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The bridge to possible

Open Line Systems Innovations and Challenges

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BRKOPT-2014

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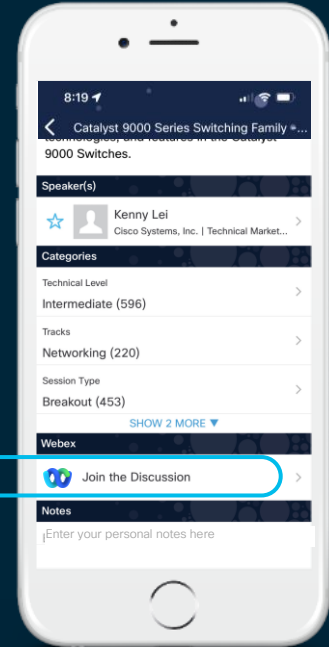
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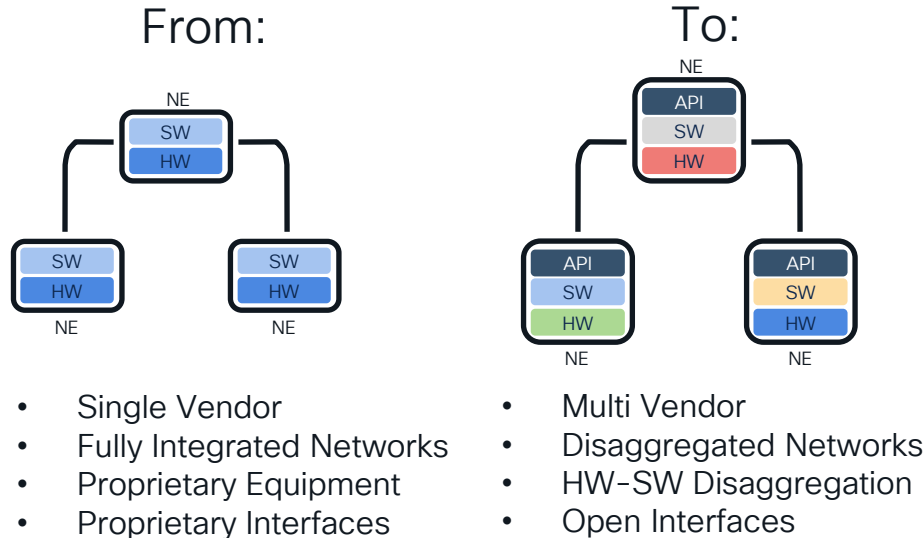
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Agenda

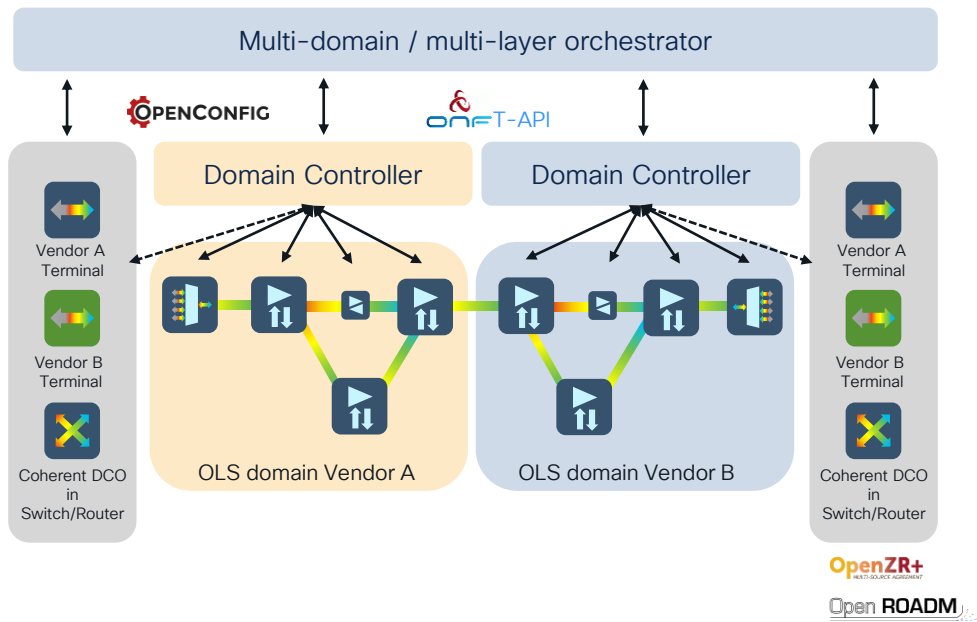
- Network Disaggregation
- Open Optical Networks
- Open Line Systems Challenges & Innovations
- Cisco's OLS Solution NCS 1010
- Conclusion

Why Disaggregating Networks?



- Improve network economics
- Accelerate innovation – each layer at its pace
- Facilitate swapping elements when better alternatives become available
- Build a more sustainable supply chain
- Increase competition
- Simplify Life-cycle management
- Reduce Total Cost of Ownership

