Advances in Beyond-400G Optical Transport Network Standards and Technologies

Tom Huber

Optical Networking Standards

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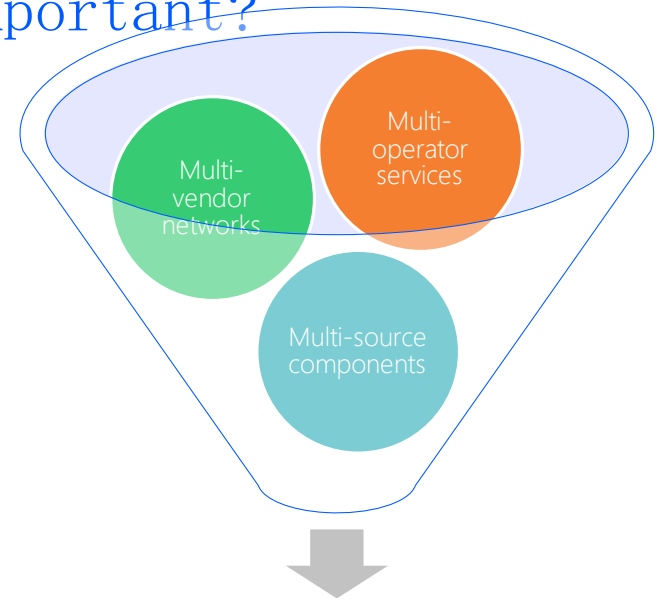
Why are transport network standards important?



Interoperability

- Service networks are interconnected over transport networks
- Transport network standards enable services to be carried over multi-operator networks
- Transport network standards enable operators to build multi-vendor networks
- Transport network standards enable vendors to multi-source components

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Technologies that enable Beyond-400G transport

Optical

- Coherent transmission and higher order modulation
- High bandwidth electro-optical components

100110101
101000111
101001111
001010110

Digital

- Improved DSPs (PCS, FEC)
- High baud rate ADC/DAC

Fiber

- New designs and architectures

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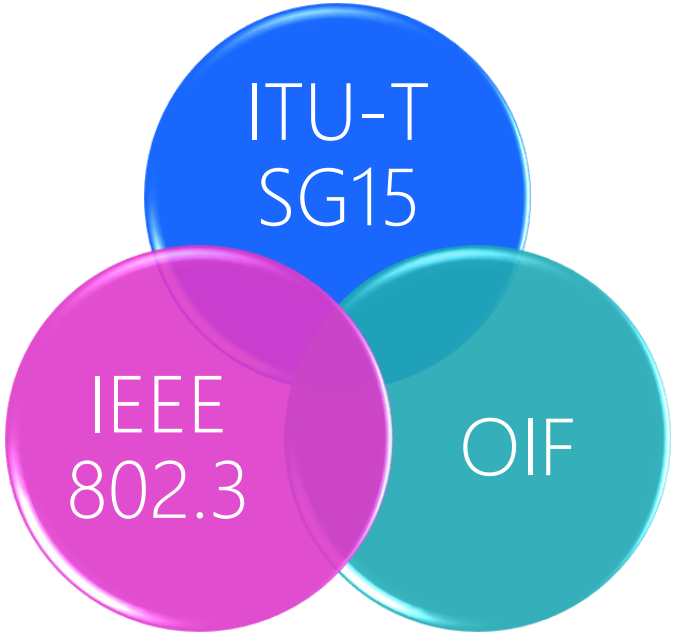
Main organizations developing optical transport Standards

Physical layer



- ITU-T SG15 – Optical Transport Network (OTN)
  - Specifies transport network architecture, digital formats for OTN, optical parameters, fiber
  - Includes metro and long-haul applications, with a focus on transparent multi-client support and networking (non-p2p)
- OIF
  - "ZR" interfaces supporting p2p DCI interconnect of Ethernet over DWDM at 400G and 800G rates
- IEEE 802.3 – Ethernet
  - Specifies Ethernet Physical layer (inherently p2p)
  - 802.1 defines Ethernet networking
- Other MSAs drive specific projects
  - OpenROADM, OpenZR+, Ethernet Technology Consortium, etc.

