DCI Trends with the Move to Disaggregation and ROADM

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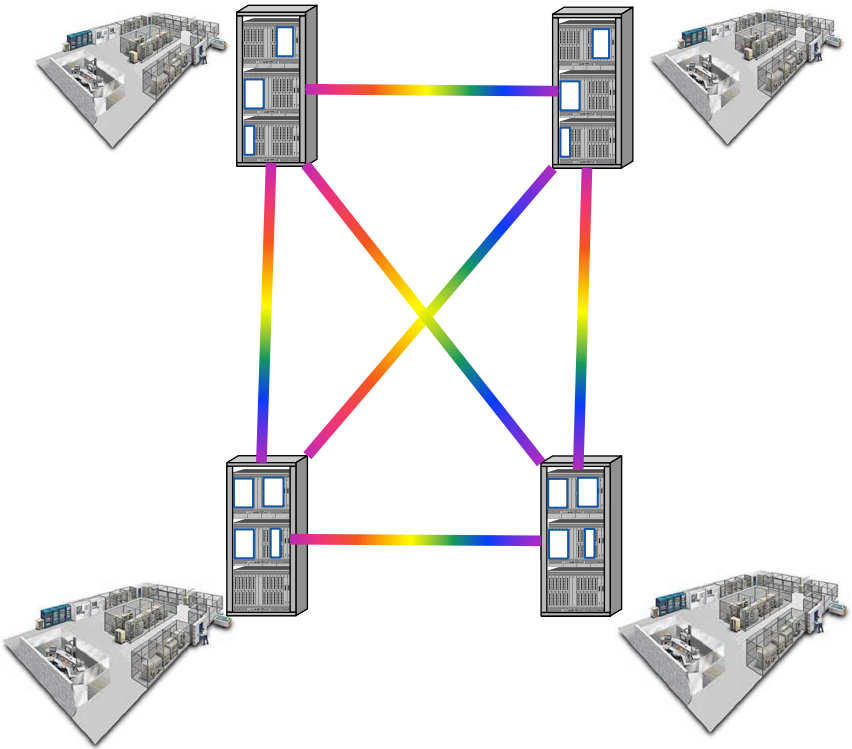
DCI Network Evolution

- Data Center Interconnect (DCI)
- Pt -2– Pt scenarios
- Migration to ROADM
- ROADM Benefits and Architectures
- ROADM Trade-offs
- Modulation Techniques - Optical Spectrum - Flexible Grid
- Restoration Option
- Conclusions

Data Center Interconnect Application

The Need to move Content from a Private or Shared Distribution Center to a Peering Location



Historical, Multi-function Platform

Physical

- Each Gen sets Physical Envelope for future
- Space is fixed, DC Power, Thermal Diss
- I/O interface over backplane
- Density improvement requires new cards

Software

- Single set of shared Controllers for all Functions
- Each new feature must “live-with” legacy features
- Large regression testing burden
- SW stack not optimized. New APIs require translation

Speed

- Different technology evolves at different speeds
- Monolithic equipment moves at the speed allowed by the physical architecture and legacy control plane

Disaggregated function – Transponder Box - was Created

The Move to Disaggregation and the Data Center

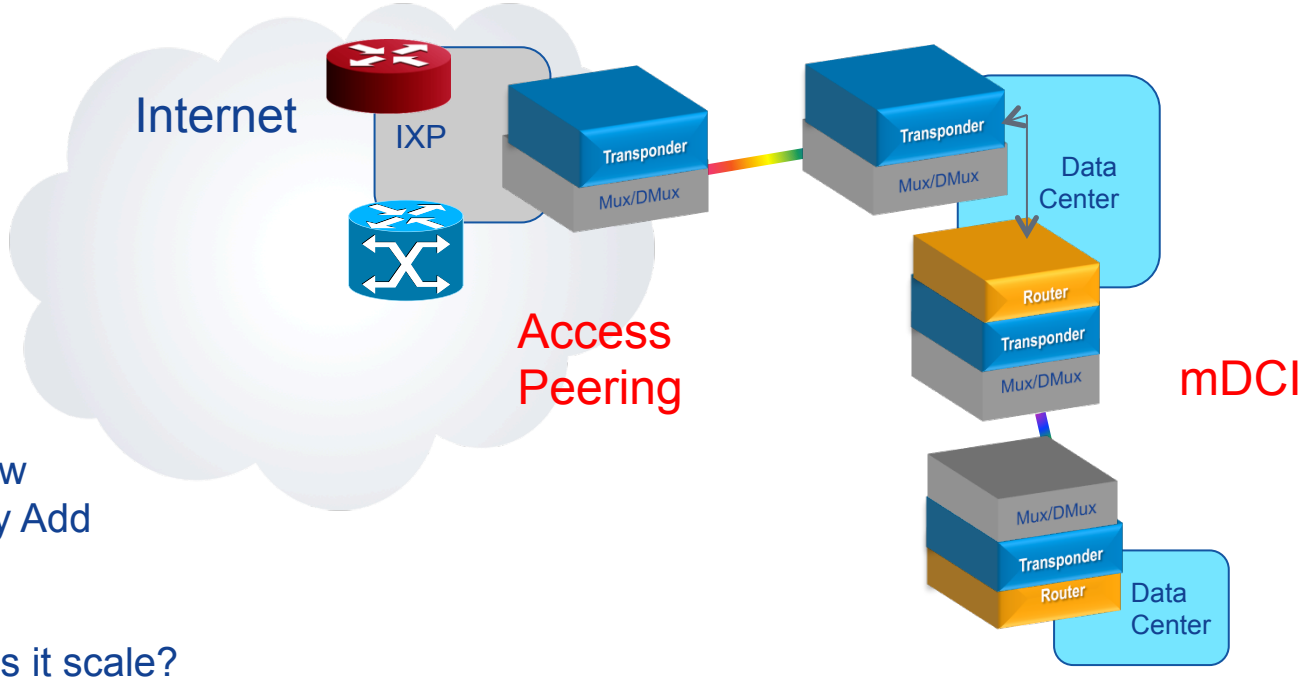
- There are various open industry initiatives that are driving the disaggregation Trend
  - Open Compute Project (OCP) *(Inside the Data Center)*
  - Facebook's Telecom Infra Project (TIP) *(Between Data Centers)*
  - ONOS (Open Network Operating System) Central Office Re-architected as a Data center (CORD) initiatives
  - AT&T's Open ROADM (Reconfigurable Optical Add Drop Multiplexer)
- Remove General Purpose platforms for optimized function boxes
  - Get what you pay for and nothing you don't want
- Reduce the price for selected features by customizing the box to single function initiatives that are driving the disaggregation Trend
  - White box
- Open transport Line Systems (OLS) that support anyone's white box
- Make vendors interoperate at the line level (mid-span meet)

