Welcome to Infinera
DTN/DTN-X Theory of Operations

Release 16.0

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what THE NETWORK will be

Infinera Training Statement

- *"A supportive environment, where everyone can learn, can be achieved by being respectful, welcoming all questions and ensuring that everyone has an equal opportunity to learn to their maximum potential."*

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Ground Rules

- Mobile Phones
- Breaks
- Health & Safety
- Questions
- Inclusiveness:
  - Respect differences of opinion
  - Allow others to speak
  - Your active participation is required

Course Learning Objectives

Upon successful completion of all of the modules contained in this course, the student should be able to describe:

- Optical Transport Networking Fundamentals
  - Optical Channel Payload Unit (OPU)
  - Optical Channel Data Unit (ODU)
  - Optical Channel Transport Unit (OTU)
  - OTN Hierarchy – ODU0, ODU1, ODU2, ODU3, ODU4)
- Photonic Integrated Chip (PIC) functions and benefits
- DTN/DTN-X Node Configurations
- DTN/DTN-X Signal Flow
  - Switching, Line coding (BPSK, QPSK), SD-FEC
- OTxM Configurations
- AOFx-100 Channel Plans and Muxing plans
- Packet Switching Module (PXM)
- FlexILS
- Management
  - OSC, ALS, Protection schemes, licensing

Optical Transporting Networking Fundamentals

OPU, ODU, OTU

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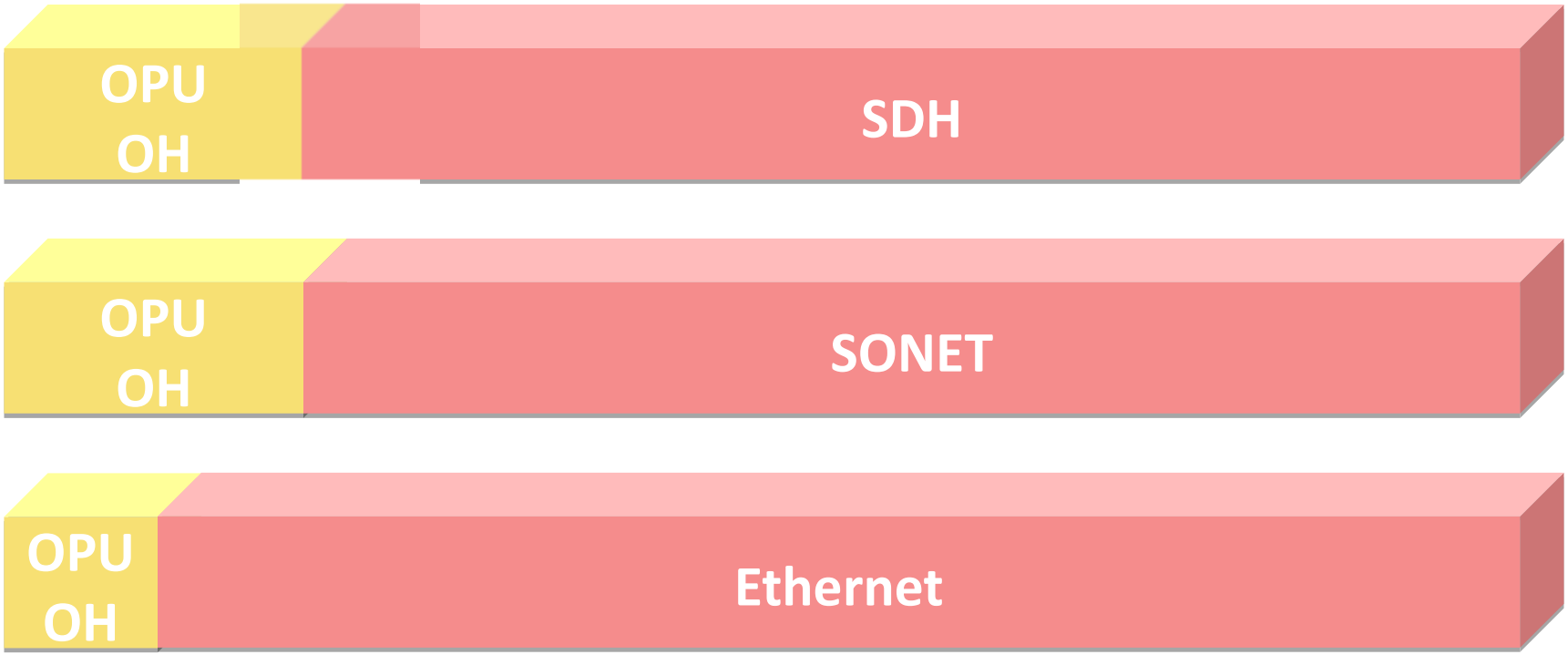
what THE NETWORK will be

Optical Transport Networking (OTN) – G709

- Transport
- Multiplexing
- Switching
- Survivability
- Management and Supervision

Optical Channel Payload Unit (OPU)



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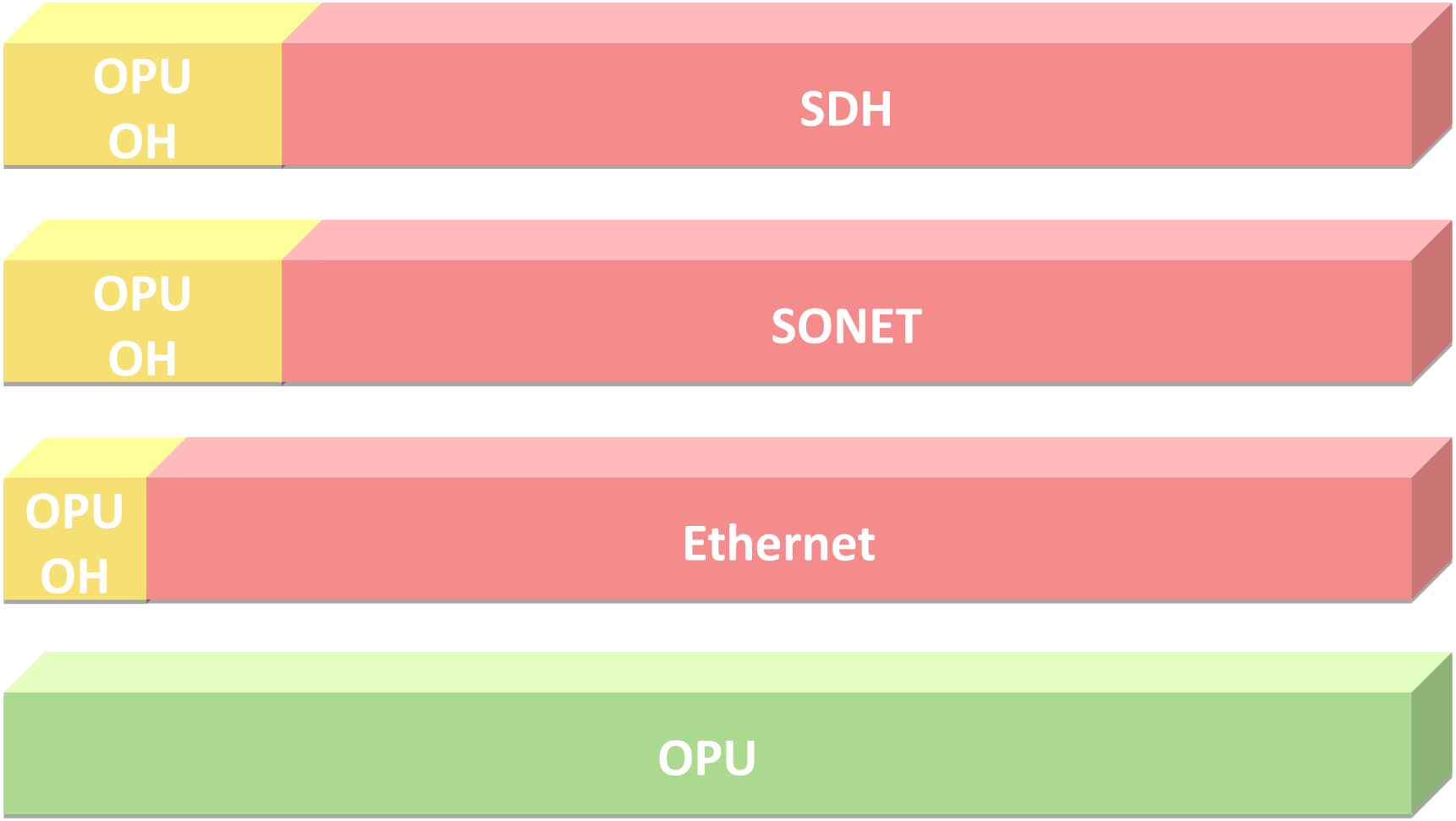
Optical Channel Payload Unit (OPU)



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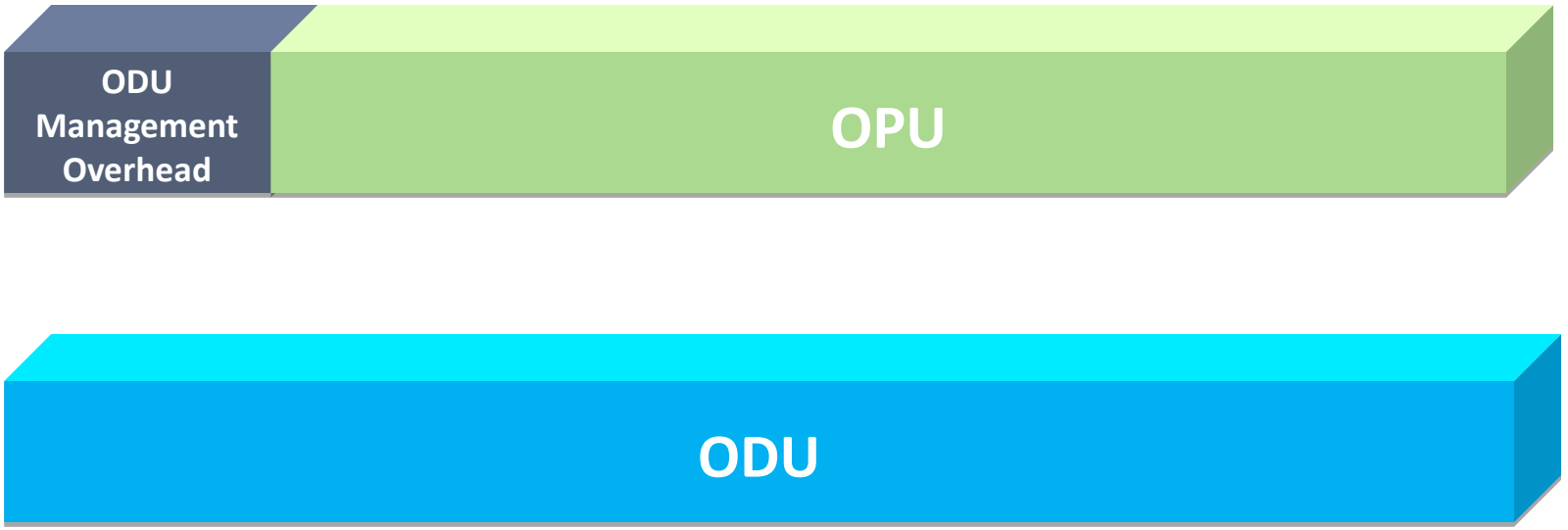
Optical Channel Data Unit (ODU)



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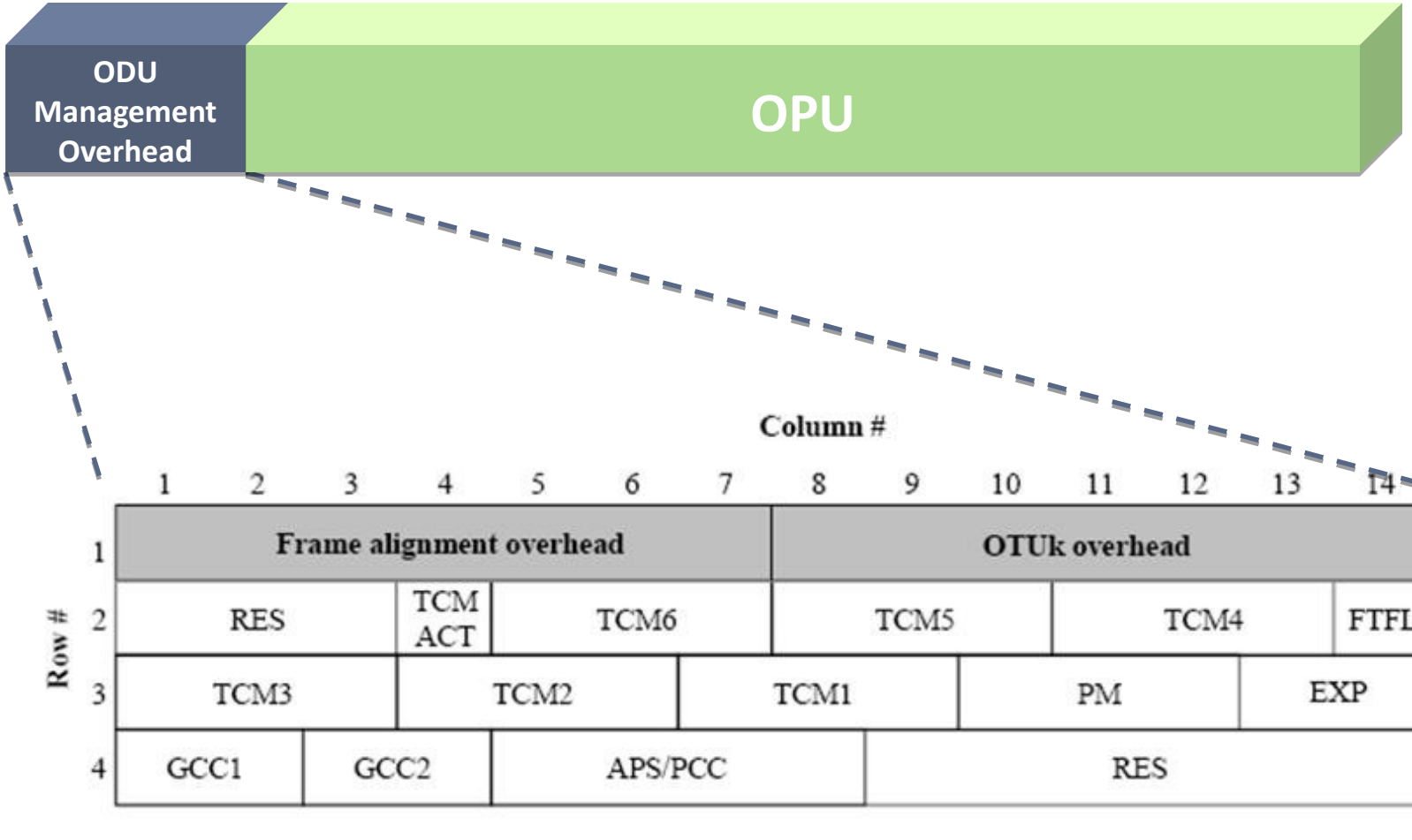
Optical Channel Data Unit (ODU)



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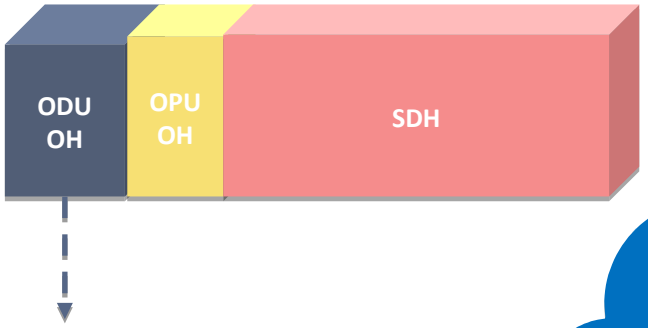
Digital Transport Layer Performance Monitoring



Tx TTI – Circuit 101 WtoE

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Digital Transport Layer Performance Monitoring

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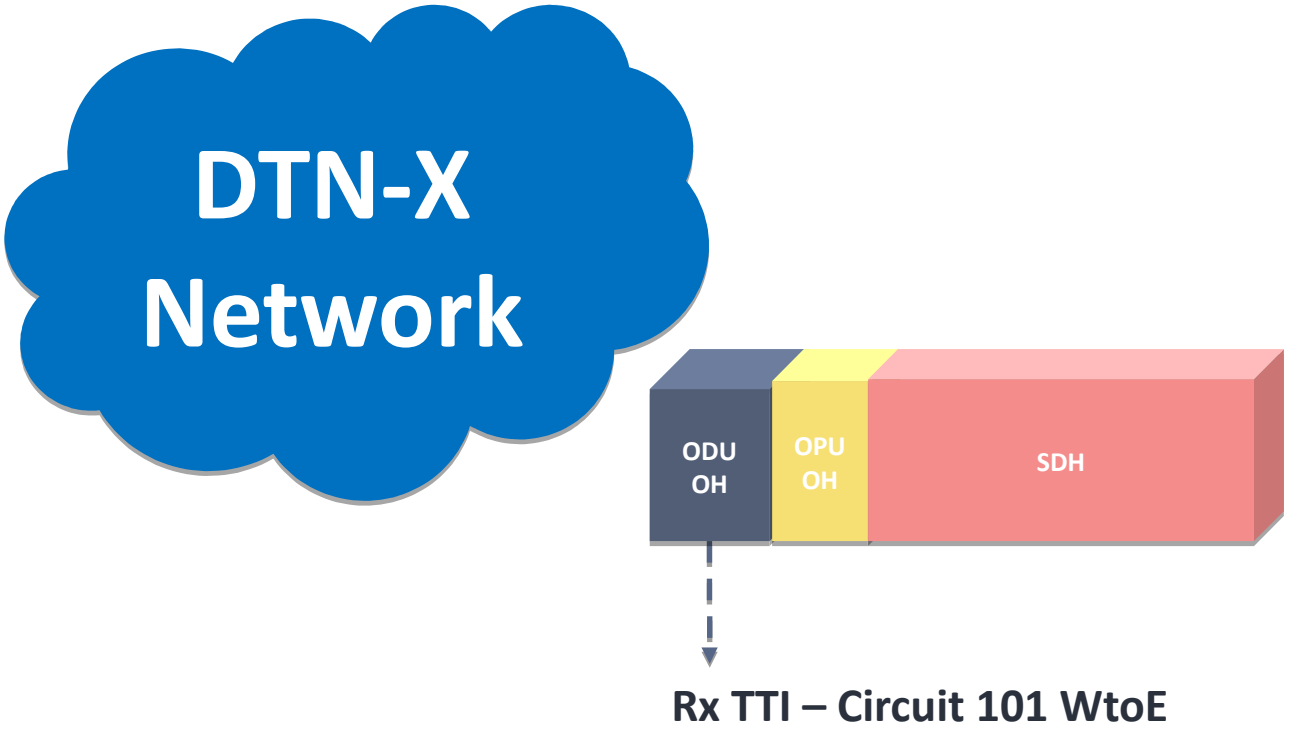
Digital Transport Layer Performance Monitoring



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Progress Check

- The client signal is first wrapped into an OPU and then into an ODU. What is the purpose of the ODU?

a) The ODU enables end to end performance management and communication

b) The ODU normalizes a range of client rates so that the same bandwidth is used regardless of the client signal technology

c) The ODU enables end to end Forward error Correction

d) The ODU adapts between 10Gbps and 100Gbps client signals

Optical Channel Transport Unit (OTU)

- Span
  - Transmission Equipment
  - Fiber Type
  - Fiber Quality

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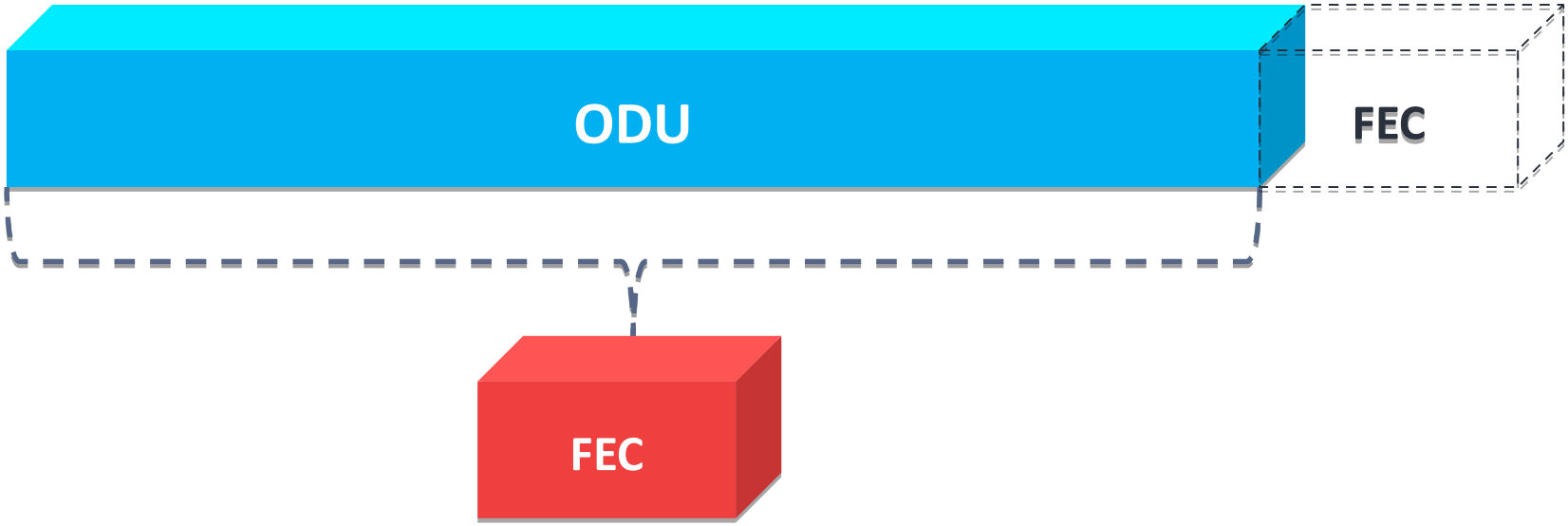
Optical Channel Transport Unit (OTU)