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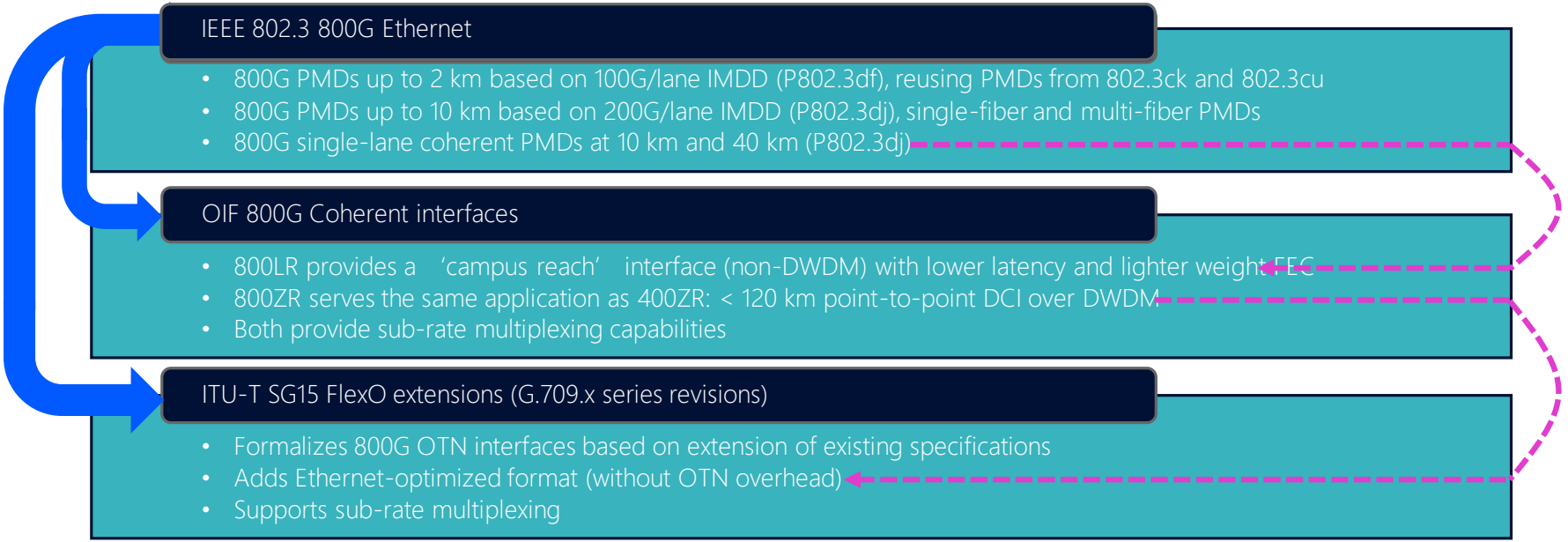
Current standards work for 800G interfaces

Significant collaboration across the main SDOs



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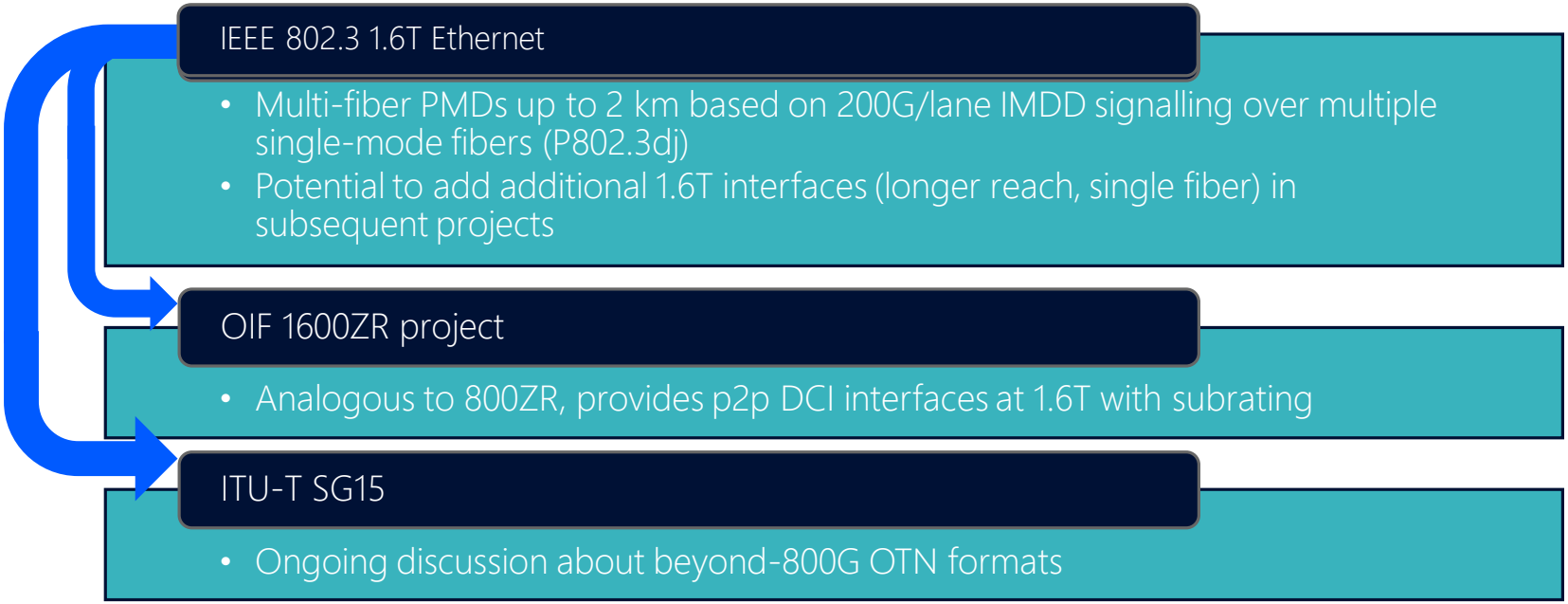
Current standards work for 1.6T interfaces



