Tom Huber
Vice Chair WP3/15 | Nokia, USA

Tom Huber is Vice Chair of ITU-T SG15, Networks, technologies and infrastructures for transport, access and home, and Vice Chair of ITU-T WP3/15, Transport network characteristics. He is also PLL-Protocol Vice Chair in the Optical Internetworking Forum and a member of the editorial team for IEEE P802.3dj. He was previously Rapporteur of ITU-T Q9/15 from 2013-2018, Associate Rapporteur of ITU-T Q11/15 from 2018-2022, and has served as editor of several ITU-T Recommendations. He began working in telecommunications more than 30 years ago at Tellabs and is currently part of the standards team for the optical business unit of Nokia. He has been involved in standards development for more than 20 years. Tom holds a B.S. in Electrical and Computer Engineering from the University of Notre Dame and an M.S. in Computer Engineering from the Illinois Institute of Technology.

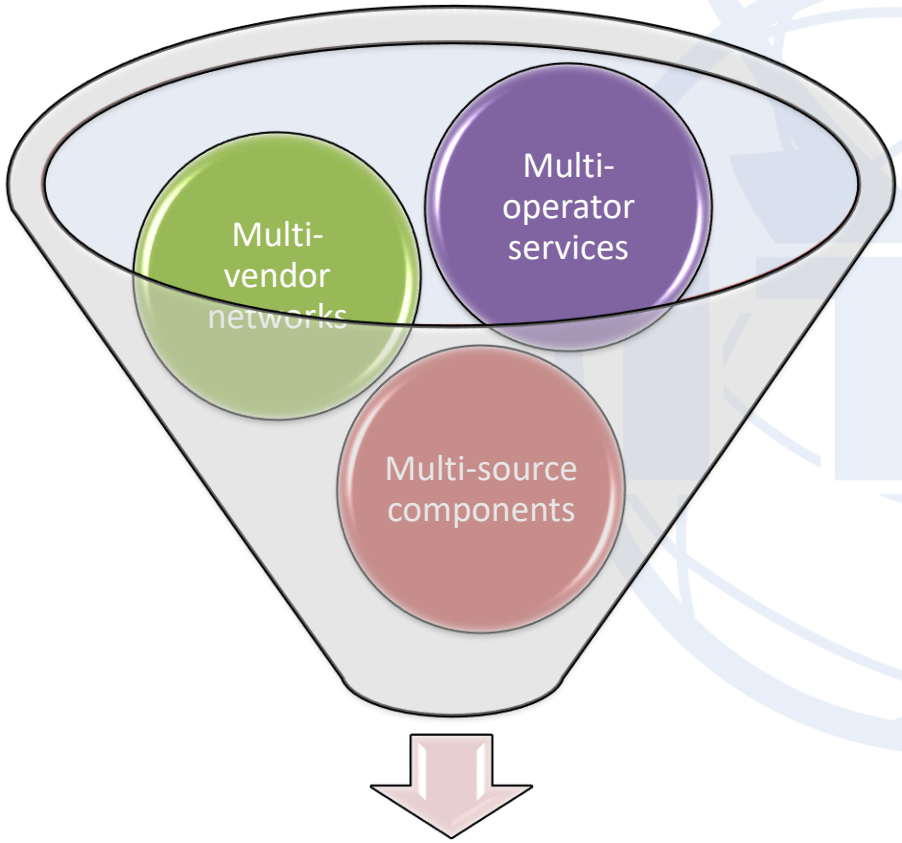
ITU Workshop on “Evolution of Optical Networks for IMT2030 and Beyond”

Charles K. Kao Auditorium, Hong Kong Science and Technology Park (HKSTP)
20 November 2024, 15:00 - 18:00

