

Optical Networking Fundamentals

CISCO Live !

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Solutions Engineer

BRKOPT-1007

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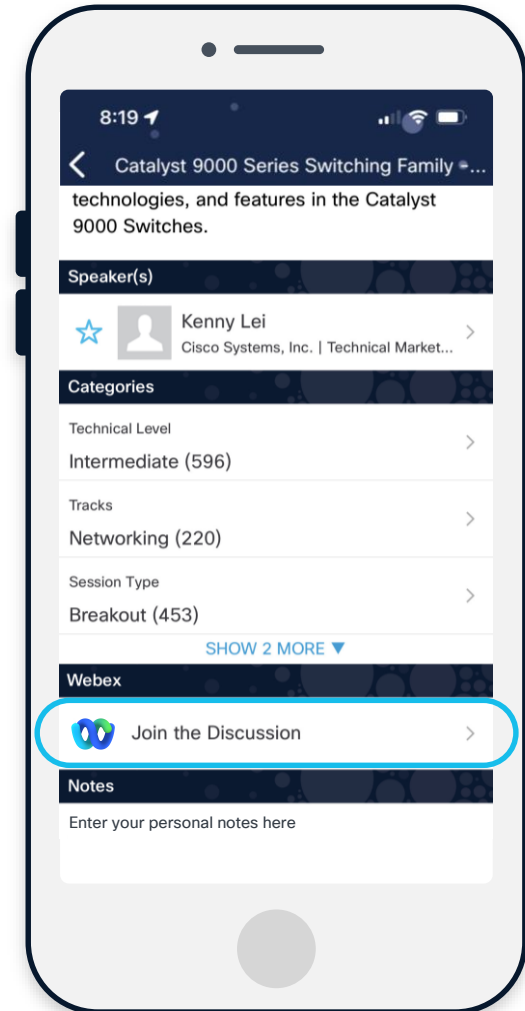
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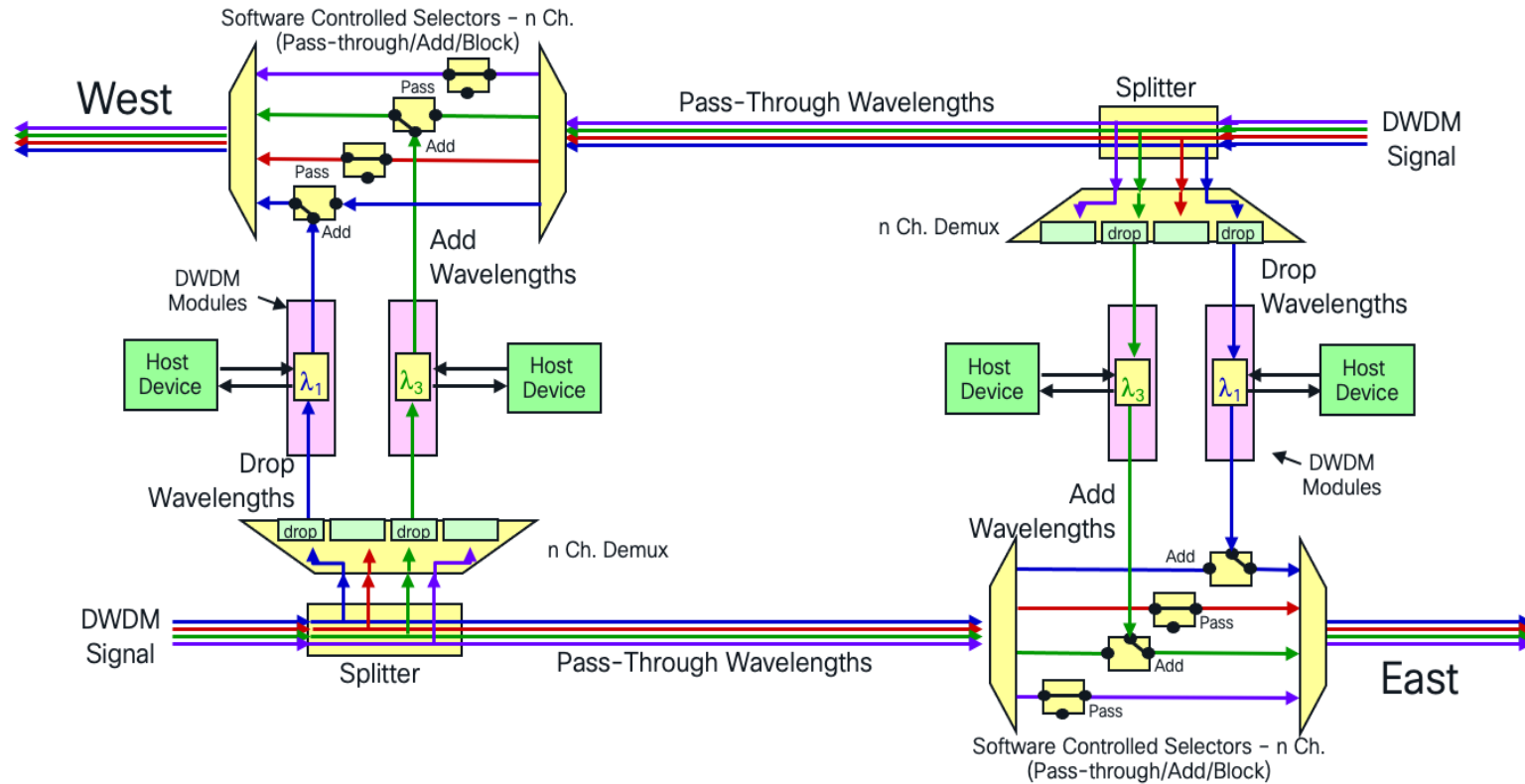


<https://ciscolive.ciscoevents.com/ciscolivebot/#BRKOPT-1007>

Agenda

- 01 Introduction
- 02 What is DWDM
- 03 Optical Fiber Crash Program
- 04 DWDM Components
- 05 DWDM in Routers
- 06 Cisco Optical Line Systems
- 07 Summary

Traditional IP Engineer's view of Optical Networking



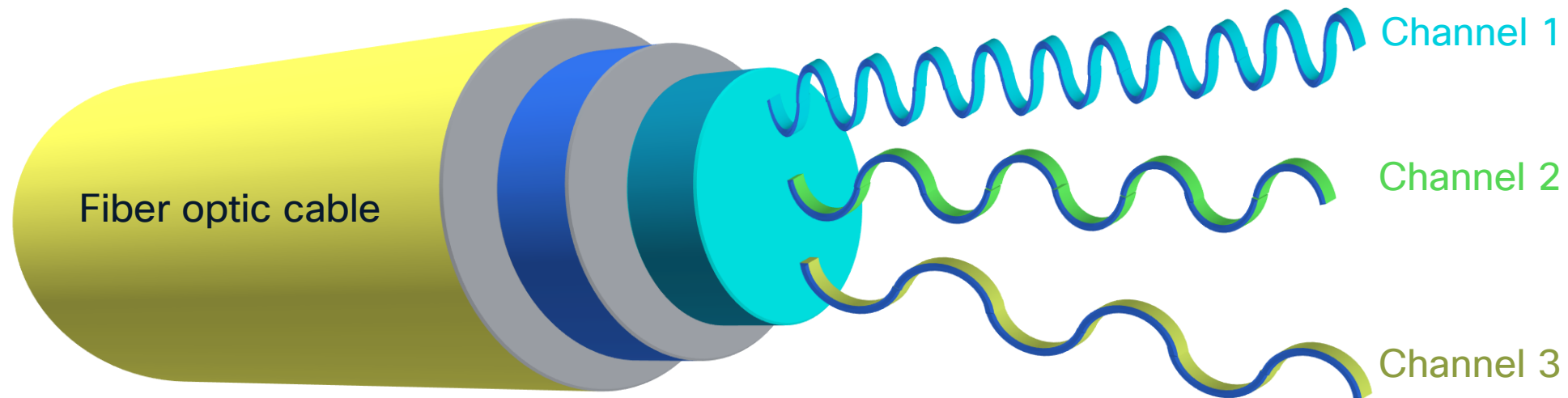
- ✓ Grey optics connect buildings/floors together, a mystery beyond
- ✓ Layer 1 demands a different skillset from Ethernet
- ✓ Fiber optic technology has a steep learning curve
- ✓ Traditional Engineers understand IP, not Transport, hard to find both skillsets
- ✓ Fiber optic networks are costly

What is DWDM

What is WDM – Wavelength Division Multiplexing

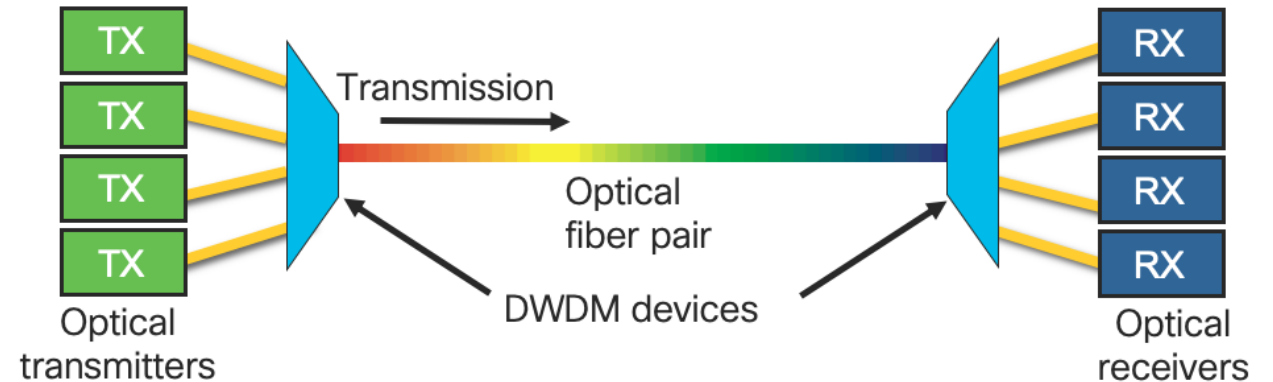
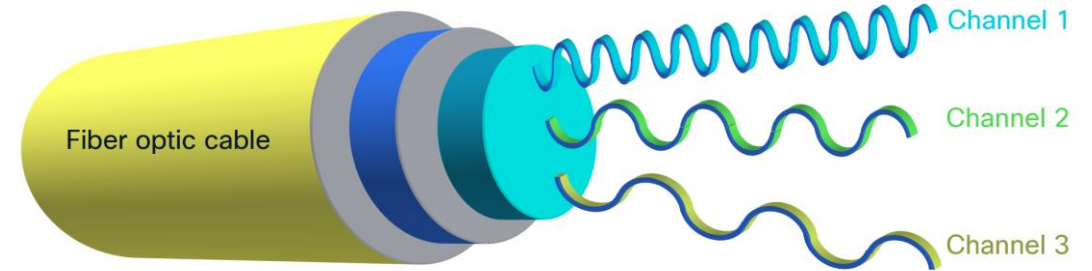
Optical (light) signals of different wavelengths do not interfere with each other on a fiber

Each wavelength represents an independent optical channel



WDM is Agnostic

- **Protocol Agnostic**—Any-Rate Ethernet, TDM, Fiber Channel, etc.
- **Bit-Rate Agnostic**—Each Wavelength can be different bit-rates
- Allows Infrastructure Evolution to meet your needs – i.e. Future Rates

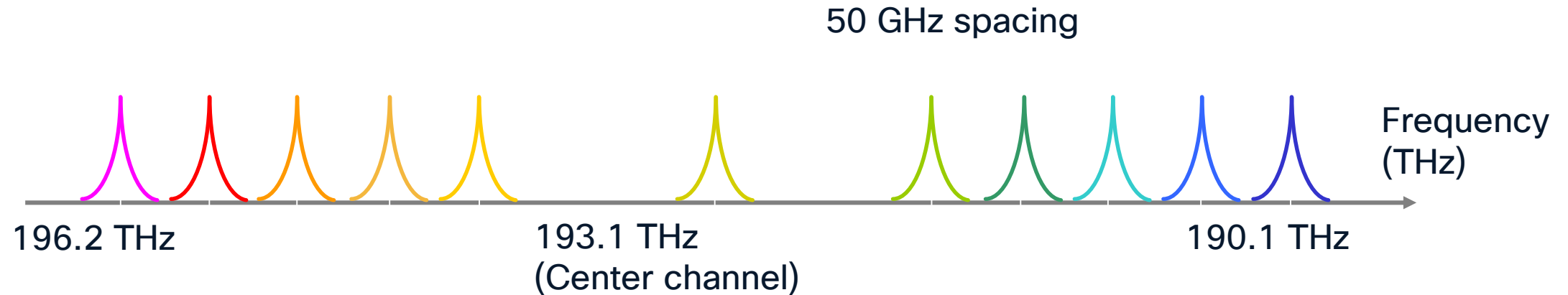
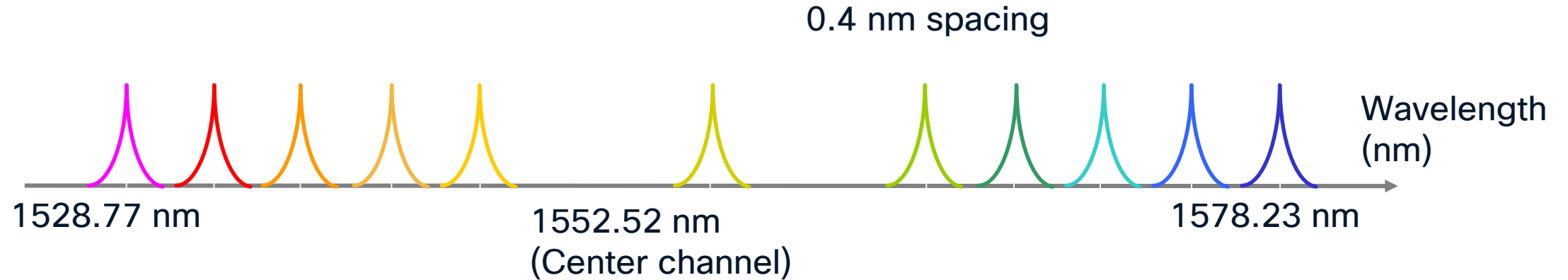


xWDM Channel Overview

	WDM	CWDM	DWDM (C-Band)
# of Wavelengths	Typically 2	Typically 8	Typically 40/80/96-channels and beyond with Flex
Typical Wavelengths	1310nm and 1550nm	1471nm, 1491nm... 1591nm, 1611nm	1528.77nm... 1566.72nm
Channel Spacing	N/A	20nm	100GHz/50GHz 0.8nm/0.4nm and lower Flex Options as well
Applicable Standards	N/A	ITU-T G.694.2 18 Wavelengths are incl. in Standard	ITU-T G.692

ITU-T Grid

ITU wavelengths = lambdas = channels centered around 1550 nm (193 THz)