Pt –to – Pt Scenarios

Building Point to Point metro DCI Networks

IXP - Internet Exchange Point
mDCI – multiple DCI

Transponder Box Deployed



Values:

- Small foot print
- Pay as you Grow
- Simple Capacity Add

Issues:

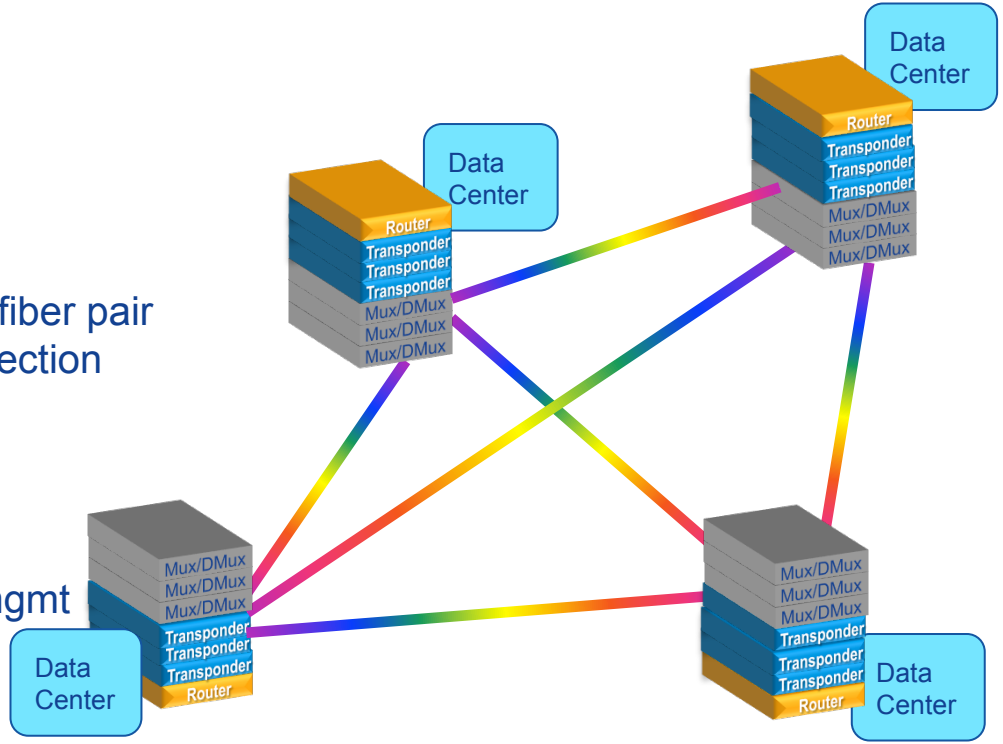
- None -- but does it scale?