Beyond 1 Tb/s networking and standards

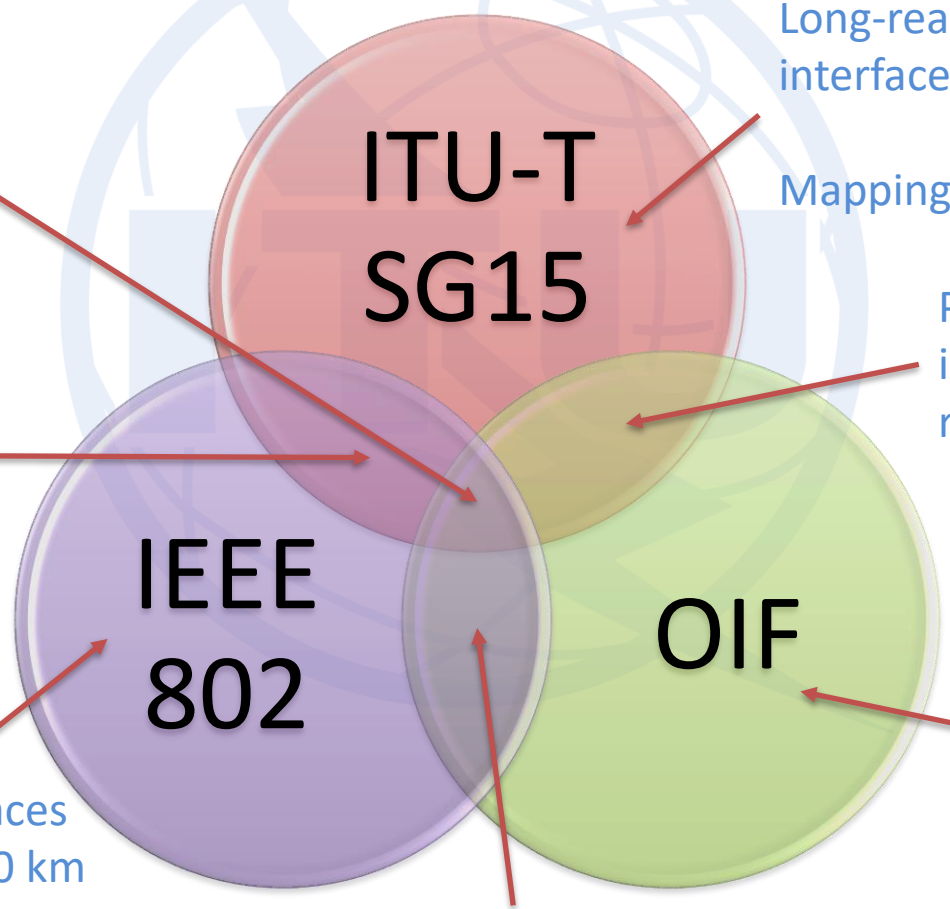
Tom Huber
Nokia USA

Value of transport network standards



- 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

Standards landscape



Long-reach and short-reach FlexO-x and ODU interfaces with L1 networking capabilities

Mapping Ethernet into OTN

FlexO-xe frame format and associated FEC and DSP frames

Point-to-point coherent Ethernet interfaces over DWDM systems with regeneration based on FlexO-xe

Networking
SG15: L0 and L1
802.1: L2

Point-to-point coherent Ethernet interfaces over DWDM systems, 80-120 km reach (using FlexO-xe formats)

802.3: Point-to-point Ethernet interfaces (non-coherent, non-DWDM), up to 40 km

Point-to-point coherent Ethernet interfaces (non-DWDM systems)

Successful collaboration at 800G

OIF and Q11 developed the frame formats used for 800G coherent interfaces with reach longer than 10km, based on extending FlexO to 800G and adding direct mapping of Ethernet

- 802.3dj later adopted the same format for 800GBASE-ER1

Revision to G.652 to take a more statistical approach to chromatic dispersion penalties

Development of a transmitter quality metric for 800G coherent interfaces is ongoing across all 3 organizations

Collaboration continues at 1.6T…

OIF has launched three 1.6T coherent interface projects since August 2023:

- ZR is a single 1.6T client, traditional DCI application
- ZR+ adds client multiplexing and metro reach applications
- LR focuses on ~10 km applications and lighter-weight FEC

Q11 is extending FlexO-xe to support the OIF ZR and ZR+ applications

802.3 work on 1.6T is currently focused on < 2km interfaces with parallel fibers

- Future single fiber interfaces (with reach ≥ 2km) will likely be coherent and based on the OIF work (IMDD at 400G/lane will also be considered)