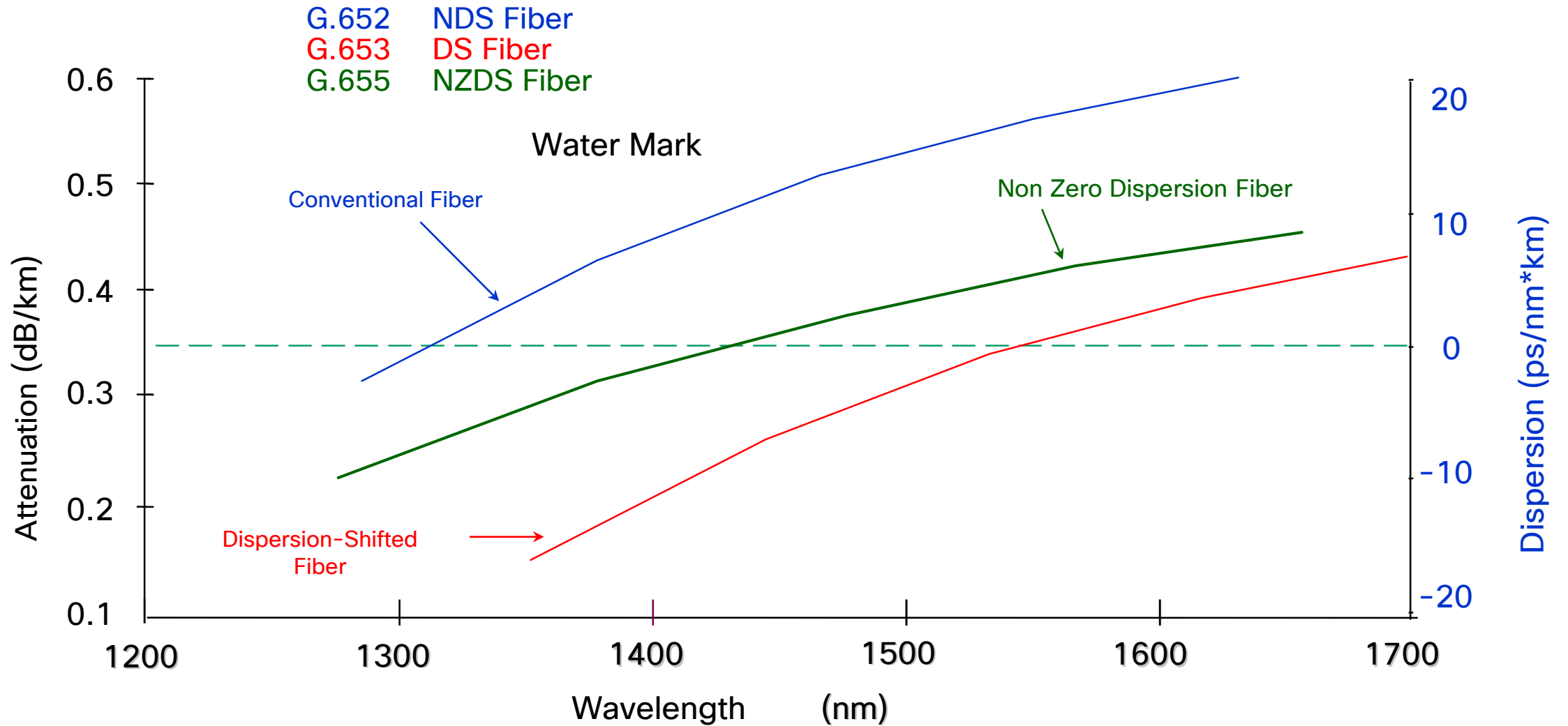


Optical Fiber Crash Program

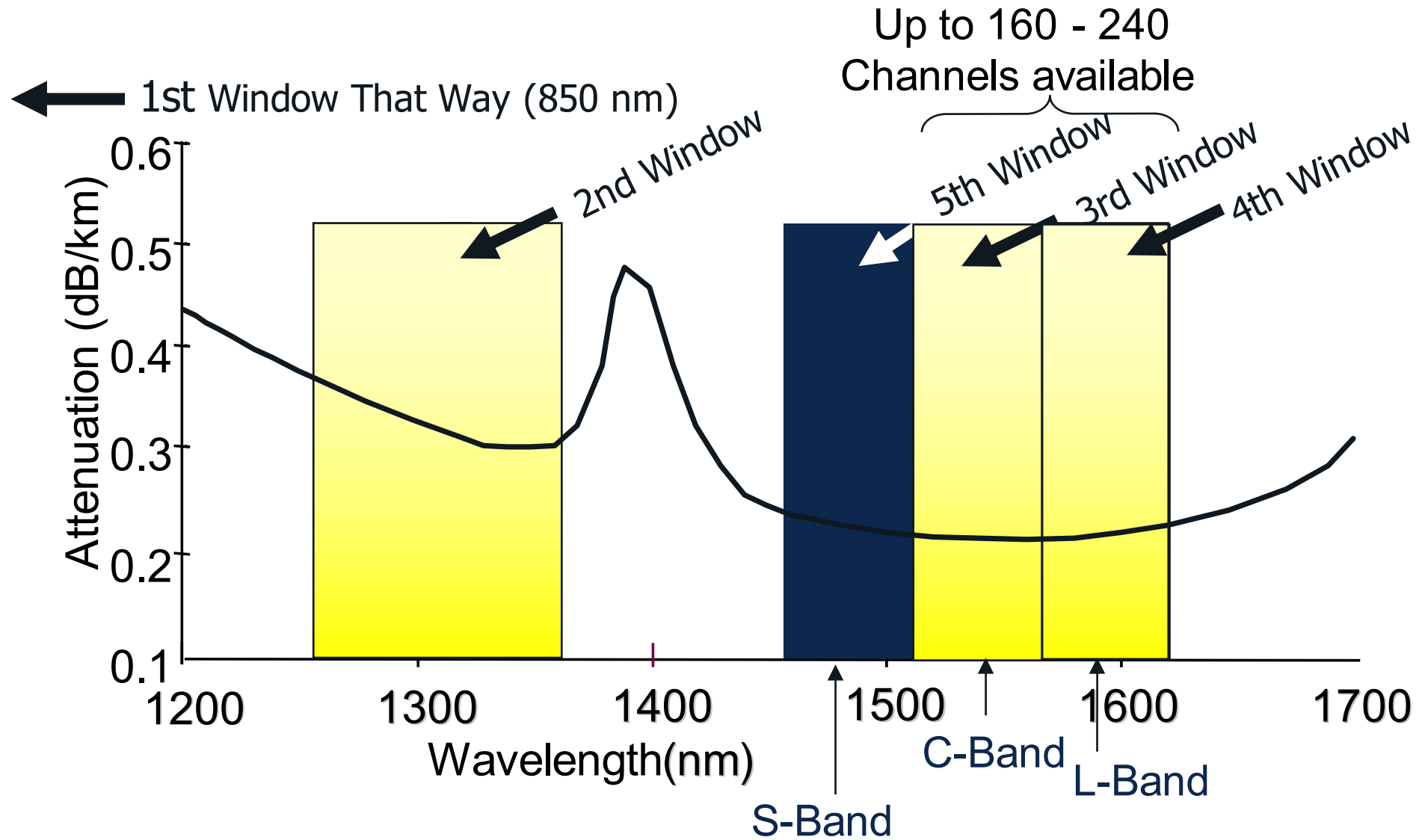
Applications for Different Fiber Types

Fiber Type	Application Notes
1 SMF (G.652) NDSF	<ul style="list-style-type: none">• Good for Single-Channel at 1310 nm• OK for Single-Channel at 1550• Good for DWDM (w/Dispersion Mgmt when needed)
DSF (G.653)	<ul style="list-style-type: none">• OK for Single-Channel at 1310 nm• Good for Single-Channel at 1550 nm• Bad for DWDM (C-Band) (causes non-linear effects)
2 NZDSF +/- (G.655)	<ul style="list-style-type: none">• OK for Single-Channel at 1310 nm• Good for Single-Channel at 1550 nm• OK for DWDM (C + L Bands)
Extended Band (G.652.C) reduced water peak	<ul style="list-style-type: none">• Good for Single-Channel at 1310 nm• OK for Single-Channel at 1550 nm• OK for DWDM (With Dispersion Mgmt.)• Good for CWDM (>8 wavelengths)

Fiber Evolution



Channel Allocation/Fiber

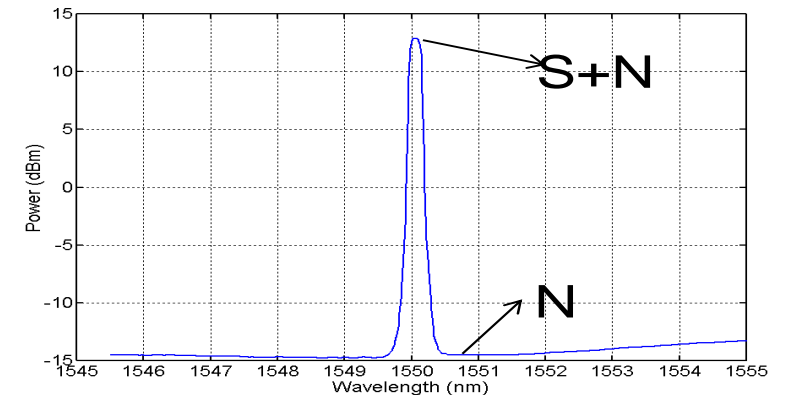
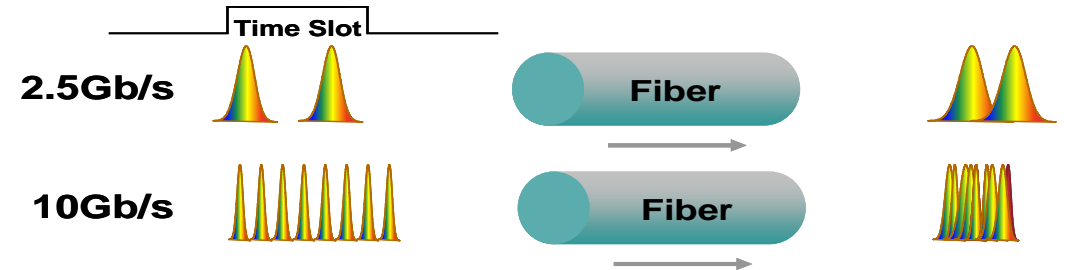
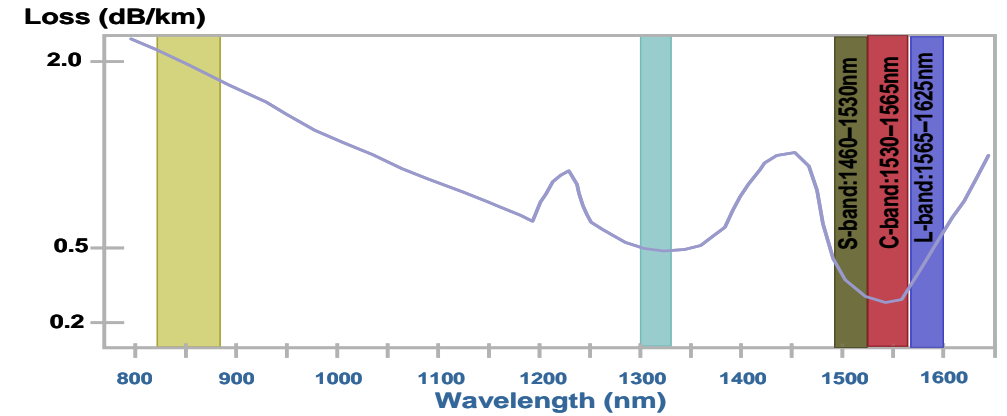


Transmission Impairments

Attenuation—Loss of Signal Strength

Chromatic Dispersion (CD)—
Distortion of pulses

Optical Signal to Noise Ratio (OSNR)—Effect of Noise in Transmission



Attenuation: Optical Budget

Basic Optical Budget = Tx Output Power – Rx Input Sensitivity



Engineered links usually assume 0.25dB/km or worse for 1550nm transmission

Simply...10dB Budget = 40km

Real Fiber Loss Measurements are preferred (i.e., OTDR, Laser Source/Meter)

- Optical Budget is affected by:
- Fiber attenuation
 - Splices
 - Patch Panels/Connectors
 - Optical components (filters, amplifiers, etc.)
 - Micro and Macro Bends in fiber
 - Contamination (dirt/oil on connectors)

Laser Output Power and Receiver Sensitivity and dBm

- **Fiber loss** expressed in **dB** but **transmitter/receiver power** is expressed in **dBm**
- This is why both the **transmitter output power** and the **receiver sensitivity** is expressed in **dBm**:

$$\text{Power}_{\text{dBm}} = 10 \log(P_{\text{mW}} / 1 \text{mW})$$

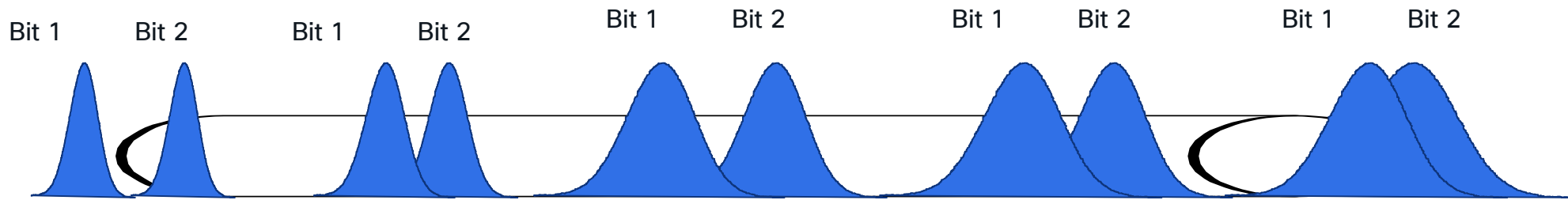
dB and **dBm** are **additive**, hence the simplification

Examples:

- 2mW is $\text{Power}_{\text{dbm}} = 10 \log(2\text{mW}/1\text{mW}) = 3\text{dBm}$
- 1mW is $\text{Power}_{\text{dbm}} = 10 \log(1\text{mW}/1\text{mW}) = 0\text{dBm}$

dB is decibels and dBm is decibels-milliwatt

Chromatic Dispersion (CD)

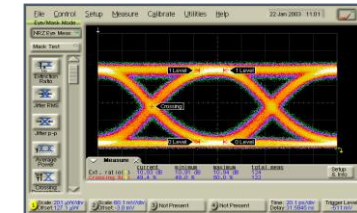
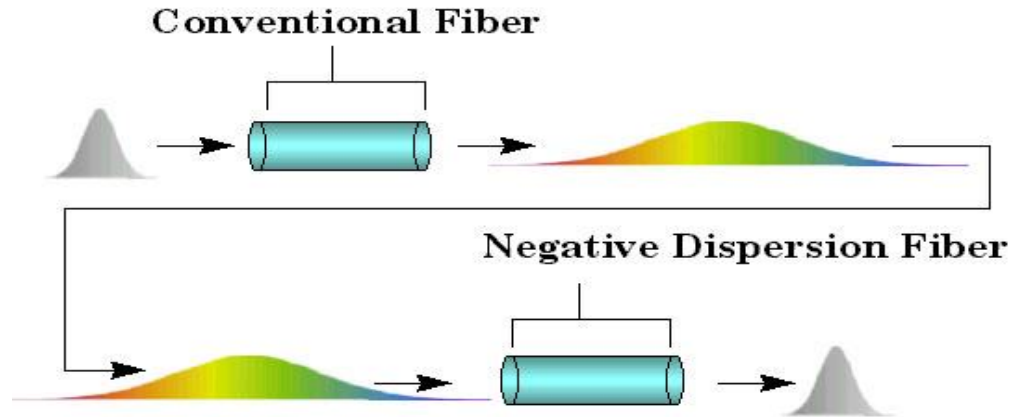
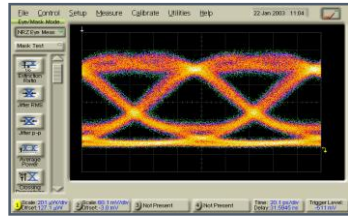


The Optical Pulse tends to Spread as it propagates down the fiber generating Inter-Symbol-Interference (ISI)

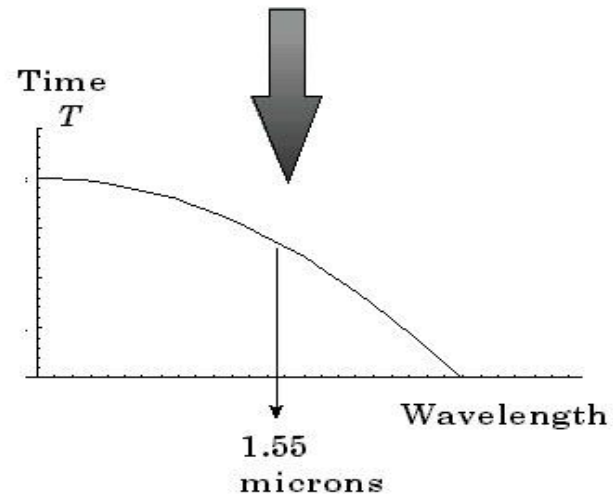
- **Total dispersion** is a function of the **length of fiber** and its **dispersion factor** – linear value
- Can **limit transmission** distance for **10G** and above wavelengths
- Can be compensated by:
 - Using negative dispersion fiber modules (DCM/DCF) – adds losses
 - Electronically with Coherent Optics generally at 100G and higher

Solution for Lower Speed Signals: Dispersion Compensating Unit

Negative Dispersion Fibers



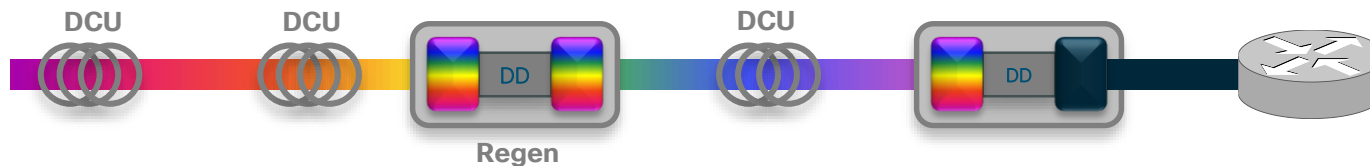
DCUs use fiber with chromatic dispersion of opposite sign/slope and of suitable length to bring the average dispersion of the link close to zero.