Disaggregation in Optical Networks



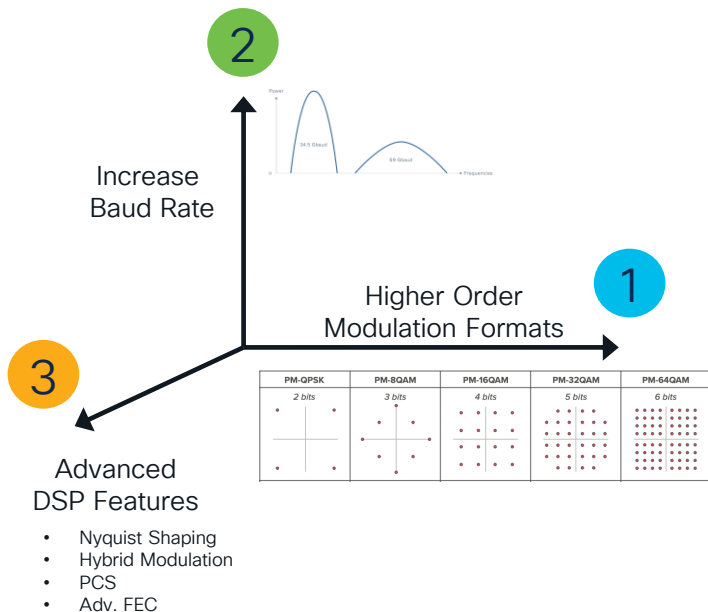
- Open Line System (OLS)
 - DWDM Network
 - ROADM Nodes: Add/drop, WSS
 - ILA Sites
- Terminals (Transponder/Muxponders)
 - Proprietary
 - Standardized interfaces, ie. Pluggables
- Control & Management
 - Device-level APIs for terminals
 - Network-level APIs to OLS Domain Controllers

Open Line Systems Innovations and Challenges

Open Line Systems Challenges

- Maximize Capacity Reach
- Increase Total Fiber Capacity
- Simplify Node and Network Operations
- Enable True Openness
- Improve Availability

Maximize Capacity-Reach



Advances in coherent technology have been **the** core technology driver in the past decade to increasing capacity of fiber optic systems.

Improvements along a few key axes, have enabled:

1. Increase the number of bits sent with each symbol (how many bits/symbol)
2. Increase the symbols sent using the same modulation (how many symbols/s)
3. Improve the performance, or noise tolerance, at a given capacity per wave

Bits, Bauds and Modulations

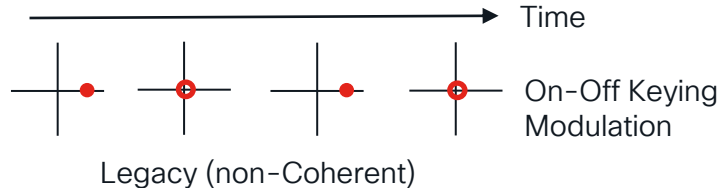
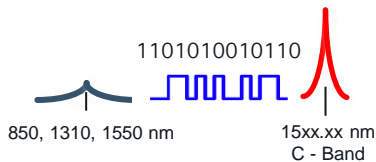
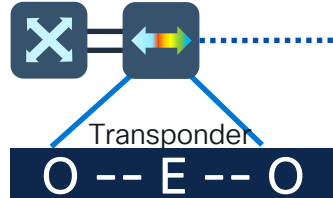
Baud Rate (aka Symbol Rate): How many symbols are transmitted per second. Defining symbol as a state or a significant condition of the communication channel that persists, for a fixed period of time

Modulation: How many bits I transmit per symbol

PM-QPSK	PM-8QAM	PM-16QAM	PM-32QAM	PM-64QAM
2 bits	3 bits	4 bits	5 bits	6 bits

Coherent

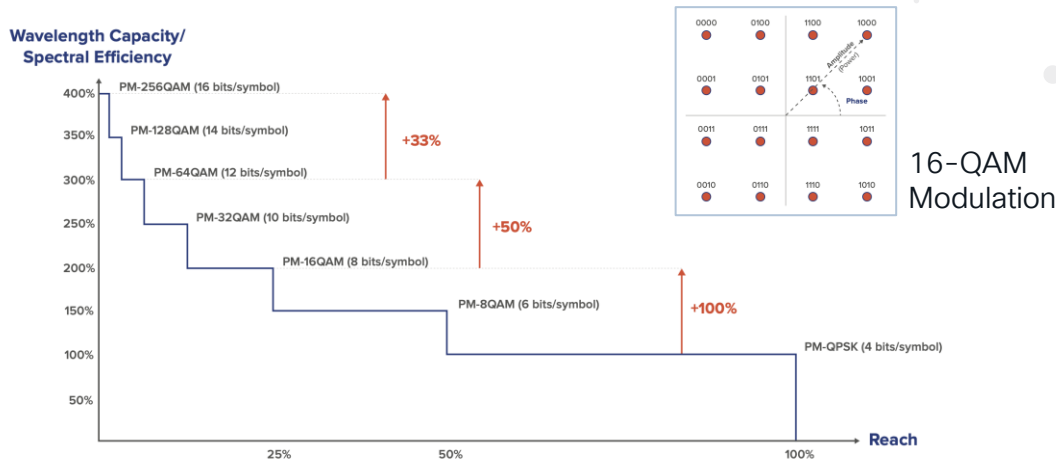
Fiber Optic



Baud Rate & Modulation Trade-offs

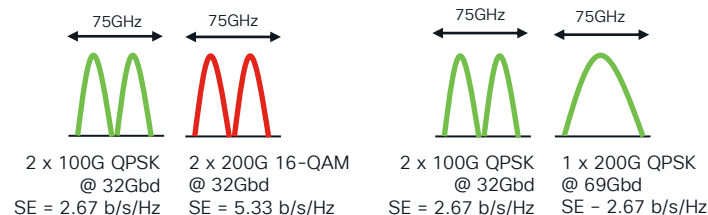
Modulation: Drives Reach

- Less points in the constellation = further apart they are. Thus, less sensitive to noise and fiber impairments = can reach longer distance.
- If desired distance is within reach for a given modulation, you get highest capacity, ie. spectral efficiency

