Optical Networks toward 2030
Webinar #1

Moderators: David Hillerkuss and Xiang Liu
April 24, 2024, 9:00-10:00am EST
About ON2030

New bi-monthly webinar series, "Optical Networks toward 2030 (ON2030)"

The webinar strives to provide an overview of the most important topics in our industry.

Key experts explore next generation technologies, including critical aspects such as

- energy efficiency,
- reliability,
- sustainability,
- efficient ecosystem scaling,
- and future-proof solutions.

Update on key advances in international optical network standards (ITU-T, IEEE, OIF and BBF etc.)

Join this series to stay up to date with latest developments and highlights.

See the website for regular updates and future instances:

https://www.optica.org/membership/member_programs/optical_networks_toward_2030/
Agenda

Optical Industry Highlights
• David Hillerkuss – Infinera
• Xiang Liu – Huawei

High-Speed Inter-Data-Center Optics, (400G/800G/1.6T ZR/ZR+)
• Paul Doolan – Infinera
• Ian Betty – Ciena
• Tom Williams – Cisco
• Jeff Rahn – Meta
• Q&A / Panel Discussion
Highlights in our Industry

1. Hollow Core Fibers with a record low loss of 0.11 dB/km (OFC2024 PDP)
2. AI for optics, optics for AI, and optics+AI
3. CPO, LPO, and half-LPO for energy-efficient connections
4. 400Gb/s pluggable transceivers enabling the AI wave in intra-data-center connections
5. 1.6Tb/s ZR/ZR+ standardization started in OIF for inter-data-center connections
6. High symbol rate long-haul coherent transmission for 1.6Tb/s and beyond
7. P2MP any-rate (XR) optics being deployed for metro aggregation networks
8. The debate between IM/DD and coherent extended to next-generation PON beyond 50Gb/s
9. Distributed fiber sensing transitioning from research to standardization (OFC2024 workshop organized by ETSI ISG-F5G)
10. ITU-T SG15 envisioning the evolution of optical transport networks to support IMT2030 (OFC2024 workshop organized by ITU-T)
At the recent OFC, a way to achieve lower propagation loss than fundamentally achievable with silica-core telecoms fibres was demonstrated using a HOLLOW CORE fibre.

**Source:** Francesco Poletti OFC 2024, PDP Th4A.8
HCFs: ultralow attenuation... anywhere

Potential to **open new communication windows** away from telecoms C-band, where technology convergence can allow cost reduction and system performance improvements

**Source:** Francesco Poletti OFC 2024, PDP Th4A.8
HCFs: additional appealing properties and optical advantages

A disruptive technology for all photonics applications

Source: Francesco Poletti, Microsoft
Developing Implementation Agreements

Paul Doolan

04/24/2024
Disclaimer

• Not speaking for OIF
• Not speaking for Infinera
• Can’t talk about WIP
Fremont, Calif.—September 8, 2023 – OIF concluded its hybrid Q3 Technical and MA&E Committees Meeting, August 8-10 in Vancouver, BC, Canada, with the launch of four groundbreaking new projects.

1600ZR Project
The 1600ZR project will define a power optimized solution for a multi-vendor interoperable 1600 Gbps coherent optical interface, with a focus on Data Center Interconnect (DCI) scenarios. This Implementation Agreement (IA) will create a comprehensive electrical/protocol/optical framework that facilitates realization into pluggable modules. It will also establish a reference point for additional applications that contribute to the growth of the coherent ecosystem.

..............

This project further validates that OIF is the platform for next-generation coherent line interface discussions and to facilitate the development of innovative applications and architectural solutions. We encourage network operators to actively participate in these efforts to help shape the specifications to best meet their needs.”
Getting to an IA

Q3/2023
Some data points

<table>
<thead>
<tr>
<th>IA</th>
<th>Start</th>
<th>Published</th>
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<tbody>
<tr>
<td>400G ZR</td>
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<tr>
<td>800G ZR</td>
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<td>1600G ZR</td>
<td>Q4 2023</td>
<td>TBD</td>
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Key sections of 400G ZR digital spec

8. Host to ZR data path
9. Adaptation
10. FEC
11. Symbol mapping
12. DSP framing
Final thoughts

• Editors work for the group
  – Under direction of chair
  – Create drafts based on proposals (accepted contributions)

• Converging on big ticket items requires specific proposals
  – Architecture, digital spec, optics

• I’m optimistic my workload is going to increase soon
Coherent Optics Unleashed

ON2030 Webinar #1
High-speed inter-data-center optics (400G/800G/1.6T ZR/ZR+)

Ian Betty
Senior Director– WaveLogic Technologies
April 24th 2024
OIF Scope is Expanding

OIF is expanding its scope
Defining coherent interfaces for “LR” 10km – Data center campus, service provider edge
Defining coherent interfaces for “ZR+” 1000km – Metro/Long-haul point-to-point Ethernet
OIF complementing other forums
800ZR and 800LR Update