Adapting Point to Point approach for Meshy DCI scenario

Consider a 4 site network
With a pt-2-pt strategy, it looks like:

Values:
- Pay as you Grow
- Add MuxDemux Unit (MDU) for each fiber pair
- Add Transponder box with each connection

Issues:
- Manual, little automation
- NxN-1 connections // 6 pairs of fibers
- Multiple IP addresses to config and mgmt
- Lacks Efficiency
- All Traffic is terminated at MDU
- No Pass thru



Adapting Point to Point DCI Meshy scenario with limited Fiber - Mapped onto a Ring

Yes, single fiber pair can be used
This is pretty manual and messy

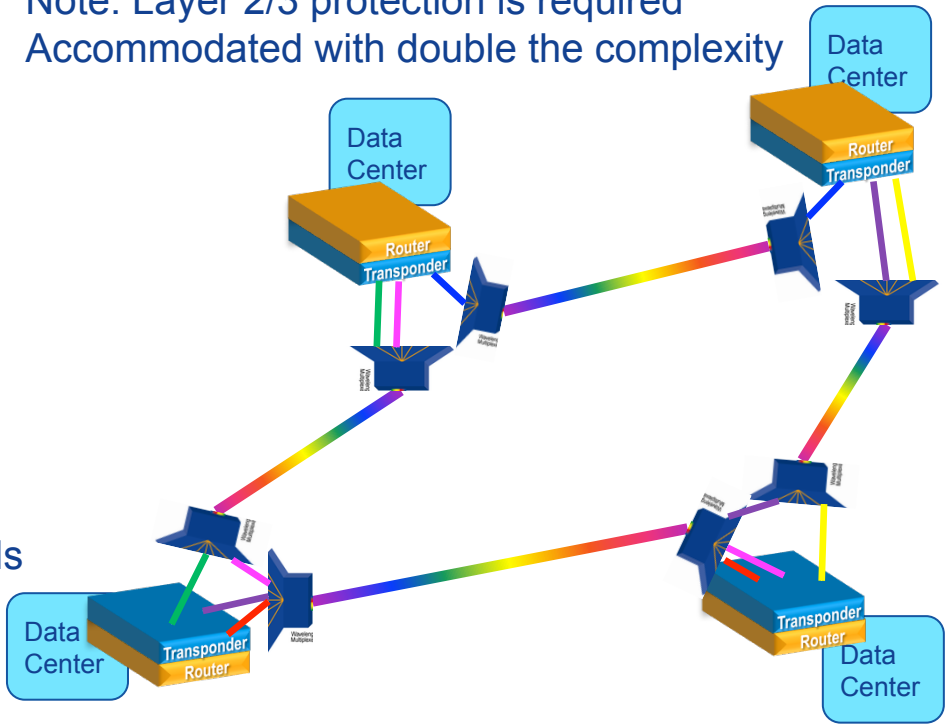
Values:

- Fewer Mux/Demux (MDU)
- Fewer fiber connections
- Pay as you Grow

Issues:

- Manual, little automation
- Terminate most traffic at MDU
- Pass through Loss -- No regeneration
- Concern about power balancing with adds
    - If Amplifiers are used

Note: Layer 2/3 protection is required
Accommodated with double the complexity



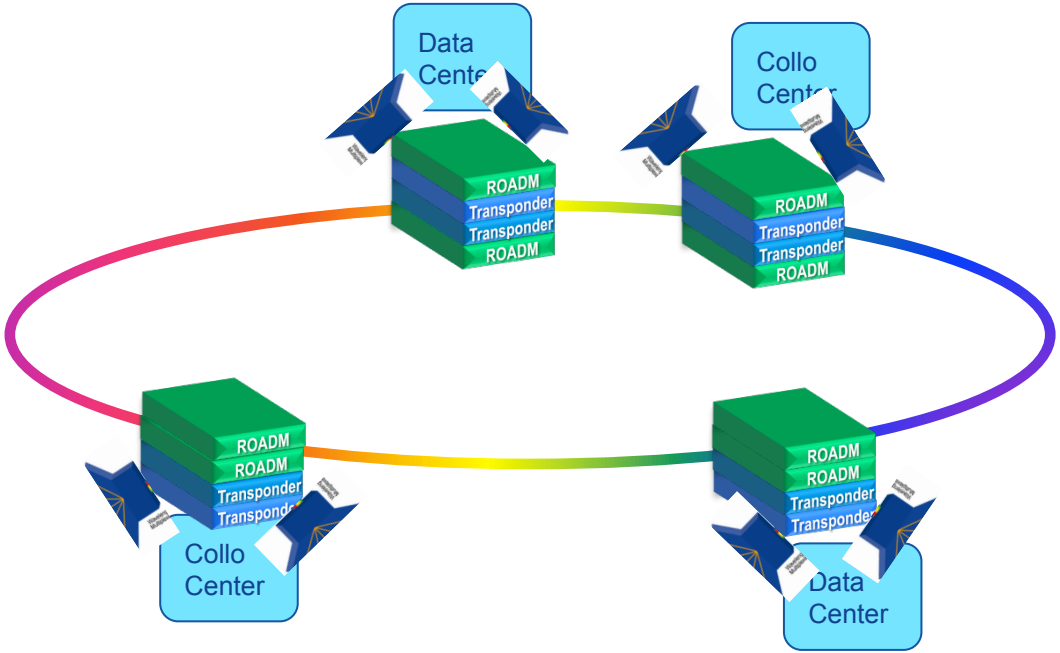
Migration to ROADM

Meshy DCI on a Ring with ROADM

Disaggregation easily accommodates moving to a ROADM:

Values
- Simplified
- 1 pair of fibers
- Pass through traffic support
- Easier addition of new capacity
- Enables dynamic BW allocation