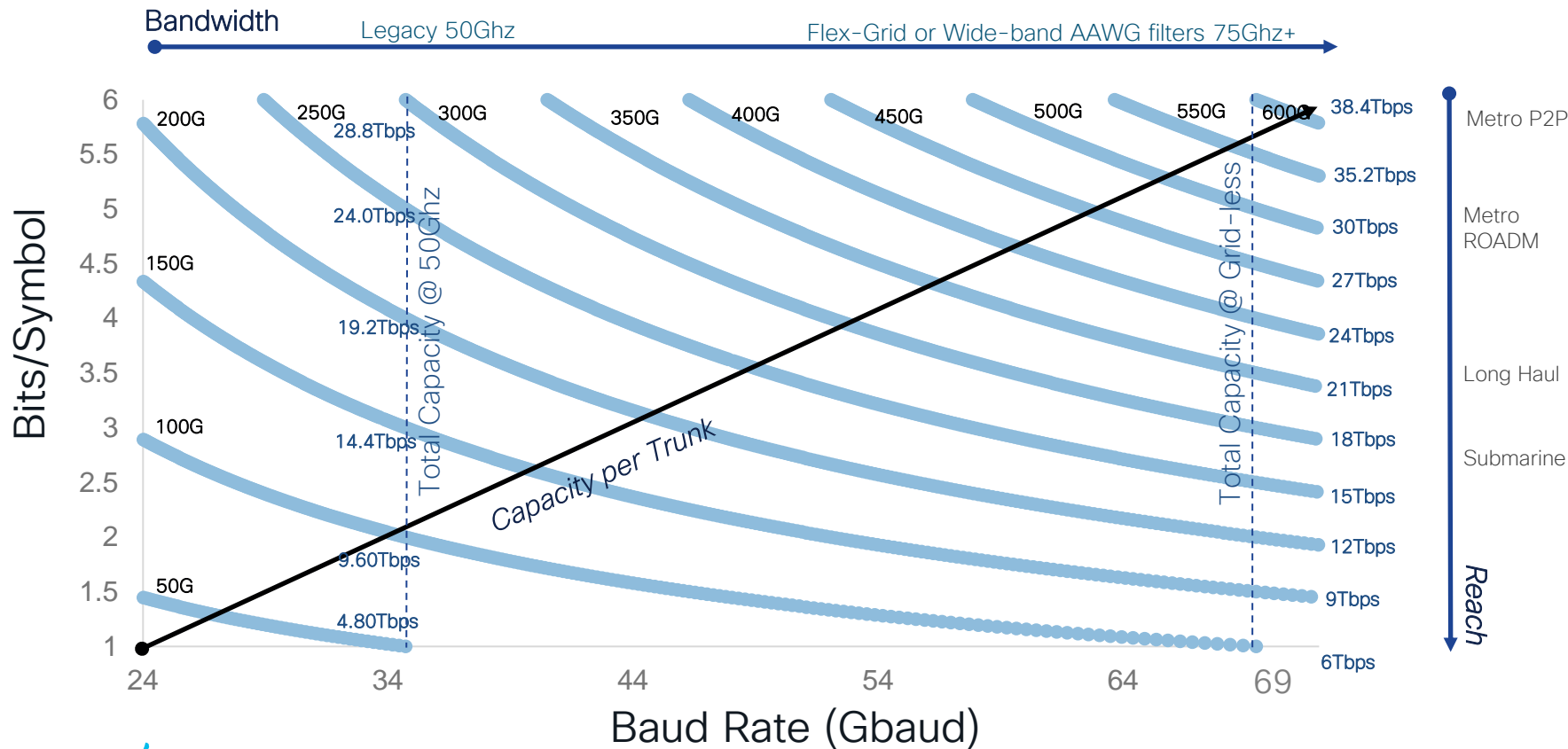


Baud Rate (aka Symbol Rate): Drives channel width

- Higher Baud Rate = Wider channel = Less number of channels in the same fiber. Less channels = Less transponders/DSPs → most expensive element
- As Baud Rate doubles, reach expects to lower 5-20%. Price paid for increase in reach vs higher modulations, is a loss in spectral efficiency

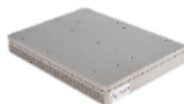


Hybrid Modulation = Baud Rate + Modulation Tuning



Coherent Interfaces Evolution

400G (32-34GB)



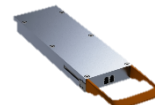
AC400

1200 (64-68GB)



AC1200

1.2T (128GB+)



CIM8

Performance
Optimized

ASICs

CMOS feature size



28nm



16nm



16nm



7nm



5nm



5nm

200G (45GB)



CFP2

400G(60GB)

400ZR/ZR+/BrightZR+



QSFP-DD

800G (120GB)