- **Combined Project start**: 2020 Q4
- **First 800ZR digital baseline**: 2022 Q2
- **First 800LR digital baseline**: 2023 Q1
- **800ZR optical details**: 2024 Q1
- **800LR optical details**: 2024 Q2

**Expected completion in 2024**

**800ZR covers more than DCI use case**
- Client muxing (100GE-800GE support)
- High performance soft-decision OFEC (2% CBER)
- Various optical power ranges (including -2dBm)
- DWDM
- 800ZR similar to OpenZR+/OpenROADM 400G

**800LR is fit-for-purpose technology**
- Low power/latency concatenated FEC (1.1% CBER)
- Synchronous clients
- O-band and C-band applications
- Higher loss budget (8dB)
1600ZR and 1600ZR+ Update

1600ZR DCI application
- Single amplified span
- Single laser for FITS considerations
- 300GHz spacing, C-Band.
- Equivalent 400ZR link budgets (<120km)
  - Proposing modem RSNR target = ~18.5dB
  - Enable 400ZR backwards compatible implementations

1600ZR+ metro/long-haul application
- Multiple amplified span
- 300GHz spacing, C and L Band.
- Equivalent 800G ZR+ link budgets (<1000km)
  - Proposing modem RSNR target = ~13.7dB
  - Enable 800G ZR+ backwards compatible implementations

Requested completion in 2026
1600ZR and 1600ZR+ Exploration

1600ZR Project Start:
Create IA to define 1.6Tbps coherent line interfaces. Single-lambda, single carrier, and 16QAM modulation is preferred for power consumption, FIT rate and interoperability considerations.

Modulation tradeoffs

- **1600ZR** 16QAM CFEC results in ~238Gbaud
- PCS-64QAM can reduce baud 236GBd → 200GBd
- **1600ZR+** PCS-16QAM + OFEC results in ~262Gbaud
- PCS-64QAM can reduce baud 262GBd → 245GBd

Tradeoffs of FEC complexity vs aggregate baud vs power

- ~15% OH with CBER at 2% (e.g. OFEC) – 800ZR
- ~15% OH with CBER at 1.2% (e.g. CFEC) – 400ZR
- ~20% OH with CBER at 1.1% (e.g. KP4+BCH2) – 800LR

FDM considerations and Interop benefits

- Clock recovery penalty
- Implementation penalty
- Lower CD compensation power

Discussion on technology options and tradeoffs to meet application requirements underway
Coherent Ethernet from LR to ZR

The industry should consider different technology bundling options
- ZR and ZR+ with ZR+ being incremental power and performance
- LR and ZR covering all applications in between including ER and ER-20

LR has the right required OSNR for ZR applications
- LR and ZR are deployed as pluggable modules in routers
- Synchronous Ethernet clients, no framing overhead required

<table>
<thead>
<tr>
<th></th>
<th>2km DR+/FR</th>
<th>10km LR</th>
<th>20km ER-20</th>
<th>40km ER</th>
<th>80-120km ZR</th>
<th>Up to 1000km ZR+</th>
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<td>800G OR+/ZR+ (PCS-QAM)</td>
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Take Aways

- OIF is a leading-edge forum for interoperable coherent interfaces and is expanding its scope.
- 800G is in final stages of definition.
- 1.6T is starting.
- OIF is exploring landscape of 1.6T technical solutions.
Thank You

ibetty@ciena.com
Evolution and Next Steps in Interoperable Coherent Interfaces

Tom Williams
Evolution of Coherent Interop Standards

Performance Improvements with each generation

- **100G**: QPSK HD-FEC (Staircase) Differential Encoding
- **400G**: 16QAM SD-FEC (CFEC/oFEC) Non-Differential Encoding
- **800G**: PCS
- **1600G**: ?

Router-based optics
Interoperable 400 Pluggables – A Success Story

- Early 400ZR project start
- Broad industry support
- Clearly defined objectives

- Higher performance
- Additional use cases
- Expand addressable market

400ZR triggered a fundamental change in the coherent transport market….and it’s not going back
## Interoperable Coherent Interfaces Summary

<table>
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<th>~60Gbaud</th>
<th>~120Gbaud</th>
<th>~240Gbaud</th>
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<td><strong>OIF</strong></td>
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<td>CFEC-16QAM</td>
<td>Ethernet Framing</td>
<td>800G Line Rate</td>
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<td>oFEC-nQAM</td>
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<td>600G &amp; 800G Line Rates</td>
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<td>200G, 300G &amp; 400G Line Rates</td>
<td>100GbE - 800GbE Clients</td>
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<td>400G(QPSK), 600G &amp; 800G Line Rates</td>
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<td>100G – 400G Clients</td>
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*Open ROADM has published interop PCS protocol for OTN and Ethernet framing*
1600G Standardization at OIF