Issues
- Cost compared to nxMDU



Node Add on a Ring with ROADM

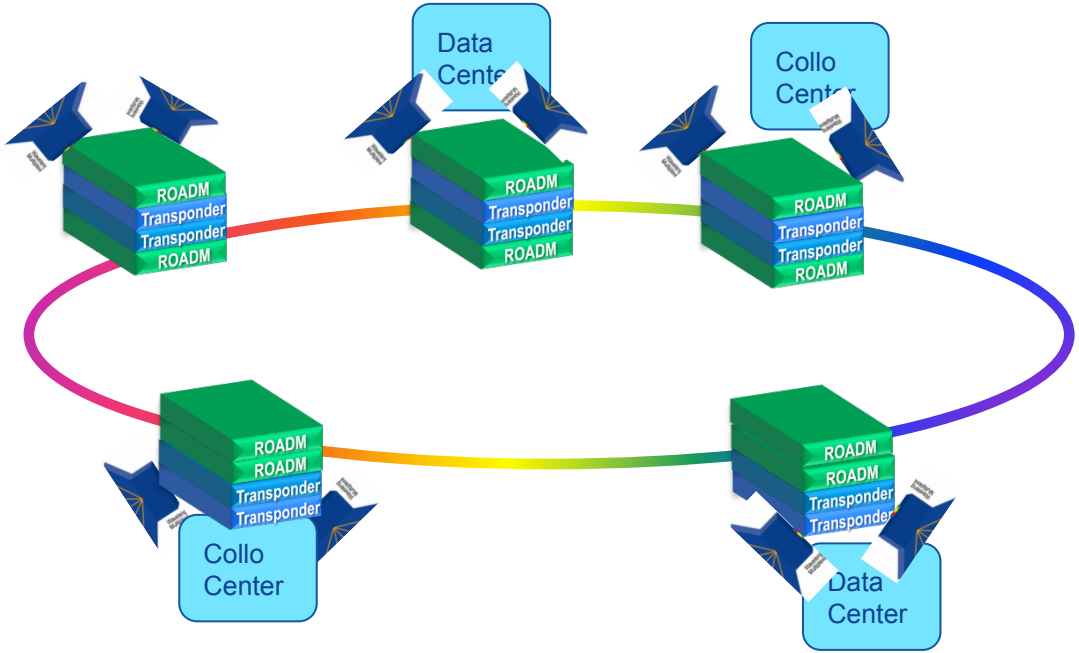
Adding a ROADM node is non-service impacting:

Value

- Simple network Node expansion
- OSC (Optical Supervisory Channel) signaling
- 2 original Nodes adjust for add Node
- Pass through traffic cross connects in new Node
- Rebalance gain for new distance
- Enables dynamic BW allocation

Issues

- Channel Planning / Availability



ROADM Benefits and Architectures

ROADM Benefits

Key Benefits

Engineering tools to pre-plan
- 0 to 44/96 channel topology up front
- Flexible-Grid and SuperChannel

Network level discovery and intelligence
- Span distance, loss, OBR, neighbors, etc.

Node adds simplified

Dynamic channel adds
- Truck Rolls to endpoints only
- Plug and play, no re-balancing

End-to-end network diagnostics
- Per channel view
- All channels view
- Service channel view
- Composite power levels

No reengineering when adding services, nodes and rings

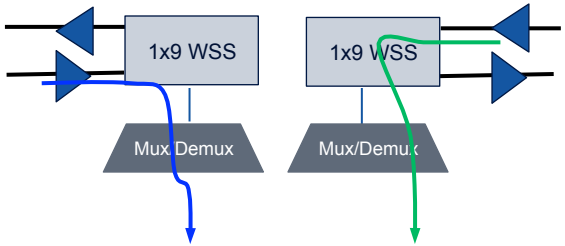
Fewer people, less overtime and fewer truck rolls

Fewer maintenance windows

OBR – Optical Backscatter Reflectometer

ROADM Architectures

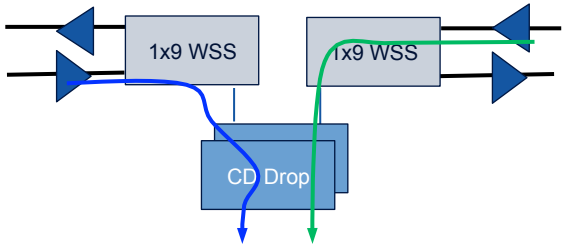
Classic ROADM



Std, Fixed ROADM

- Mux/Demux for each degree
- Colored, Directional
- Fixed ports per wavelength

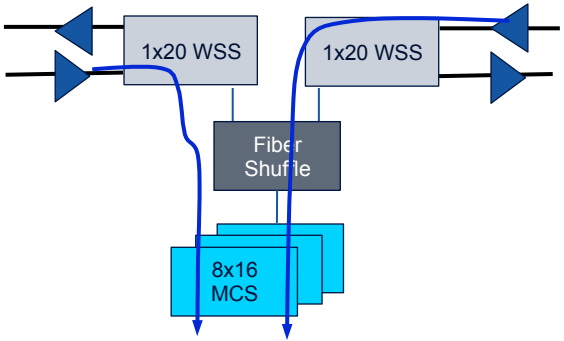
CD ROADM



Colorless / Directionless ROADM

- Wavelengths from any degree
- Colorless – any wavelength can be assigned to any port
- Drop side modules added to expand capacity
- Contention on drop side

