CRC
GNM (Group Number Mismatch)	Configuration Alarm	Accepted group number does not match the Rx configured value.
INM (Instance Number Mismatch)	Configuration Alarm	Accepted FlexE 100G Instance number does not match the RX configured value
FMAPM (FlexE Map Mismatch)	Configuration Alarm	Accepted FlexE Map does not match the enabled PHYs.
CM (Calendar Mismatch)	Configuration Alarm	TX/RX calendar in use don't match.
CCM (Calendar Configuration Mismatch)	Configuration Alarm	"Accepted calendar" of the "Accepted calendar in use" is different from the configured" RX calendar" of the "RX calendar in use".
Synchronization Configuration Mismatch	Configuration Alarm	Synchronization Configuration bit mismatch
OH Block #1 Error	Error	Overhead anchor block error
CRC-16 Error	Error	CRC-16 to protect FlexE overhead. FlexE Map values are only accepted from overhead frames with good CRC.
C-Bit Error	Error	3 C-Bit in majority vote define the Calendar in Use.

ONT FlexE Test Application

FlexE HISTORY

OIF FlexE IA Version	Date	Key Features / Changes
FlexE-01.0	Mar-16	• 100GBASE-R PHY • Calendar with 5G granularity
FlexE-01.1	Jun-17	• Introduction of LLDP for shim-to-shim management channel to verify connectivity of the FlexE PHYs between FlexE Shims or in the section management channel to verify connectivity of PHYs between a router and transport equipment in a FlexE aware network configuration. • Test Vectors for the overhead format • FlexE mux timer for calendar change request
FlexE-02.0	Jun-18	• 200GBASE-R and 400GBASE-R PHY in addition to 100GBASE-R • Nomenclature update – 100G FlexE Instance Number and FlexE Map • Unequipped 100G FlexE Instances • Coarser calendar granularity: 25G as applicable for use case • Optional Synchronization Messaging Channel • Refined definition for LLDP (Link Layer Discovery Protocol)
FlexE 02.1	Jul-19	• 50GBASE-R PHY in addition to 100GBASE-R PHY, 200GBASE-R PHY, 400GBASE-R PHY

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