400G TECHNICAL POSTER

400G/200G Ethernet

Ethernet frame format and rates

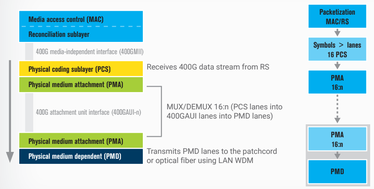
Packetized data

Ethernet interface	Line rate
400G Ethernet	425 Gbit/s

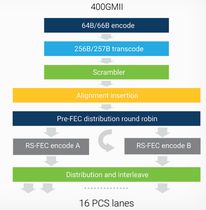
IEEE 802.3bs highlights

- Support a MAC data rate of 200 Gbit/s
- Support a MAC data rate of 400 Gbit/s
- Use of FEC is mandatory (544,514)
- Preserve minimum and maximum frame size
- Include Energy Efficient Ethernet (EEE)
- Provide BER < 10-13 at MAC layer

400GE packet transmission



PCS layer full chain



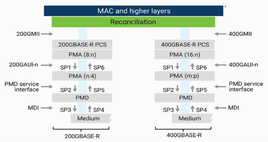
PCS lane skew

- Skew is the difference between the times of the earliest PCS lane and latest PCS lane for the 1 to 0 transition of the alignment marker sync bits.
- Skew variation may be introduced due to electrical, thermal or environmental variations.

Skew points	Maximum skew (ns) [a]	Maximum skew for 200GBASE-R or 400GBASE-R PCS lane (UI) [b]
SP1	29	≈ 770
SP2	43	≈ 1142
SP3	54	≈ 1434
SP4	134	≈ 3559
SP5	145	≈ 3852
SP6	160	≈ 4250
At PCS receive	180	≈ 4781

Notes
a. Skew limit includes 1 ns allowance for PCB traces that are associated with the skew points.
b. The symbol ≈ indicates approximate equivalent of maximum skew in UI, based on 1 UI equals 37.64706 ps at PCS lane signaling rate of 26.5625 GBd.

Maximum skew and skew variation at physically instantiated interfaces are specified at skew points SP1, SP2 and SP3 for the transmit direction and SP4, SP5 and SP6 for the receive direction.



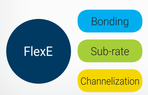
* Source: 802.3bs-2017, IEEE Standard for Ethernet

Legend	
200GAUI-n	200 Gbit/s attachment unit interface
200GMII	200 Gbit/s media-independent interface
400GAUI-n	200 Gbit/s media-independent interface
400GMII	400 Gbit/s media-independent interface
MAC	Media access control
MDI	Medium-dependent interface
PCS	Physical coding sublayer
PMA	Physical medium attachement
PMD	Physical medium dependent
n	8 or 4
m	16 or 8
p	16, 8 or 4

FlexE (Flex Ethernet)

FlexE capabilities

- FlexE Version 1.0 is an implementation agreement published by the Optical Interworking Forum (OIF)
- It is a generic mechanism that enables the support of a multitude of Ethernet MAC rates that may or may not correspond to an actual Ethernet PHY rate.
- It provides a flexible physical mapping structure to transport different Ethernet rates.
- It is the alternative to other aggregation protocols in layer 3.
- FlexE provides easy integration for future Ethernet rates.



- Creates high capacity data pipes by aggregating several Ethernet PHYs to transport MAC rates greater than 100G
- An action that allows network elements to sub-divide physical interfaces in order to transport lower data pipes over partially filled Ethernet PHYs
- Provides network elements with the capability to create specific transport channels for multiple data pipes through associated Ethernet PHYs, on the same or even different directions

FlexE general structure

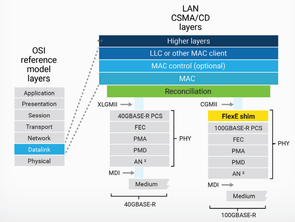
The FlexE group is composed from 1 to n bonded Ethernet PHYs.
- The version 1.0 of FlexE supports only 100GBASE-R PHYs
- Higher rates are intended to be added once available