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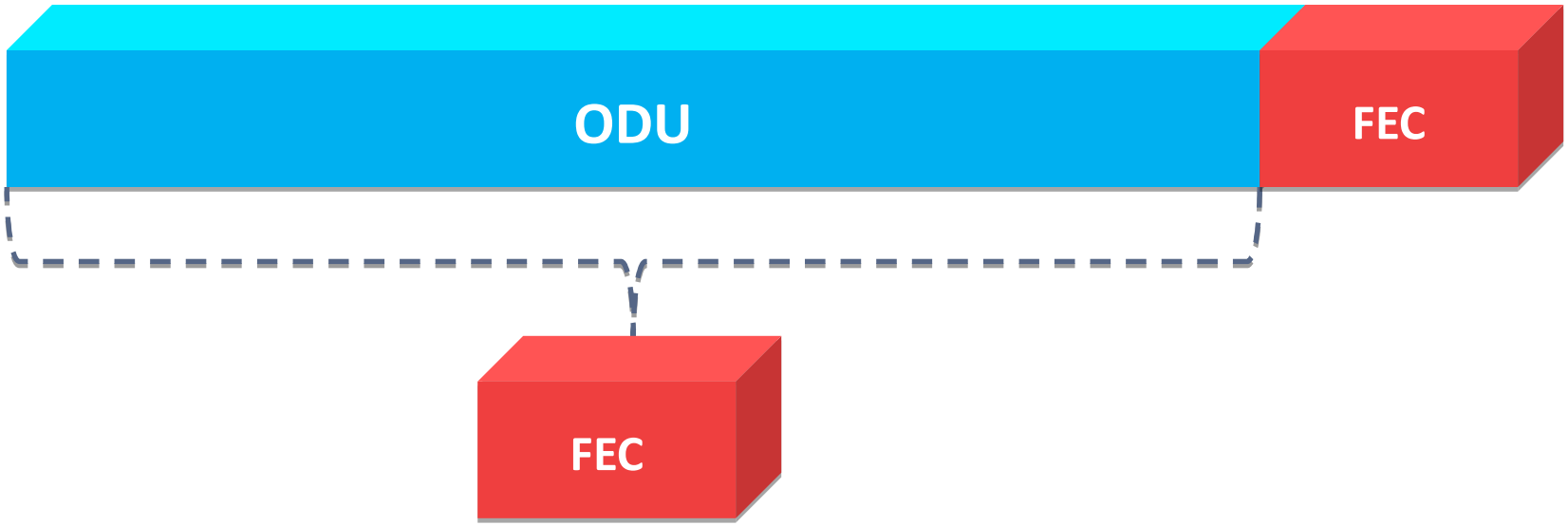
Optical Channel Transport Unit (OTU)



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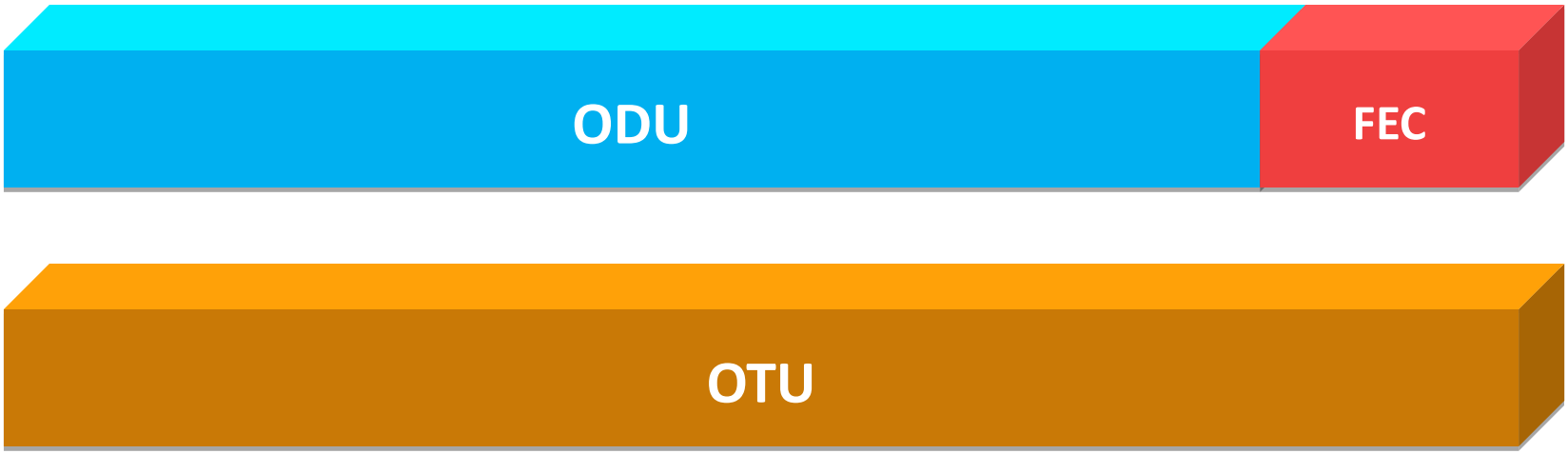
Optical Channel Transport Unit (OTU)



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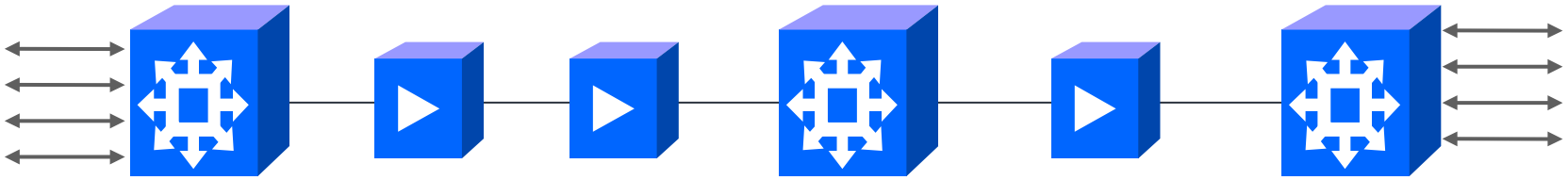
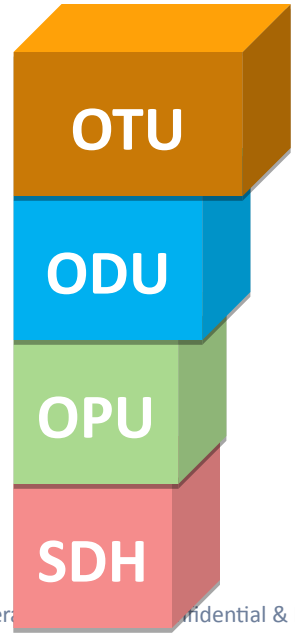
Digital Transport Layer Performance Monitoring





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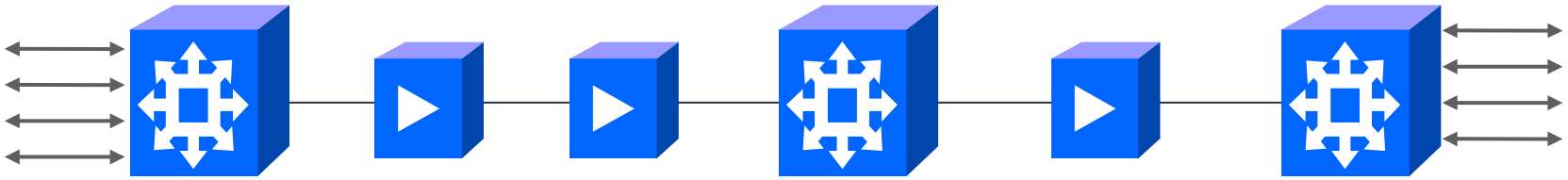
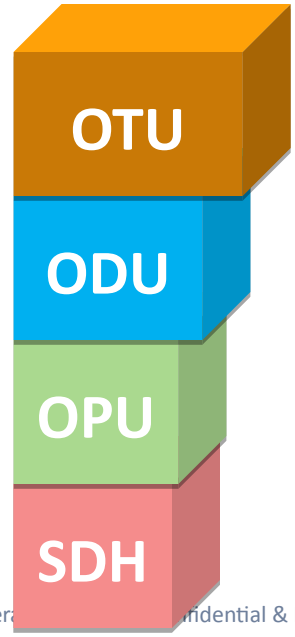
Digital Transport Layer Performance Monitoring





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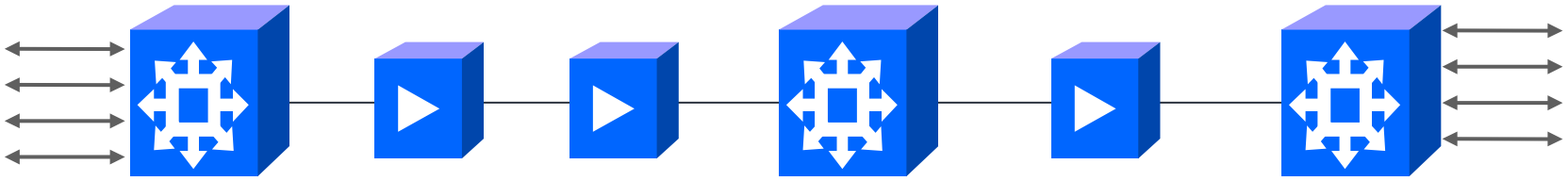

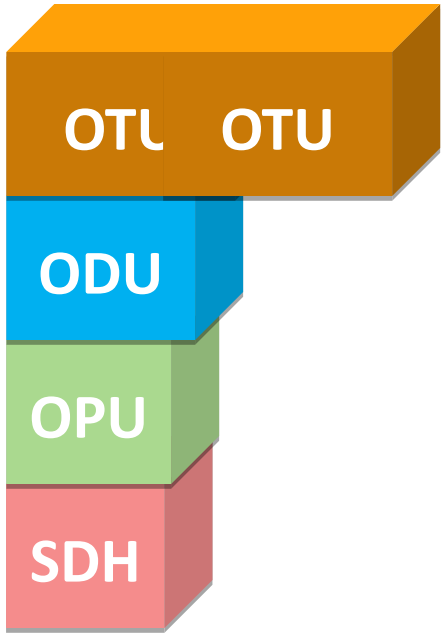

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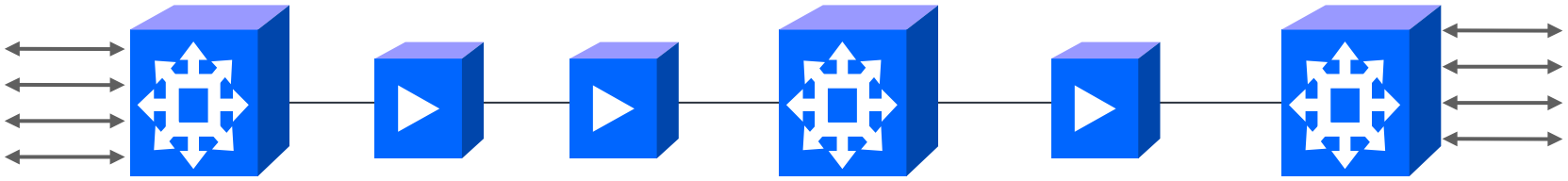

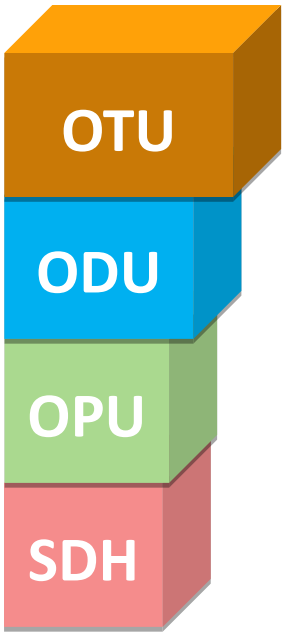

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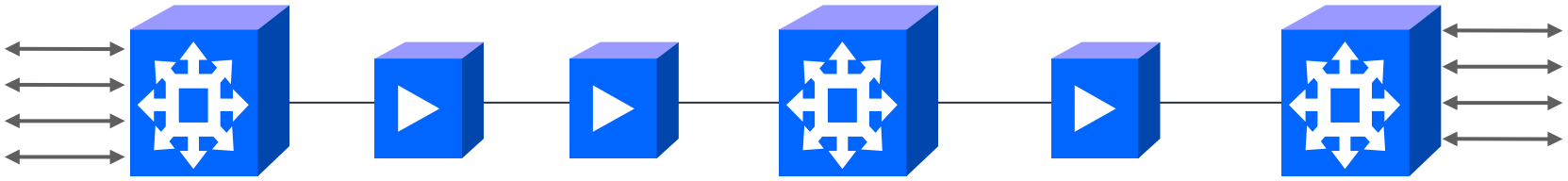

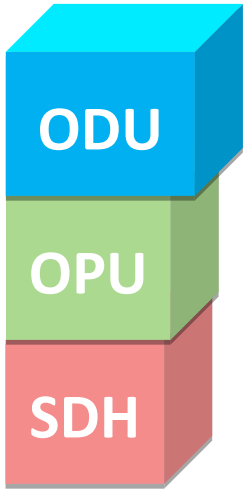

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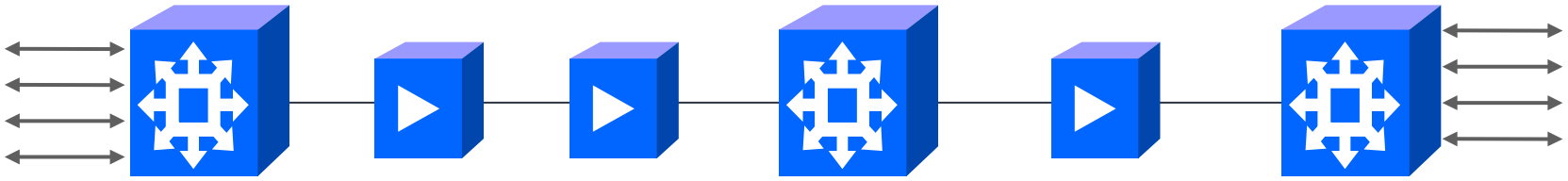
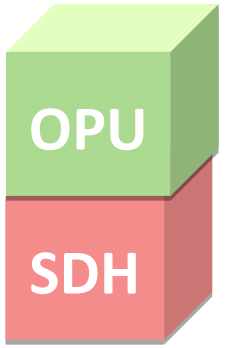
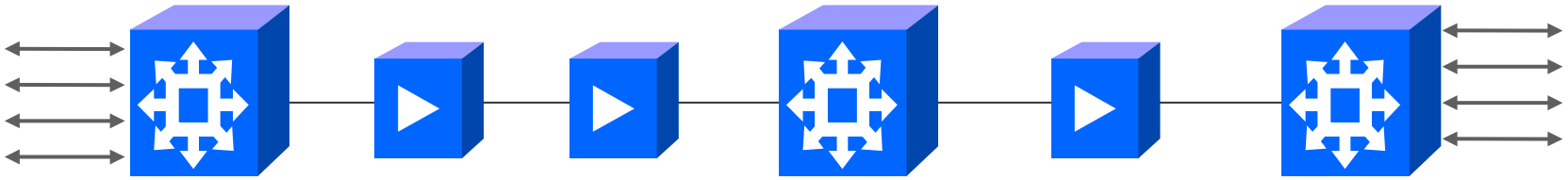


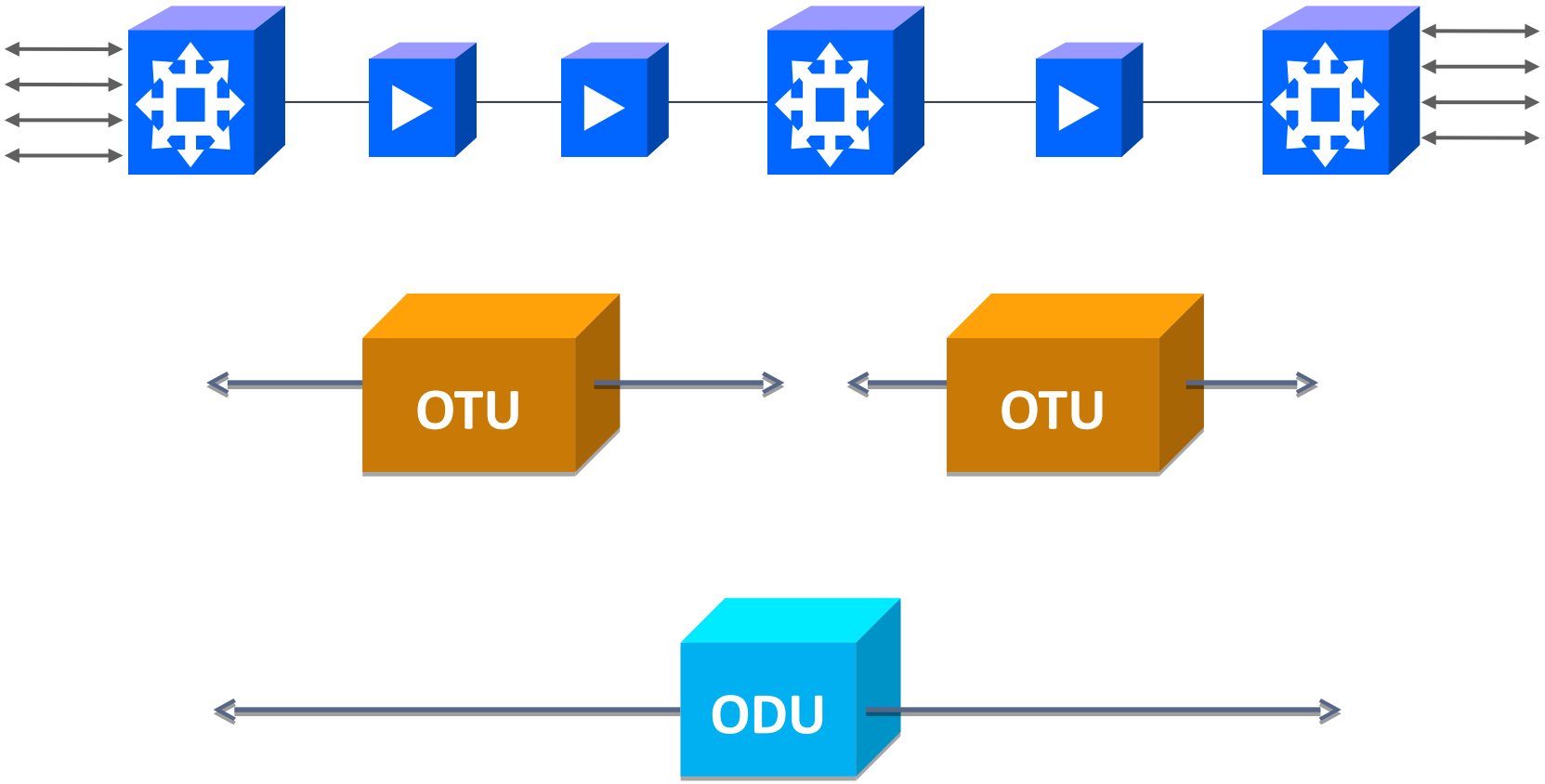


Digital Transport Layer Performance Monitoring



SDH

Digital Transport Layer Performance Monitoring



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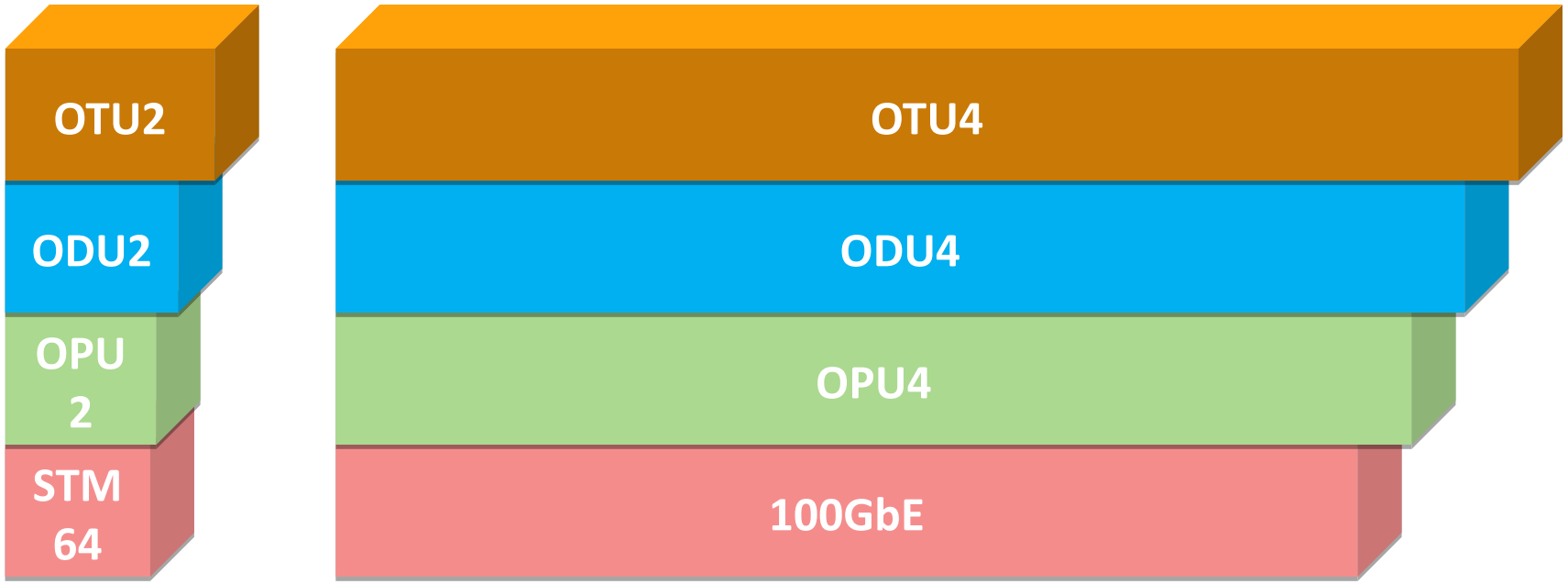
OTN Naming Conventions

OTN Name	Contains	Rate	Payload
ODU0	OPU0	1.25Gbps	1GbE
ODU1	OPU1	2.5Gbps	STM16 or OC48
ODU2	OPU2	10Gbps	STM64 or OC192 or 10GbE
ODU3	OPU3	40Gps	STM256 or OC768 or 40GbE
ODU4	OPU4	100Gbps	100GbE