Solution for Higher Speed Signals: Coherent Detection

Direct Detection

- Must correct for impairments in the physical domain (insert DCU's)
- Forced to live with non-correctable impairments via network design (limit distance, regenerate, adjust channel spacing)
- Dumb detection (OOK), no Digital Signal Processing, only FEC



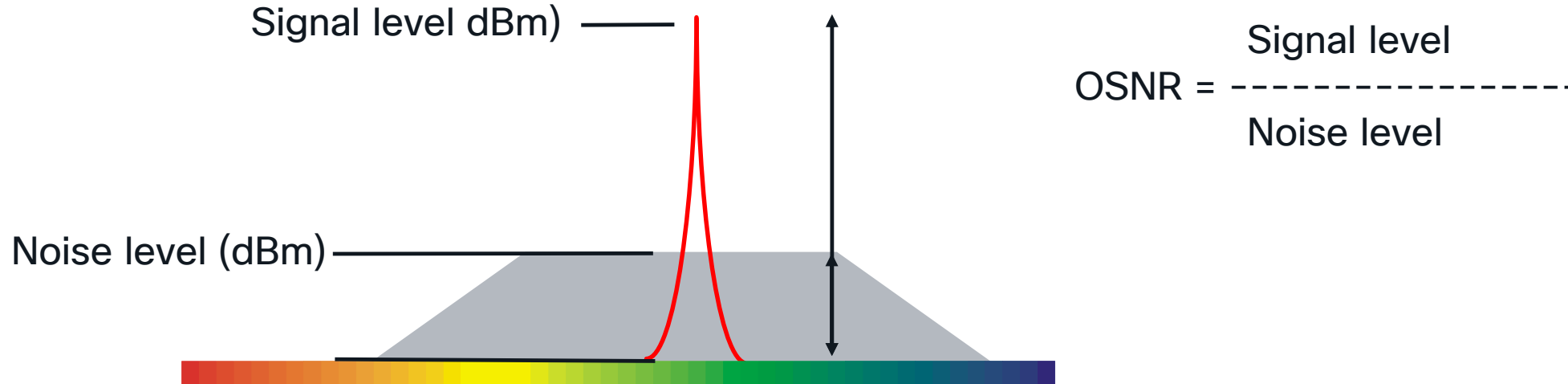
Coherent Detection

- Moves impairment correction from the optical domain into the digital domain
- Allows for digital correction of impairments (powerful DSP) vs. physical correction of impairments (DCU's). Adds advanced FEC
- Massive performance improvements over Direct Detection



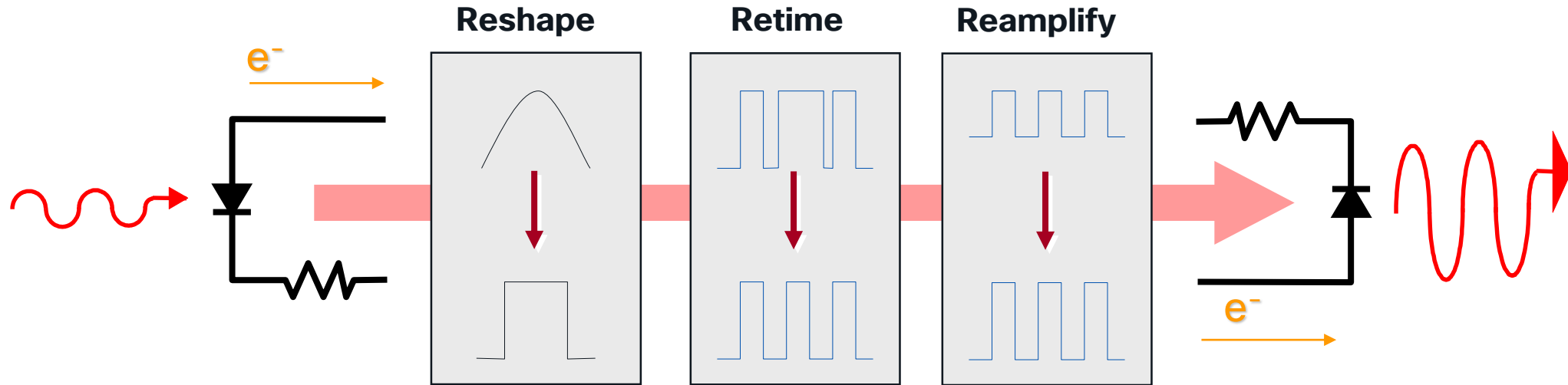
Optical Signal-to-Noise Ratio (OSNR)

- **OSNR** is a measure of the ratio of signal level to the level of system noise
- As **OSNR** decreases, possible errors increase
- OSNR is measured in decibels (dB)
- **EDFAs** are the source of noise



Final Solution: Regeneration

Regeneration involves the 3'R's:



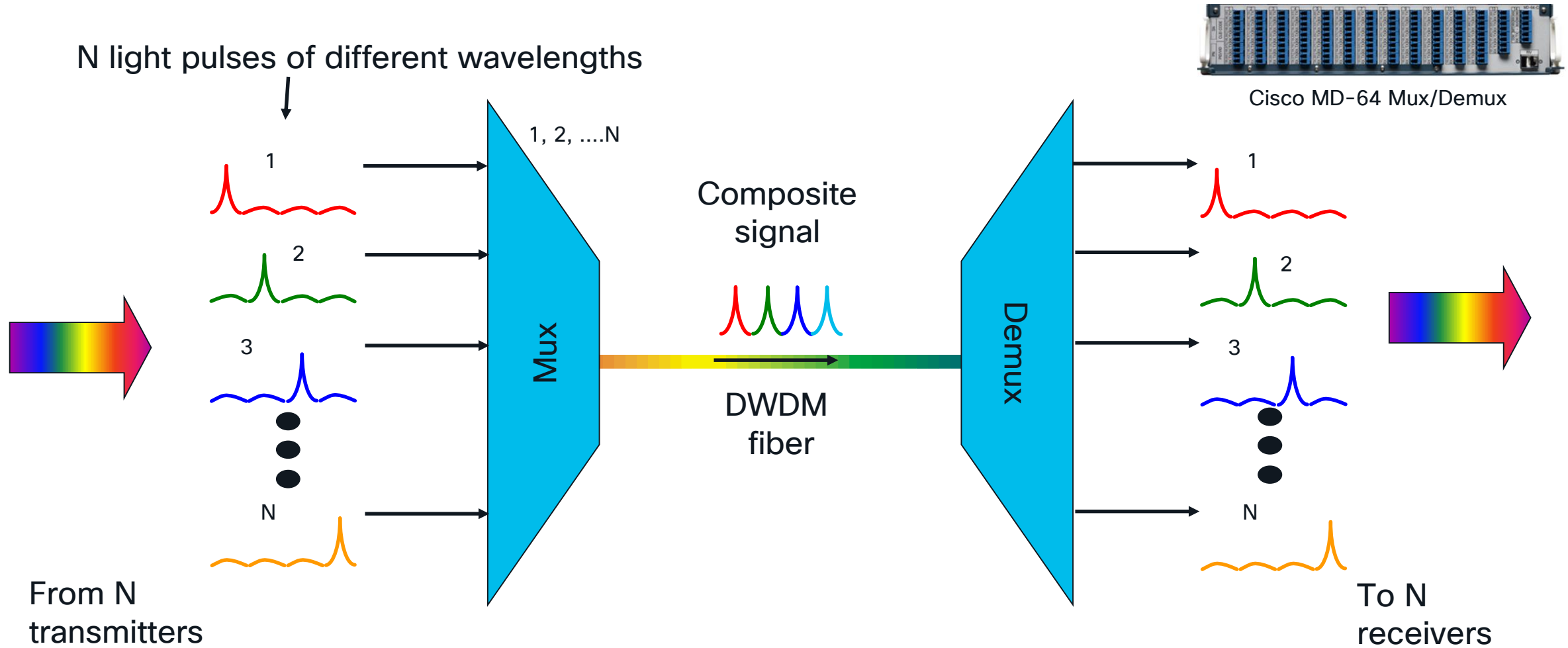
- Bit-Rate and Protocol Specific
- Most Costly Solution for multi-channel WDM Networks – 2x Interfaces required for every Channel

DWDM Components

Typical Components of DWDM Systems

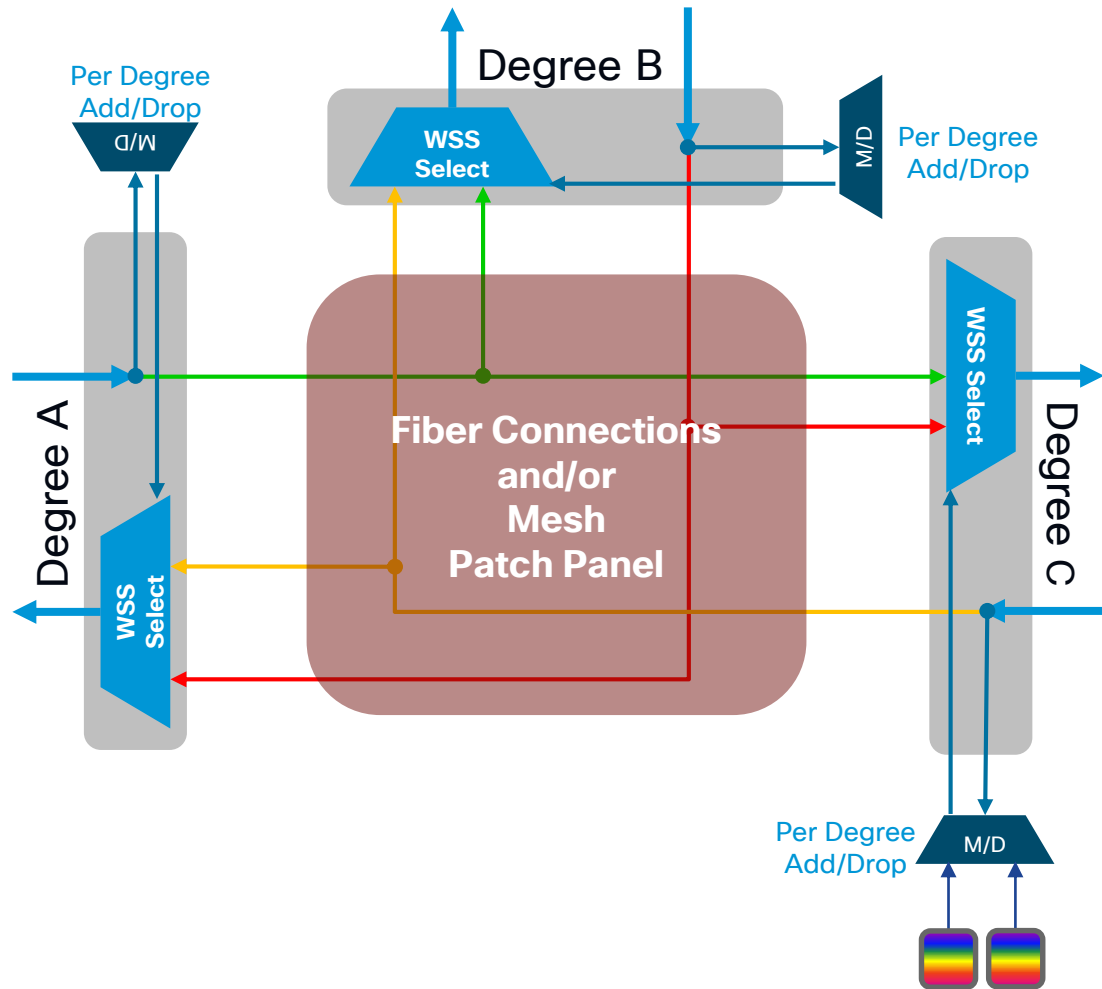
- DWDM **Mux/Demux** filters
- Optical Add/Drop Multiplexers (**OADM**s)
- Reconfigurable OADM (**ROADM**)
- Optical **amplifiers** (EDFA or RAMAN)
- **Transponders/Muxponders**