CDC –F ROADM

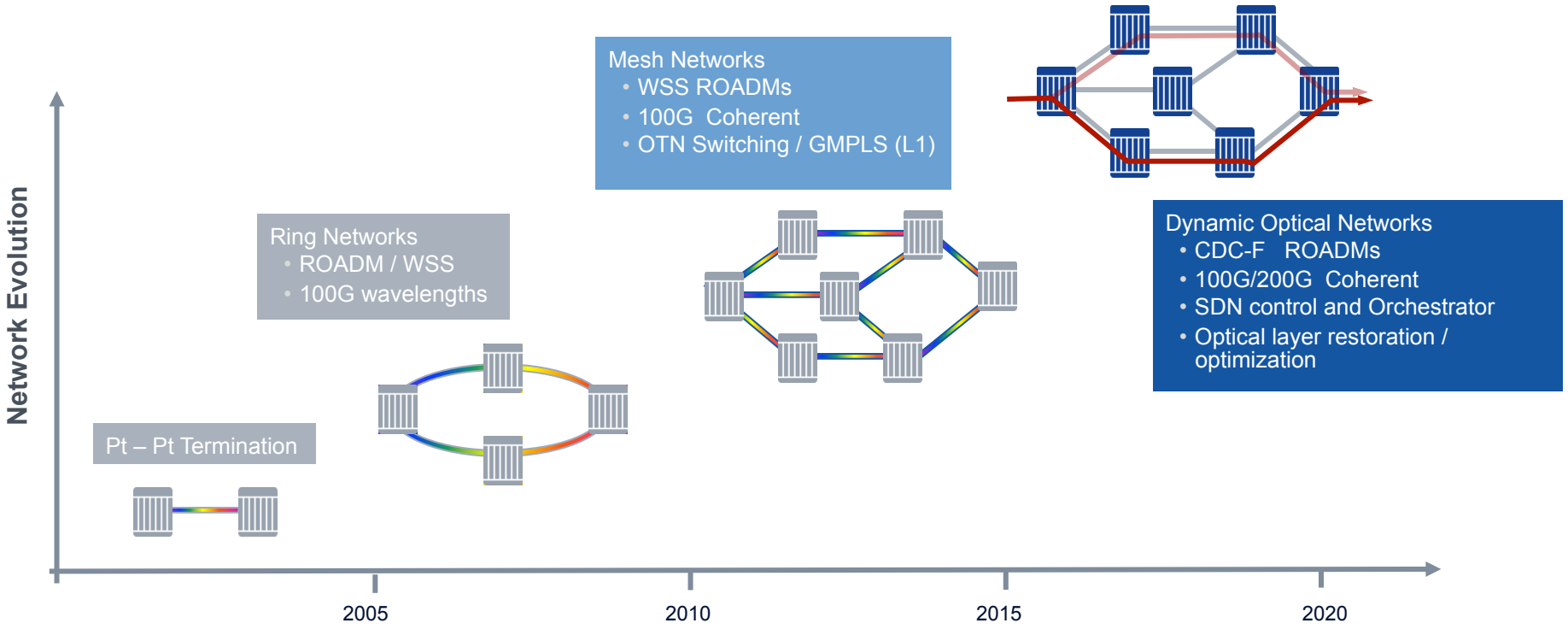


Colorless / Directionless / Contentionless ROADM

- Wavelength from any degree
- Colorless ports
- Drop side modules added to expand capacity
- Supports “contentionless”

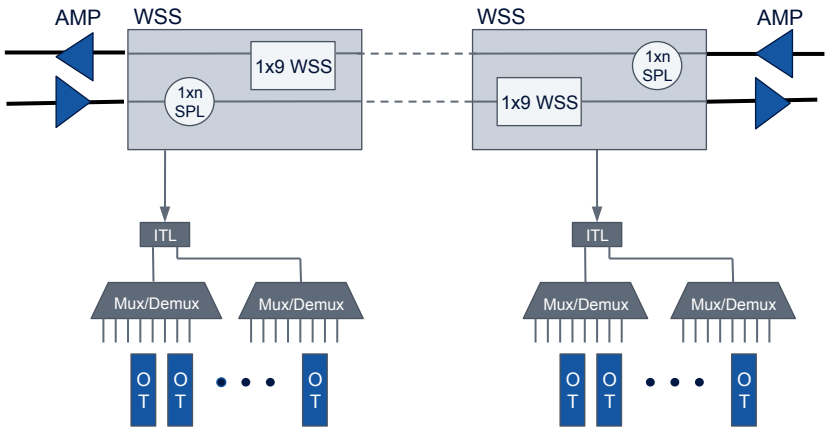
WSS – Wavelength Selective Switch
MCS – Multi-cast Switch