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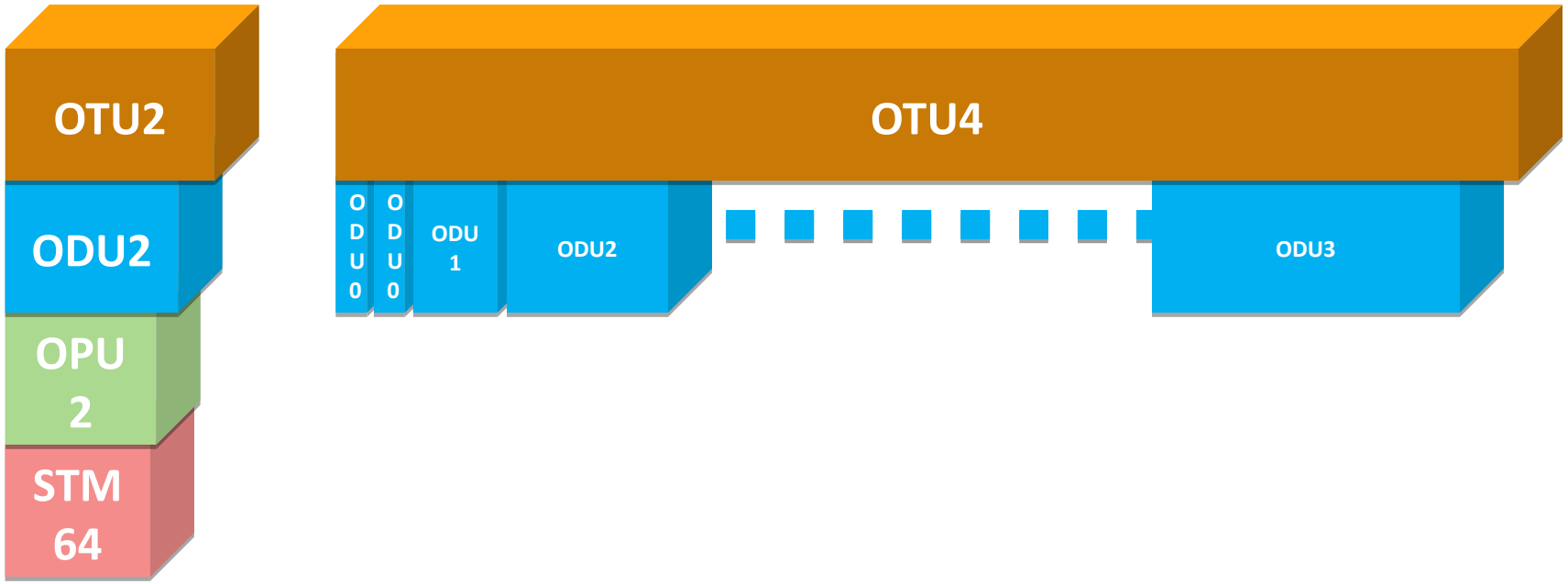

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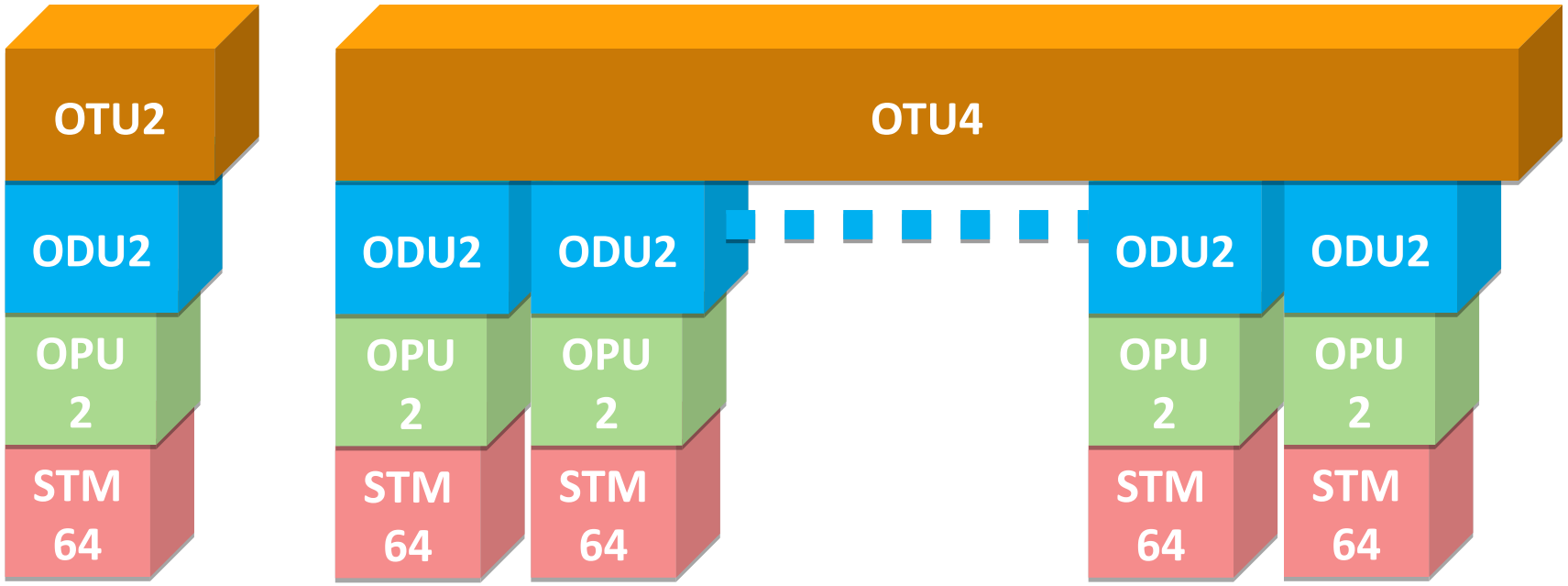

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Experienced with DTN?

DTN	DTN-X
-	ODU0 (1.25G)
DTF (2.5G)	ODU1 (2.5G)

- DTN-X switching granularity - 1.25G
- DTN switching granularity of - 2.5G

Progress Check

- What is the bandwidth of the following:

a) ODU4 ?
b) ODU2 ?
c) ODU3 ?
d) ODU0 ?
e) ODU1 ?

Photonic Integrated Chip (PIC)

Features and benefits

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what THE NETWORK will be

The Service Provider Challenge

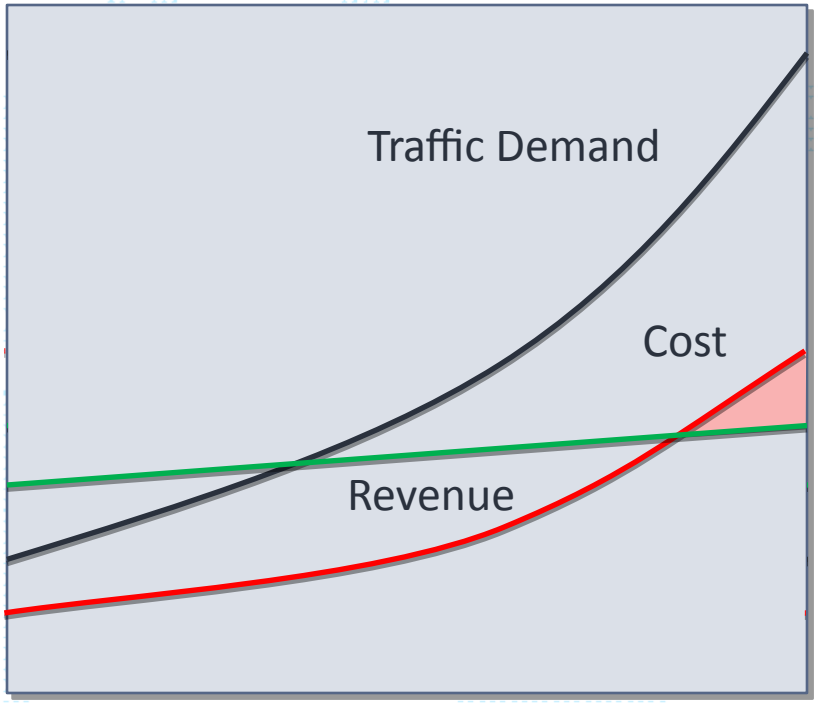
The Drivers

Video

Mobility

Cloud

$



The Impact

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Unwieldy DWDM Architecture

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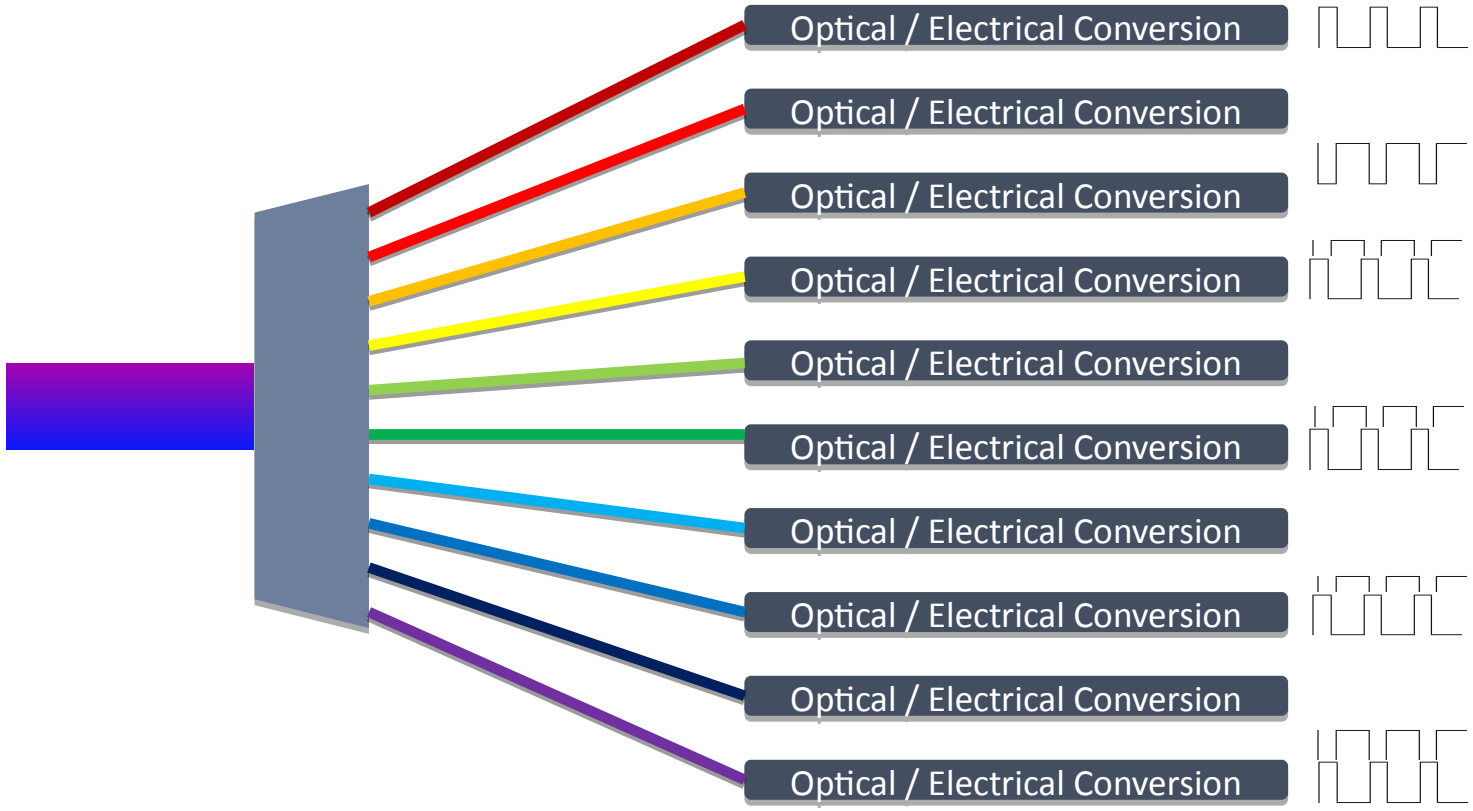
DTN-X PIC Functionality

- PIC Transmits/Receives 10 Optical Channels
- Muxed/Demuxed into Optical Carrier Group (OCG)



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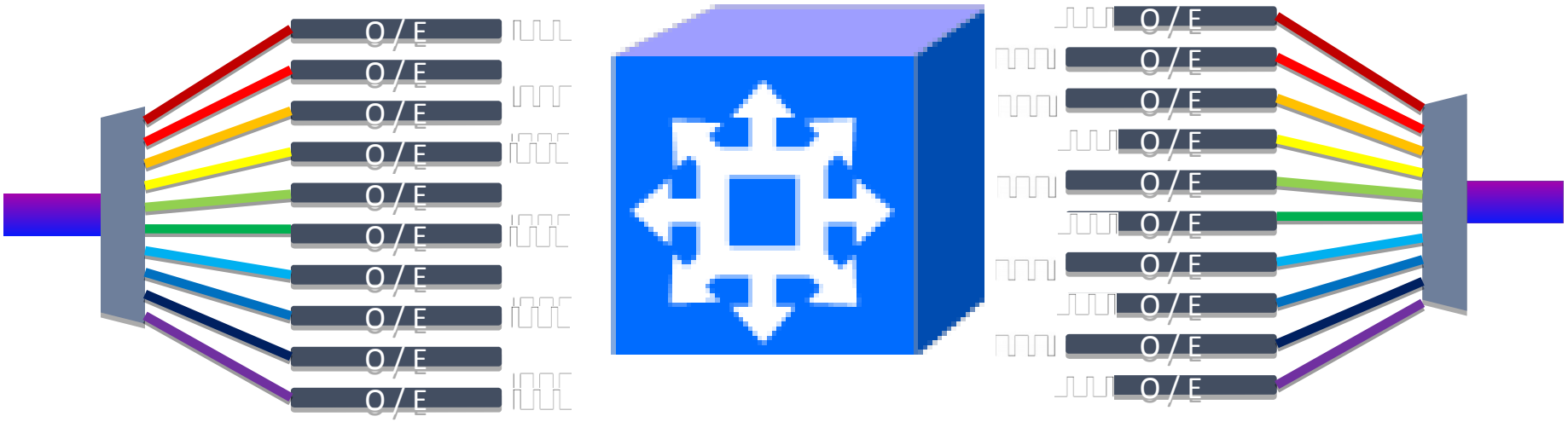
PICs Enable Digital Switching

Photonic Integration

- Enable cost-effective OEO
- "WDM system on a chip": 100Gb/s to 1Tb/s and more
- Affordable OEO enables integrated digital switching

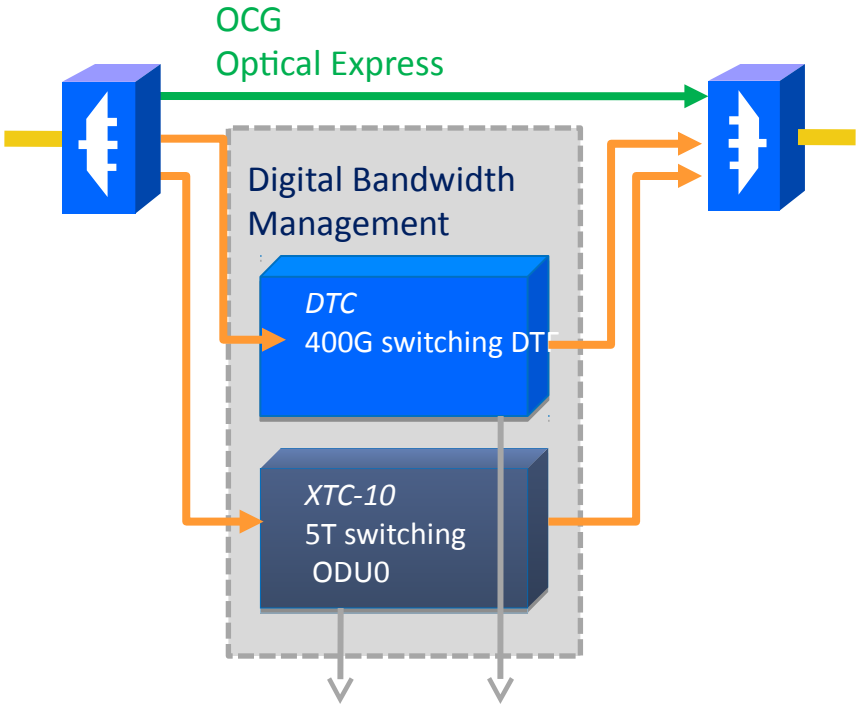
O / E /O cleans signal in a Regenerator



- 4R:
  - Re-Shaping, Re-Timing, Re-FEC, Re-Amplification
- Removes Noise
- Removes Chromatic Dispersion

Optimized Bandwidth Management

Comparing Infinera to All-Optical solution



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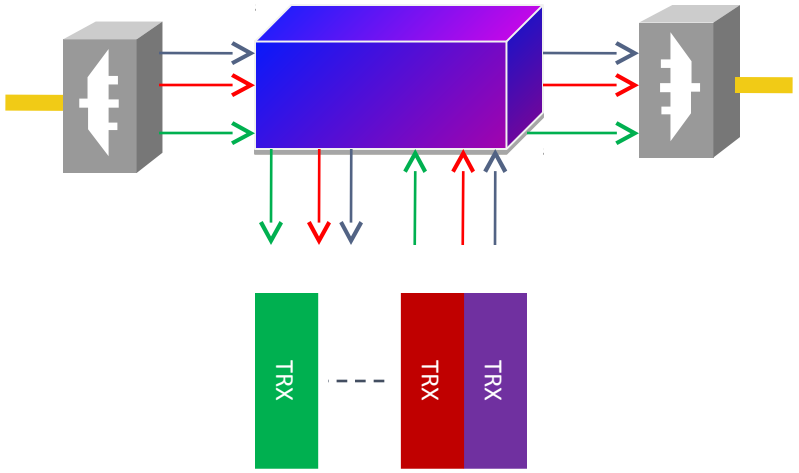
- Optical Express for cost-effective trunks
- PIC based Digital Bandwidth Management and add/drop



Wavelength level optical management

All-optical Solution

- Wavelength level optical management only
- Needs additional bandwidth managers for sub-lambda traffic

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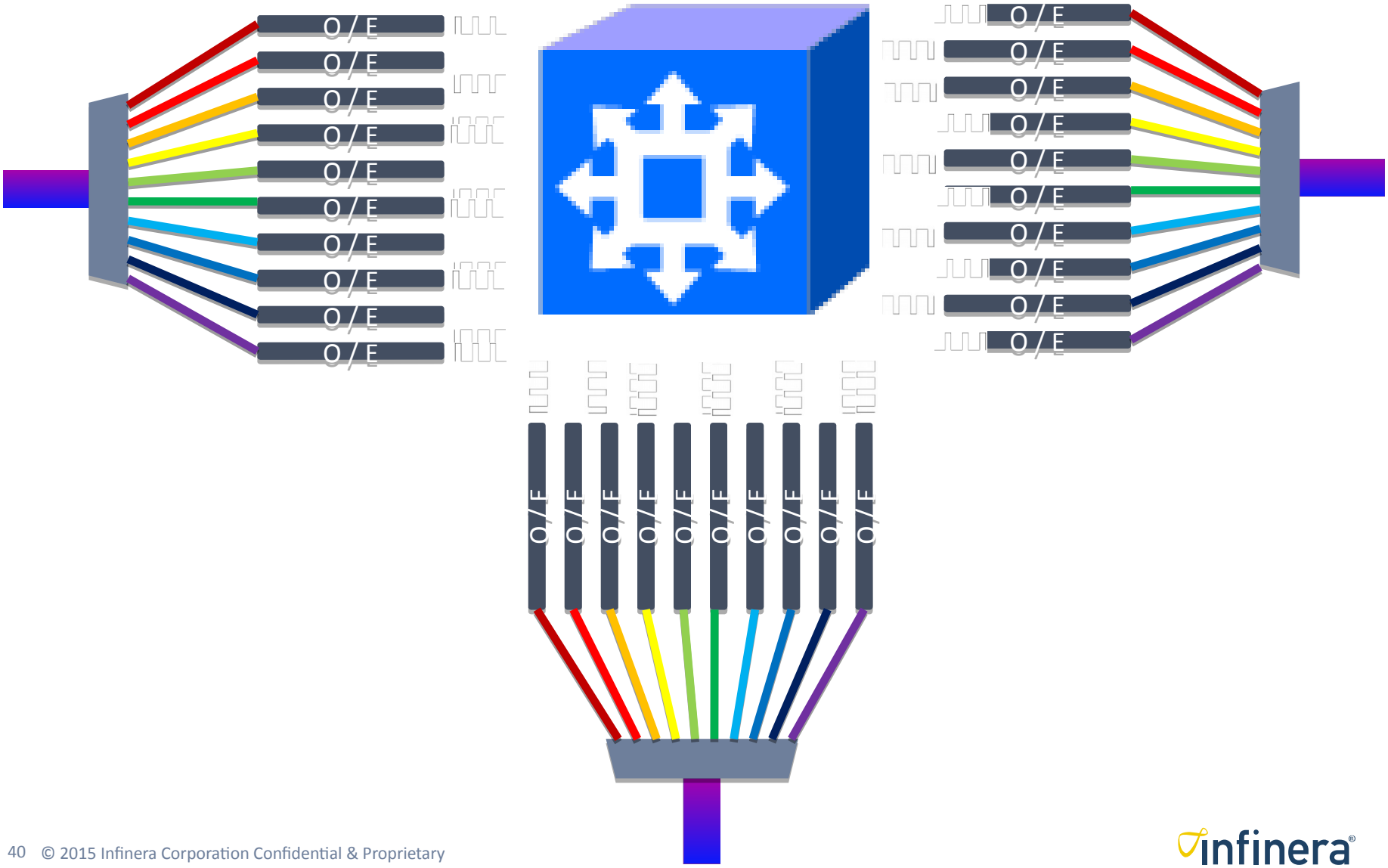
Other Benefits of O E O

- Troubleshooting:
  - Digital PM (e.g. Errored Seconds)
  - Loopbacks
  - Trail Trace Identifier
  - Insert Pseudo Random Bit Sequence (PRBS)

Optical Electrical Conversion enables switch-ability



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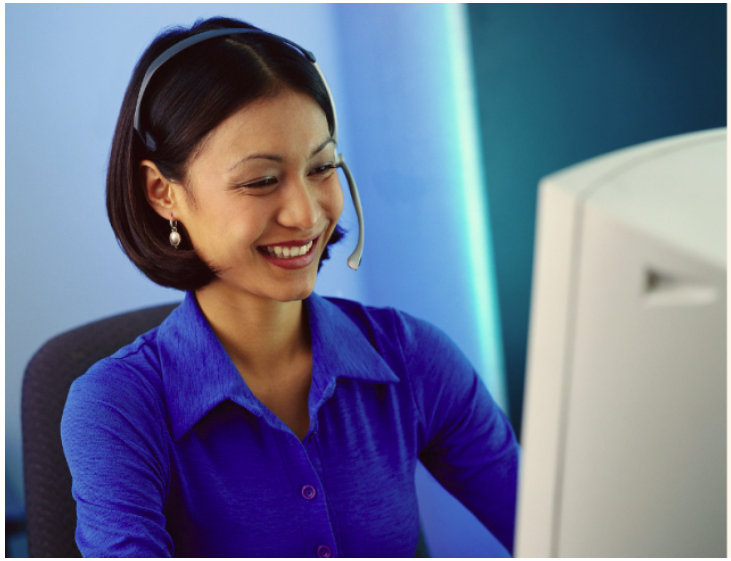
Instantly Reconfigurable / Bandwidth Virtualization

Vs.