DWDM Mux and Demux Filters Block Diagram

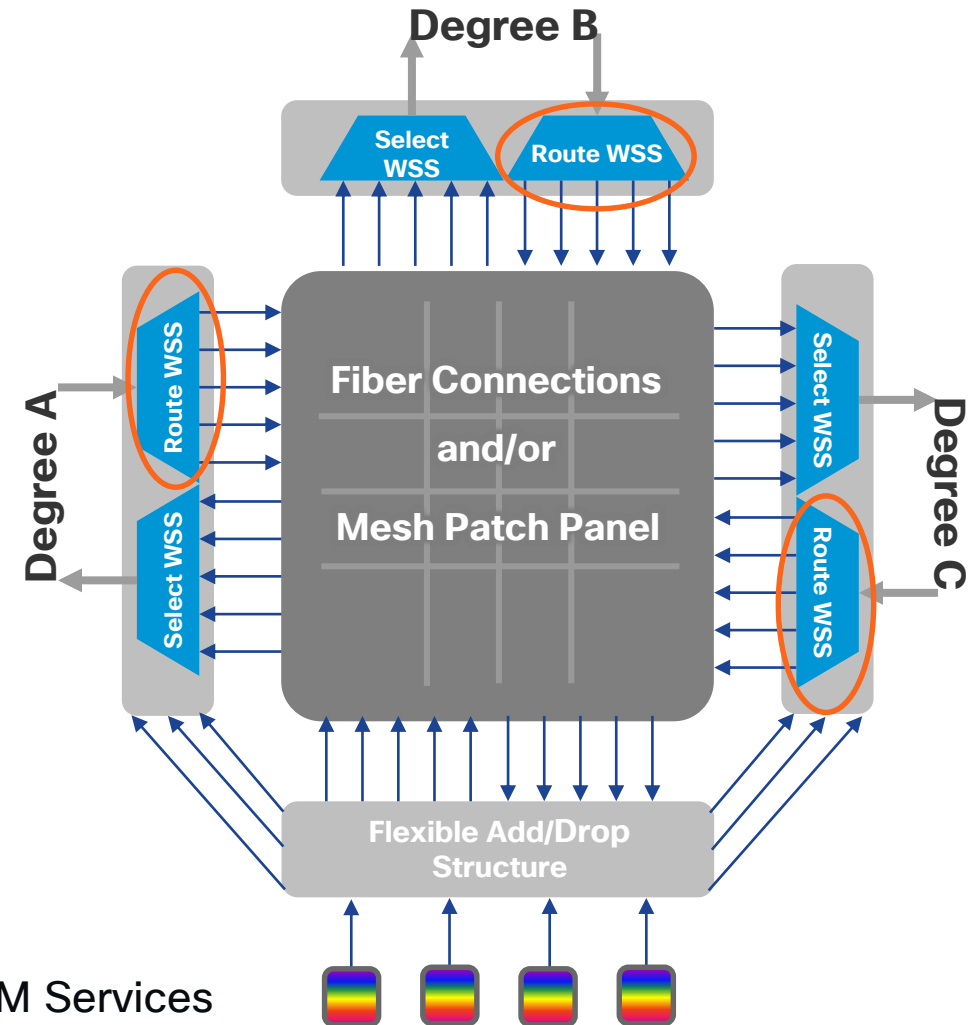


ROADM Types

“Broadcast and Select” Architecture



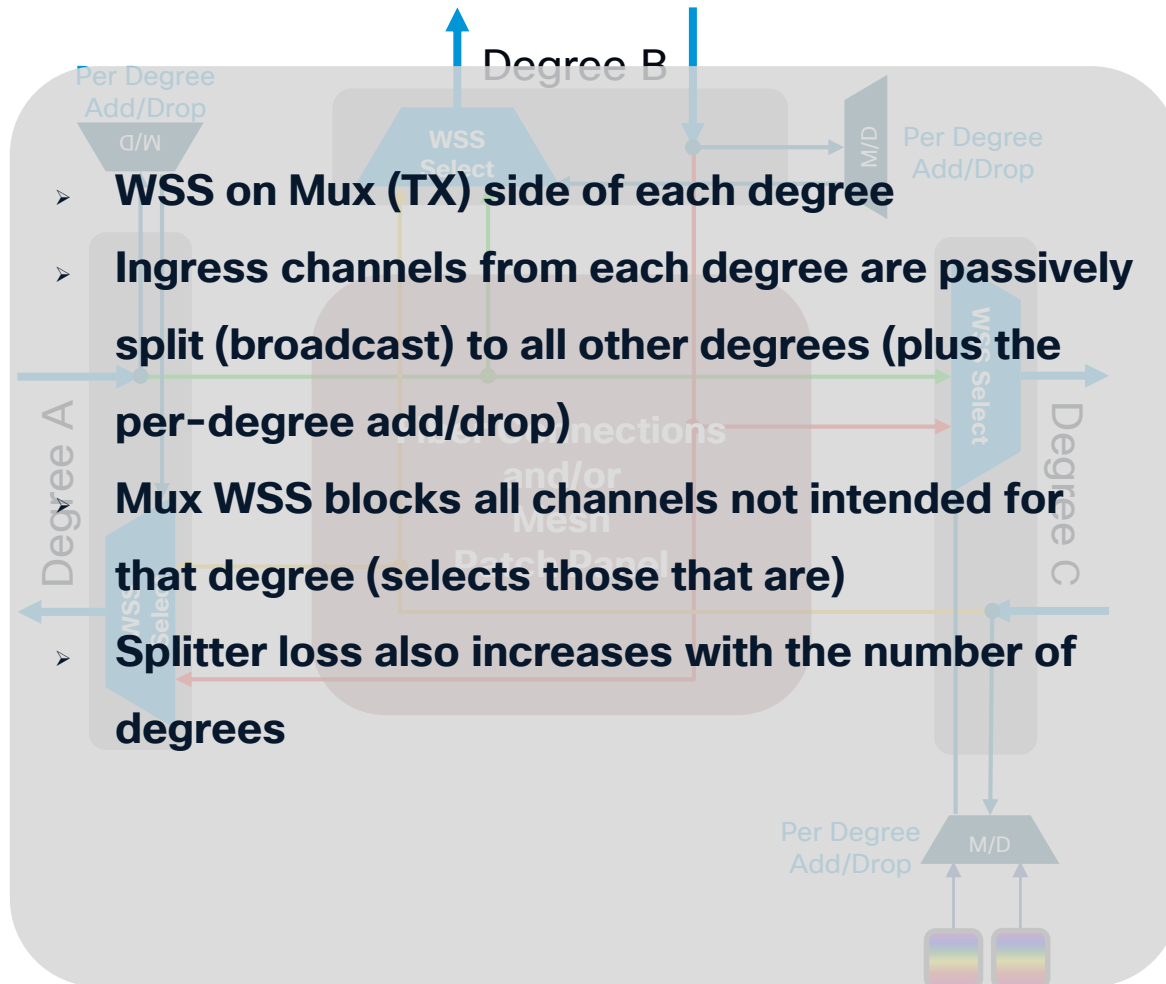
“Route and Select” Architecture



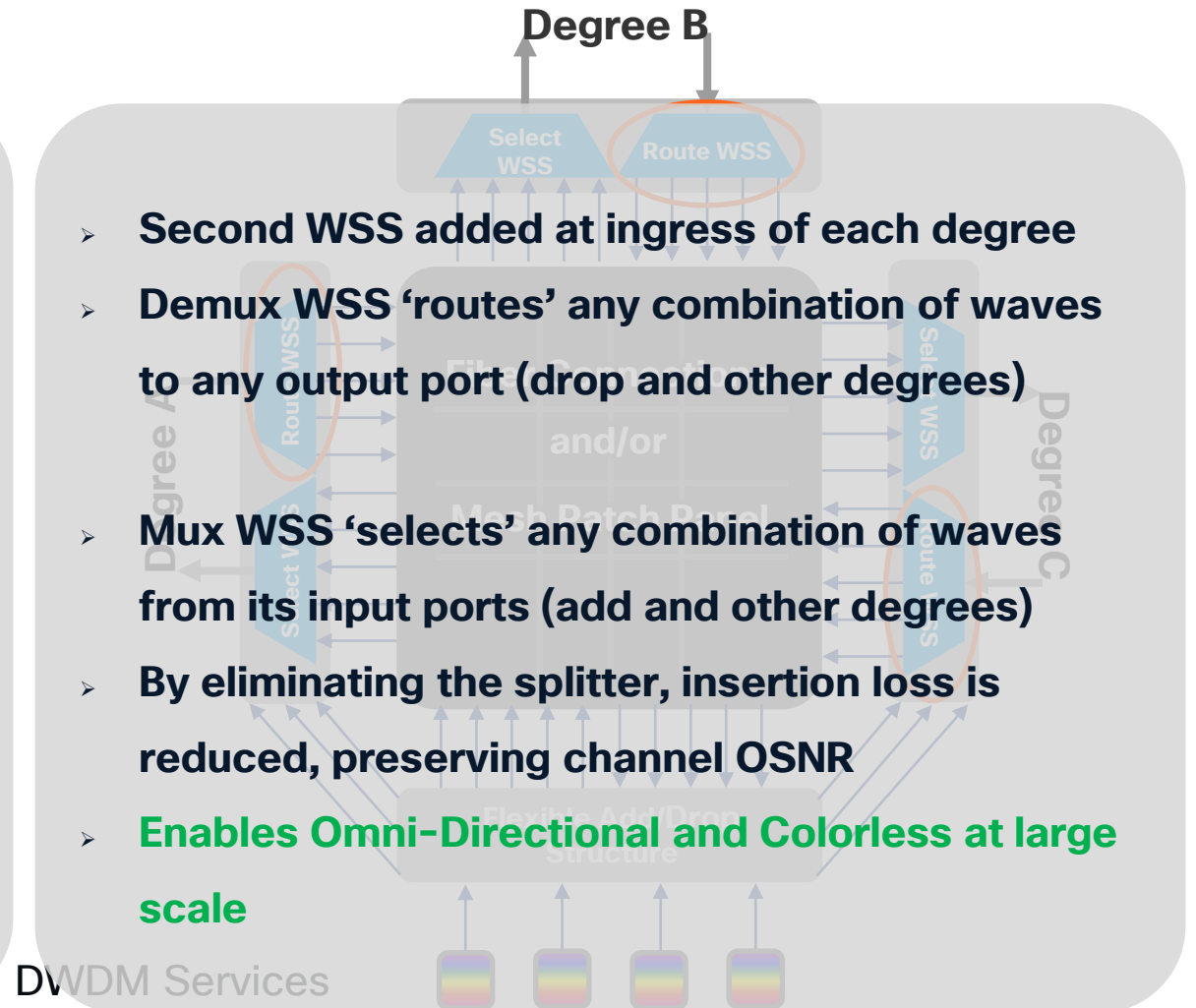
DWDM Services

ROADM Types

“Broadcast and Select” Architecture

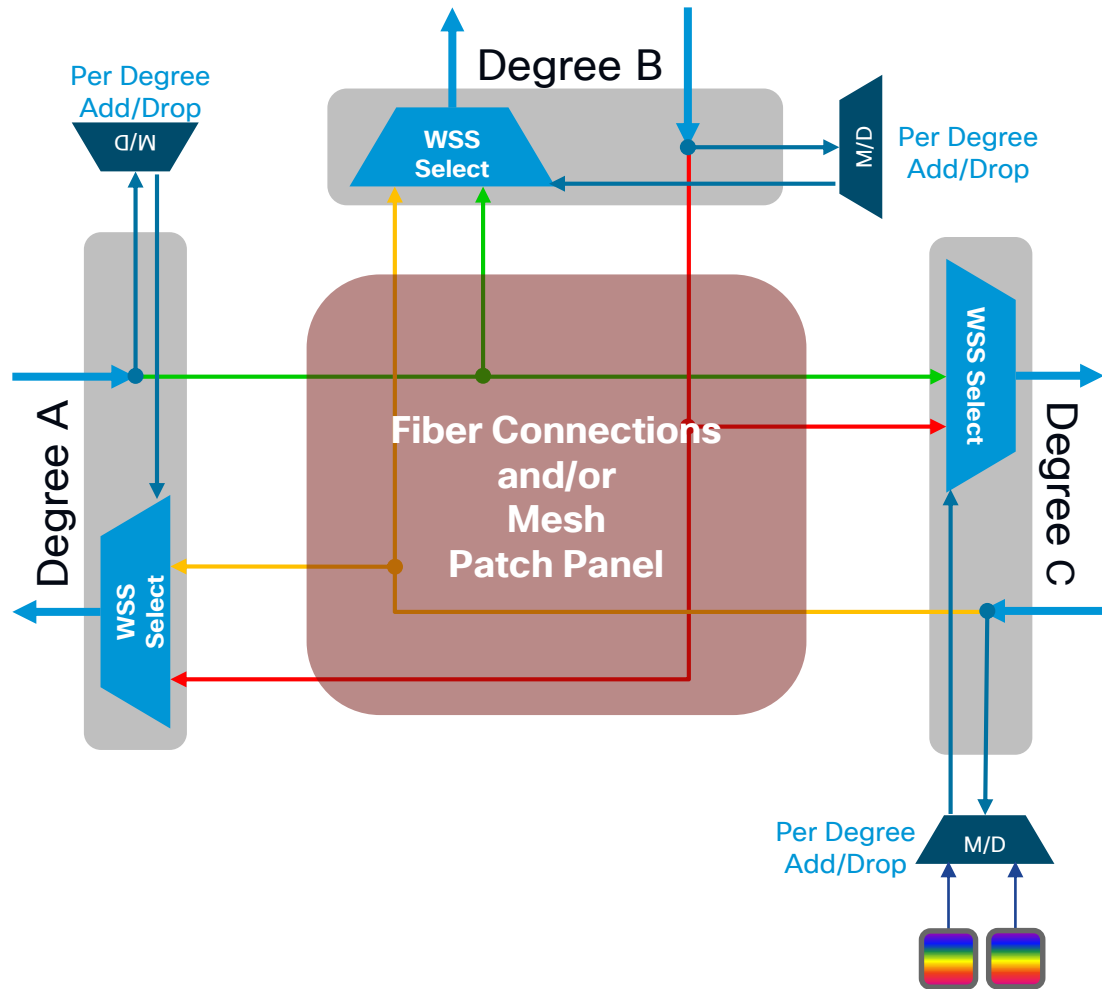


“Route and Select” Architecture

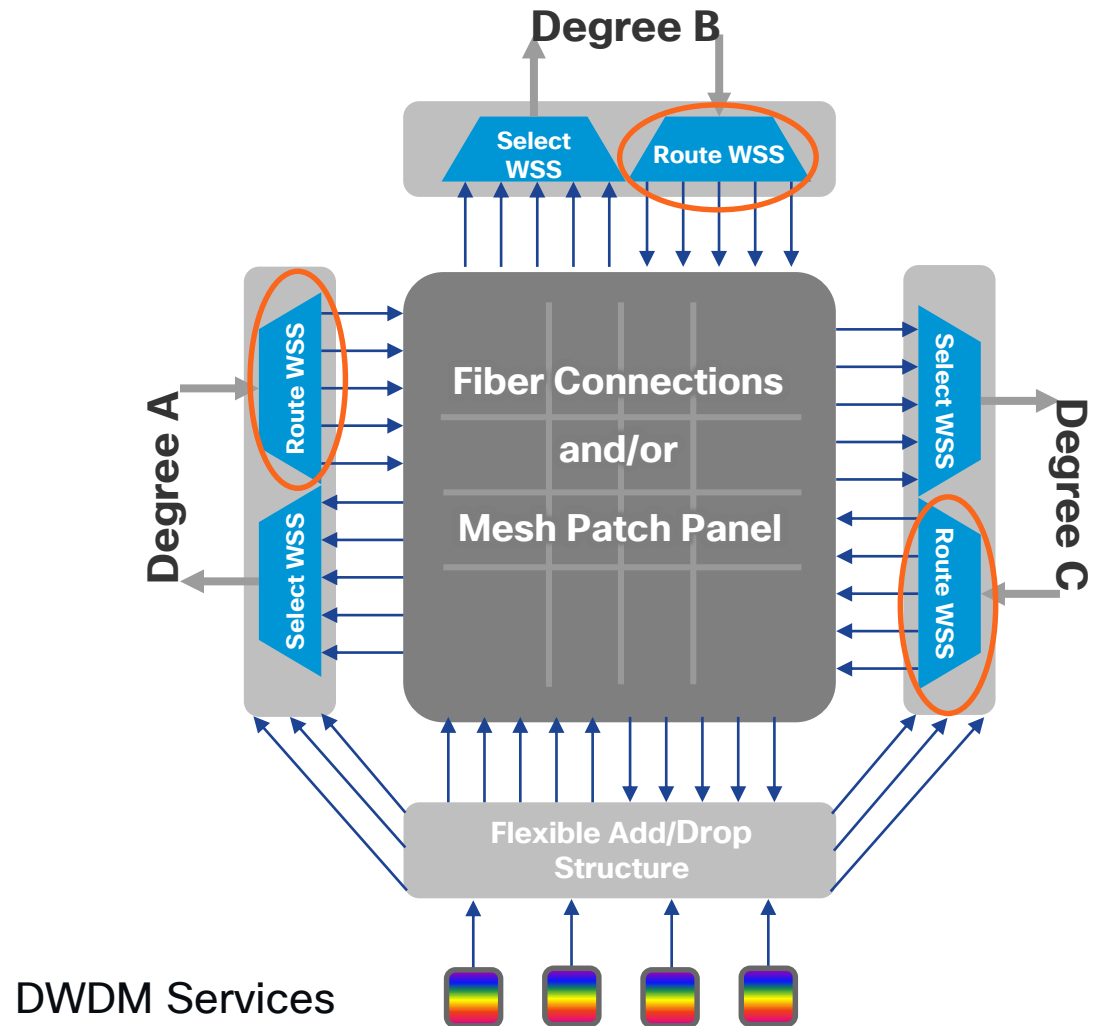


ROADM Types

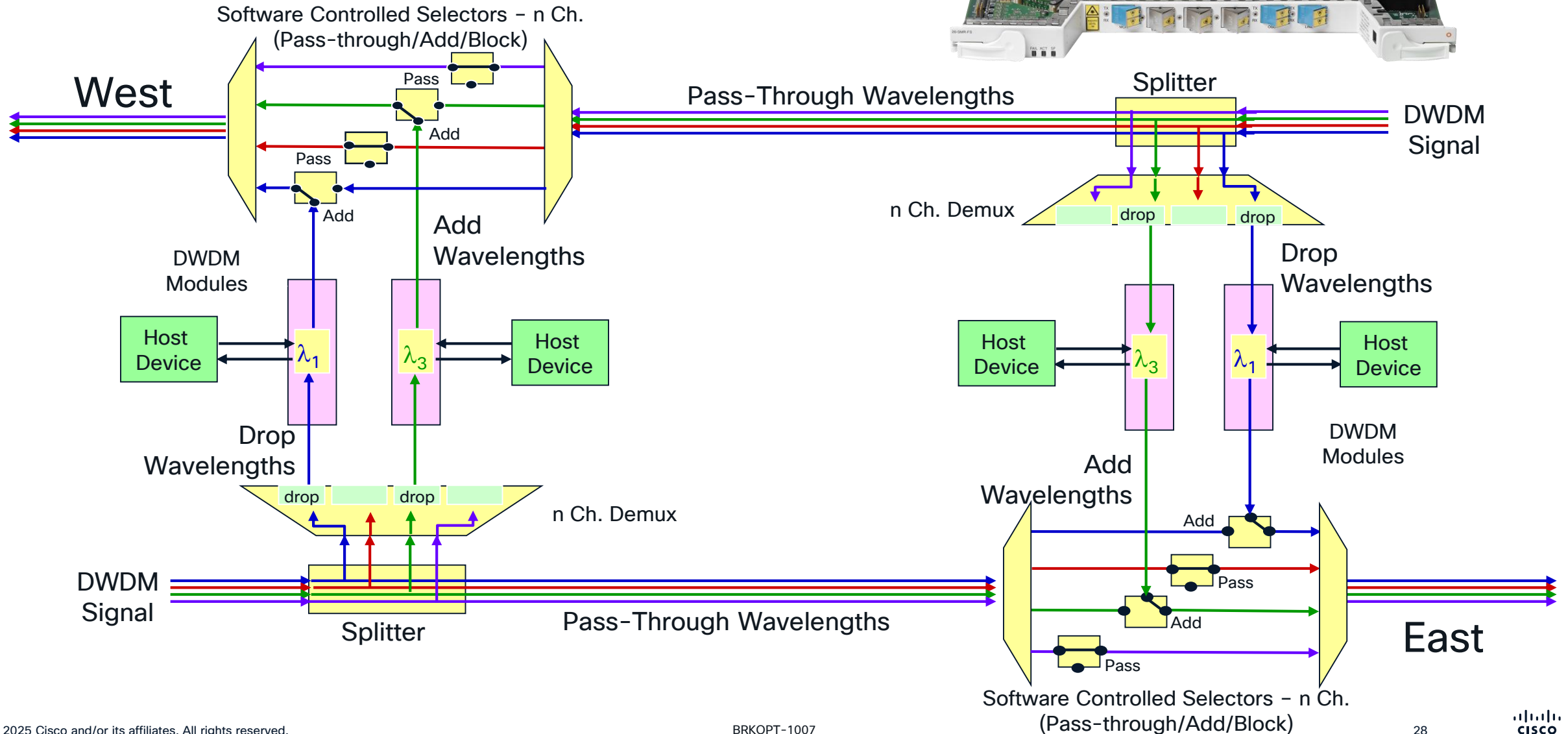
“Broadcast and Select” Architecture



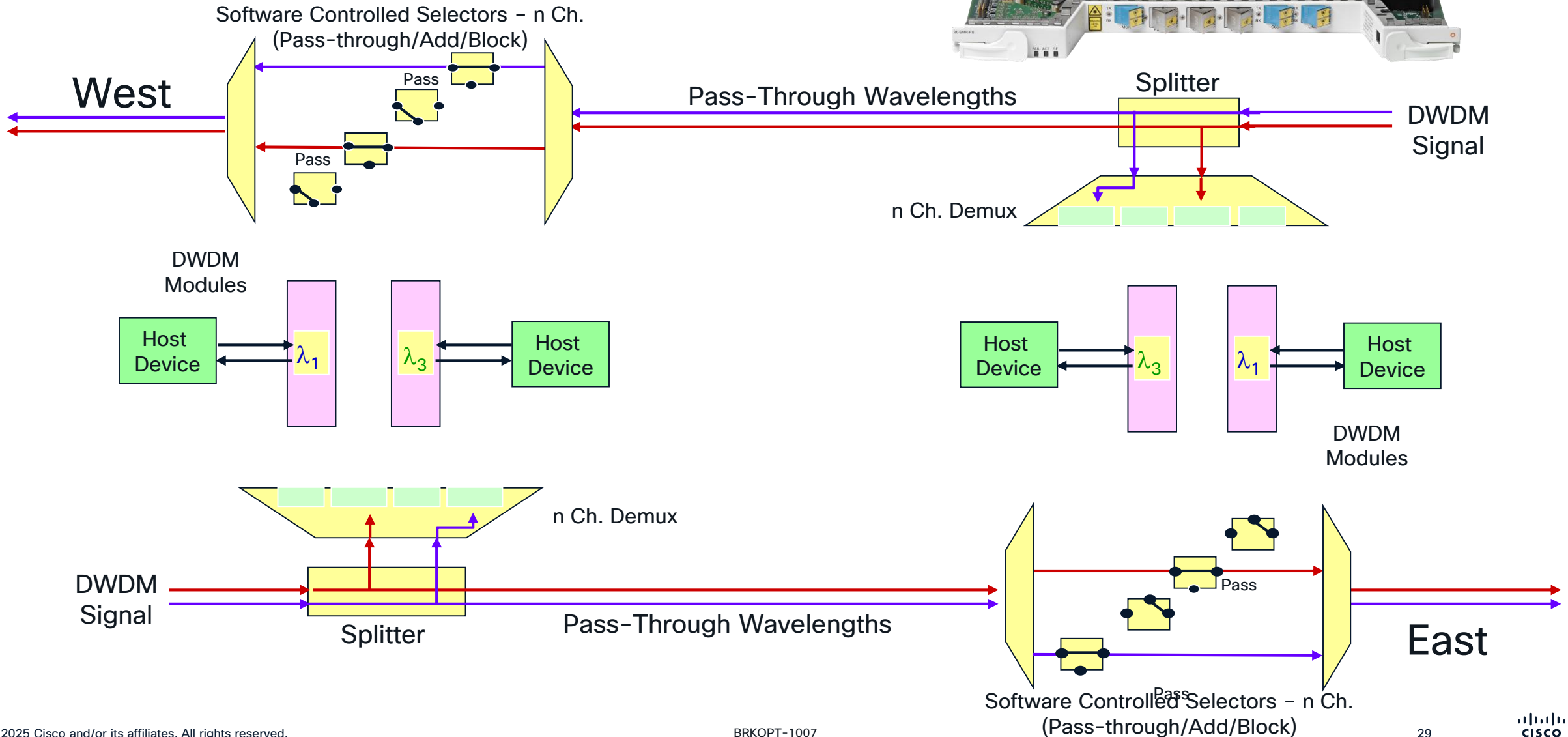
“Route and Select” Architecture



Simple ROADM Architecture

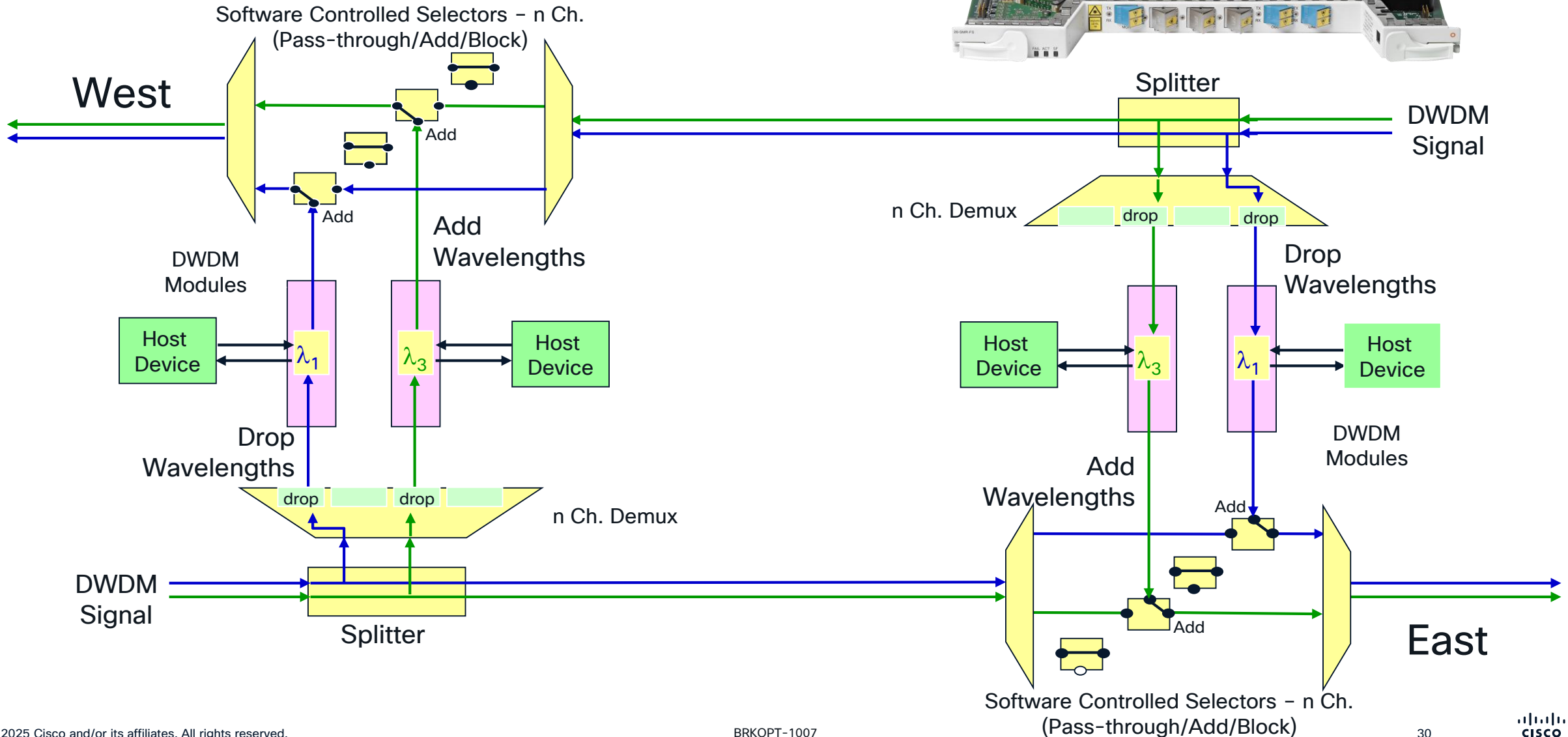


Simple ROADM Architecture

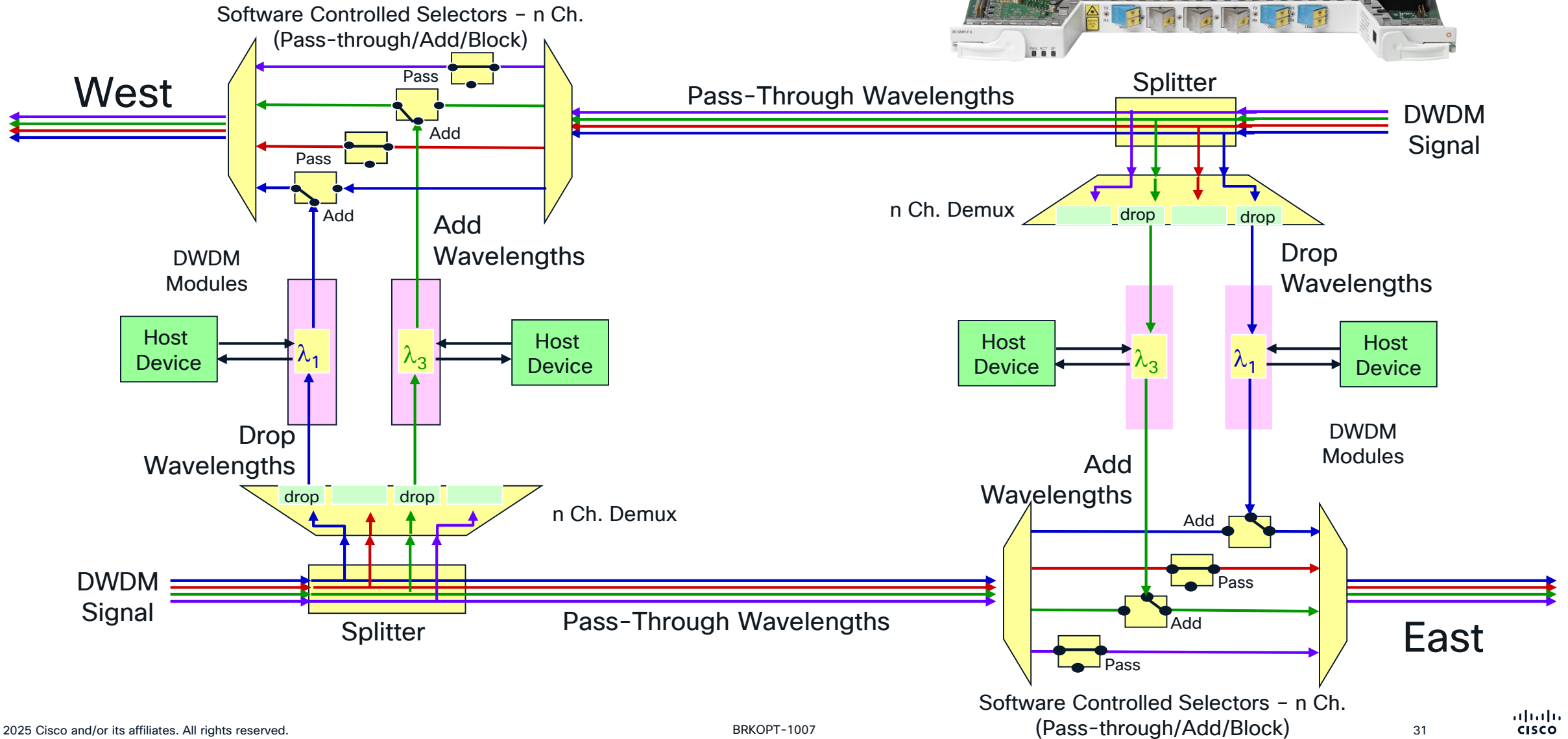