800ZR/ZR+/LR



QSFP-DD

Power
Optimized

True Multi-Haul Open Line System



800G Transponders

1T+ Transponders



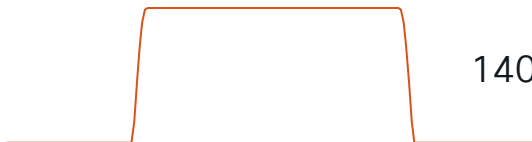
60GBd -10dBm



71.8GBd +3dBm



96GBd +3dBm

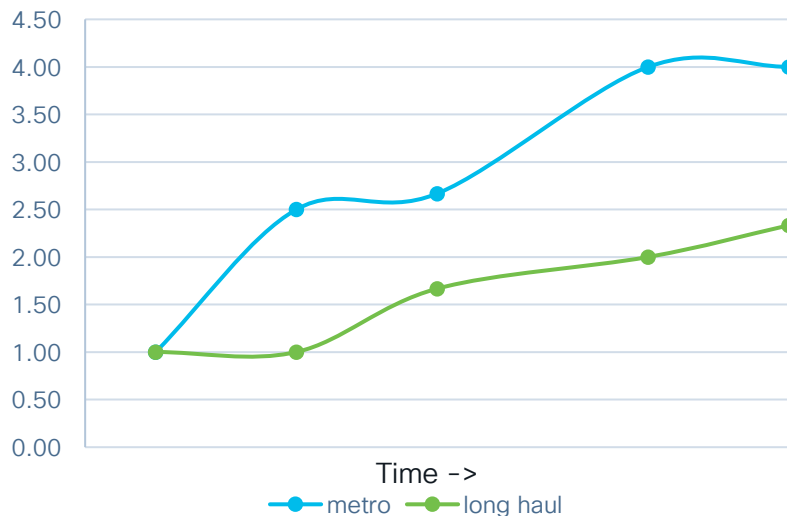


140GBd +6dBm

Line System
must be
ready to
handle a
wide variety
of coherent
sources

Fiber Capacity

Fiber capacity normalized over time



Long Haul capacity incremental with new DSP technology

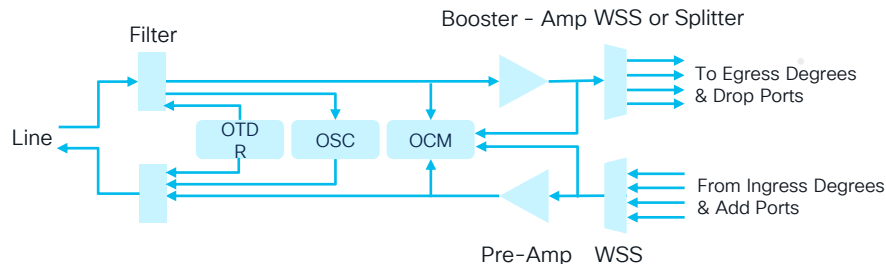
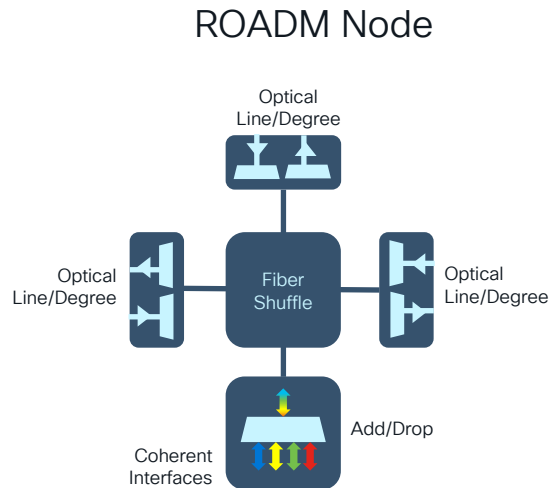
Band Expansion:

- C-Band 4.8THz → Super C-Band 6THz
- L-Band Upgrade → C+L 9.6THz

Capacity optimization with Routed Optical Networking:

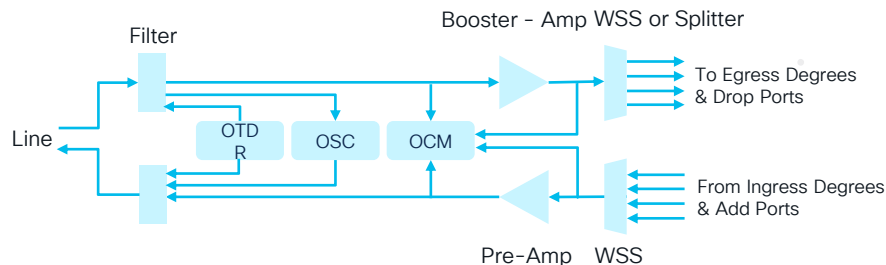
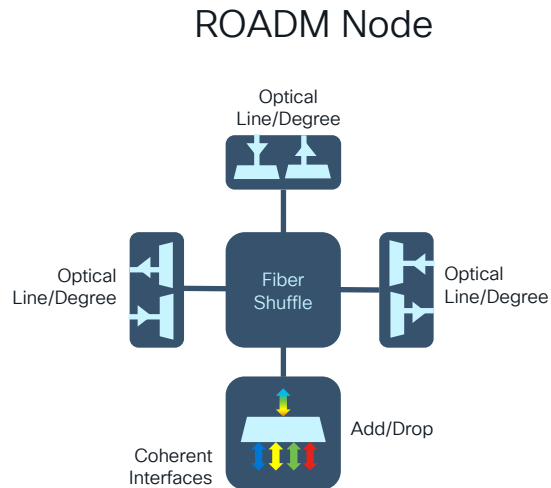
- Reducing ROADM usage
- Shorter distances with additional routers

Simplify Node and Network Operations - Footprint



- Reduced size on key components: WSS, Amplifiers
- OSC, OTDR functions moving to pluggables
- WSS: Single → Twin → Quad
- Chassis based systems with line card per function to:
 - RADM on a blade
 - Node on a blade

Simplify Node and Network Operations – Add/Drop

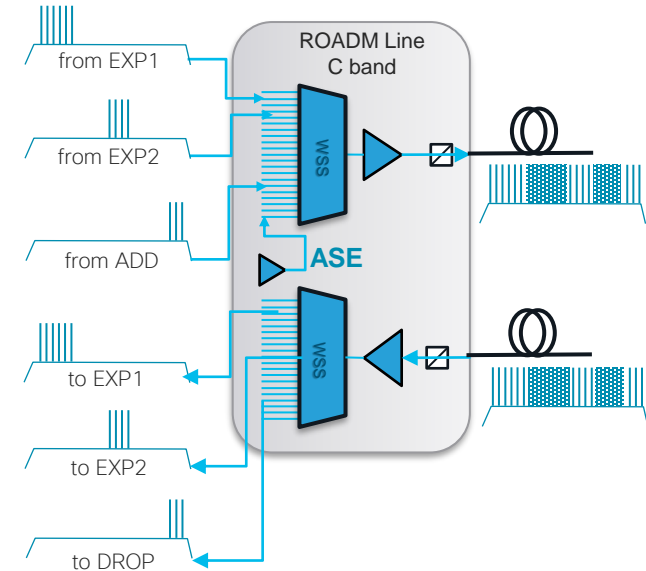


- As Higher Baud Rate channel increase, number of channels is reduced, ie. ports
- WSS port number increasing
 - 1 x 2/4/9/20/32 ... 48/60
 - Added flexibility on how to use ports
- Embedded amplifiers in add/drops designated for low TX power coherent interfaces
- Routed Optical Networking architecture driving simpler and cost-effective options, i.e. Fixed/Color-less Directional