Optical Network Evolution



OTN – Optical Transport Network
SDN – Software Defined Network

Classic, Fixed Bandwidth, ROADM



Note: 2D ROADM shown in diagram

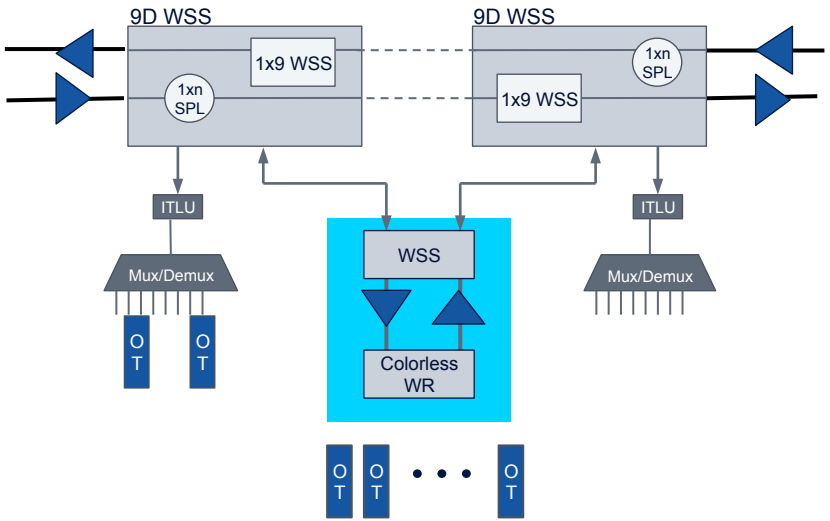
Classic ROADM

- Multiple cards to implement
  - Ingress / Egress AMPs, OSC, WSS, OCM
- Broadcast & select architecture
  - 1:n splitter (broadcast) drop channels & 1x9 WSS (selects) add channels
  - AWG Mux / Demux
    - Wavelength filtering for add/drop channels
  - Wavelengths are assigned to specific physical Mux/Demux port (colored) & specific degree (ie direction)
  - Changes require manual reconfiguration of node & optical transponders (time, $$)
- Supports up to 8D nodes

Standard industry architecture since ~ Yr 2005

AMP – Amplifier
OCM – Optical Channel Monitor
AWG – Array Waveguide Grating
ITL – Interleaver
SPL - Splitter
OT – Optical Transponder

CD ROADM



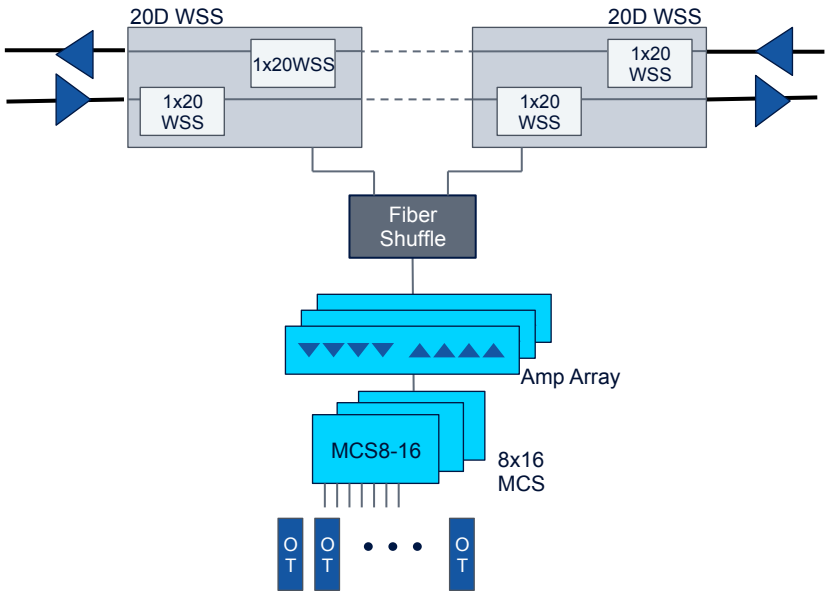
CD ROADM

- CD drop modules enable colorless, directionless applications
  - Optical Transponders connect to any port (colorless), switched to any degree (directionless)
  - Key Benefit – ability to add CD wavelengths to existing, legacy classic ROADM nodes in hybrid configuration

Note: 2D ROADM shown in diagram

Key Benefit – Adding CD capability to existing networks

CDC-F ROADM



CDC-F ROADM

- Route & Select
  - Twin 1x20 WSS used to drop (route) & add (select)
  - Amp Array
    - Compensates for optical losses through drop units (MCS)
  - 8x16 MCS (MCS8-16) Multicast Switch
    - Enables CDC-F operation
    - 8 (degrees) x 16 (client drop ports)
    - Shared drop unit, only added as capacity needed
  - 100G / 200G / 250G capable per port
  - Fiber shuffle
    - Passive fiber distribution & interconnect panel
    - MPO connectors to minimize cabling