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A Better Approach to DWDM

The "Digital Optical Network"

PIC-based DWDM

- Lower space and power
- Higher reliability
- Service-ready bandwidth

Digital Switching

- Service flexibility
- Integrated WDM + switching
- Digital protection & restoration

Software Intelligence

- Rapid provisioning
- Operations simplicity
- Enhanced features

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Progress Check

Which two answers best identify the benefits of a PIC

a) Low Cost Scalability combined with Flexible service delivery

b) High Cost Scalability combined with Radio Transmission

c) Utilizes discrete components and architecture of legacy DWDM solutions

d) Enables full O-E-O conversion

DTN Node Configurations

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what THE NETWORK will be

Objectives

- To describe the functions of:
  - Terminal Nodes
  - Regeneration Nodes
  - ROADM Nodes
  - Optical Express Nodes
- To describe the basic DTN anatomy
- To describe the Digital Bandwidth Management functions

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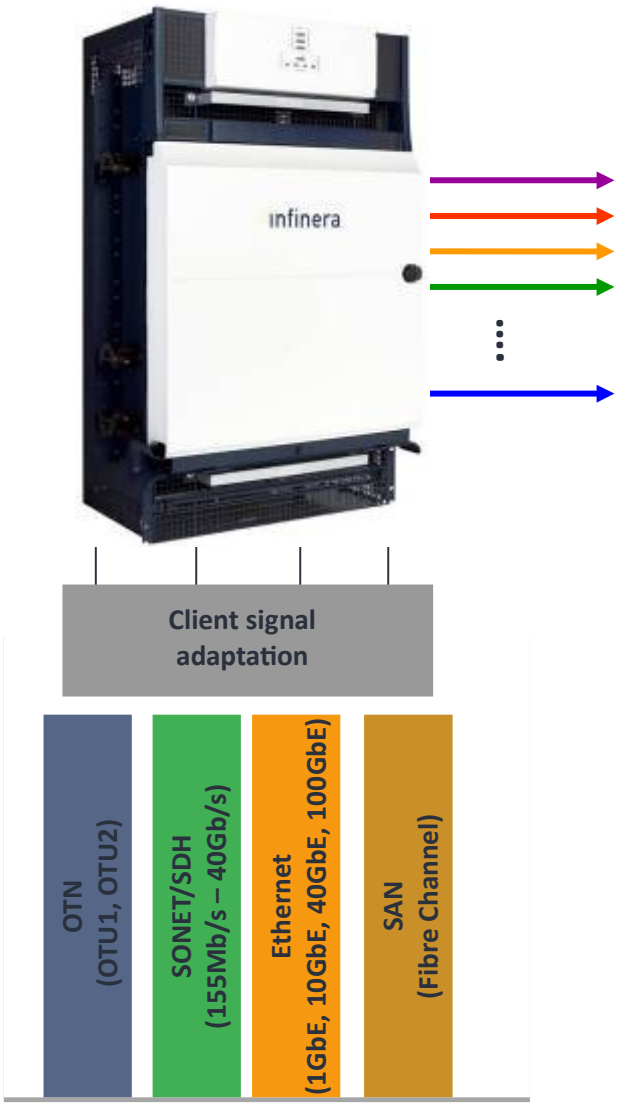
DTN – Terminal Mode



- DWDM Line Side
  - Up to 160 x 10Gbps Channels / 16 x OCGs = 1.6Tbps
  - Single fiber pair
- Multi-Service Client Interfaces
  - Ethernet
  - SONET
  - SDH
  - OTN
  - Fiber Channel

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DTN – Regeneration Mode

- DWDM Line Side
  - Single fiber pair
  - Up to 160 x 10Gbps Channels / 16 x OCG = 1.6Tbps
  - Single fiber pair on either side
- No Client Interfaces
- Regeneration of signal
  - Removes Noise
  - Removes Chromatic Dispersion

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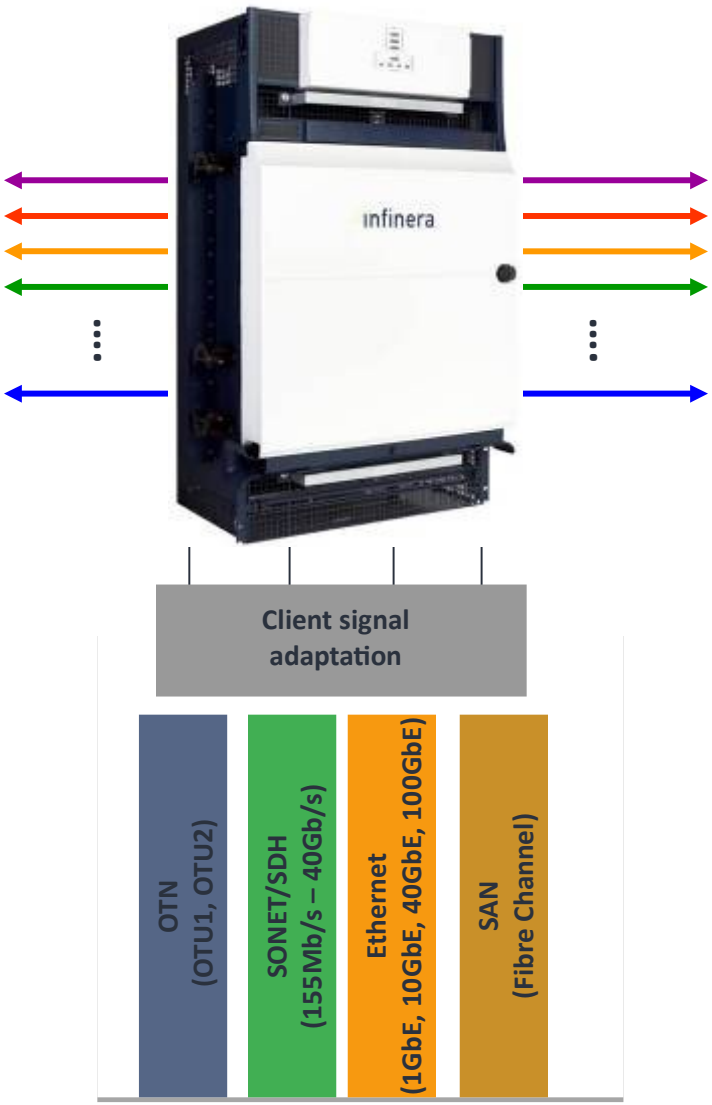
DTN – ROADM (Reconfigurable Optical Add/Drop Mux)



- DWDM Line Side
  - Up to 160 x 10Gbps Channels / 16 OCGs = 1.6Tbps
  - Single fiber pair
- Multi-Service Client Interfaces
  - Ethernet
  - SONET
  - SDH
  - OTN
  - Fiber Channel

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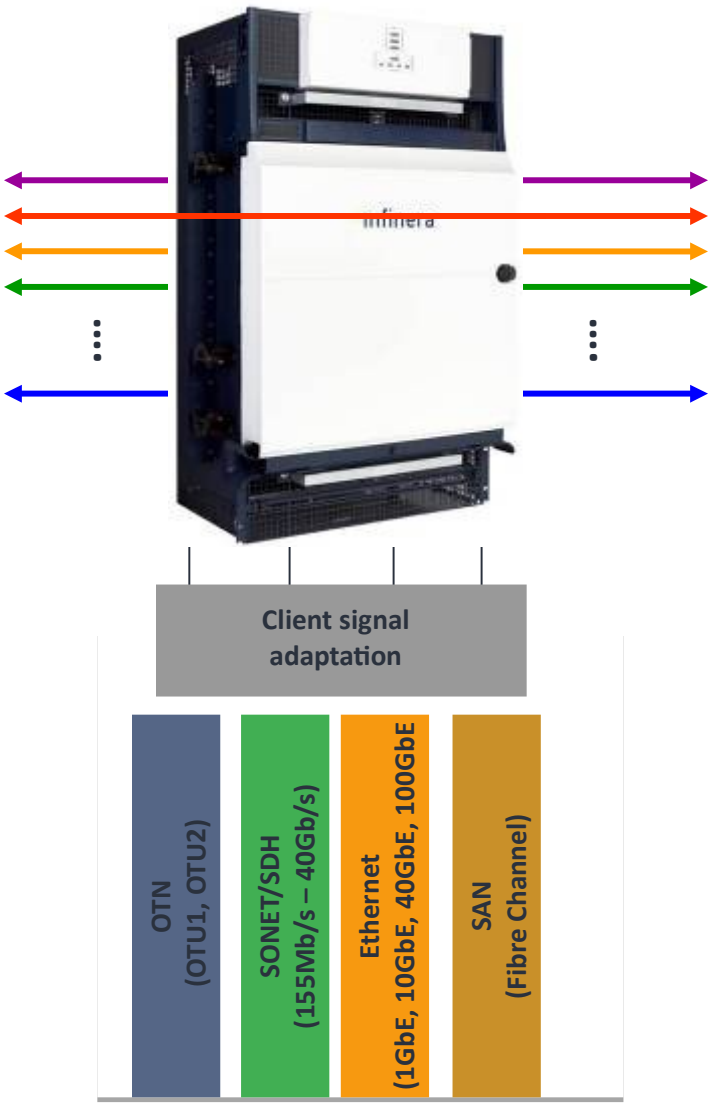
DTN – Optical Express



- DWDM Line Side
  - Up to 160 x 10Gbps Channels / 16 OCGs = 1.6Tbps
  - Single fiber pair
- Multi-Service Client Interfaces
  - Ethernet
  - SONET
  - SDH
  - OTN
  - Fiber Channel
- Low Latency
  - High Value Service
  - Amplified Only / No Regeneration

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DTN-X Node Configurations

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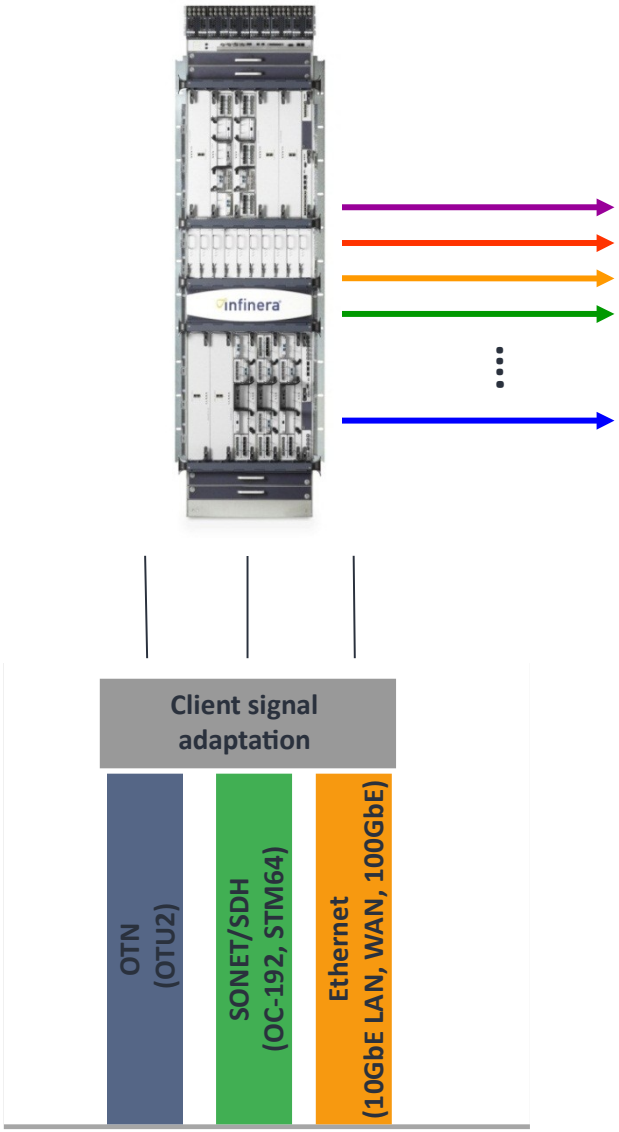
DTN-X – Terminal Mode



- DWDM Line Side
  - Up to 16 x OCGs
  - Max 8 Tbps capacity
  - Single fiber pair
- Multi-Service Client Interfaces
  - Ethernet
  - SONET
  - SDH
  - OTN

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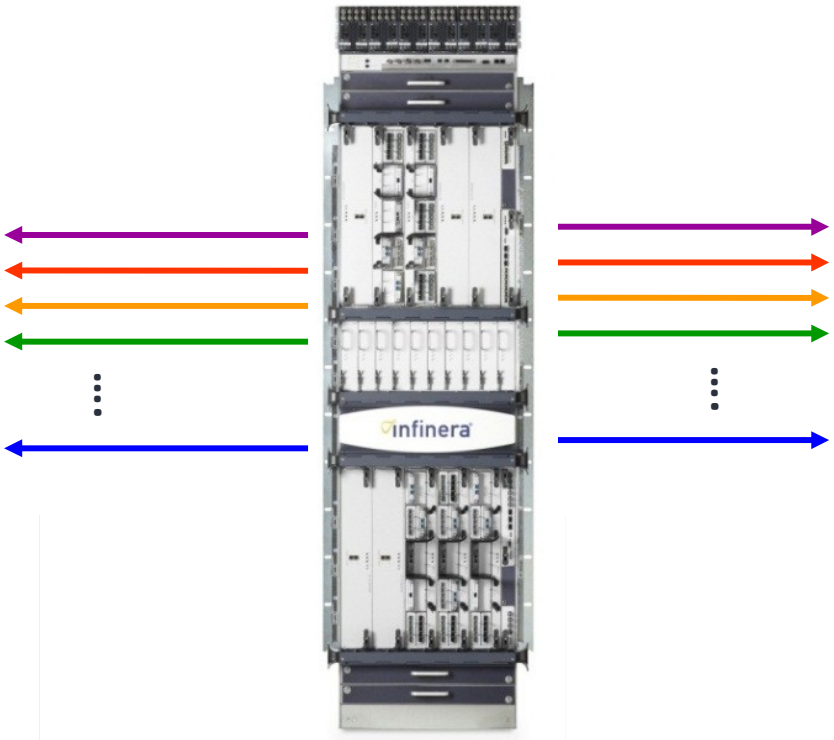
DTN-X – Regeneration Mode



- DWDM Line Side
  - Up to 16 x OCGs
  - Max 8 Tbps capacity
  - Single fiber pair
- No Client Interfaces
- Regeneration of signal
  - Removes Noise
  - Removes Chromatic Dispersion

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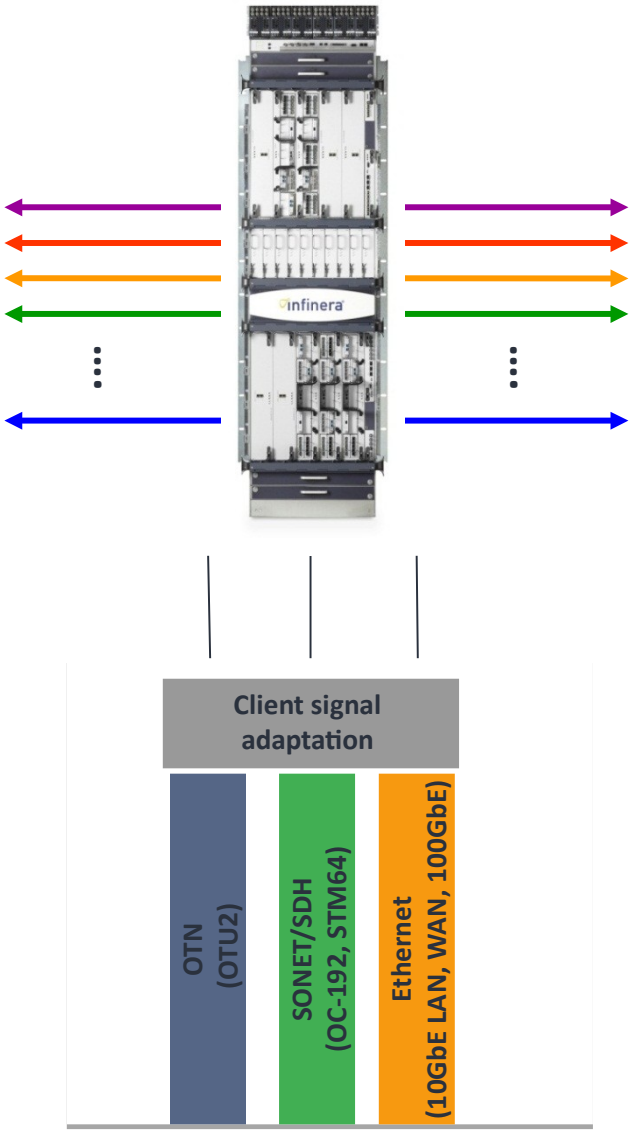
DTN-X - Reconfigurable Optical Add/Drop Mux (ROADM)



- DWDM Line Side
  - Up to 16 x OCGs
  - Max 8 Tbps capacity
  - Single fiber pair
- Multi-Service Client Interfaces
  - Ethernet
  - SONET
  - SDH
  - OTN

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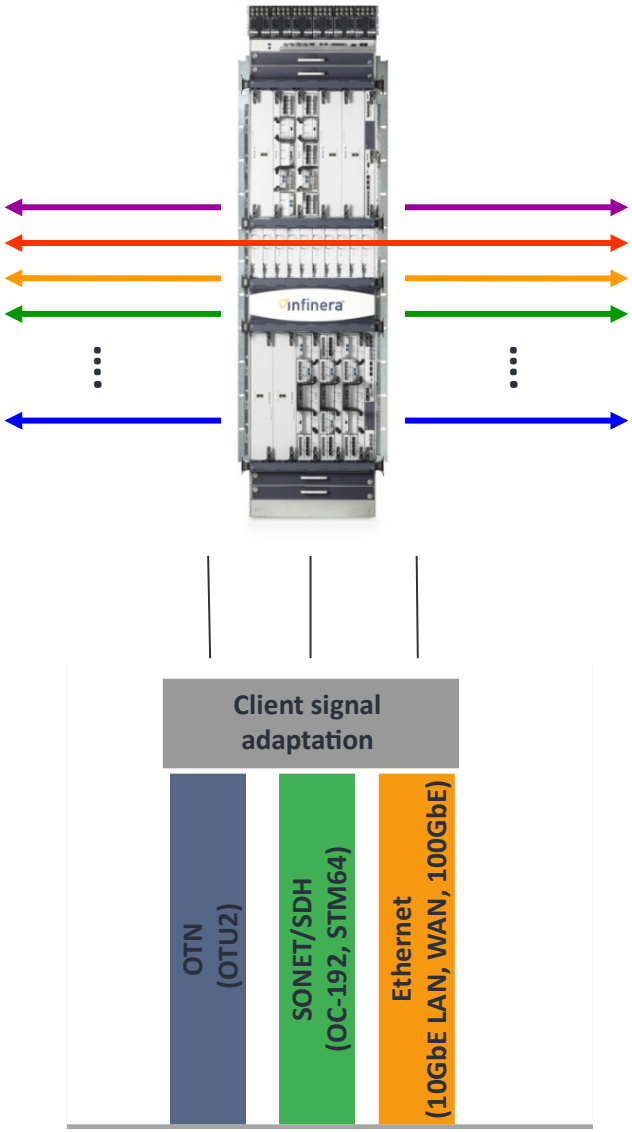
DTN-X – Optical Express



- DWDM Line Side
  - Up to 16 x OCGs
  - Max 8 Tbps capacity
  - Single fiber pair
- Multi-Service Client Interfaces
  - Ethernet
  - SONET
  - SDH
  - OTN
- Low Latency
  - High Value Service
  - Amplified Only / No Regeneration

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Progress Check

- What is the current maximum line rate using a DTN-X?

a) 1.6Tbps

b) 1.6Gbps

c) 8Tbps

d) 80Gbps

Progress Check

- What OTN functionality is performed by the Tributary Interface Module (TIM) in the client to line side direction?

a) Stripping the OPU from the ODU and then the client signal from the OPU

b) Wrapping client signals into OPU and then ODU structure

c) Performing Client side electrical to Line side optical conversion

d) Performing Client side optical to Line side electrical conversion

DTN Signal Flow

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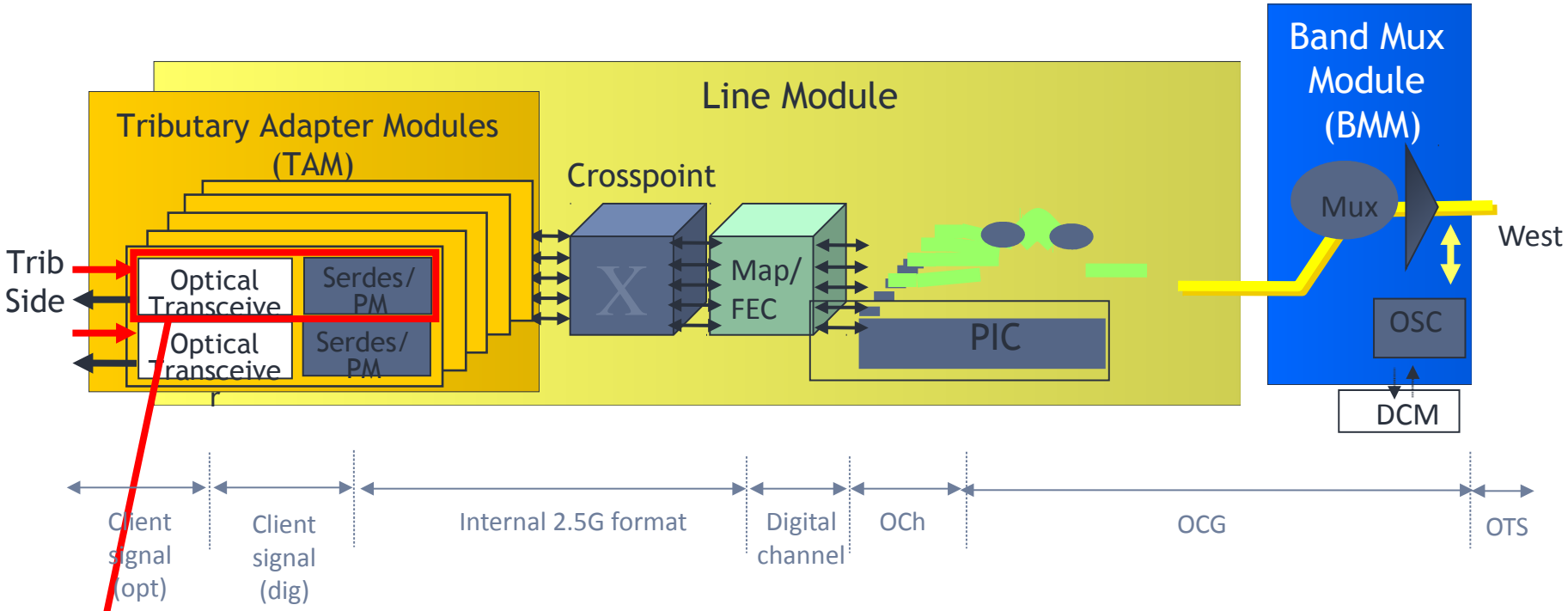
what THE NETWORK will be

DTN System Data Plane Signal Flow



Tributary Optical Module – TOM

- Receive – The incoming native client signal is converted from optical to electrical (digital).
- Transmit - The outgoing native client signal is converted from electrical (digital) to optical.
- Both digital and optical performance monitoring statistics are collected.