Simplify Node and Network Operations – Performance

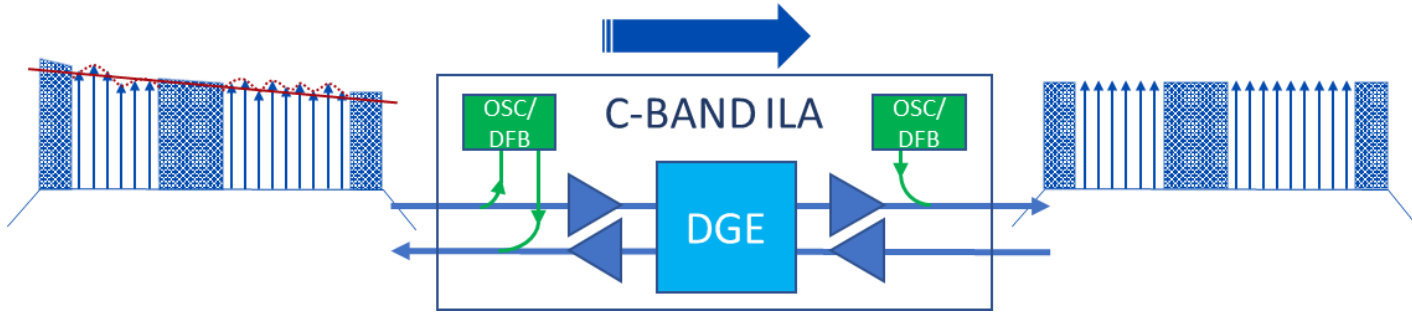
Channelized Noise Loading

- Maintain & Guarantee Optical Performance from day-1 to Max System Capacity
- True Open Line System (OLS) Behavior – Validate End-to-End Performances without depending on Wavelengths being available / installed
- Collaborates with Amplifier Power Control (APC) and EDFA Variable Gain Algorithms to compensate against Transient Effects (Fiber Cuts or Channel Count Variations)



Simplify Node and Network Operations – Performance

ILA Nodes with Embedded DGE

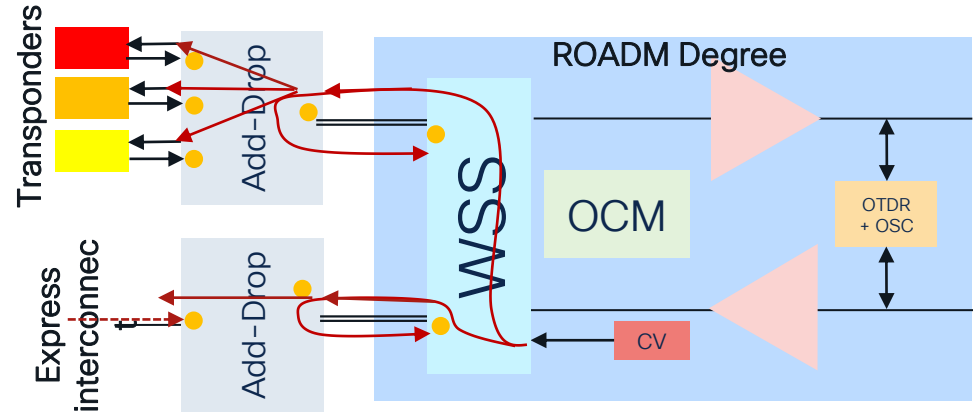


- Raman-based Systems typically suffer 1dB Gain Ripple per Span
- To Optimize C+L-band Systems performances it is required to create a parabolic per-channel Power profile
- Optical Channel Monitoring (OCM) Capabilities required to control the DGE
- Optimized DGE specs to balance Insertion Loss and Power Control Granularity

Simplify Node and Network Operations – Performance

Automated Connection Verification

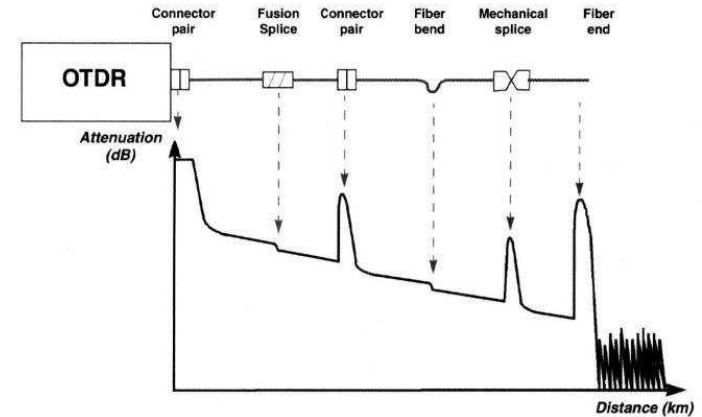
- Independent Validation of all Add/Drop and Degree Interconnect Optical Paths
- Continuous Monitoring of System Behavior
- Auto-Tuning of Transponders Wavelength on the Add/Drop Path