Introduction of new rates in transport networks

New line rates are introduced primarily as trunks, carrying a multiplex of lower speed client signals

- This can be via muxponders and/or L1 switches

New clients at the trunk rate are much less common, and are carried as ‘wavelength services’ initially, with regeneration and L0 switching as needed

- As such, path layers for these clients tend to appear only at the edge of the network initially
- Switching migrates to L1 when higher trunk rates are introduced

This is reflected in the standards development – p2p interfaces tend to lead

Enabling technologies for beyond-1T networks

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

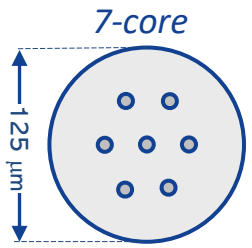
- New designs and architectures

Key technologies: Probabilistic constellation shaping

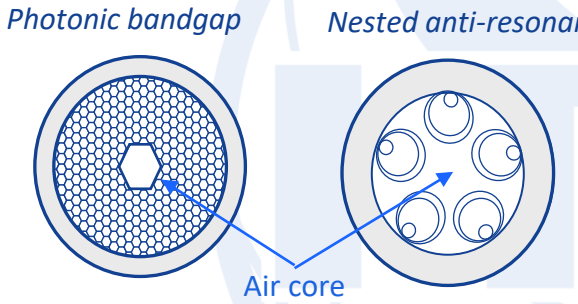
- Increasing link rates requires either larger channels or higher order modulation (beyond 16QAM)
  - Using larger channels reduces the number of wavelengths per fiber (not desirable)
  - Using higher order modulation requires complex receiver designs to overcome OSNR, especially at the outer constellation points (not desirable)
- Probabilistic constellation shaping (PCS) has proven to be a valuable tool for fine-tuning the reach-bandwidth tradeoff with 16QAM (and would be used with higher order modulation also to mitigate the difficulties with using the outer constellation points)
- Up to 800G, it was possible to close many 16QAM links without PCS, so most existing PCS solutions are proprietary
  - OpenROADM MSA includes a PCS specification for a limited number of use cases at 800G and 600G
- At 1.6T, closing links without PCS is more difficult, and a standard PCS will be required to enable multivendor links with suitable performance
  - OIF is evaluating multiple options (including the OpenROADM approach) in the 1600ZR+ project

Key technologies:
Space division multiplexing

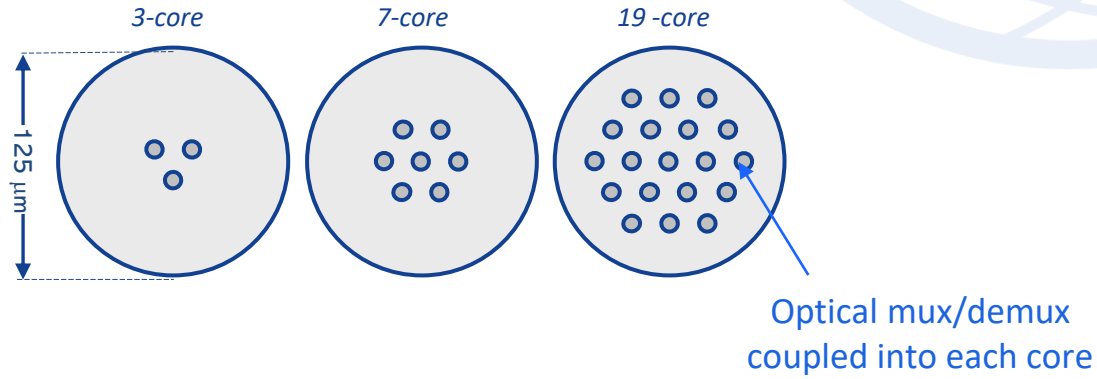
Uncoupled-Core Multicore Fibers (UC-MCF)



Hollow-Core Fibers (HCF)



Coupled-Core Multicore Fibers (CC-MCF)



- Problem statement: Increasing bit rate without increasing spectral efficiency doesn't increase capacity per fiber
- Extending the C band, or using C+L band, is a stopgap solution
- 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

Thank you !