Simple ROADM Architecture

Add/Drop Wavelengths

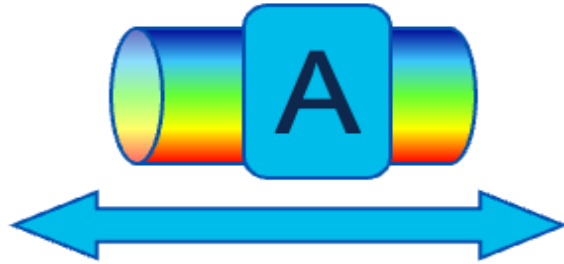


Simple ROADM Architecture

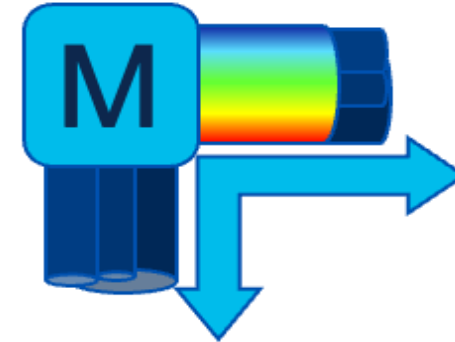


DWDM Services Types

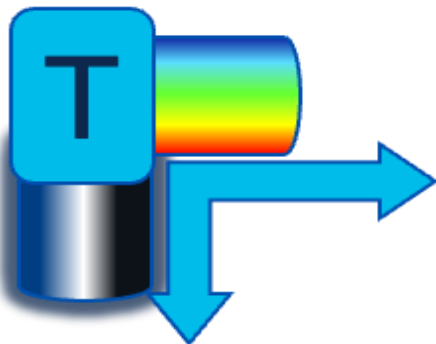
these terms are often interchanged, and many cards can support multiple



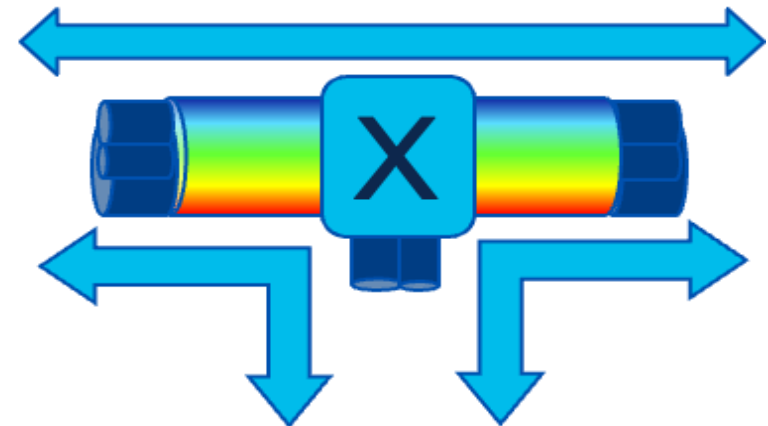
Alien: Foreign DWDM → Wavelength



Muxponder: Many → Wavelength



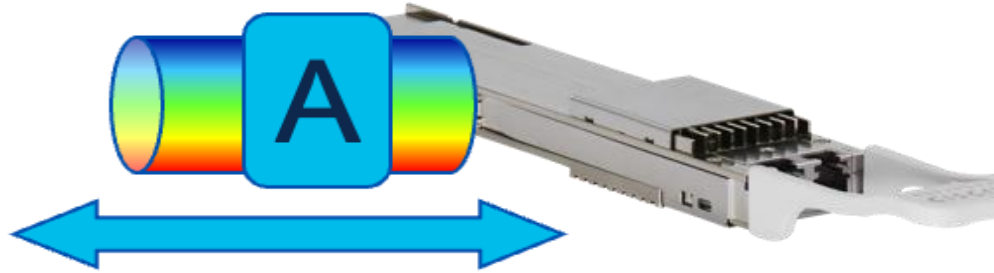
Transponder: One → Wavelength



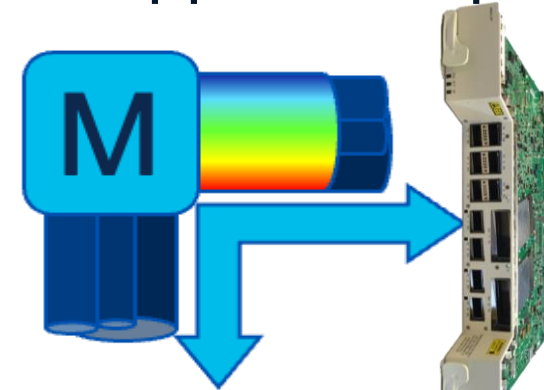
Crossponder: Muxponder +

DWDM Services Types

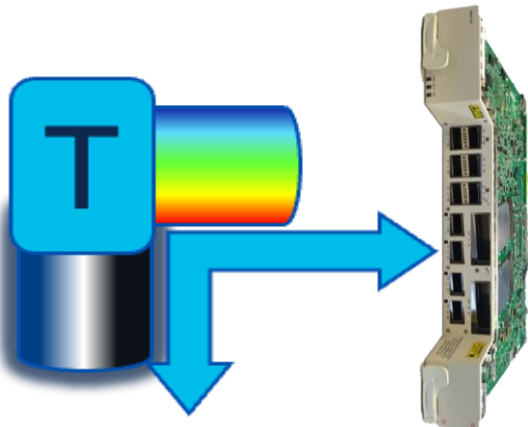
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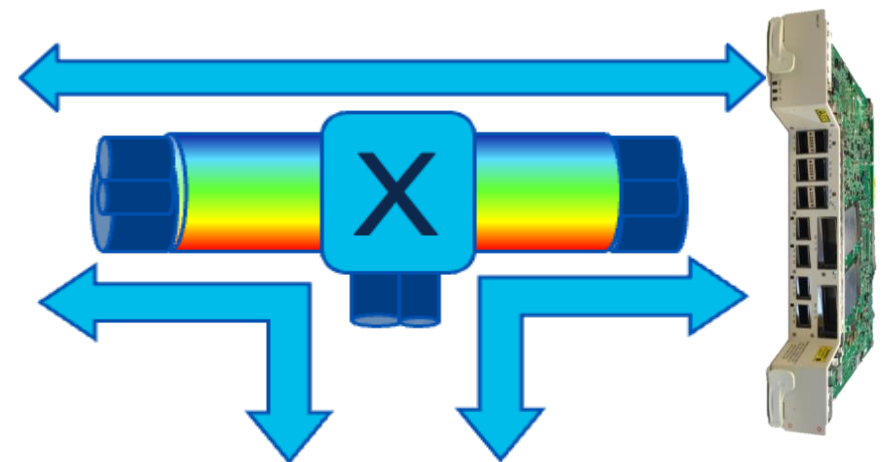
Alien: Foreign DWDM → Wavelength