Simplify Node and Network Operations – Performance

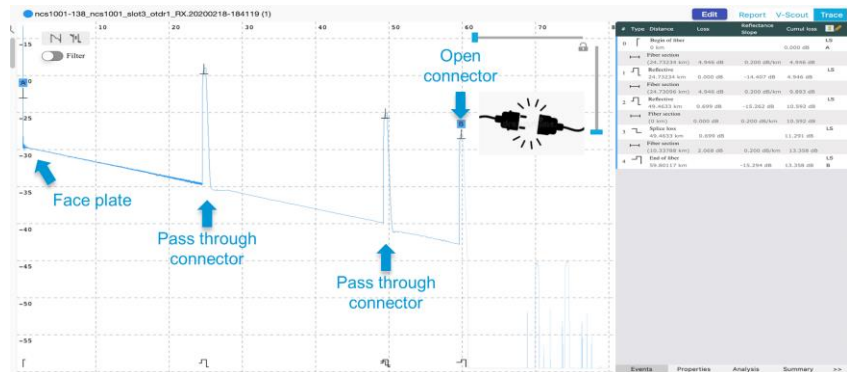
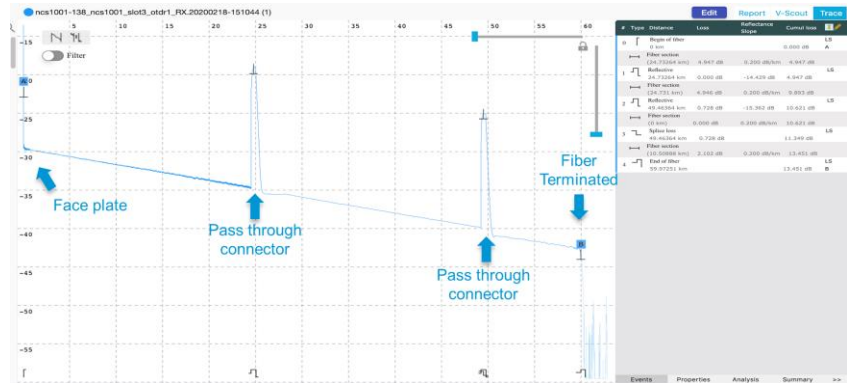
Embedded OTDR

- Span Fiber is a key component of any WDM System, even more so in case Raman is used
- OTDR instruments are normally used to survey the fiber before systems deployment
- OTDR integration in WDM Systems is nothing new
- Traditional OTDR results are a .sor file with
 - OTDR Trace
 - Event Table (with details of Concentrated Loss and Reflection Events through the fiber)



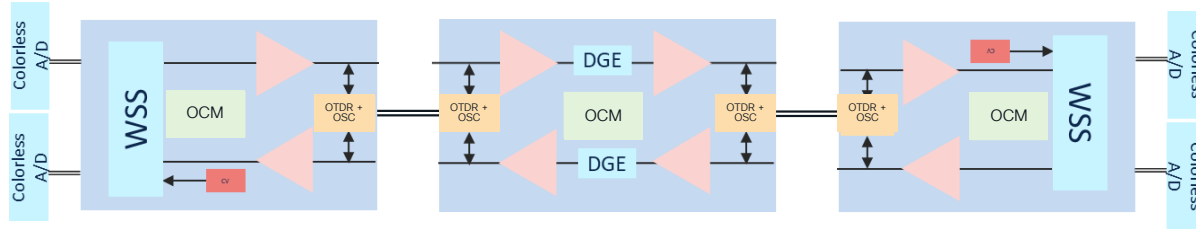
Machine Learning OTDR

- A Traditional OTDR only measures reflection and loss points, without providing any additional details and associating them with a specific root cause
- Machine Learning (ML) applied to OTDR allows to provide details of each Fiber Event
- For the End of the Span it is also possible to distinguish between a Fiber Cut and a Connector inserted in the Far-End Equipment



Simplify Node and Network Operations – Performance

Automated Link Turn-Up



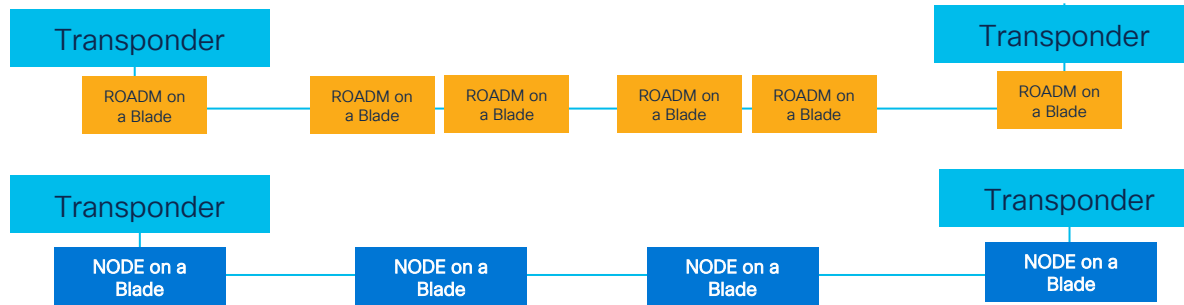
- Connection Verification assures proper cabling of the Node components
- Embedded OTDR assures proper connectivity between Nodes
- Channelized Noise Loading allows to Test and Optimize all Active elements
- Zero Touch Provisioning (ZTP) allows Automatic Configuration of the System and Guarantees Compliance with Deployment Rules and Parameters

Openness

- TL1/SNMP to open APIs (NETCONF, RESTCONF, gRPC, gNMI)
- Model driven implementations: ONF, OpenConfig, OpenROADM, TIP
- SDN end to end control and orchestration
- Alien Wavelength support (still needs manual vendor knowledge/teaks) vs true open line system (designed to receive any type of DWDM source)

Availability

- Full degree separation with reduced footprint, step towards OMS interop
- Node on a blade approach increasing availability by reducing number of components at each intermediate node