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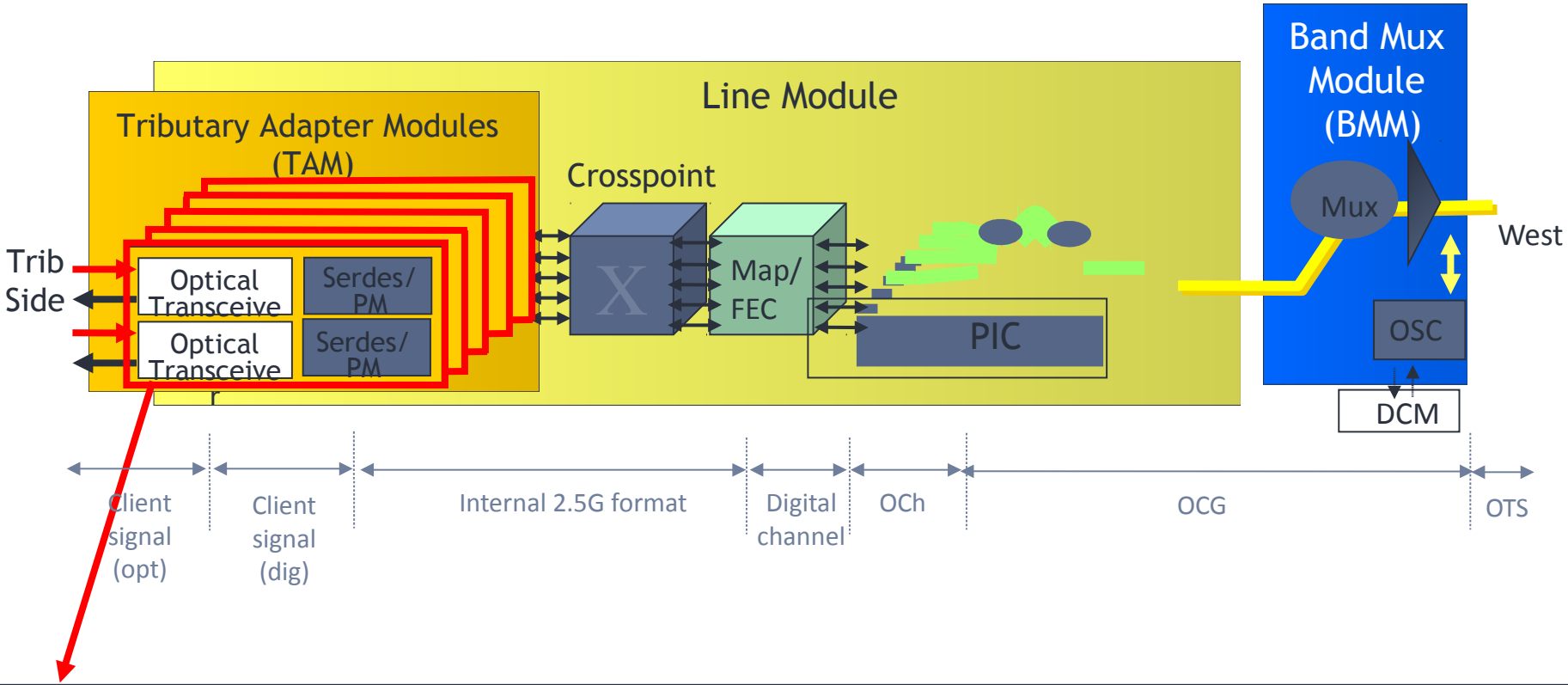
DTN System Data Plane Signal Flow (cont)



Tributary Adapter Module – TAM

- Incoming: The signal from the TOM is wrapped in the Trib DTF and performance data is collected.
- Outgoing: The signals performance data is collected and the Trib DTF is stripped off the native client signal and then it is sent to the TOM .

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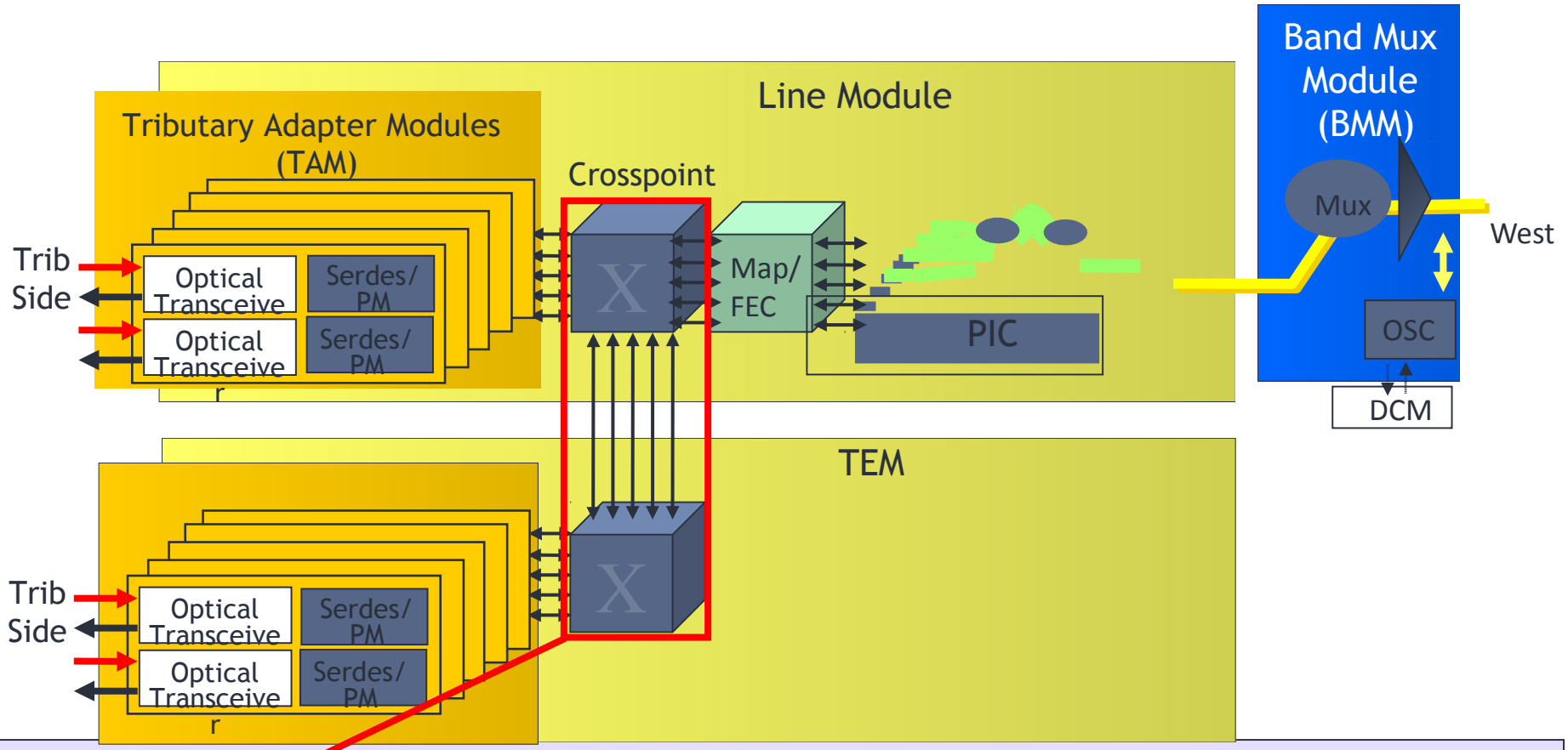
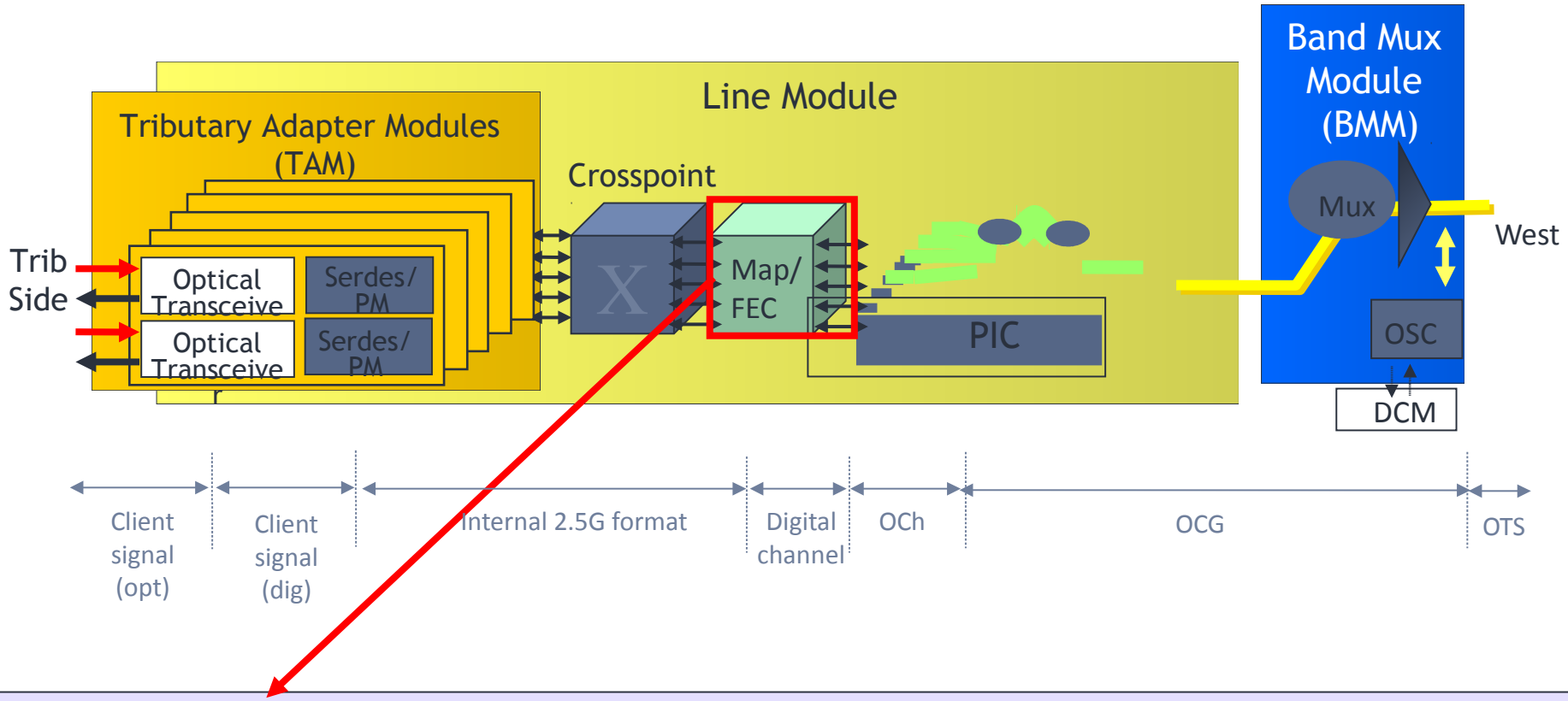
DTN System Data Plane Architecture (cont)



Crosspoint

- From the TAM, in the transmit direction, the Local Route Internal DTF (iDTF) will pass through the Crosspoint to the Mapper.
- From the Mapper, in the receive direction, the Local Route iDTF will pass through the Crosspoint to the TAM.
- A DTF to or from an another Line Module will be routed across the backplane via the Crosspoints to the appropriate outbound Line Module.

DTN System Data Plane Signal Flow (cont)



Line Module Mapper

- In the transmit direction the Mapper assembles the Line DTF then codes in the Forward Error Correction (FEC) algorithm creating the Digital Channel. The Digital Channel is then forwarded to the PIC.
- In the receive direction the Mapper receives the Digital Channel from the PIC, decodes, applies, and removes the FEC, then sends the Line DTF to the Crosspoint.
- Digital Channel, FEC, and Line DTF performance monitoring statistics are collected.

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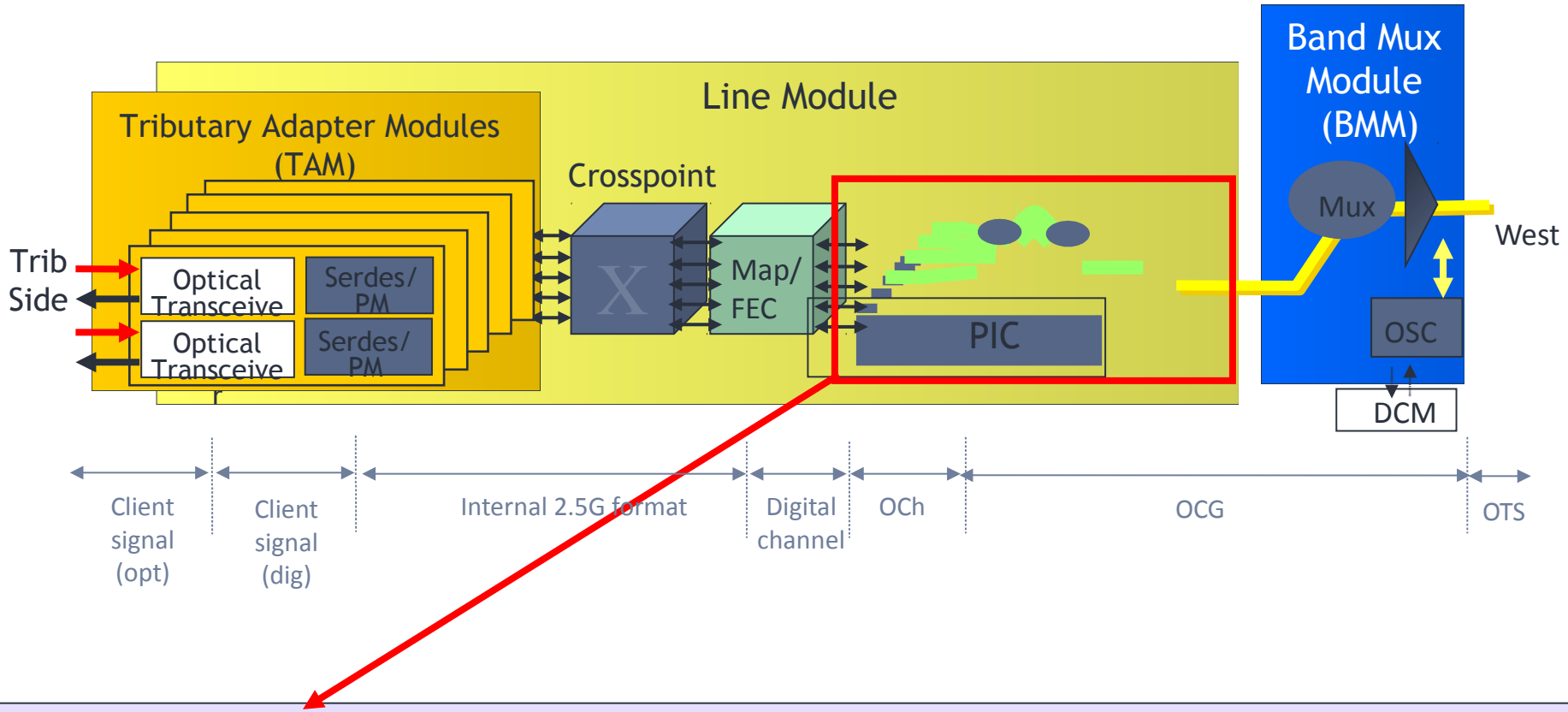
DTN System Data Plane Signal Flow (cont)



Line Module Transmit

- The PIC converts the Digital Channel sent from the Mapper from electrical (digital) to a ITU DWDM optical wavelength channel. The ten 10G wavelength channels are multiplexed onto a common optical path as a 100G Optical Carrier Group (OCG).
- Both digital and optical channel performance monitoring statistics are collected.

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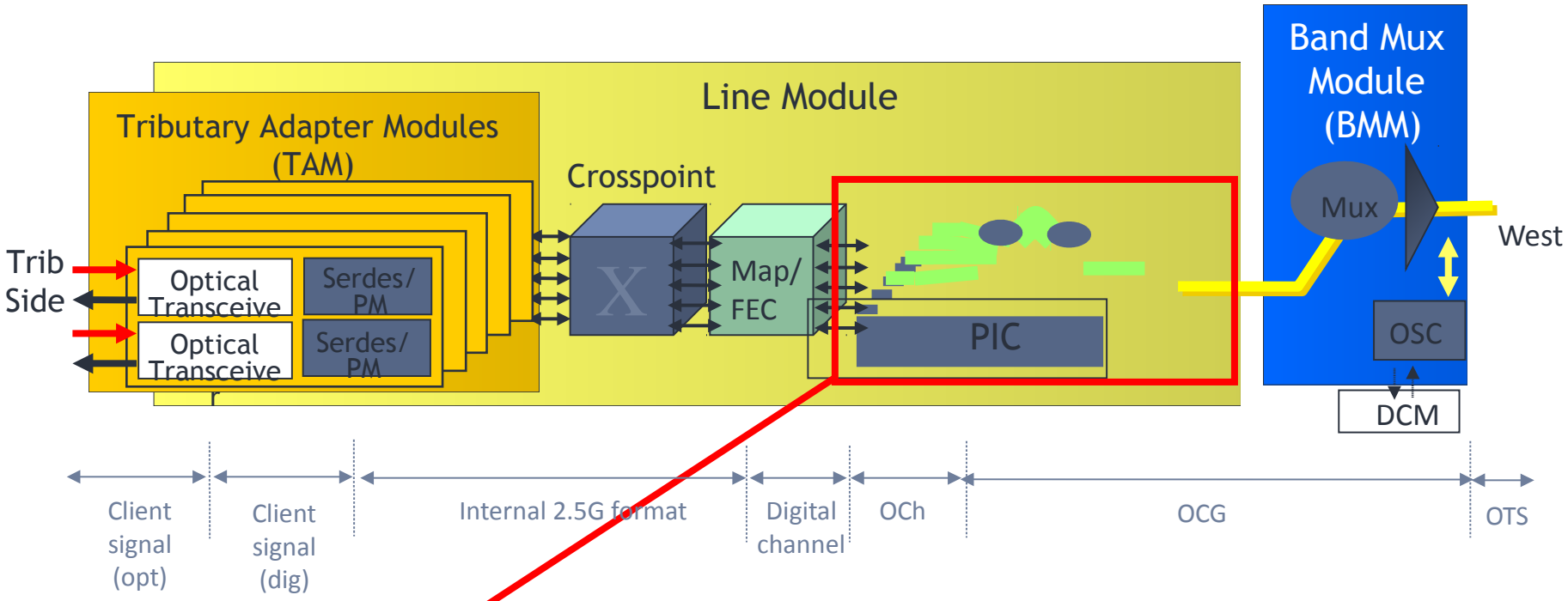
DTN System Data Plane Signal Flow (cont)



Line Module Receive

- The PIC demultiplexes (separates) the 100G OCG into ten ITU wavelength Optical Channels (OCh). Each OCh is applied to (strikes) the appropriate receive diode that converts the OCh to a Digital Channel.
- Both digital and optical performance monitoring statistics are collected.