Muxponder: Many → Wavelength



Transponder: One → Wavelength



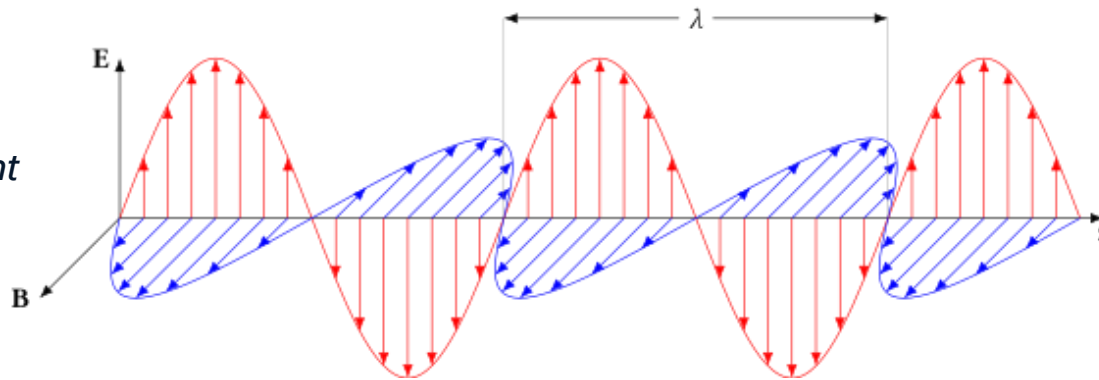
Crossponder: Muxponder+

Optical Modulation Brief

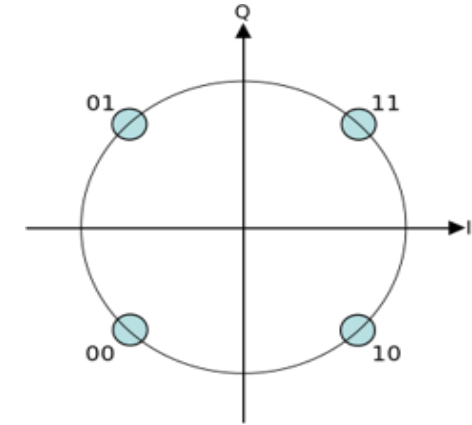
Modulation	Description	bps	Polarization Multiple	Total BW Multiple
OOK	On-off Keying	1	1	1
BPSK	Binary Phase Shift Keying	1	2	2
(D)QPSK	(Differential) Quadrature Phase Shift Keying	2	2	4
8-QAM	8-state Quadrature Amplitude Modulation	3	2	6
16-QAM	16-state Quadrature Amplitude Modulation	4	2	8
32-QAM	32-state Quadrature Amplitude Modulation	5	2	10
64-QAM	64-state Quadrature Amplitude Modulation	6	2	12

All of these can be and generally are polarization-multiplexed to double the symbol rate

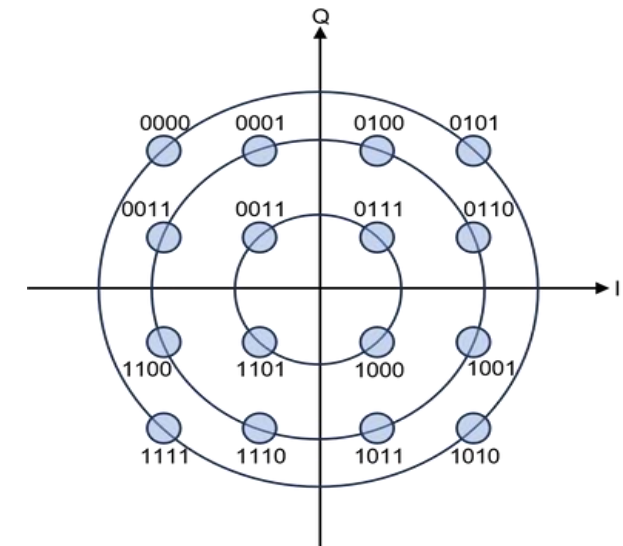
Transverse polarization of light



Constellation diagram of QSPK modulation



Constellation diagram of 16-QAM modulation

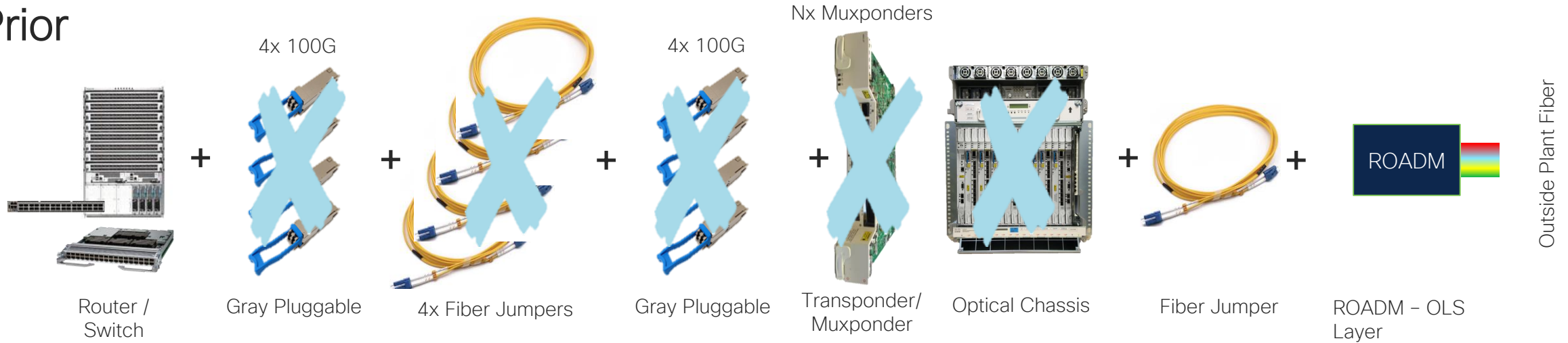


<https://www.cisco.com/c/en/us/support/docs/optical-networking/routed-optical-networking/221071-understand-coherent-optical-modulation.html>

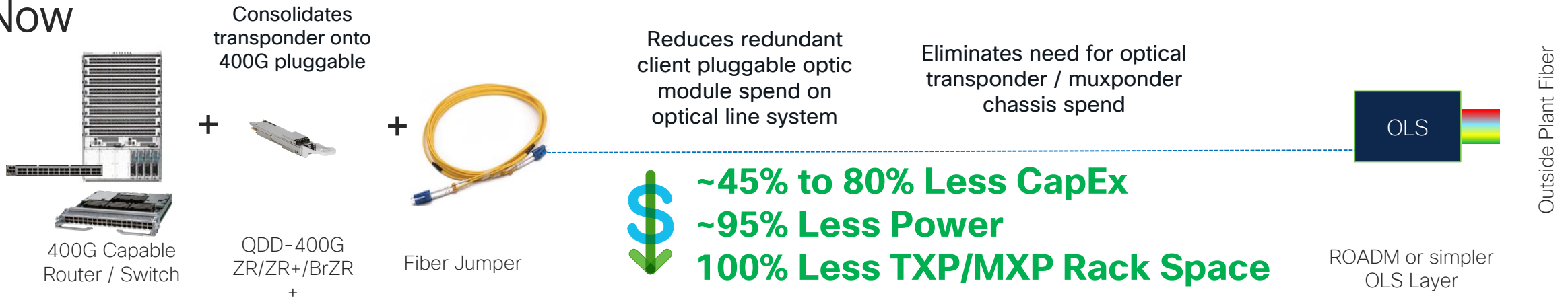
DWDM in Routers

Traditional vs. Coherent Deployments

Prior



Now



~45% to 80% Less CapEx
~95% Less Power
100% Less TXP/MXP Rack Space

DWDM Service Card Shelves vs. Native Routers



Cisco NCS 2015
14-RU
15x Service Slots
Up to 8.5Tbps
Up to 5,250W



Cisco NCS 1014
2-RU
4x Service Slots
Up to 12.8Tbps
Up to 2,500W



Cisco 8201-32FH
1-RU
32x 400Gbps
Up to 12.8Tbps
Up to 2,000W fulfill



*Add Pluggables as
needed
Use 400G Coherent or
Gray Optics*

400G DCO's: Native DWDM Interfaces in Routers



400G-ZR



Access to Metro Networks

400GE Client

400G Trunk

Up to 120km

TX Power
-10dBm

C-FEC

400G-ZR+



Access to Long Haul Networks

100GE, 200GE, 400GE,
n x100GE MXP Mode

100G, 200G, 300G, 400G
Trunk Rates

Up to 1,400km at 400G
Longer distances at lower trunk rates

TX Power
-10dBm

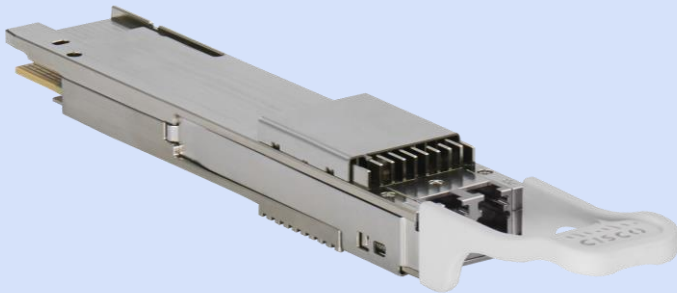
C-FEC and
O-FEC

TX Power
+0dBm

400G-ZR+
Bright



Cisco Bright QSFP-DD ZR+

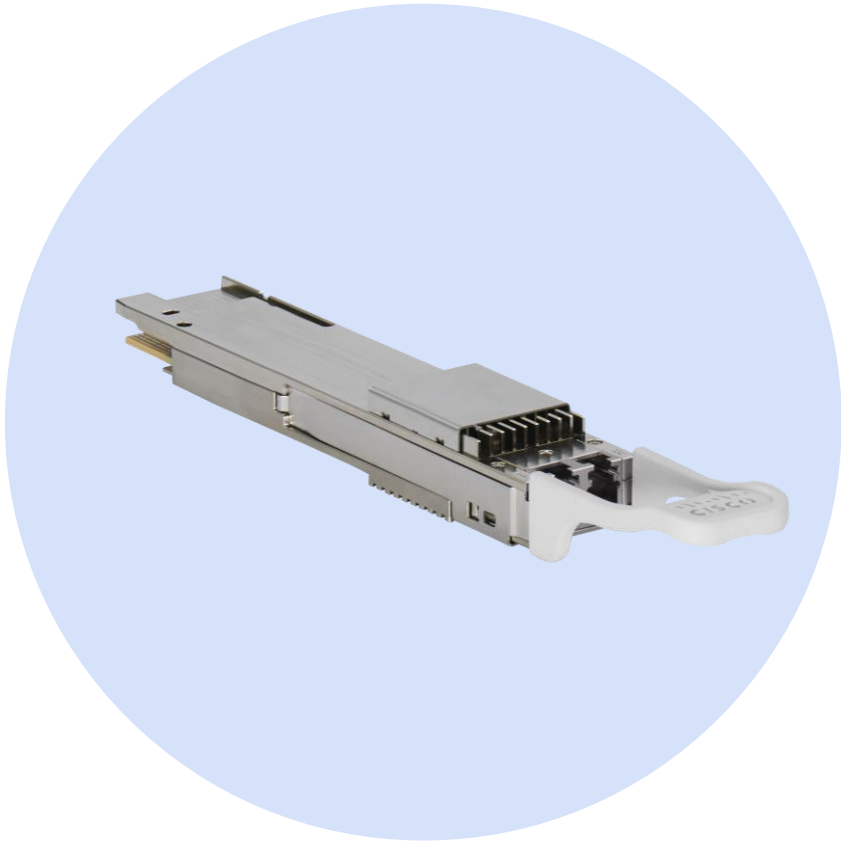


Product ID: DP04QSDD-HE0=*

* Ethernet variant

- 400G ZR+ QDD pluggable with **+0dBm EOL TX Power**
- **Easier interoperability** with all deployed Add/Drop architectures
- **Enhances un-amplified reach** by about 10dB
- Optical specifications aligned with current OpenZR+
- **Improved OSNR Sensitivity of 0.6dB (EOL)**
- Two different versions
 - **Ethernet** only (for Routers and Switches)
 - **OTN** (for **OpenROADM** hosts)
 - OTN option offers support of **L1 Encryption**

Cisco 400G-ULH QSFP-DD ZR+



Product ID: DP04QSDD-ULH-A1= (C-Band)
DP04QSDD-LLH-A1= (L-Band)*

- 400G ZR+ QDD pluggable supporting Ultra Long-Haul Applications
 - Designed for existing QSFP-DD Ports and Platforms
 - Similar Power Consumption (<24W)
- Supports Multiple Baud Rates
 - 118GBaud QPSK – 3,000km
 - 98GBaud PCS – 2,500km
 - 87GBaud PCS – 2,000km
 - 75GBaud PCS – 1,600km
 - 66GBaud PCS – 1,200km
 - Existing 400G-ZR+ Modes for interoperability
- Easier provisioning with Appsel Codes
- Two different versions – C-Band and L-Band*

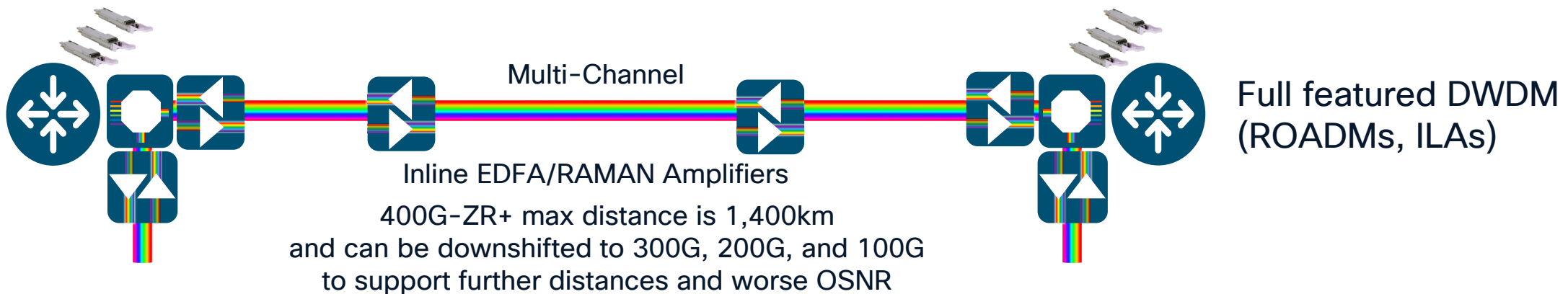
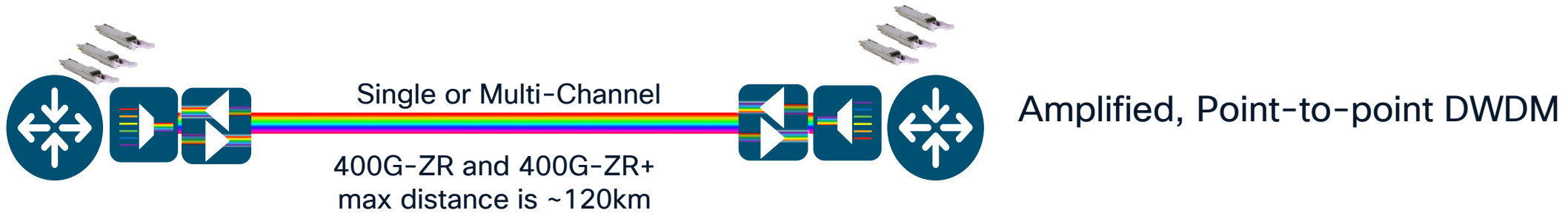
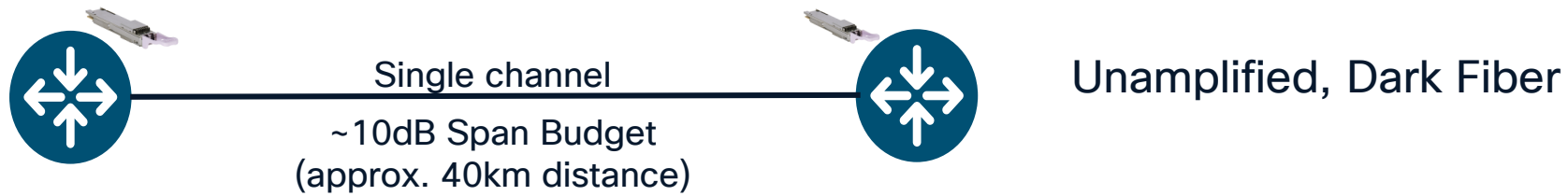
*Disclaimer: L-Band Version is pending Release.
Please confirm availability with Cisco.