Note: 2D ROADM shown in diagram

CDC-F Wavelength Routing Accommodates any Modulation Bandwidth

MPO – Multifiber Connector

Additional Benefits CDC-F Wavelength Routing

Key Benefits

- Improved optical layer flexibility
- Enhanced optical protection / restoration
- Network re-grooming / re-optimization
- Hot-standby Optical Transponders
- Flexible Grid channel sizes
- Super Channels

40 – 70% additional network capacity

Reduce Operational cost by eliminating of manual reconfigurations

Support higher capacity channels with FlexGrid & Super Channels

ROADM Trade-Offs

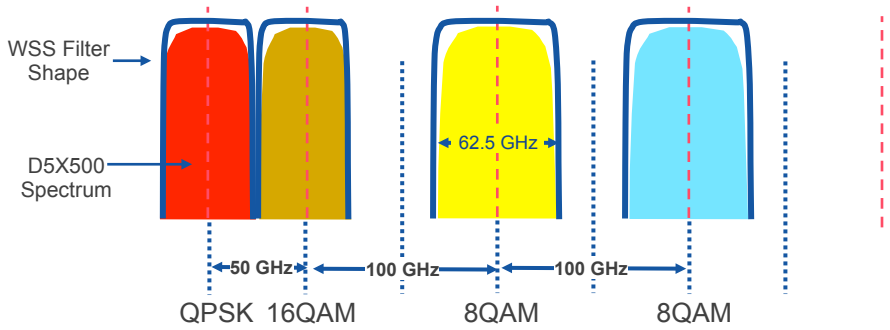
Which ROADM Architecture is the Right Deployment

Lots of people want state of the art – but are they willing to pay for it

- How Much Bandwidth is enough?
- Fixed wavelength Grid; 50GHz 88/96 CH Mux/Demuxes are a lot less than the MCS architecture of CDC (39%)
- Super Channels for stuffing as much spectrum as possible in the C-band but require CDC (4Tb)
- What do you do with legacy deployment and filters when you move to ROADM
  - Fixed WL Filters can support additional spectrum growth using new modulation techniques (64QAM)
  - CDC requires you to rip and replace or overlay the entire infrastructure
- What to do with a Legacy (3-5 yr) ROADM network
  - Add new channels with new modulation techniques for more bandwidth in same spectrum
  - Works better in Metro deployments – cross talk / guard-banding (less impactful)
  - Alien wavelength support for new modulation techniques

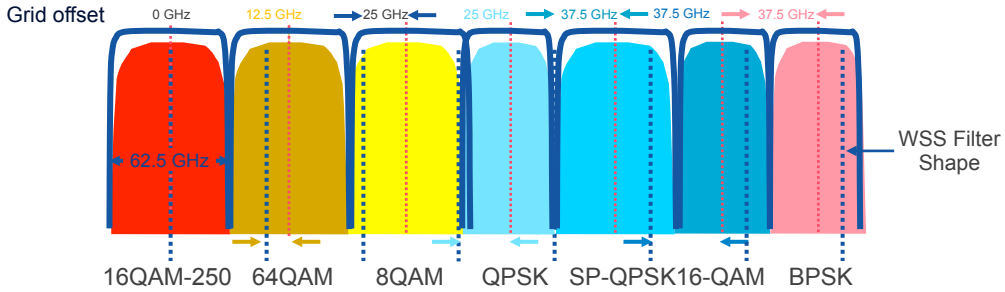
Flex Grid Evolution

Fixed Filter Requirement 50GHz Grid or 100 GHz



Modulation	Spectrum	4.4 THz Capacity
8QAM	62.5 GHz	44x200G=8.8T
16QAM	50 GHz	88x200G=17.6T
QPSK	50 GHz	88x100G=8.8T
SP-QPSK	62.5 GHz	44x100G=4.4T

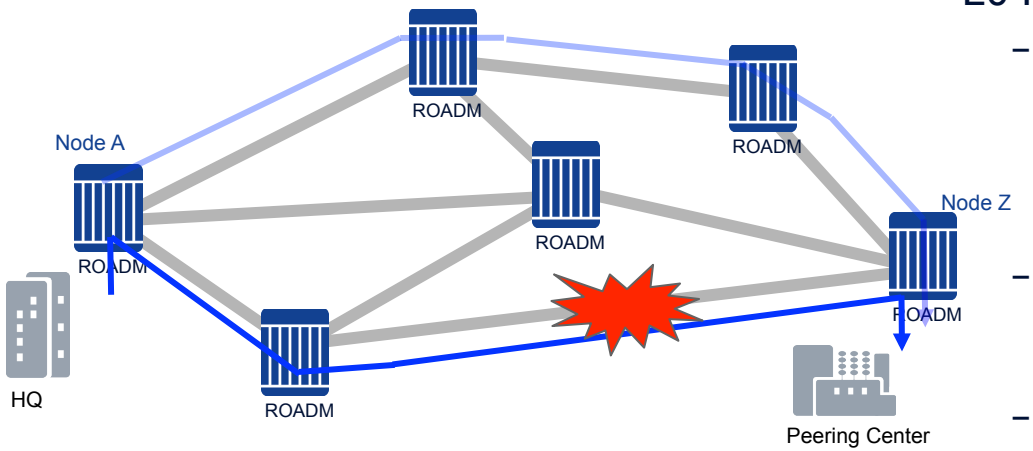
Flex Grid Channels offset from ITU 50 GHZ grid improves capacity