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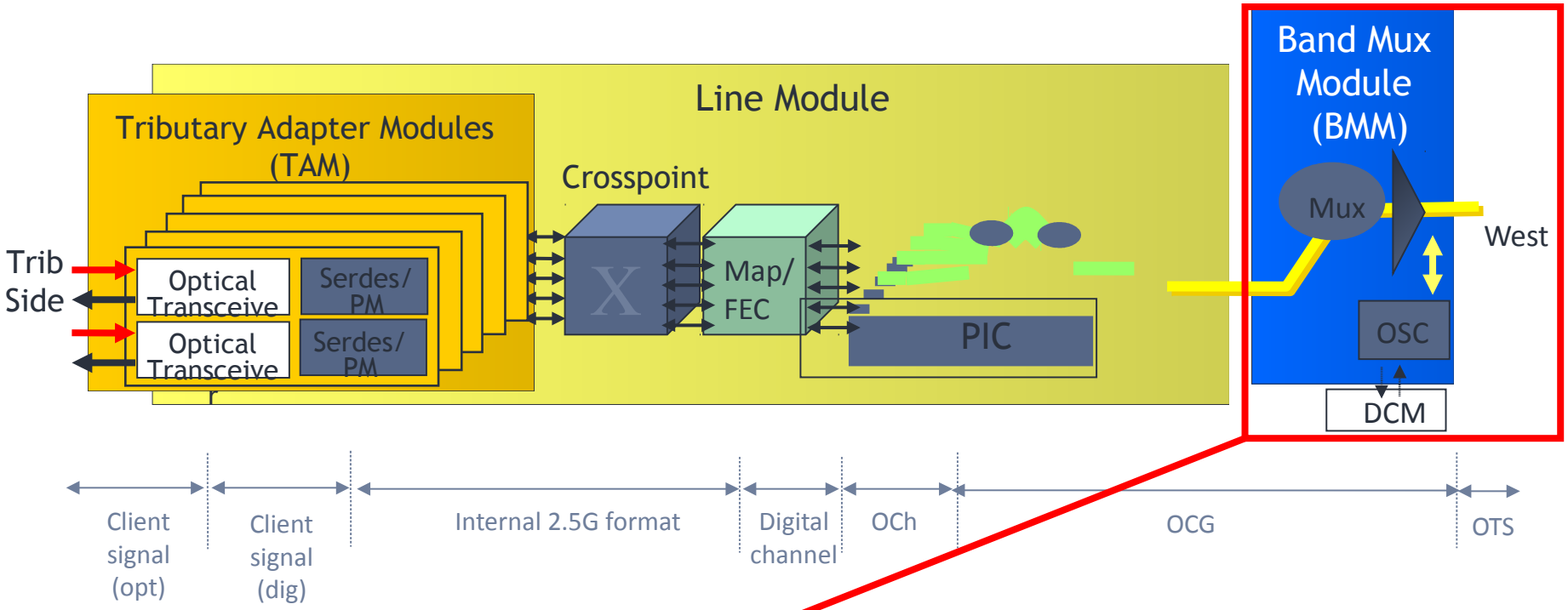
DTN System Data Plane Signal Flow (cont)



Band Multiplexer Module – BMM Transmit

- The BMM combines the OCGs onto a common optical path creating the C Band signal.
- The C Band signal is amplified by the transmit Erbium Doped Fiber Amplifier (EDFA).
- The Optical Supervisory Channel (OSC) is coupled on to the C Band signal creating the Optical Transport Signal (OTS) and sent to the Line Out port.
- OCG, EDFA, Span, C Band, and OTS performance monitoring statistics are collected.
- Both optical and digital OSC performance monitoring statistics are collected.

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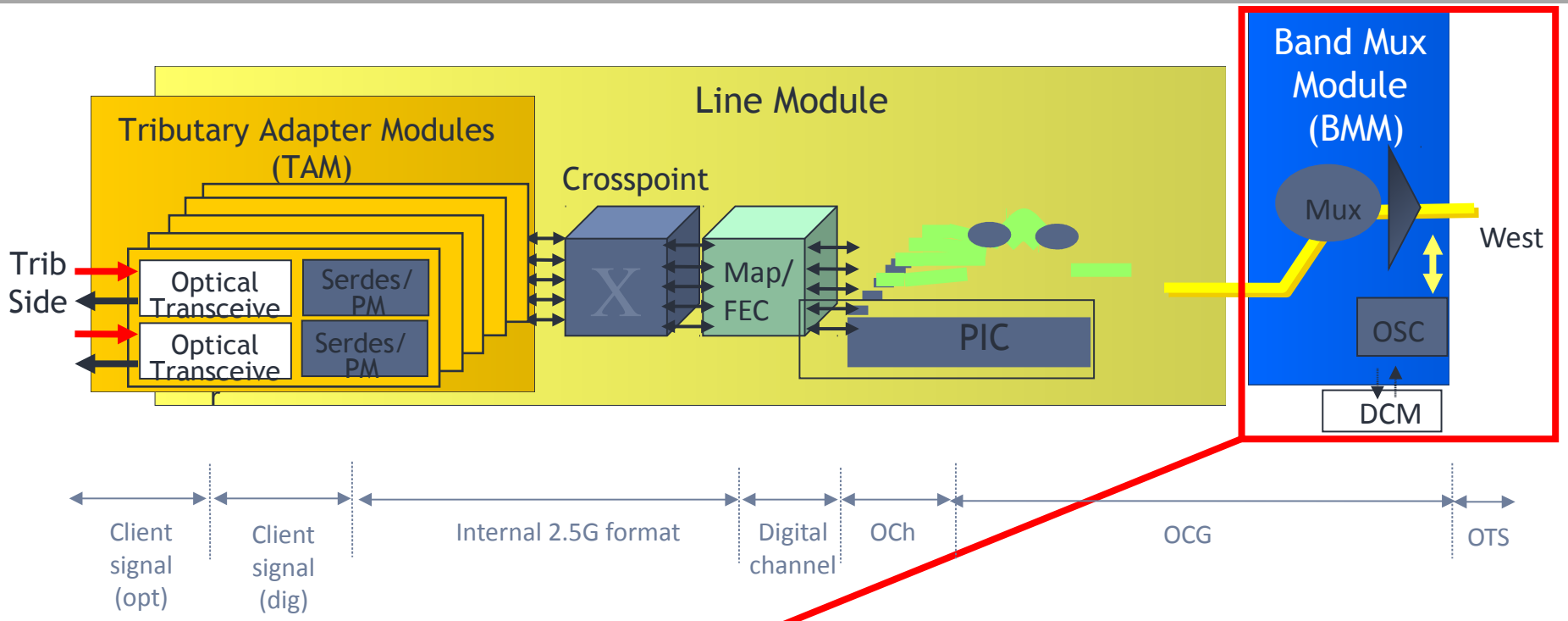
DTN System Data Plane Signal Flow (cont)



Band Multiplexer Module – BMM Receive

- The OTS is received at the Line In, the Optical Supervisory Channel (OSC) is removed and sent to the MCM for processing.
- The C Band signal is sent through the Pre Amp EDFA then out the DCM port for dispersion compensation, followed by the second stage of amplification by the Post Amp EDFA.
- The BMM then demultiplexes the C Band into the 100G OCGs and each is sent to the appropriate OCG connector.
- Both optical and digital OSC performance monitoring statistics are collected.

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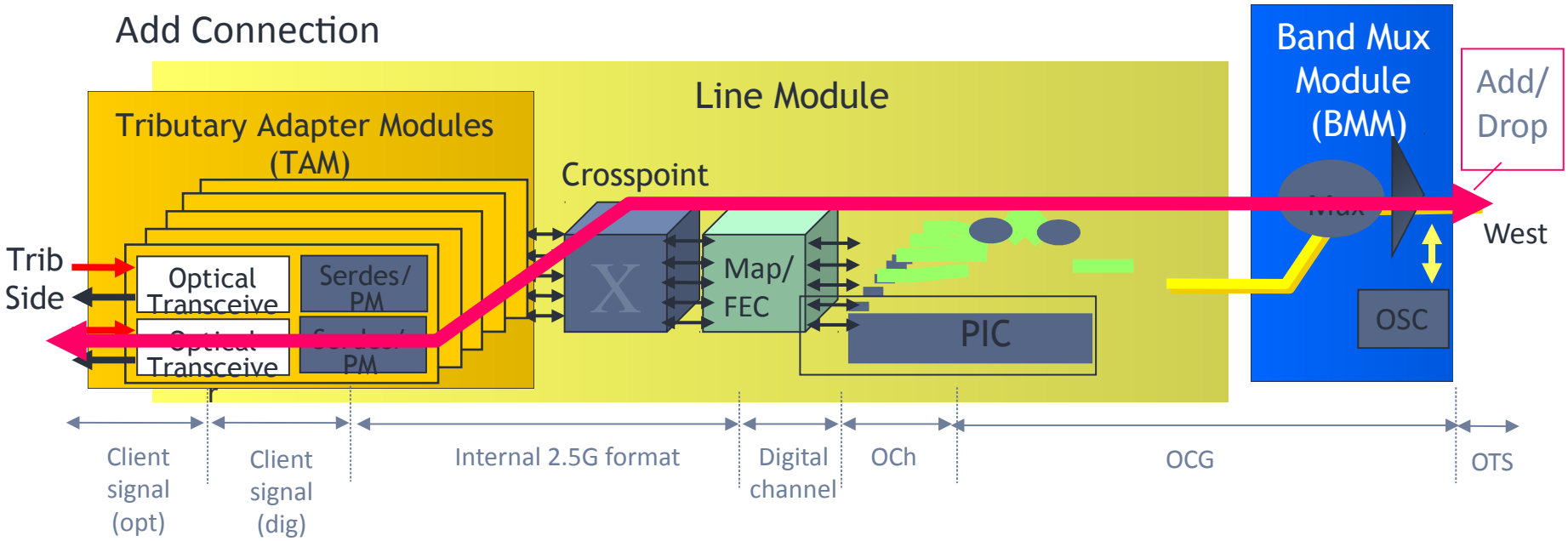
DTN System Data Plane Signal Flow (cont)



Add Direction

- On the TOM the native client signal is converted from optical to electrical (digital) and sent to the TAM.
- On the TAM the client signal is wrapped in the Trib DTF and sent to the Crosspoint on the Line Module.
- On the Line Module the Crosspoint sends the iDTF to the Mapper on the outbound Line Module.
- On the Line Module Mapper the iDTF is mapped to a Line DTF, FEC code is loaded, and the Digital Channel is sent to the Transmit PIC.
- The Transmit PIC converts the Digital Channel to an Optical Channel (OCh) then multiplexes the ten Ochs to create the Optical Carrier Group (OCG).
- The BMM multiplexes the OCGs into the C Band signal, the C Band is amplified by the Transmit EDFA, and the OSC is coupled onto the C Band to create the OTS that is sent to the Line Out connector.

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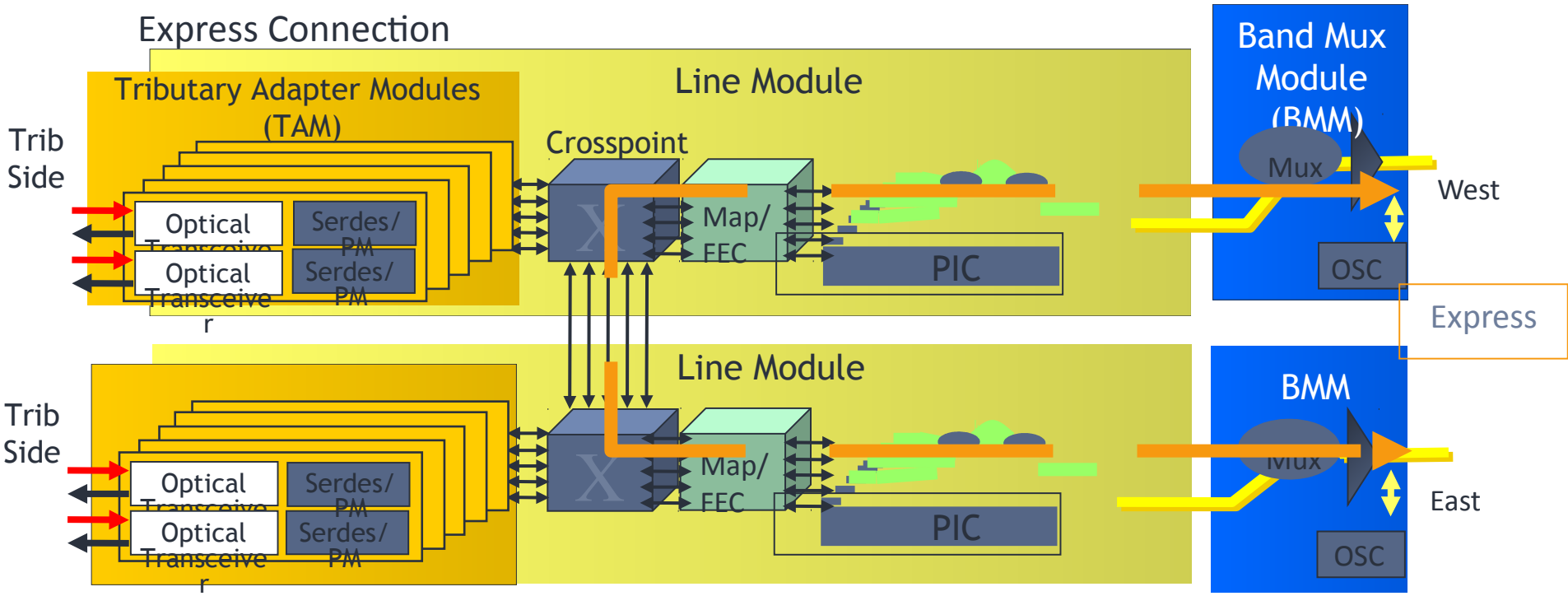
DTN System Data Plane Signal Flow (cont)



Express Connection

- The OTS is received at the Line In, the C Band is amplified by EDFA, the BMM then demultiplexes the OCGs and each is sent to the appropriate OCG connector.
- On the Line Module, the PIC converts the signal from optical to electrical, the Mapper decodes and applies FEC, and then the signal is routed by the Crosspoint to the outbound Line Module.
- On the outbound Line Module the signal comes in from the Crosspoint to the Mapper, new FEC is coded and read into the DTF, then the PIC converts the signal from electrical to optical and multiplexes the OChs into the OCG.
- The BMM combines the OCGs onto a common optical path creating the C Band signal.
- The C Band signal is amplified by the EDFA, the OSC is added, and the OTS is sent to the Line Out.

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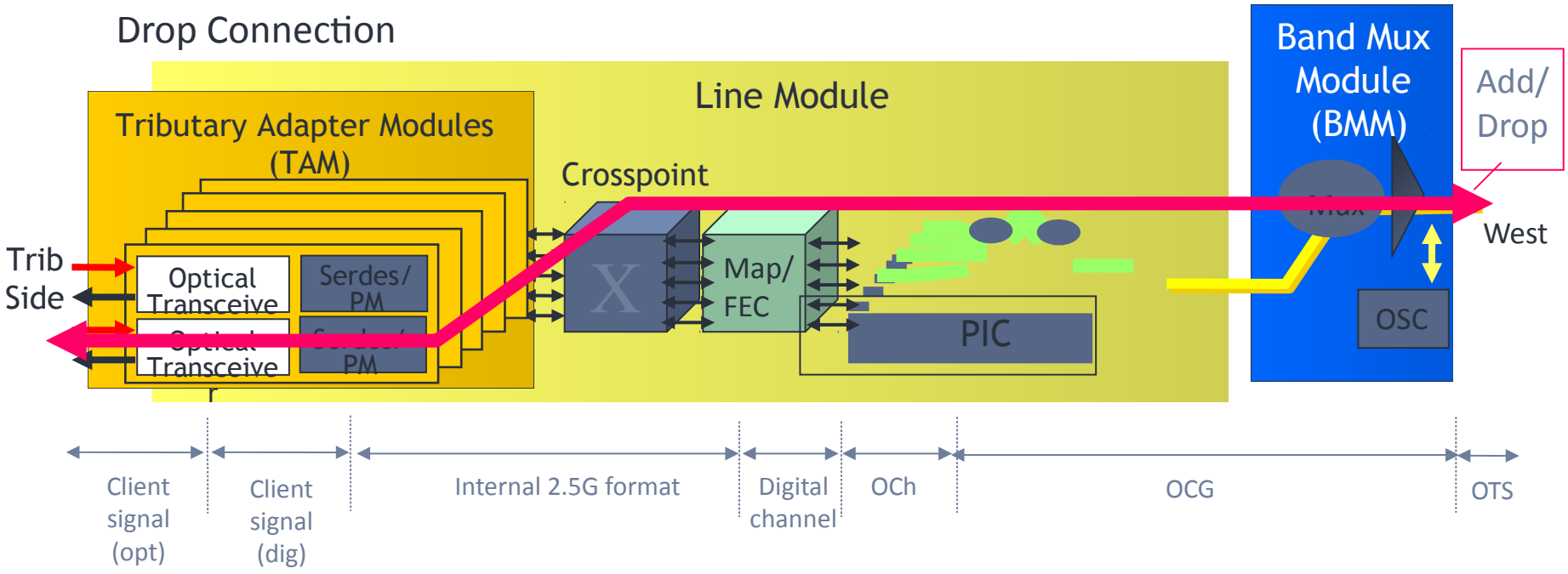
DTN System Data Plane Signal Flow (cont)



Drop Direction

- The OTS is received at the Line In, the OSC is stripped and sent to the MCM for processing, the C Band signal is amplified by EDFA, the BMM then demultiplexes the C Band signal into OCGs and each is sent through the appropriate OCG connector to the Line Module.
- On the Line Module, the PIC converts the signal from optical to electrical, the Mapper decodes and applies FEC, and then the signal is routed by the Crosspoint to the outbound Line Module or TEM where the signal from the Crosspoint is sent to the TAM.
- On the TAM the DTF is removed and the native client signal is routed to the appropriate TOM.
- On the TOM the signal is converted from electrical to optical and sent to the client.

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OTN Tributary Module 600G

OTSM-600 & OTXM-600 (XTC-2 and XTC-2E)

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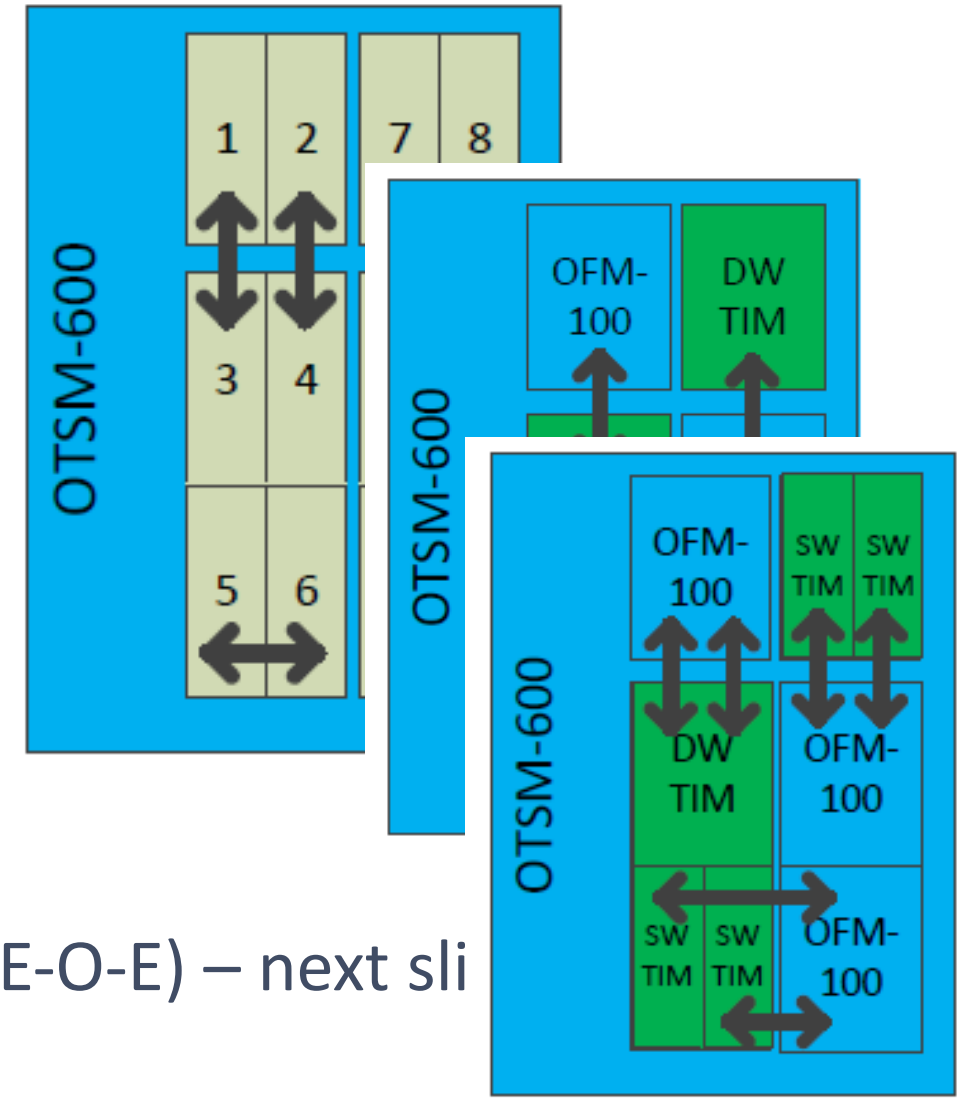
what THE NETWORK will be

OTSM-600 Slot Pairing and Configurations

- Slot Pairing
- Transponder
- Muxponder
- Regenpoder (E-O-E) – next sli



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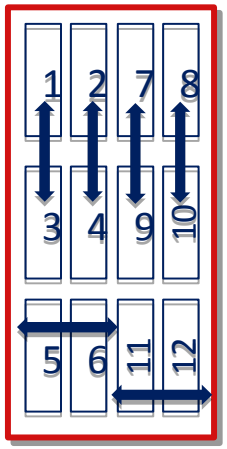
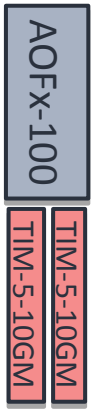
OTSM-600 Slot Pairing Configurations



OTSM-600

1 x 100GE -> 100GE
- Transponder
- 6 per chassis



10 x 10G -> 100G
- Muxponder
- 6 per chassis

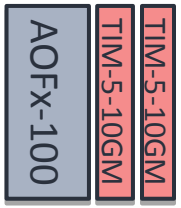
16 x Sub-10G -> 100G
- Muxponder
- 6 per chassis

100G <-> 100G
- Regenponder
- 6 per chassis

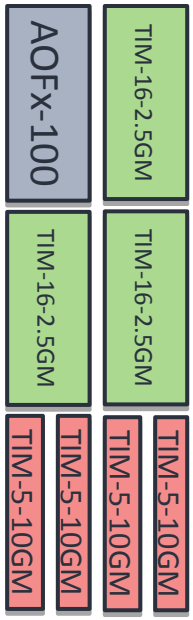
- Transponders, muxponders and regenponder can be flexibly mixed
- TIMs and DWDM line modules can be flexibly placed within a paired set of slots

Example Configurations with OTXM-600

1 x 100GE -> 100GE
- Transponder
- 6 per chassis

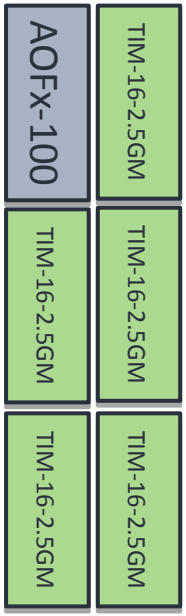


10 x 10G -> 100G
- Muxponder
- 6 per chassis



N x 10G + M x Sub-10G -> 100G
- Muxponder
- Flexible mix of Sub-10G and 10G TIMs

16 x 10GE -> 100GE
- Packet Muxponder
- 4 per chassis



80 x Sub-10G -> 100G
- Muxponder
- 2 per chassis

- Time slots from any TIM can be connected to any AOFx-100 in either OTXM
- TIM and DWDM line modules can be placed into any available slots without restriction