Cisco 400G-ULH Appsel Codes

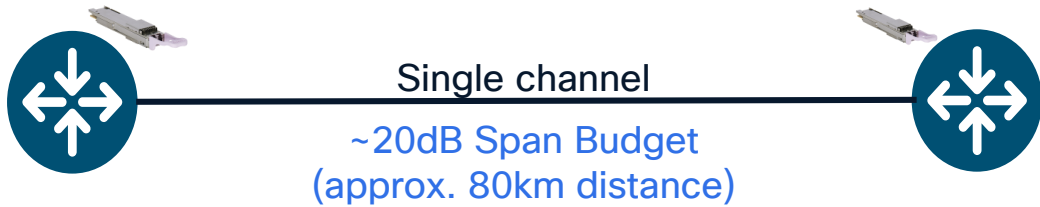
RP/0/RP0/CPU0:8201-161_ULH#sh controller optics 0/0/0/0 appsel advertised
 Sat Jun 7 00:45:07.316 UTC

App-ID	Host-ID	Media-ID	Standard	Host Supported	Power Consumption (W)
1	17	ETH 400GAUI-8 C2M (Annex 100	OpenROADM FLEXO-4e-DO-QP OpenROADM	Yes	n/a
2	15	ETH 200GAUI-4 C2M (Annex 100	OpenROADM FLEXO-4e-DO-QP OpenROADM	Yes	n/a
3	13	ETH 100GAUI-2 C2M (Annex 100	OpenROADM FLEXO-4e-DO-QP OpenROADM	Yes	n/a
4	17	ETH 400GAUI-8 C2M (Annex 216	ACA FlexO-4e-MPCS098-OS ACA	Yes	n/a
5	15	ETH 200GAUI-4 C2M (Annex 216	ACA FlexO-4e-MPCS098-OS ACA	Yes	n/a
6	13	ETH 100GAUI-2 C2M (Annex 216	ACA FlexO-4e-MPCS098-OS ACA	Yes	n/a
7	17	ETH 400GAUI-8 C2M (Annex 201	ACA FlexO-4e-MPCS087-OS ACA	Yes	n/a
8	15	ETH 200GAUI-4 C2M (Annex 201	ACA FlexO-4e-MPCS087-OS ACA	Yes	n/a
9	13	ETH 100GAUI-2 C2M (Annex 201	ACA FlexO-4e-MPCS087-OS ACA	Yes	n/a
10	17	ETH 400GAUI-8 C2M (Annex 194	ACA FlexO-4e-MPCS075-OS ACA	Yes	n/a
11	15	ETH 200GAUI-4 C2M (Annex 194	ACA FlexO-4e-MPCS075-OS ACA	Yes	n/a
12	13	ETH 100GAUI-2 C2M (Annex 194	ACA FlexO-4e-MPCS075-OS ACA	Yes	n/a
13	17	ETH 400GAUI-8 C2M (Annex 192	ACA FlexO-4e-MPCS066-OS ACA	Yes	n/a
14	15	ETH 200GAUI-4 C2M (Annex 192	ACA FlexO-4e-MPCS066-OS ACA	Yes	n/a
15	13	ETH 100GAUI-2 C2M (Annex 192	ACA FlexO-4e-MPCS066-OS ACA	Yes	n/a
16	17	ETH 400GAUI-8 C2M (Annex 198	ACA OpenZR400-16QAM-OS-E ACA	Yes	n/a
17	15	ETH 200GAUI-4 C2M (Annex 198	ACA OpenZR400-16QAM-OS-E ACA	Yes	n/a
18	13	ETH 100GAUI-2 C2M (Annex 198	ACA OpenZR400-16QAM-OS-E ACA	Yes	n/a
19	17	ETH 400GAUI-8 C2M (Annex 70	OpenZR+ ZR400-OFEC-16QAM OpenZR+	Yes	n/a
20	15	ETH 200GAUI-4 C2M (Annex 70	OpenZR+ ZR400-OFEC-16QAM OpenZR+	Yes	n/a
21	13	ETH 100GAUI-2 C2M (Annex 70	OpenZR+ ZR400-OFEC-16QAM OpenZR+	Yes	n/a
22	17	ETH 400GAUI-8 C2M (Annex 54	OpenZR+ ZR400-OFEC-16QAM OpenZR+	Yes	n/a
23	15	ETH 200GAUI-4 C2M (Annex 54	OpenZR+ ZR400-OFEC-16QAM OpenZR+	Yes	n/a
24	13	ETH 100GAUI-2 C2M (Annex 54	OpenZR+ ZR400-OFEC-16QAM OpenZR+	Yes	n/a
25	60	OTN-ITU-T FOIC1.2 (ITU-T 220	ACA FlexO-4-MPCS101-OS ACA	No	n/a
26	60	OTN-ITU-T FOIC1.2 (ITU-T 202	ACA FlexO-4-MPCS087-OS ACA	No	n/a
27	60	OTN-ITU-T FOIC1.2 (ITU-T 196	ACA FlexO-4-MPCS079-OS ACA	No	n/a
28	60	OTN-ITU-T FOIC1.2 (ITU-T 193	ACA FlexO-4-MPCS069-OS ACA	No	n/a

What's the Reach - ZR and ZR+

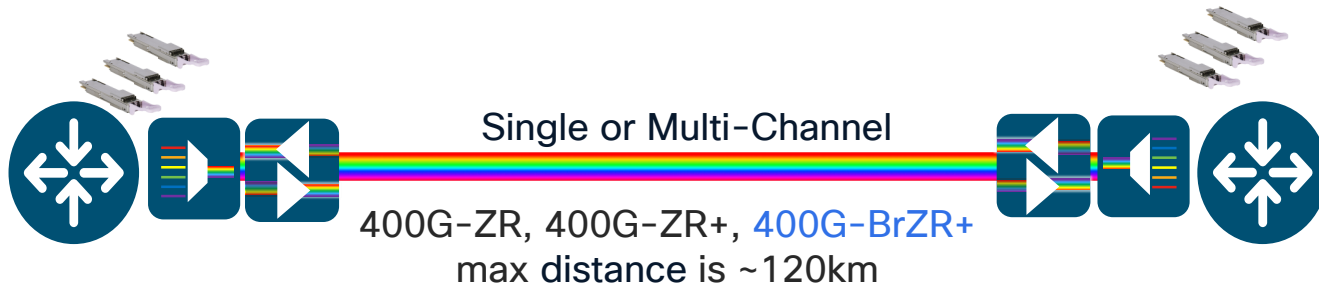


What's the Reach – including Bright ZR+



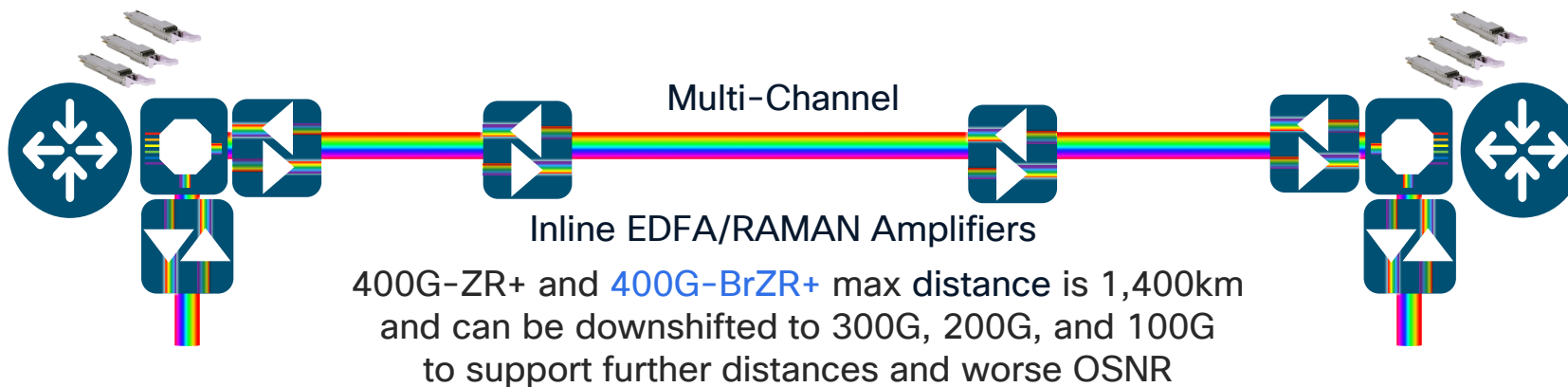
Unamplified, Dark Fiber

400G-BrZR+ supports up to 2x the loss and distance



Amplified, Point-to-point DWDM

400G-BrZR+ could require less amplification due to the increased TX Power



Full featured DWDM (ROADMs, ILAs)

400G-BrZR+ has 0.6dB of OSNR Improvement

What's the Reach – including ULH

Baud Rate	Modulation	Circuit Size	Approx Distance
118GBaud	QPSK	137.5GHz	+3,000km
98GBaud	PCS	112.5GHz	+2,500km
87GBaud	PCS	100GHz	+2,000km
75GBaud	PCS	87.5GHz	+1,600km
66GBaud	PCS	75GHz	+1,200km
OpenZR+ Modes	16-QAM	75GHz	variable

Single channel

Single or Multi-Channel

Unamplified, Dark Fiber

Amplified, Point-to-point DWDM



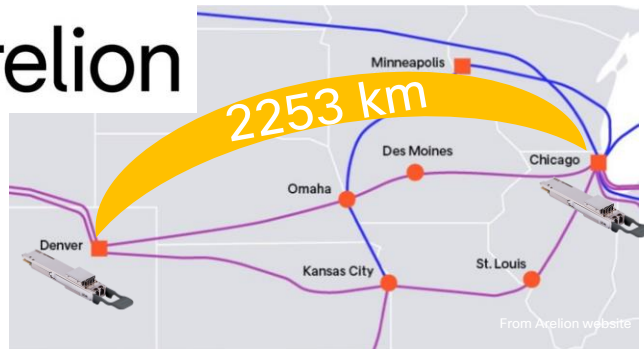
400G-ULH Field Trials

Enables Ultra Long-Haul Routes

Arelion: 2,253km Link

- Denver-Chicago, w/ margin
- 112.5 gigahertz spectrum
- Cisco 8000 series routers

*Arelion



Reduces
Costs

35%
CAPEX

84%
OPEX

<https://www.arelion.com/about-us/press-releases/cisco-field-trial>

Internet2: 3,000km Link

- Albany-Indianapolis w/ margin
- Cisco 8000 series routers
- Third-party OLS

INTERNET²



Reduces
Power

68%*

* Enabled by optical and routing advancements

<https://internet2.edu/internet2-and-cisco-push-coherent-optics-farther/>

800G MSA Pluggables

- Module Portfolio
 - 800ZR in QSFP-DD/OSFP*
 - 800ZR+ in QSFP-DD/OSFP*
 - 400G Long-haul in QSFP-DD
- Low Power 4nm DSP – Delphi
- Up to 130Gbd Optics
- 400G ULH Pluggables:
 - Designed for existing 400G platforms
 - Integrated EDFA and TOF with PCS
- 800ZR/ZR+ Pluggables:
 - Comply to OIF 800ZR
 - Comply to 800G OpenROADM and OpenZR+



400H ULH



800ZR/ZR+



56G SerDes

112G SerDes

<24W

<28W & 30 W

4nm CMOS

***Disclaimer: These products are pending release. Please confirm availability with Cisco.**

Comparison of Network Protection Mechanisms

Optical Protection Schemes				IP Protection
None – 1:1	1+1	1+1+R	PSM	
“Easily” done	< 50ms Electrical Switching (OTN)	N-x Optical Paths available for restoration	Fast Optical Switching	IP Protection is as fast as Optical Switching
Diverse Hardware and Paths	Diverse Paths could have diverse HW	No additional Optical Trunk (2)	Minimal Additional Hardware	All Paths are useable
<50% Link Utilization	+1 Optical Trunk/Card/HW	Requires Omni-directional, CDC HW	Loss of Light Switching prone to problems	Less Hardware
No or little IP Layer Interaction	Failback is not coordinated with IP Layer	Failback is not coordinated with IP Layer	Failback is not coordinated with IP Layer	New Skillset within IP
	Only 2-paths for redundancy	Multi-path support if available	Only 2-paths for redundancy	
Additional Power, real estate, and costs				

Cisco Optical Line Systems

Cisco Optical OLS Summary

QDD-OLS

Native OLS Integration in QDD Host Devices



- Native Booster and Pre-Amplifiers
- Reduce Network Hardware
- Supports all ZR Variants

NCS 1001 Compact P2P OLS



NCS 10x4 Multi-Role Platform



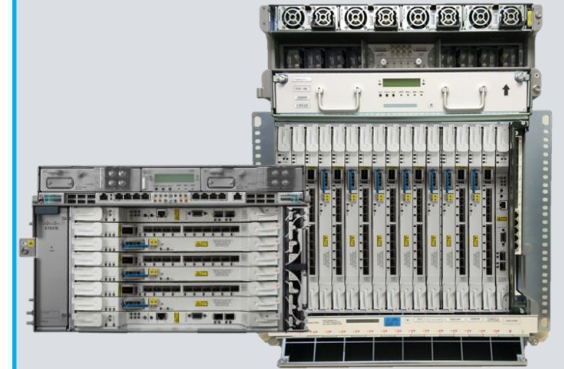
- Compact Modular Platforms – 1RU-2RU
- NCS 1001 has EDFA, PSM, and OTDR LC's
- NCS 1014 has EDFA, Colorless, and TXP LC's
- Supports all ZR Variants

NCS 1010 NG Open Line System



- Completely Integrated Solution with all functions combined
- ROADM and ILA Configurations
- Supports all ZR Variants

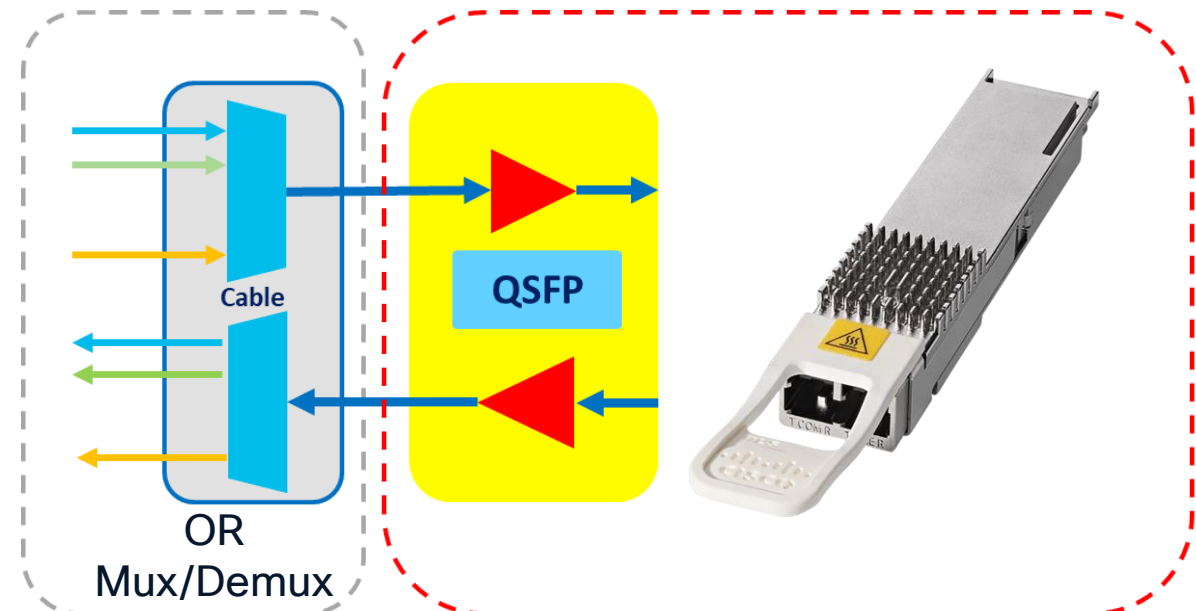
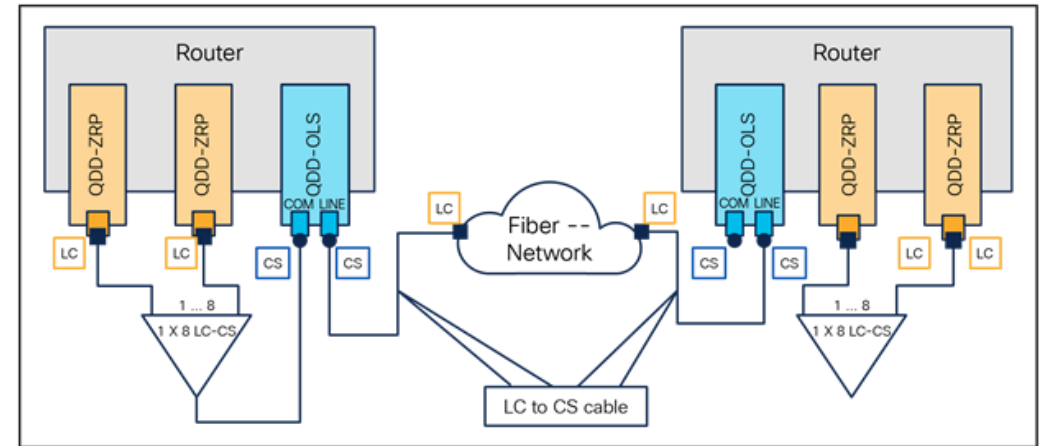
NCS 2k OLS with Services Cards



- Chassis Based System
- Multiple ROADM Cards
- Multiple Add/Drop Configurations
- Supports all ZR Variants

QSFP-DD OLS EDFA's Native to Routers

- Transforms separate EDFA system into a QDD Pluggable – continuing platform reduction options
- Extends the distance capabilities of ZRx Pluggables further
 - Supports 4/8/16/32 channel systems
 - Colored or Colorless Add-Drop
 - 2.4THz Bandwidth – B/W range – 1539.1 to 1558.4 nm
 - Combines Booster and Pre-amplifiers – each with 17dBm output and up to 25 dB gain
 - Dual CS connector pairs for LINE and MUX