Cisco NCS 1010

Key Hardware Components

Compact Modular Transponder



NCS 1004

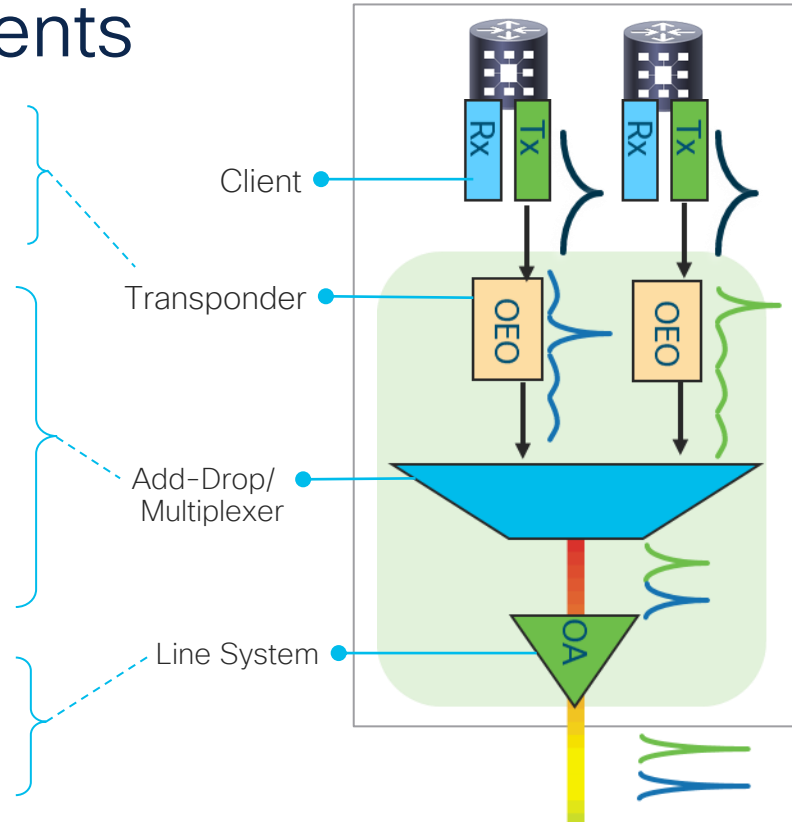


MD32/48/64 fixed filter Passive MUX-DMX



ROADM and Raman supported

NCS 1010



NCS 1010 Key Values – Shelf

- 300mm compliant, Front to Back Airflow.
- Field replaceable optical module/line card.
- Field replaceable 1KW AC or DC PSUs, Fan-tray.
- Field replacement controller card.
- Redundant SSDs for copies of SW image and configuration.
- Bluetooth and NFC support – support read-only UI on handheld devices.
- Rail kits with thumb-screws for shelf replacement without any tools.
- USB ports for passive device management – inventory, LEDs, optical power
- 1588v2 PTP timing support – GNSS, 10Mhz, TOD inputs and output ports.
- Secure – crypto-processors on shelf, controller, optical module to ensure integrity of HW, SUDI certificate installed at manufacturing.
- IOS-XR software for Zero Touch Processing, vendor-neutral YANG models, streaming telemetry.



NCS 1010 Line Card Options

- OLT C-Band
- OLT C-Band with Raman amp – Raman can operate at C or C+L
- OLT L-Band
- ILA C-Band
- ILA C-Band with 1x Raman amp
- ILA C-Band with 2x Raman amps
- ILA L-Band



Optical Line Terminal (OLT) Building Blocks



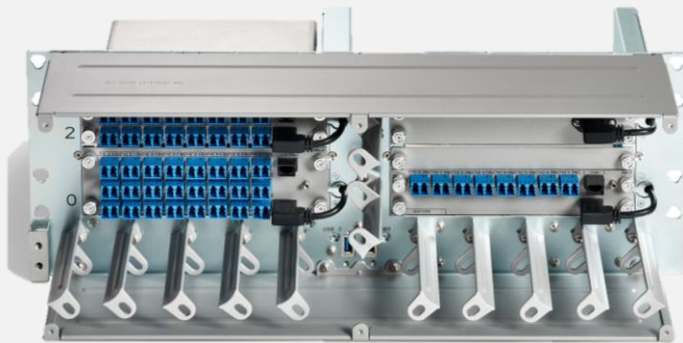
NCS 1010 OLT - Optical Transport Platform – 3RU

- 32 ports WSS-based Terminal Box
- w/ embedded EDFA + Raman Amplification,
- Including OTDR, OCM, OSC and ASE Source



32 ODD/EVEN Colored MUX-DEMUX -1RU + 1RU

- Athermal AWG, w/ USB-powered power monitoring
- 32 + 32 Channels, interleaved grids



COLORLESS BREAK OUT – Color-less Modular patch panel – 4RU

- 4x Passive Optical modules, w/ USB-powered power monitoring
- Up to 72 Channels MUX/DMX + 8-Dir interconnection

NCS 1010 OLT Key Values

OSC can be switched to both fibers for 5G class timing support, latency measurements, OSNR readings.

CV laser for bidirectional connection verification and patch-cord loss checks

2x33-WSS – allows for design with low loss add-drop couplers & high drop power for next gen baud-rates

Embedded bidirectional OTDR for fiber characterization.