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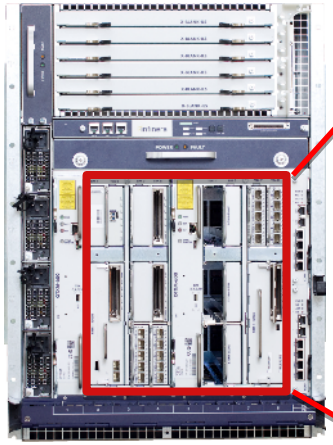
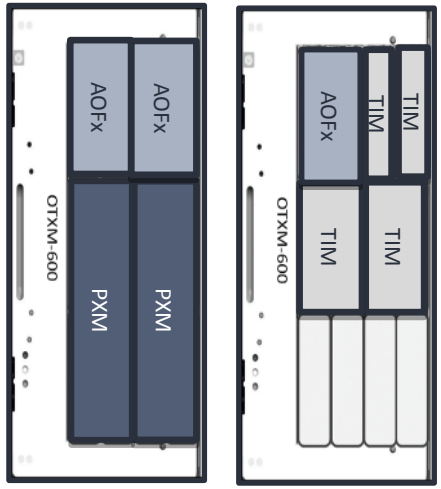
XTC-2/2E and OTXM-600 Overview

XTC-2E



OTXM-600 Modules Vertically Oriented in Chassis



Client service modules (TIM)

1G-2.5G 10G 40G 100G

1.2Tb Non-Blocking switching at ODU0

Integrated Switching, Timing and Framing Function

Multiple Module Support

TIM Modules

Packet Switching Modules (PXM)

AOFX-100 Module

PXM Module

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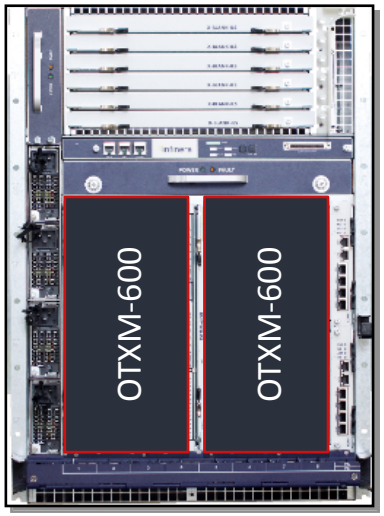
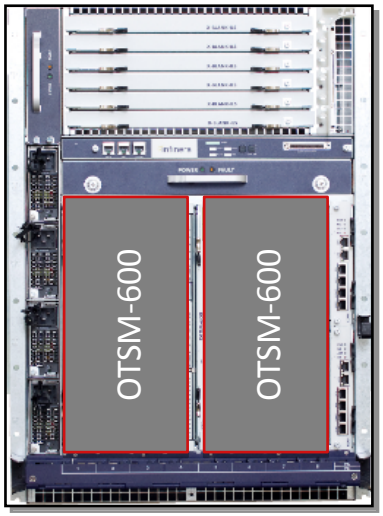
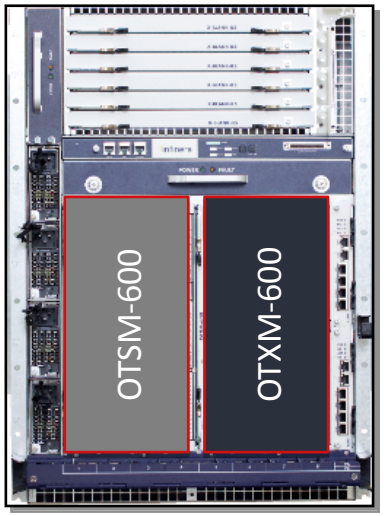
Supported OTxM Configurations



1.2Tbps ODUk switched shelf



1.2Tbps muxponder shelf



- 600Gbps ODUk switched capacity
- 600Gbps muxponder capacity
- No switching between OTSM and OTXM
- Switching within OTXM allowed

NB: XTC-2E shown for illustrative purposes; XTC-2 supports the same configurations

DTN-X Signal Flow

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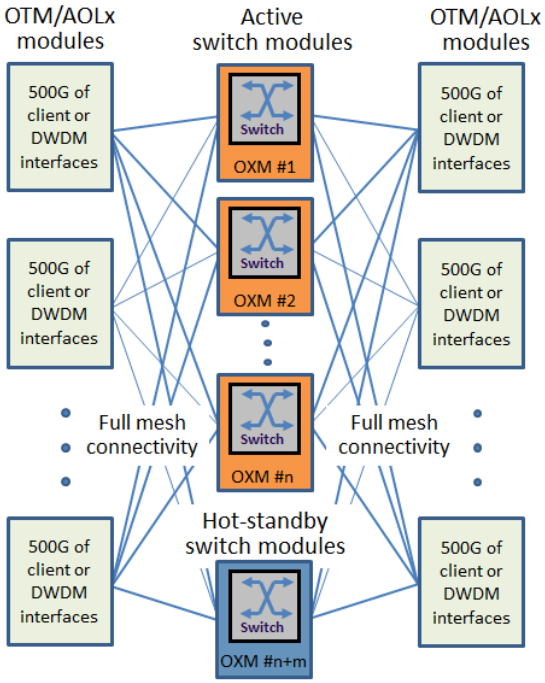
what THE NETWORK will be

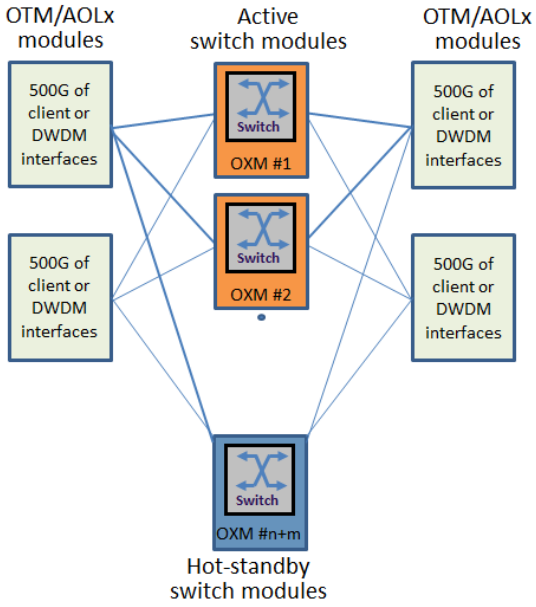
ODU Routing Options

- To an OTM-500 for client side delivery
- To an OTN Line Module for multiplexing into an OTU4

XTC-10 to any one of 10 universal slot



XTC-4 to any one of 4 universal slots



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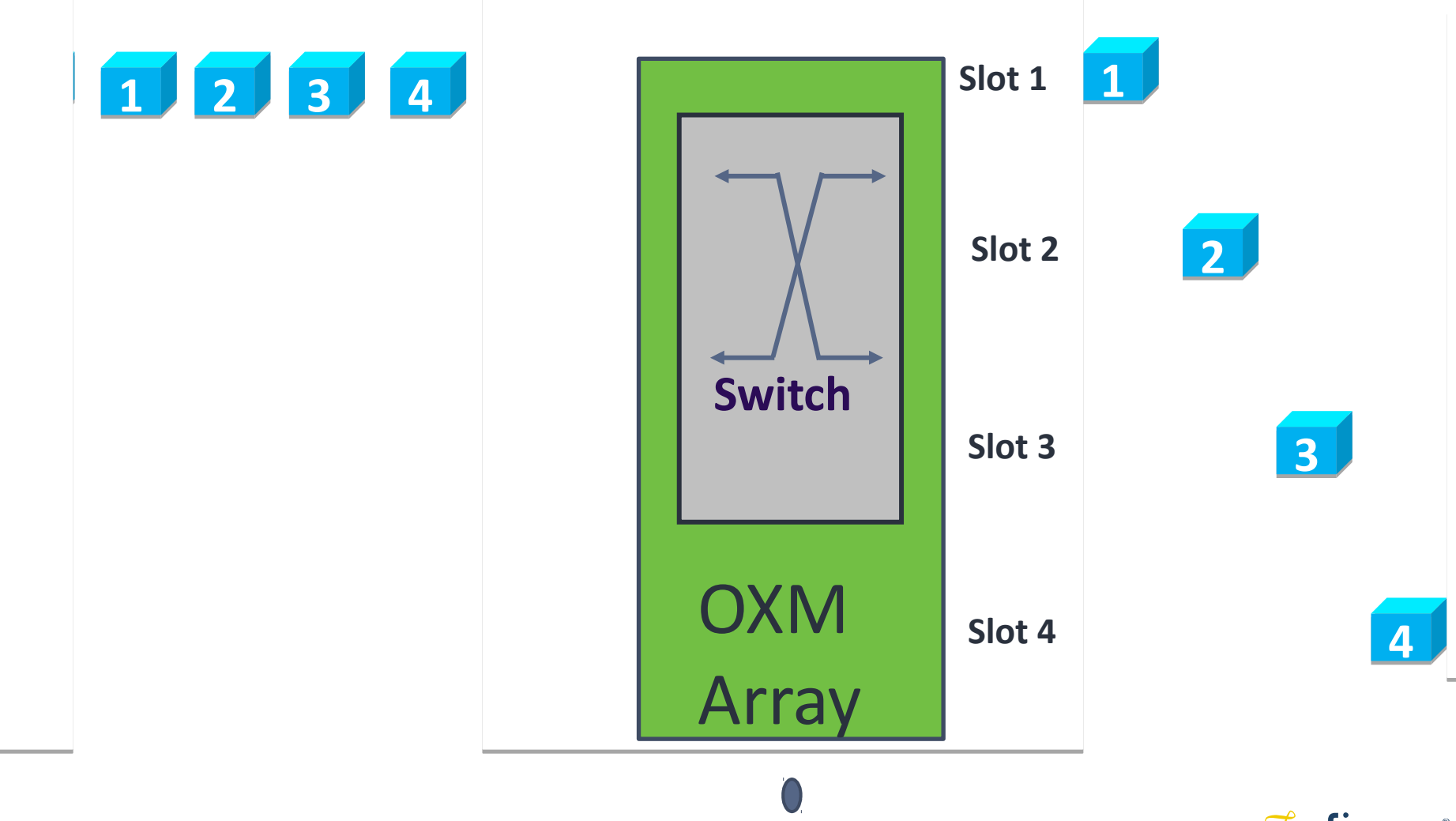
Virtual Switching Plane



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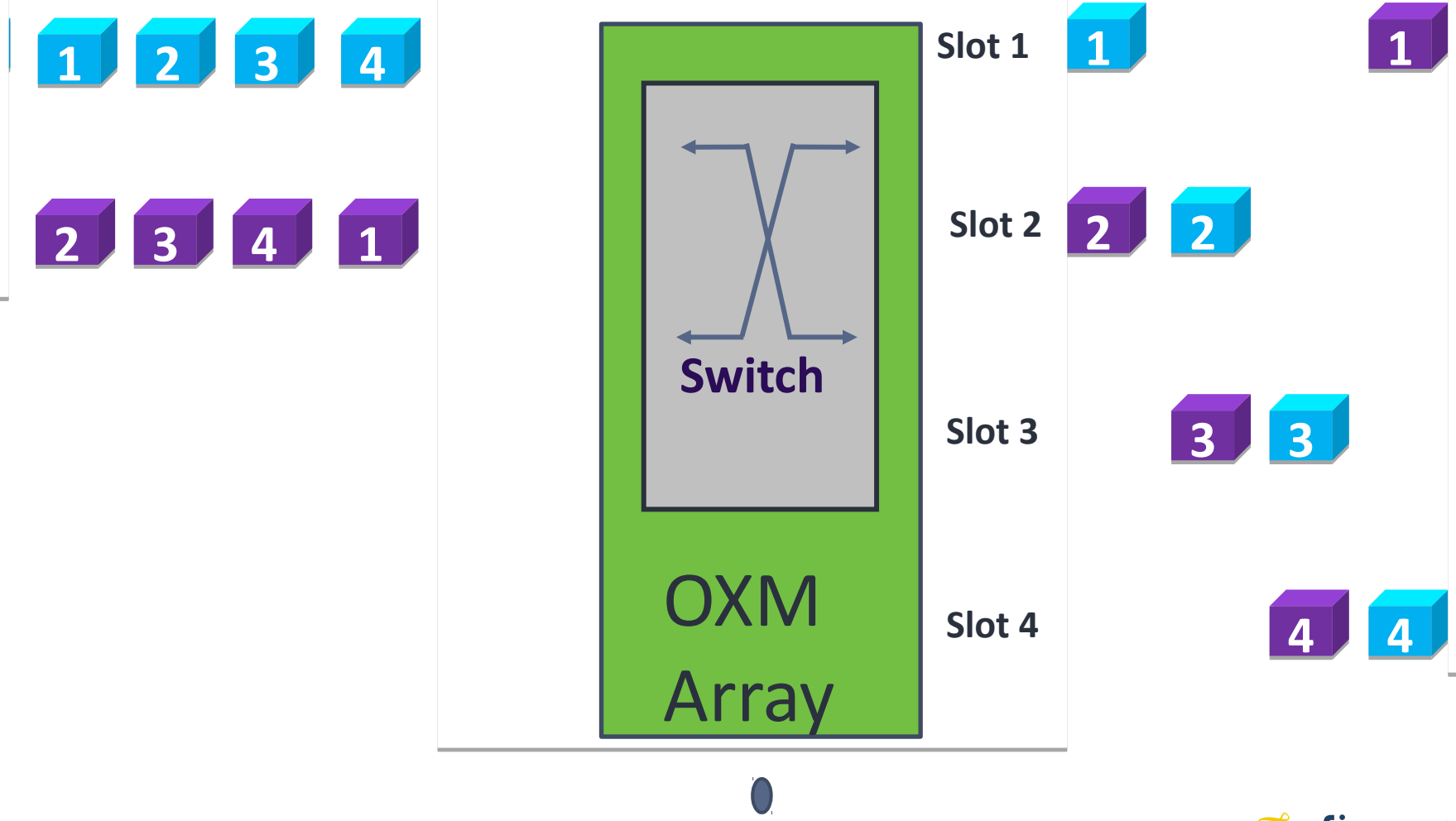
Virtual Switching Plane



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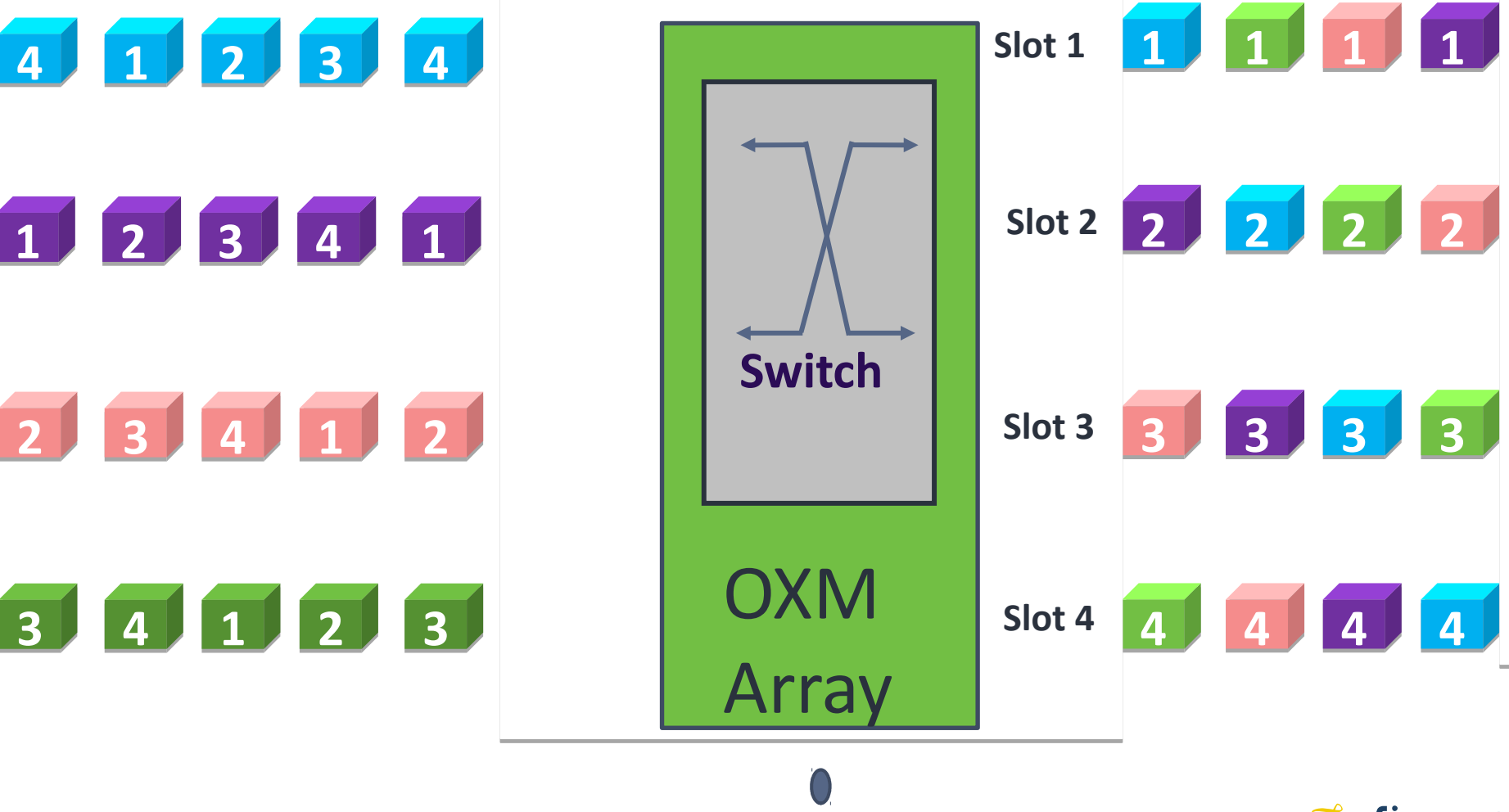
Virtual Switching Plane



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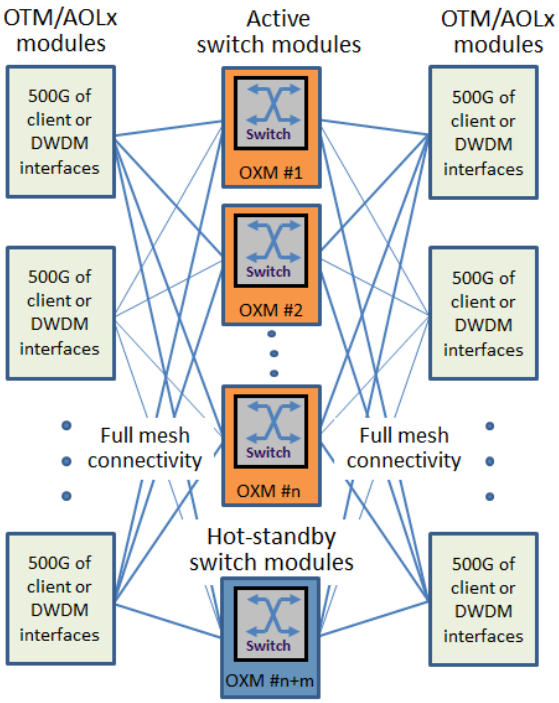
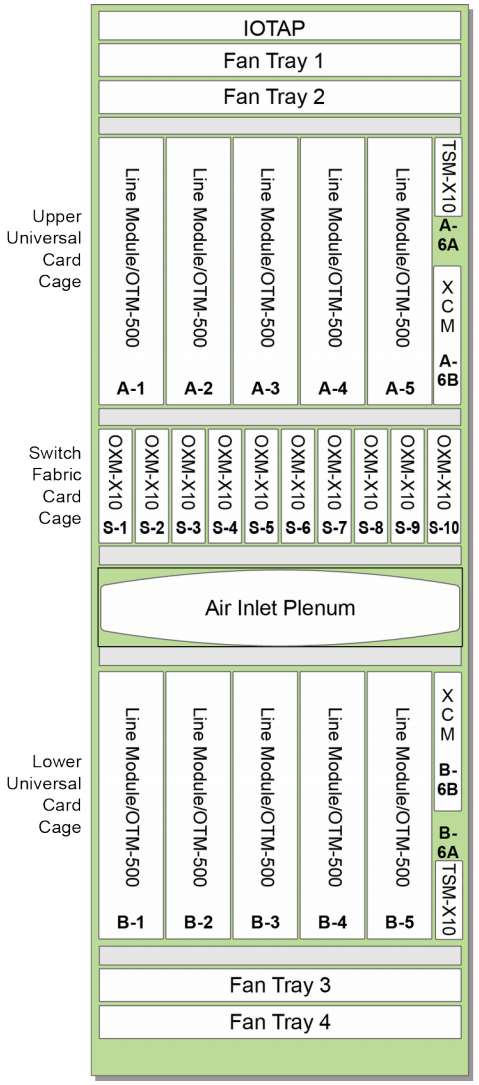
OTN Switch Module (OXM-10)

- 8 OXM-10s required for XTC-10 array to operate
- 10 slots provide 8:2 protection
- Any Universal Slot to any Universal Slot