Leverage QDD-OLS with Passive Filters



Collapse the OLS into a QDD

pluggable and put on router directly

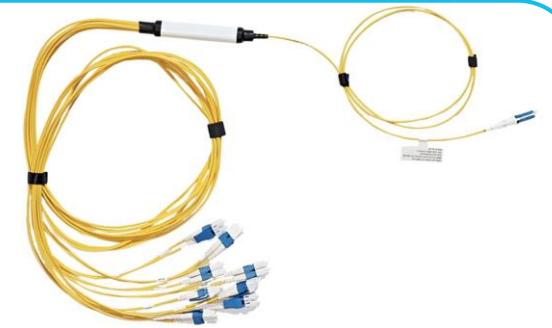


DWDM
Filter
Options

Typical DWDM
75GHz Passive
Filters



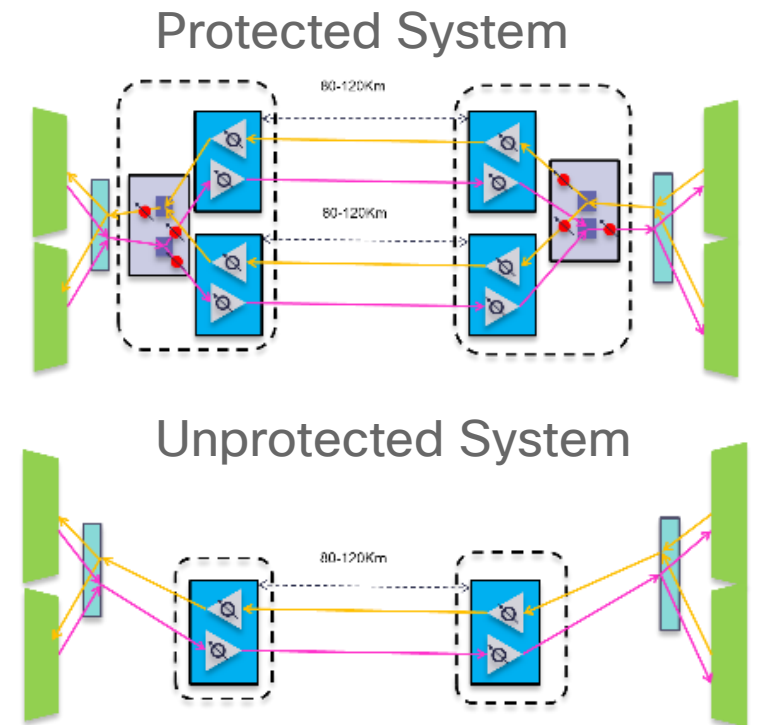
8 or 16-Ch
Combiner/Splitter
Cable



NCS 1001 Point-to-point DWDM



- **Point to Point** metro DWDM networks
- **Protection and unprotected** topologies
- 3-Module Slots: Dual EDFA, PSM, and OTDR Options
- **Optical Performance** optimized for high baud-rate, higher-order modulation formats
- **Visibility** with Channel monitoring, OTDR
- Automated turn-up

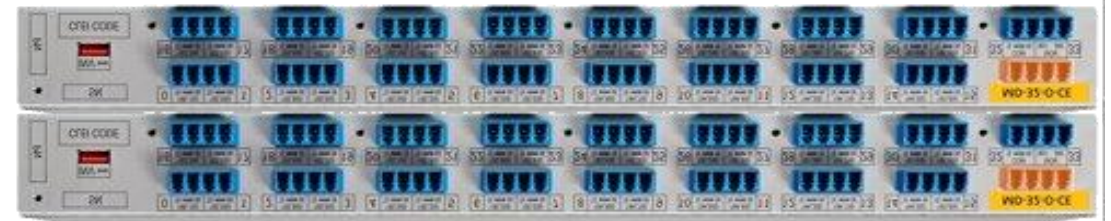


NCS 1014 Optical System

Compact and feature rich next gen Metro-DCI OLS



- Compact Open Line system hosted on Cisco NCS 1014 chassis
 - EDFA Linecard (integrated PRE and BST)
 - 32ch passive patch panels, Odd and Even each
- Pluggable OTDR, OSC and probe
 - Automated Optional OTDR function
 - Optional OSC function for link management/comms
 - Optional probe function for link performance/setup
- Co-host any Line card in other slots:
 - A transponder cohosted beside the line system
 - An A/D module like the CCMD
 - Another line system line card for a multi-rail set up
- Fully automated Link Turn-up and Power-control



NCS 10x4 Optical System – DWDM Line Cards



1.2T WDM Line Card

- 12x 100G clients
- 2x WDM trunks @ 600G
- Hybrid modulation @ 50G steps, 24 to 72GBaud and 1 to 6bits/symbol
- Full Line Rate L1 Encryption
- C-band & L-band versions



800G QDD Line Card

- 8x 100G or 2x 400G Clients
- 2x WDM trunks @ 400G
- Hybrid modulation @ 50G steps, 24 to 72GBaud and 1 to 4bits/symbol
- Full Line Rate L1 Encryption
- C-band version



1.2T OTN XPonder Line Card

- Pluggable based Line Card
- 400G, 100G, 10G & FC Clients
- 2x 400G CFP2 or QSFP-DD WDM Trunks
- Ready to support OTN Switching and L1 Encryption



3.2T QDD Line Card

- Pluggable based Line Card
- 32x 100G or 8x 100G Clients
- 8x QSFP-DD WDM Trunks
- Each Trunk can be operated at 100G, 200G, 300G or 400G
- Ready to support Optical Regeneration and L1 Encryption

Supported in both NCS 1014 and 1004

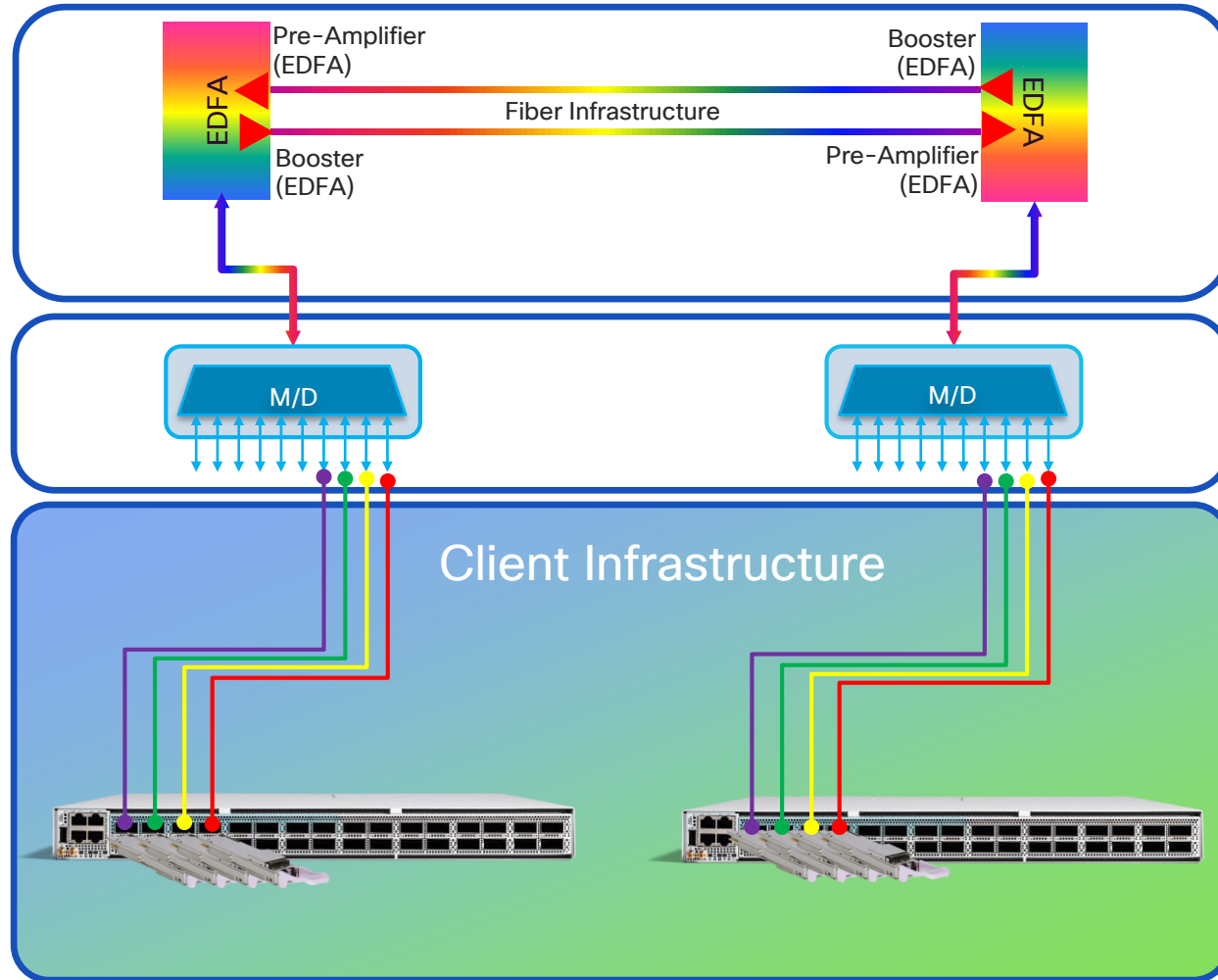
Currently supported in NCS 1004

NCS 1014 2.4TX DWDM Line Card

- 2x DWDM Trunk Pluggables: CIM-8 each up to 1.2T
- 3x CIM-8 Versions
 - Standard C-Band
 - Enhanced C-Band with Pre-amplifier EDFA
 - Provides enhanced performances with lower RX-side Power Levels
 - L-Band with Pre-amplifier EDFA – supports 400G-1000G Trunk Rates
- Trunk – 400G-1200G DWDM in 100G increments per carrier
- Variable Trunk Baud Rates up to 140GBaud
- Clients – 6x 400GE QSFP-DD, 4x100GE QSFP-DD, 800GE QSFP-DD800 (Roadmap)



DWDM Directly in Routers with NCS 1001/1014



Optical Line System

NCS 1001
Line Terminal/ILA



NCS 1014
Line Terminal/
Add/Drop/TXF



4,32,48,64-ch
Optical
Mux/Demux



- Point-to-Point Networks
- ZR @ 400G & ZR+ @ 100/200/300/400G
- Compact 1RU/2RU Solutions with each Platform
- OTDR options with each Platform

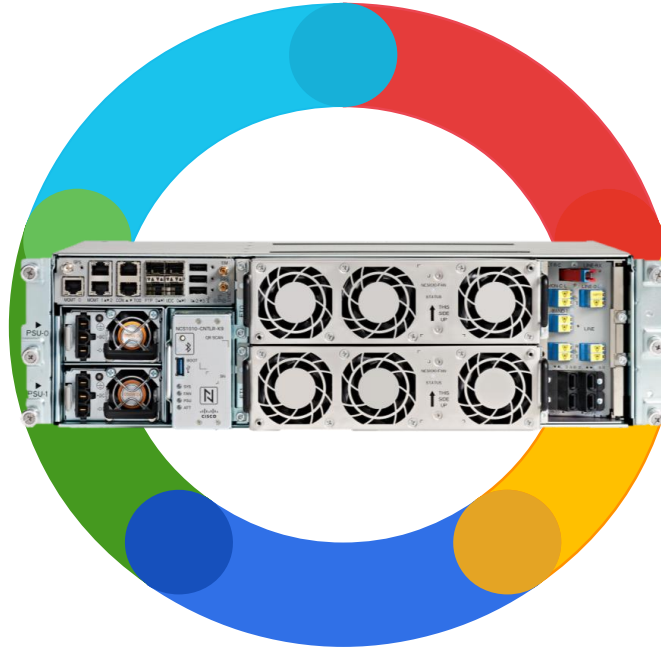
Why NCS 1010 for High Capacity Networks

Any coherent source?

- Ingress EDFA to support 400ZR and **OpenZR+ DCOs** operate at -10dBm
- Low loss couplers for 95/140 GBaud-Rates that need higher RX power

Scale

- Hitless upgrade from C to **C+L**
- **Embedded channelized ASE** for consistency in performance from day-1 to full capacity growth
- **33-port Twin-WSS** architecture to use as express or add-drop



Simplicity

- Simpler patching – integrated module
- **Independent** degree operation
- Automated turn-up
- Full spectrum loading from the start
- **DGE on ILAs** for equalization and better control of Raman Gain ripple

Complete life-cycle automation

- **Device automation** – ZTP, OC YANG config, Telemetry
- **Automated E2E turn-up** with embedded control loops
- Automated **Connection Verification** for patch loss checks at each site.
- Enhanced **visibility** – OTDR, OSC, OCM
- Machine Learning on OTDR traces to improve event detection

Optical Line Terminal (OLT) Building Blocks



NCS 1010 OLT - Optical Transport Platform - 3RU

- 32 ports WSS-based (33rd for NL)
- w/ embedded EDFA + Raman Amplification (optional)
- 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 - Colorless Modular Passive Patch Panel - 4RU

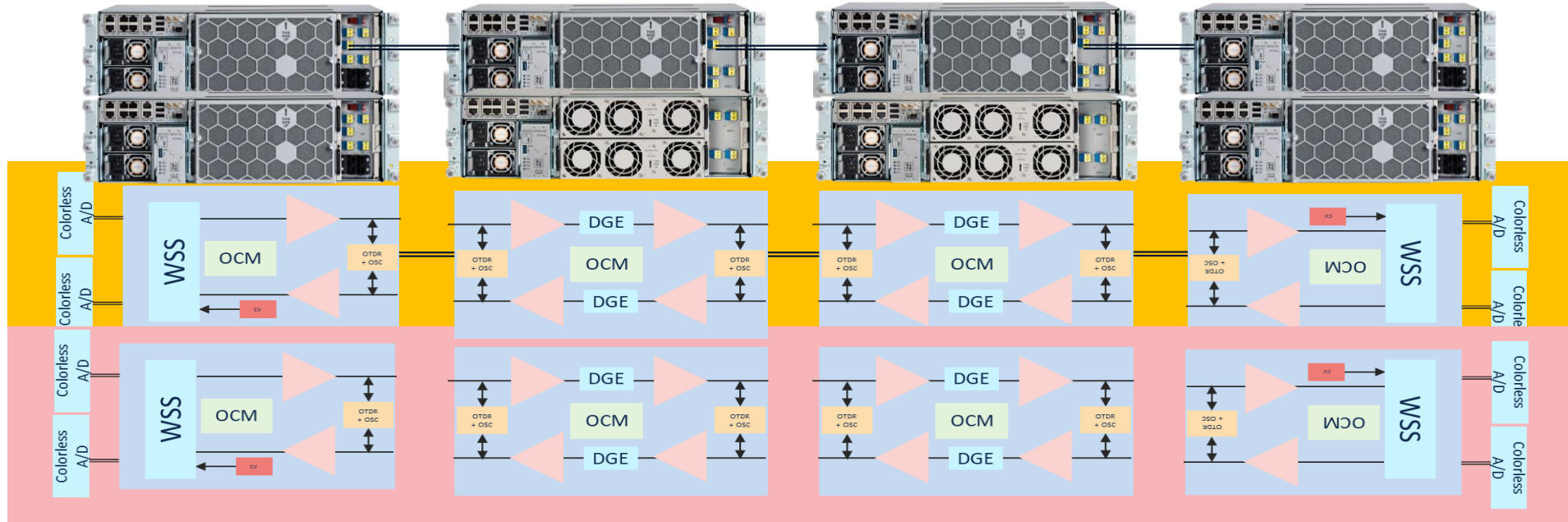
- 4x Passive Optical modules, w/ USB-powered power monitoring
- Up to 72 Channels Add/Drop + 6-Dir interconnection

COLORLESS BREAK OUT - Colorless Modular Passive Patch panel - 1RU

- 2x Passive Optical modules, w/ USB-powered power monitoring

FLEXIBLE Add/Drop Structure
Sites can be different
Add only when & where needed

NCS 1010 High Performance OLS



C+L-Band support

ASE loading

Equalization Everywhere

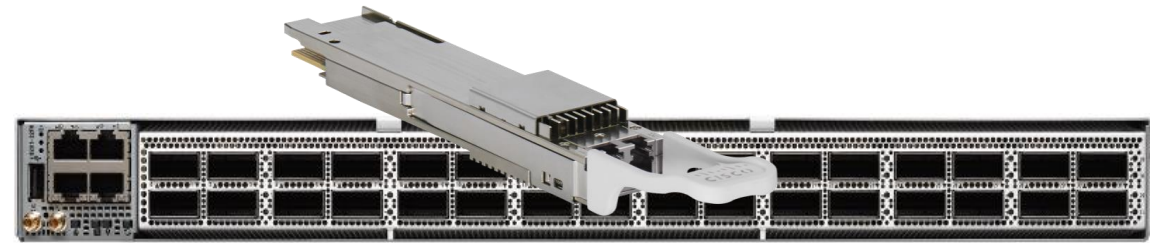
OCM, OTDR, OSC, CV

Flex-grid Open Line System

Summary

DWDM Network Capacity at a Glance

- DWDM Network Capacity has grown exponentially over the last 20-years
- Fueled by Coherent Wavelengths
- And now by 400G Pluggables directly in Routers
- Cost per Bit has dramatically decreased as well
- 800G Pluggables will continue the cost reductions



Bit-Rate	C-band		L-band		Total (Tbps)
	# Channels	Capacity (Tbps)	# Channels	Capacity (Tbps)	
10G	96	0.96	96	0.96	1.92
100G	96	9.6	96	9.6	19.2
200G	96	19.2	96	19.2	38.4
400G	64	25.6	64	25.6	51.2

Fiber Pair Capacities

Summary

- DWDM is not any harder than **IP Networks**
- DWDM Networks are growing and advancing
- Industry advances include DWDM Interfaces in Routers
- Like-for-Like and additional functionalities are available
- Don't be afraid to get started

Optical Networking Simplification is Routed Optical Networking



- Lower CapEx and OpEx
- Quicker time-to-market
- Improved Troubleshooting

Complete your session evaluations



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Thank you

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