Modulation	Spectrum	4.8 THz Capacity
BPSK	50 GHz	48x(2x50G)=4.8T
QPSK	50 GHz	96x100G=9.6T
16QAM	50 GHz	96x200G=19.2T
8QAM	62.5 GHz	76x200G=15.2T
SP-QPSK	62.5 GHz	76x100G=7.6T
16QAM-250	62.5GHz	38x(2x250G)=19T
64QAM	62.5GHz	76x400G=30.4T

Restoration Option

Optical layer Restoration

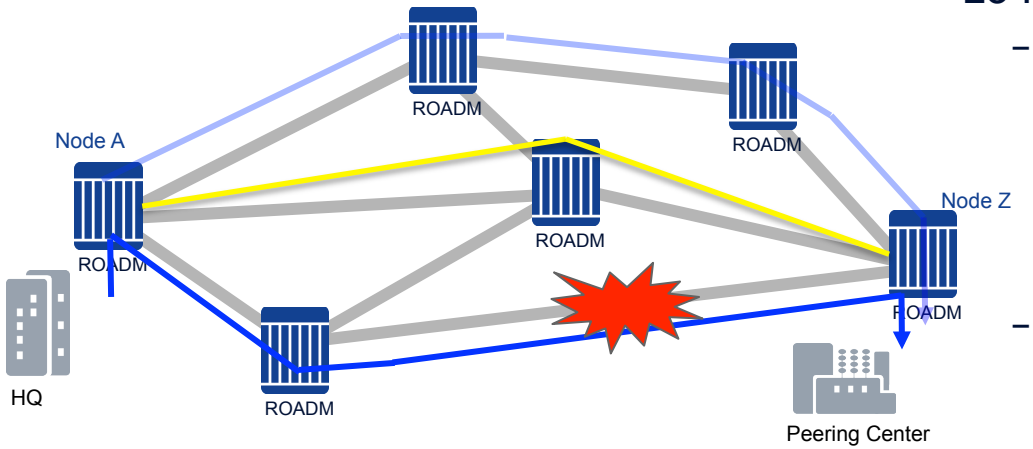


L0 Restoration

- Fast restoration of traffic in event of fiber cut
  - ~10 to 30s for all channels
  - Compared to ~1 – 3 days to manually re-splice fiber
- GMPLS based L0 restoration
  - Nodes signal / calculate new path automatically
- Shared optical protection
  - Improved utilization over 1+1 wavelength protection (50% bandwidth used for protection)

Automatic Optical Layer Protection/Restoration

Higher layer Restoration



L3 Restoration

- restoration of traffic in event of fiber cut
  - ~100 to 500s for selected channels
  - Compared to ~10 to 30s for all channels using L0
  - TXP channel on alternate path does not have to be open. Just avail TXP connected to Router
- L0 restoration is taken out of the picture
  - Calculate new paths upon termination of old path
- Shared optical protection
  - Improved utilization over 1+1 wavelength protection (50% bandwidth used for protection)

Automatic Optical Layer Protection/Restoration

Conclusions

Should Fixed ROADM be a Disaggregated solution – It depends

Shelf Based Architecture

Function-centric Architecture

- Each Degree is housed in a single chassis to support interconnect and shared management resource for the entire sub-system
- Minimize Space, Power, Heat, Compliance
- Integrated Degree per card or Single degree per shelf

Physical

- Each disaggregated ROADM degree has its own physical design. Multiple IP addresses
- Minimize Space, power
- Independence from previous functions
- Enables continuous density/performance improvement

- Each new feature must "live-with" existing features
- Regression testing of complete function
- Single system for ease of debug trouble shooting

Software

- Disaggregated Function does NOT interact with other functions. NOT AWARE of other degrees
- Changes regression testing schema
- Simple "data-descriptor" assimilates to "Integrator"
- New features faster

- Different technology evolves at different speeds
- Monolithic equipment moves at the speed allowed by the physical architecture

SPEED

- Disaggregated function can be developed at the speed of component advancements without the need for other aspects of the network keeping pace
- New hardware can be developed faster

Conclusion

- This disaggregation approach to DCI is well suited to CSP, ICP and CNP/Collo providers
- ROADM simplifies Adds and Changes in a Network
- ROADM accommodates larger meshy scenarios
- Dynamic Bandwidth allocations for Scale
- Save on Fiber pairs – Fixed Cost and OpEx
- Simple ROADM may be a better solution for DCI Metro than CDC Flexgrid
- There are various open industry initiatives that are driving the disaggregation Trend
  - Open Compute Project (OCP)
  - Facebook's Telecom Infra Project (TIP)
  - ONOS Central Office Re-architected as a Data center (CORD) initiatives
  - AT&T's Open ROADM
- We believe some of the challenges are: Multivendor controllers, Multi-layer protection, Wavelength routing, and Analog functions; to name a few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