• **1600ZR**  
  - Project start in Q3 2023  
  - Key Requirements  
    • 24dB span without optical protection switch  
    • 20dB with optical protection switch  
    • No mid-span amplification in either case  
    • Define max power consumption per module  
  - 224G PAM4 host signaling

• **1600ZR+**  
  - Project start in Q1 2024  
  - Key Requirements  
    • 1-2dB improved ROSNR compared to ZR enabling 1,000km reaches with RAMAN  
    • Support for 1200G mode  
    • Align key building blocks with 1600ZR where possible  
  - 224G PAM4 host signaling

**OIF defining both 1600ZR and 1600ZR+ enabling broad industry alignment**
Connecting at the speed of light
Applications for power efficient optics in Meta backbone network

ON2030 Webinar #1
High-speed inter-data-center optics (400G/800G/1.6T ZR/ZR+)
April 24, 2024

Jeff Rahn
Optical Engineer, Backbone & Edge Networks
Agenda

- Meta Global Network
- Power and Performance Considerations
- Application to Meta’s Network
Give people the power to build community and bring the world closer together

More than 3.98 Billion people using the Meta family of apps each month
North America Long Haul Network
IP Connectivity

Data Center

DC Metro

Backbone

Edge Metro

Subsea

Peerings

CLS
Optical Solutions Enabling IP Connectivity

**Current Solution**

- **Not distinct from backbone**
  - High-performance Transponders
  - Layer 0 switching via ROADM sites

- **Standalone Metro Transponders**
  - C-band point-to-point line system
IP + Optical Power Efficiency

- Power efficiency
  - L3 switch
  - Transponder
  - Line system w/ILAs

- Power efficiency worse with L3 regen
  - Optimum uses long paths
  - Wavelength switching

- ZR+ gives better power efficiency
  - Despite lower spectral efficiency

- ZR+ enables efficient L3 regen
  - Shorter, high-capacity links
  - Frequent IP grooming
  - Wavelength switching replaced with direct fiber routing

Power Efficiency for 1200 km link

Gen 6
IP + Optical Power Efficiency

- Power efficiency
  - L3 switch
  - Transponder
  - Line system w/ILAs

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Power Efficiency for 1200 km link

- Gen 6
- Gen 6, L3 Regen
- 800ZR+
- 800ZR+, L3...

Power Efficiency [PJ/BIT]
CDC node supporting Optical Express

Core Router

Transponder Pools

CDC Mux

Multiple racks

Example with 4 degrees

Gray optic connections to transponder pools

C-band CDC Interconnects

L-band CDC Interconnects

ROADM

1 rack
Node Simplification with ZR and P2P

Example with 4 degrees
## Meta Point-to-Point Optimized Line System

<table>
<thead>
<tr>
<th>Core Router</th>
<th>ZR+ Module</th>
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<td>ILA</td>
<td>Mux</td>
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- Raman
- L
- C

~100 km
Upgrade Process and Flexibility Required

Optical interface backward compatibility needed to modes deployed in volume in existing network
Optical Solutions Enabling IP Connectivity

Current Solution

- Not distinct from backbone
- New application
- 400ZR+, 800ZR+, 1600ZR+
- High-performance Transponders
- Layer 0 switching via ROADM sites
- C+L Band Transmission
- 400ZR+, 800ZR+, 1600ZR+ on shorter links
- P2P optimized line system
- Standalone Metro Transponders
- C-band point-to-point line system
- 400ZR, 1600ZR

Trend

- New application
- 400ZR+, 800ZR+, 1600ZR+
- C+L Band Transmission
- 400ZR+, 800ZR+, 1600ZR+ on shorter links
- P2P optimized line system
- 400ZR, 1600ZR
Generations of High-Performance Transponders

- **Gen 5**
  - 95+ Gbaud
  - 400-800G/ch

- **Gen 6**
  - ~200 Gbaud
  - 800-1600 Gbps/ch

- **400ZR**
  - 60 Gbaud

- **400ZR+**
  - 95+ Gbaud
  - 400-800G/ch

- **800ZR+**
  - ~130 Gbaud
  - 600/800 Gbps/ch

- **1600ZR+**
  - ~240 Gbaud
  - 1200/1600 Gbps/ch

**Specifications**

- **Gen 5**
  - 95G
  - 112.5G
  - 122.5G

- **400ZR**
  - 60G
  - 75G
  - 125G

- **400ZR+**
  - 75G
  - 65G
  - 60G

- **Gen 6**
  - 225G
  - 215G
  - 200G

- **800ZR+**
  - 130G
  - 140G
  - 130G

- **1600ZR+**
  - 240G
  - 290G
  - 300G
Summary: Enabling Network at Scale

• ZR optics are significantly more power efficient
• ... this enables new network architectures
  • Shorter reach optimized
  • Point-to-point line system with simplified mux

• Standardized optical modes critical for IP/Optical integration
  • Industry Ecosystem
  • Interop for operational efficiency
  • Network upgrades
Panel Discussion
Thank you