The FlexE client is an Ethernet flow based on a MAC data rate that may or may not correspond to an existing Ethernet PHY rate.
- The FlexE client MAC rates supported are 10, 40 and $n \times 25G$

The FlexE shim is the layer that maps and demaps the FlexE clients transported over a FlexE group.
- The MUX operates in the transmit direction
- The DEMUX operates in the receive direction

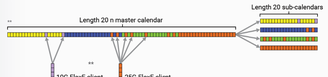
FlexE shim layer

The FlexE shim maps or demaps the FlexE clients carried over a FlexE group. The FlexE shim layer is located in the middle of the PCS in the 100GBASE-R.



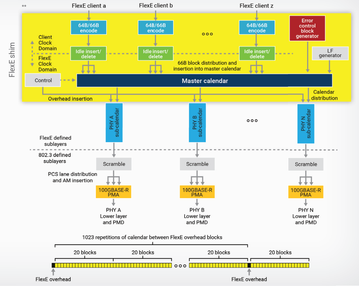
FlexE calendar

- FlexE uses a calendar that assigns 66B block positions on sub-calendars for each PHY that belongs to the group, for each FlexE client. The calendar granularity is 5G, and the length is 20 slots per 100G of group capacity.
- Each client is assigned to a particular place in the master calendar, somewhat similar to how it is done with transport, where a tributary is assigned to a higher-order frame. Clients are inserted in the master calendar in terms of 64/66 blocks.



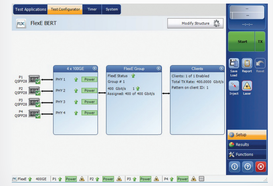
- The steam of 64/66 blocks of each PHY (100G in our case) is then distributed to the PCS lanes of that PHY, along with the insertion of alignment markers.
- The PCS lanes are then presented to the PMA the same way as regular 100G PHYs.
- If 802.3bj FEC is used, these 64/66 blocks are transcoded to 256/257 and FEC encoded.

** Source: OIF-FLEXE-01.0, Flex Ethernet, Implementation Agreement, Optical, Internetworking Forum (OIF)



FlexE BERT

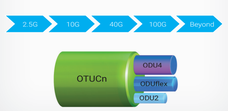
Our FTBx-88460NGE Power Blazer 400G multiservice tester is the most compact solution on the market and includes basic and advance capabilities for lab and field implementations, including our Flex BERT application.



OTUCn/FlexO

OTN evolution

- ITU G.709 was adapted in 2016 with the addition of Y.1331 "OTUCn"
- OTUCn, the "C" corresponds to the roman numeral for 100
- OTUCn associates PHYs thru FlexO (almost like FlexE)
- The objective of OTN beyond 100G technology is to provide a long term evolution of an OTN protocol that can carry, in a flexible manner, payloads demanding bandwidth above 100 Gbit/s—such as 200GE, 400GE and FlexE



OTUCn highlights

The OTUCn signal is made of the same classical OTN constituents but adapted to handle a concept of "slice interleaving" similar to SONET/SDH that is used to increase the transport capacity.

OTUCn functionality involves the following:

- Client mapping in ODUk
- Mapping ODUk containers in the OPUCn payload area
- Overhead generation and extraction

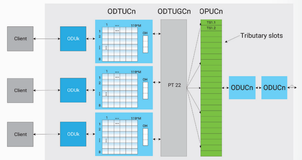
A basic frame structure with 100 Gbit/s capacity is defined and referred to as OTUC

The payload area is a contiguous container made of tributary slots, these are part of the OPUCn