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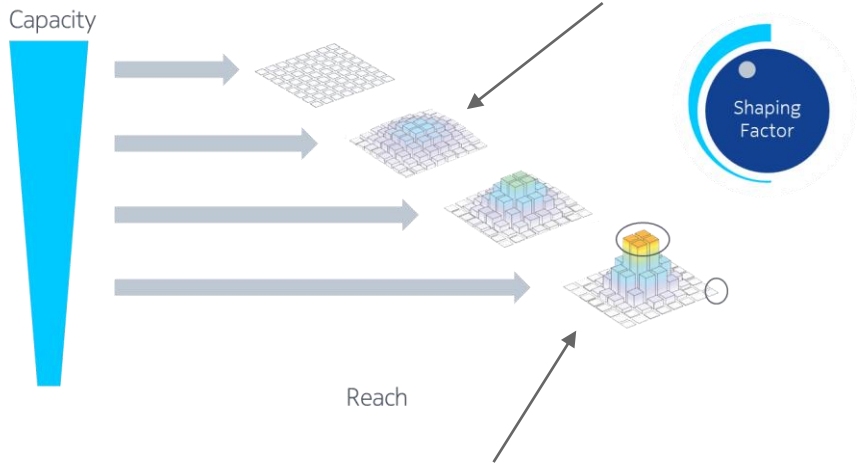
Future standardization topics

Probabilistic Constellation Shaping (PCS)

- Problems to be solved:
  - Inefficient use of bandwidth due to discrete steps between xQAM modulation constellations
  - Higher order modulation (beyond 16QAM) requires complex receiver designs to overcome OSNR, particularly at the outer constellation points
- PCS allows finer grained tuning between reach and bandwidth than what is possible with discrete constellations
  - Proprietary solutions available now
  - Discussion of potential standard solutions well underway in OpenROADM, beginning in ITU-T SG15

2-dimensional Gaussian probability distribution of how frequently different symbol values are used decreases average bits represented per symbol



Using the outer (highest power) constellation points less frequently improves OSNR

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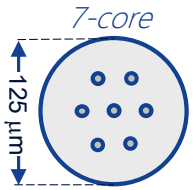
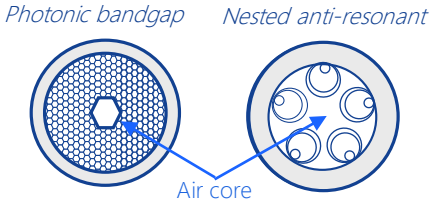
Future standardization topics

Space Division Multiplexing (SDM)

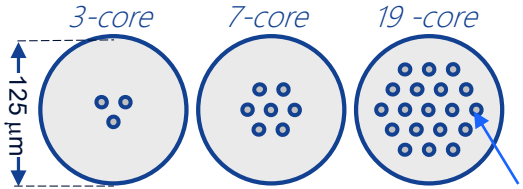
Uncoupled-Core Multicore Fibers (UC-MCF)



Hollow-Core Fibers (HCF)



Coupled-Core Multicore Fibers (CC-MCF)



Optical mux/demux coupled into each core

- Problem statement: Increasing bit rate without increasing spectral efficiency doesn’ t increase capacity per fiber
- SDM is effectively parallel reuse of the same spectrum within a single fiber
  - Requires new multi-core fibers and greater integration within components to take advantage of the new fiber types
- Standardization activities are in the very early stages, and will focus primarily on the fiber and components initially
  - New management/control models will also be required

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Future standardization topics

1.6T and beyond – many technical challenges

Will coherent transmission be required for all reaches?

- Unclear that IMDD is viable beyond 200 Gb/s signaling rates
- Unclear that more than 4 wavelengths of CWDM would work even with 200 Gb/s signaling

Is 16QAM single carrier transmission still viable?

- Going to multiple carriers or larger channel bandwidth with higher baud rate requires additional spectrum
- Going to higher order modulation has its own complexities

Are higher coding gain FECs needed?

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