Intrinsic degree separation

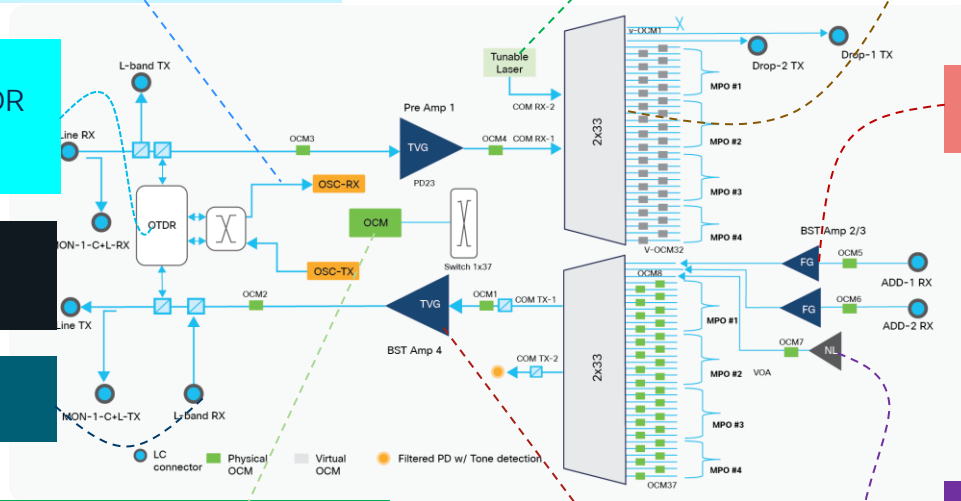
Embedded C+L filter

Embedded OCM for “OSA-like view” of spectral profile on all ports.

Switchable gain range, Variable gain PRE

Ingress EDFAs for low output power DCOs.

Embedded channelized ASE for true-OLS, operational ease to scale channels.



ILA C/L-Band Line Card Details

- Two independent “true variable-gain” EDFA blocks w/ identical characteristics
- 23dBm total output power in fiber for both C and L-Bands
- 24dBm output power @LINE-TX ports for both C and L-Band Box variants
- Monitor ports for Amplifiers output
- 4-ports OCM: parallel scan or shared device w/ optical switch
- DGE continuous embedded capability, to compensate different channel's power among the spectrum
- Embedded OSC C-Band and OSC L-Band for both direction and for ILA-C and ILA-L respectively
- Embedded OTDR capability for ILA-C only towards both direction (single device + optical switch)
- Each integrated optical amplifier shall provide the following features:
 - Switchable Gain ranges, to provide optimized Noise-Figure across the whole Gain Range
 - ASE compensation in Constant Gain and in Constant Output Power mode
 - Fast transient suppression
 - Programmable tilt
 - Full monitoring and alarm handling capability
 - Supporting optical safety functionality by signal loss detection, HW LOS signal generation and alarm at any input port, fast power down control and reduced max output power in safe power mode.
 - Safety Class 1M at any optical port.



Conclusion

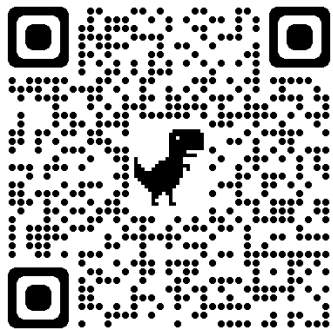
Key Take Aways

- Open Disaggregated Optical Networks allow operators to embrace innovation that allows to keep up with capacity requirements, while simplifying operations and improving overall network economics
- Cisco NCS 1010 Open Line System, is a multi-haul platform designed to future proof optical transport networks.

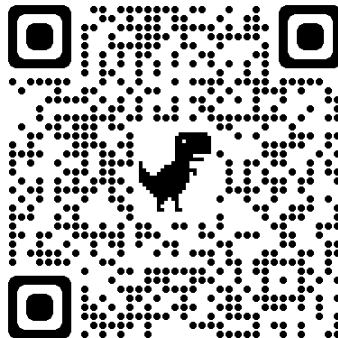
Packet Optical Networking Conference

Tuesday June 28th – Thursday June 30th
7am–10am Pacific Time/10am–1pm Eastern Time

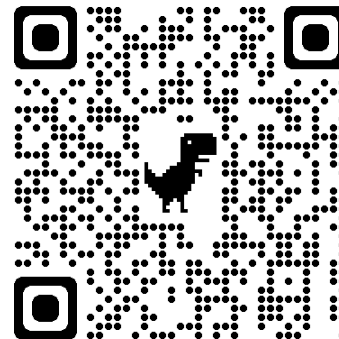
Registration is OPEN!



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[Day 2](#)



[Day 3](#)

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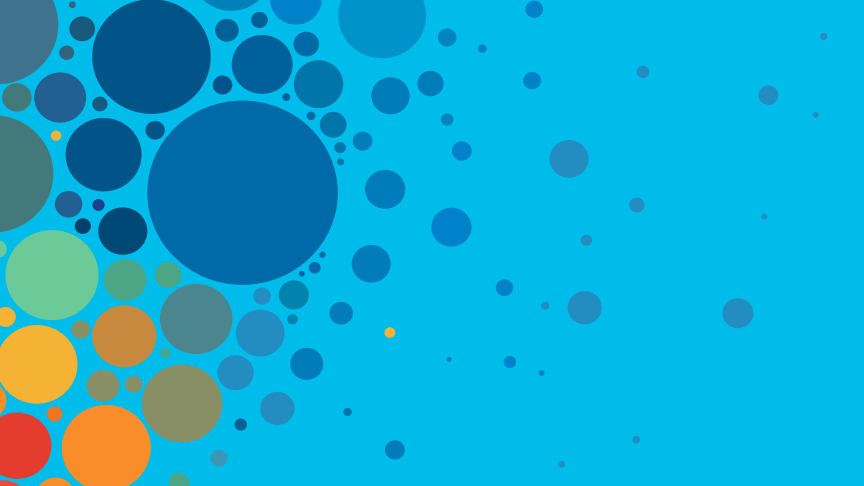
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The bridge to possible

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