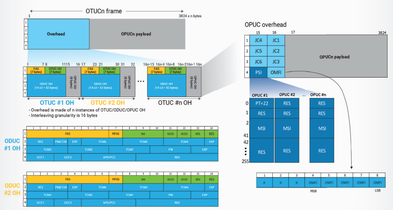
FEC is not part of the basic frame since there will be different interface types (e.g., 100G, 200G, SR, LR) to carry the OTUCn and each interface will have its own requirements in terms of strength of FEC required

There are 20 tributary slots entities per OTUC slice

- Tributary Slot rate: 5.24089 Gbit/s, granularity 16 bytes



OTUCn frame structure



Flexible OTN (FlexO) highlights

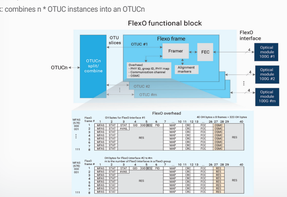
FlexO is an adaptation layer which provides a flexible, modular mechanism to support different line rates beyond 100G signals.

FlexO enables a set of n 100 Gbit/s PHYs to be bound together to carry an OTUCn, with each 100 Gbit/s PHY carrying an OTUC slice.

FlexO provides frame alignment, deskew, group management and a management communication channel.

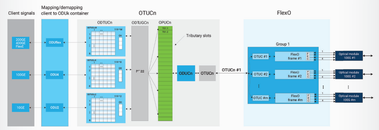
FlexO processes an OTUCn signal as follows:

- Source: splits the OTUCn frame into n * OTUC slices
- Sink: combines n * OTUC instances into an OTUCn



OTUCn/FlexO signal flow

Figure below includes all structures together and depicts signal flow from the client signal to the optical module.



FlexO BERT

EXFO's FTBx-88460 multiservice test solution supports advanced capabilities. Ready for lab and field implementations, it covers the complete 400G ecosystem, and includes our FlexO BERT application.

400G/200G interfaces and pluggable transceivers

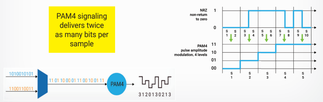
Physical-layer specifications

IEEE 802.3bs standard provides physical-layer specifications that support:

Physical characteristics	Optical interfaces	PCS lanes	Optical lanes	Modulation	Rate
100 m over MMF	400GBASE-SR16	16	16	NRZ	26.5625 Gbit/s
2 km over SMF	400GBASE-FR8	16	8	PAM4	53.125 Gbit/s
10 km over SMF	400GBASE-LR8	16	8	PAM4	53.125 Gbit/s
500 m over MMF	400GBASE-DR4	16	4	PAM4	106.25 Gbit/s
2k over SMF	400GBASE-FR4	16	4	PAM4	106.25 Gbit/s

New modulation schemes

New modulation schemes allow the transporting of more data in the same transceiver form factors



PAM4 Challenges

The complexity of the new modulation(PAM4) on 400G technologies bring a new set of testing challenges to the Lab. Technicians require solutions on a single tester that help them manipulate the transmission signal and receiving signal.

Its important to have solutions that help user to manipulate and monitor the following parameters:

- Pre-Emphasis
- RX- Equalization
- PAM4 Histogram

Interfaces

QSFP-DD
- Support for 200G-400G rates
- High port density
- Still technical challenges to solve

OSFP
- Supports 400G and 800G
- High thermal capability
- Accommodates full range of optics

DAC
- Designed for short distances, typically less than 5 m
- Low power consumption
- Low cost

CFP8
- Electrical interface supports both 400GAUI-8 and 400GAUI-16
- Form factor is approximately the same size as CFP2

EXFO solutions

Test in the lab, field or on the production floor

400G Ethernet & multiservice test solution

FTBx-88400NGE Power Blazer

FTBx-88460 Power Blazer

iOptics: 400G ecosystem pluggable optics and cable validation

Open Transceiver System (OTS): supports today's and tomorrow's optical interfaces

EXFO

400G
TECHNICAL POSTER

EXFO

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