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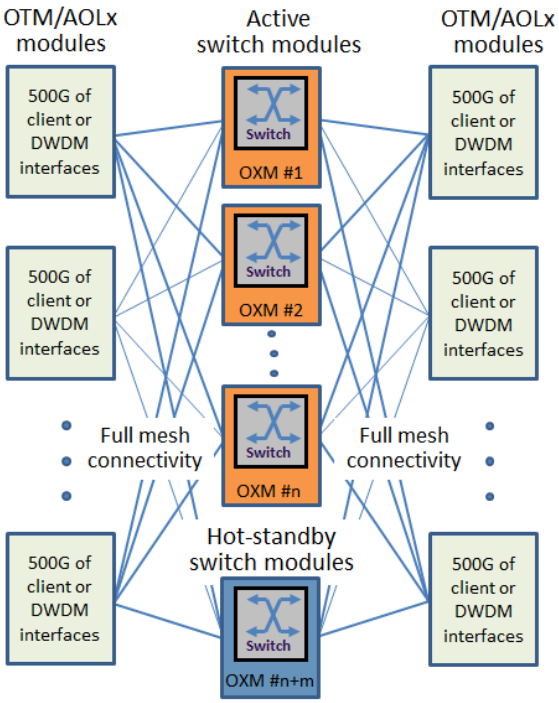
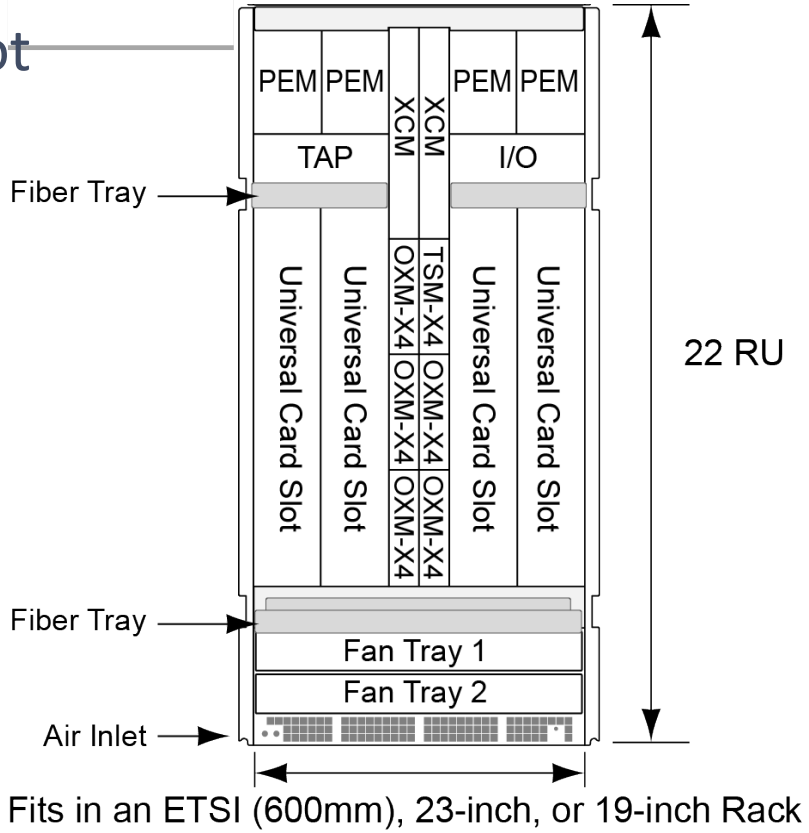
OTN Switch Module (OXM-4)

- 4 OXM-4s required for XTC-4 array to operate
- 5 slots provide 4:1 protection
- Any Universal Slot to any Universal Slot





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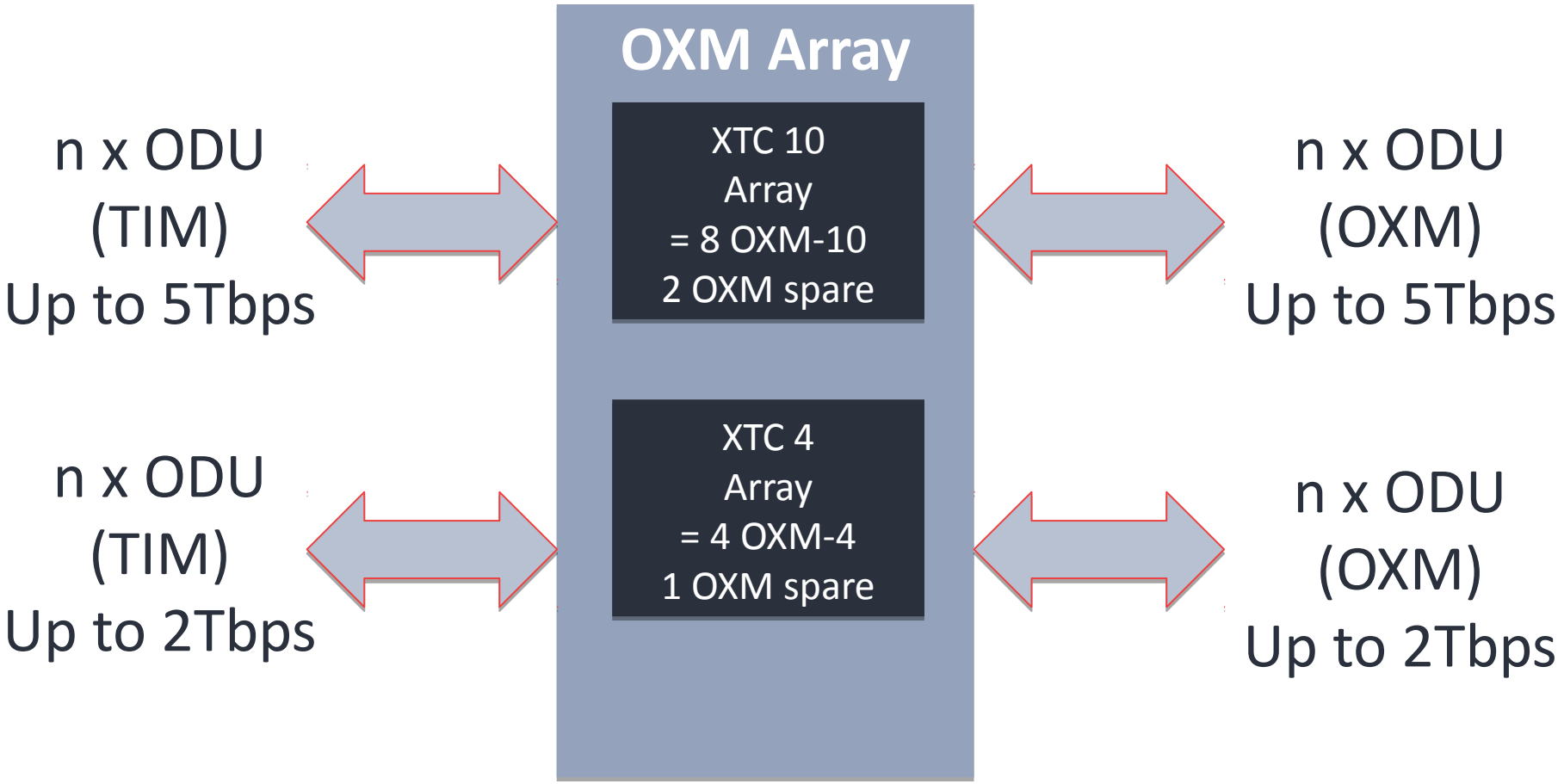
OXM Standbys

- XTC-10
  - 10 OXMs
  - 8 as part of the switching array
  - 2 standby
  - Breaks all ODU0s into 16 timeslots and sends 2 timeslots per OXM simultaneously
- XTC-4
  - 5 OXMs
  - 4 as part of the switching array
  - 1 standby
  - Breaks all ODU0s into 16 timeslots and sends 4 timeslots per OXM simultaneously

OXM Array Summary



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Progress Check

- What OTN functionality is performed by the OTN Switch Module?

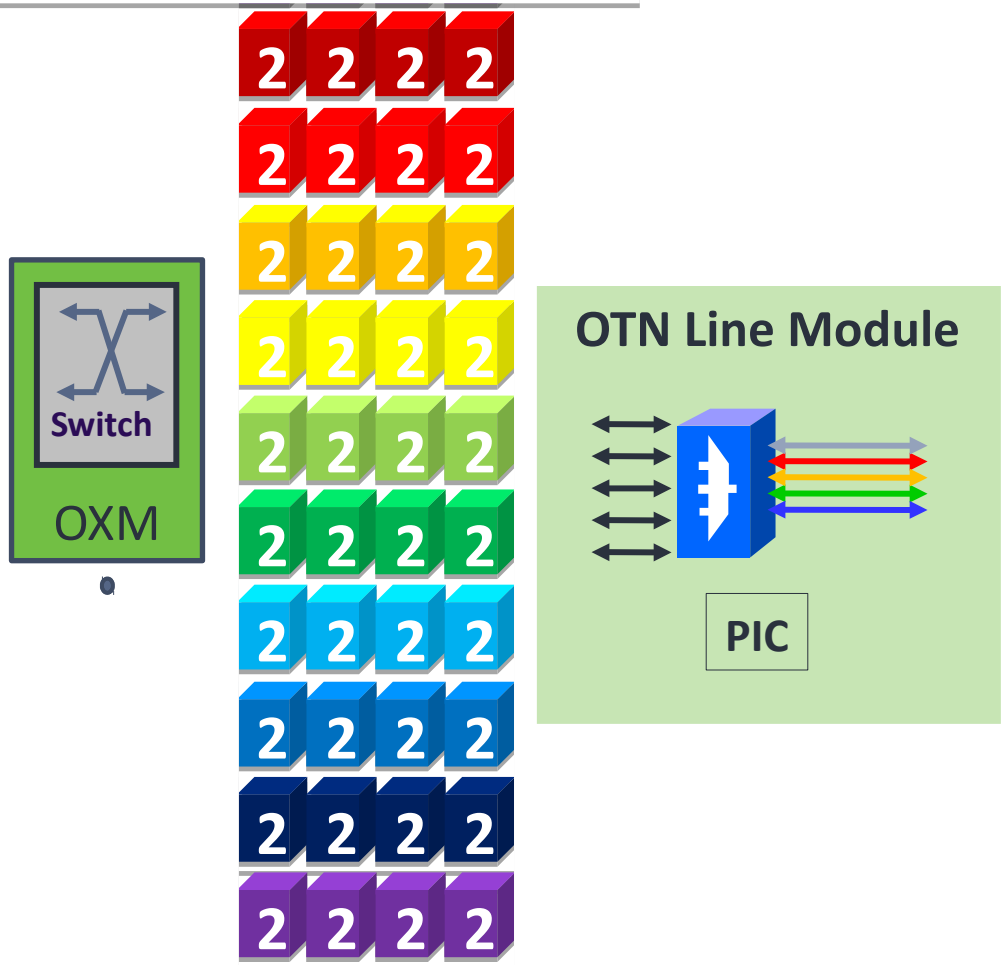
a) Routing Client signals with FEC from one universal slot to another

b) Routing OTUs from one universal slot to another

c) Routing ODUs from one universal slot to another

d) Routing OPUs from one universal slot to another

Line Module – ODU to OTU4



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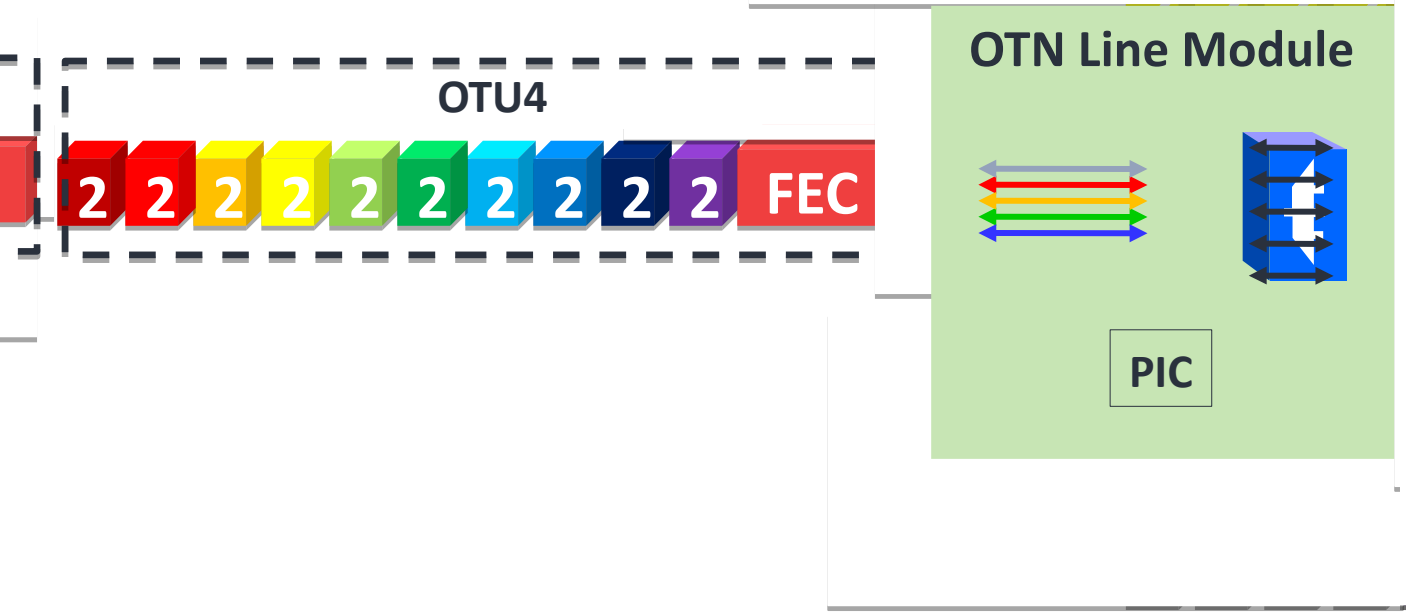
Virtual Switching Plane



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OTN Line Module Summary

n x ODU
(OXM)
Up to 500G

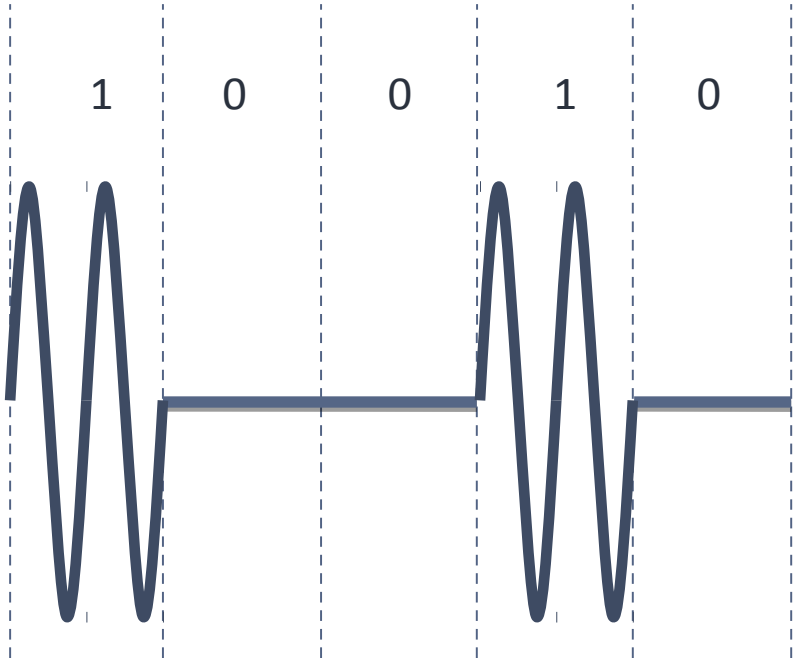
5 x OTU4
1 x OCG
10 x Optical Channels

1 x Optical Channels = 50Gbps
1 x OTU4 = 100Gbps

Therefore, 1 OTU4 has to be
spread over 2 x Optical Channels

Line Codes

- On Off Keying (OOK)



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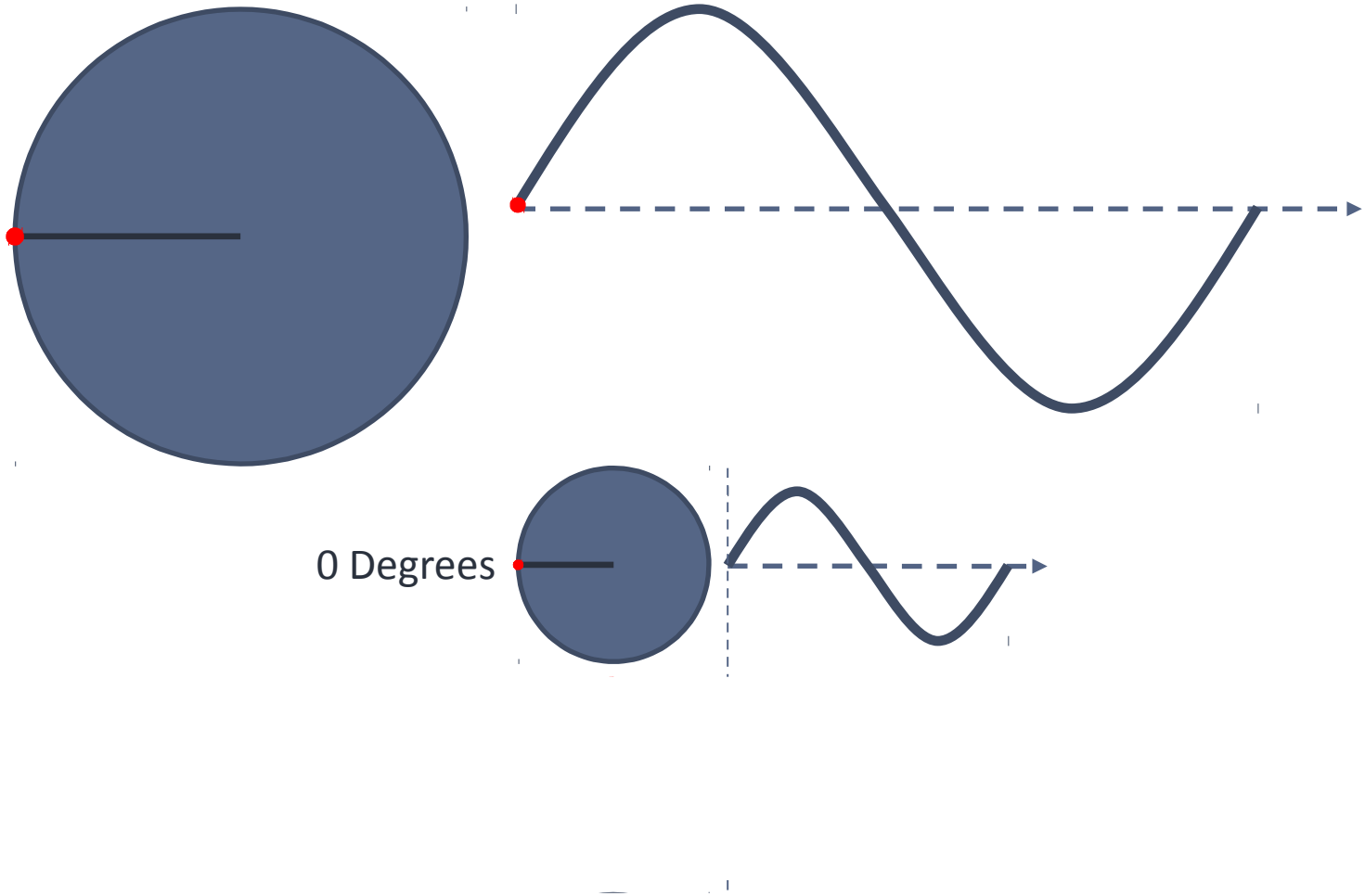
How Phase is measured



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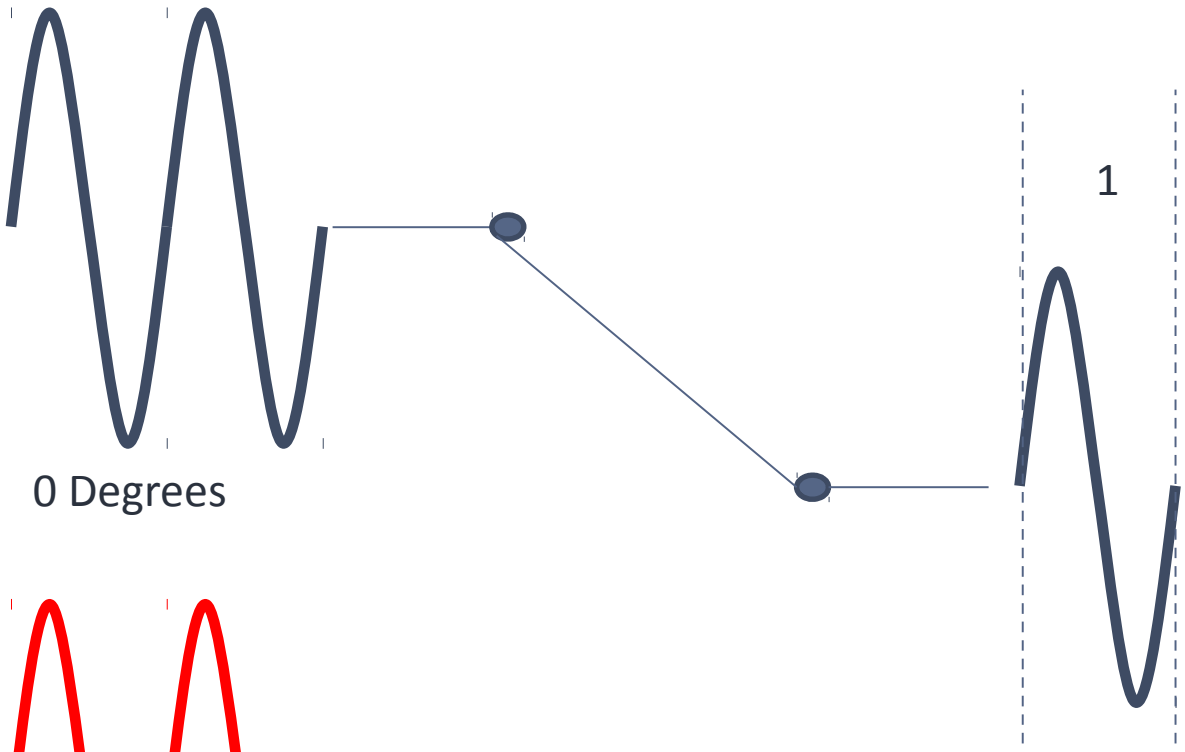
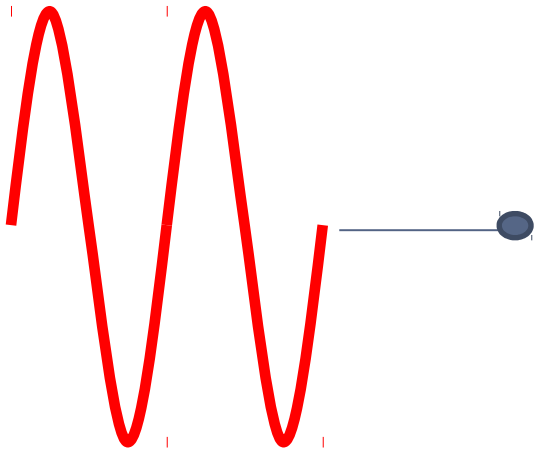
Binary Phase Shift Keying (BPSK)



0 Degrees



180 Degrees

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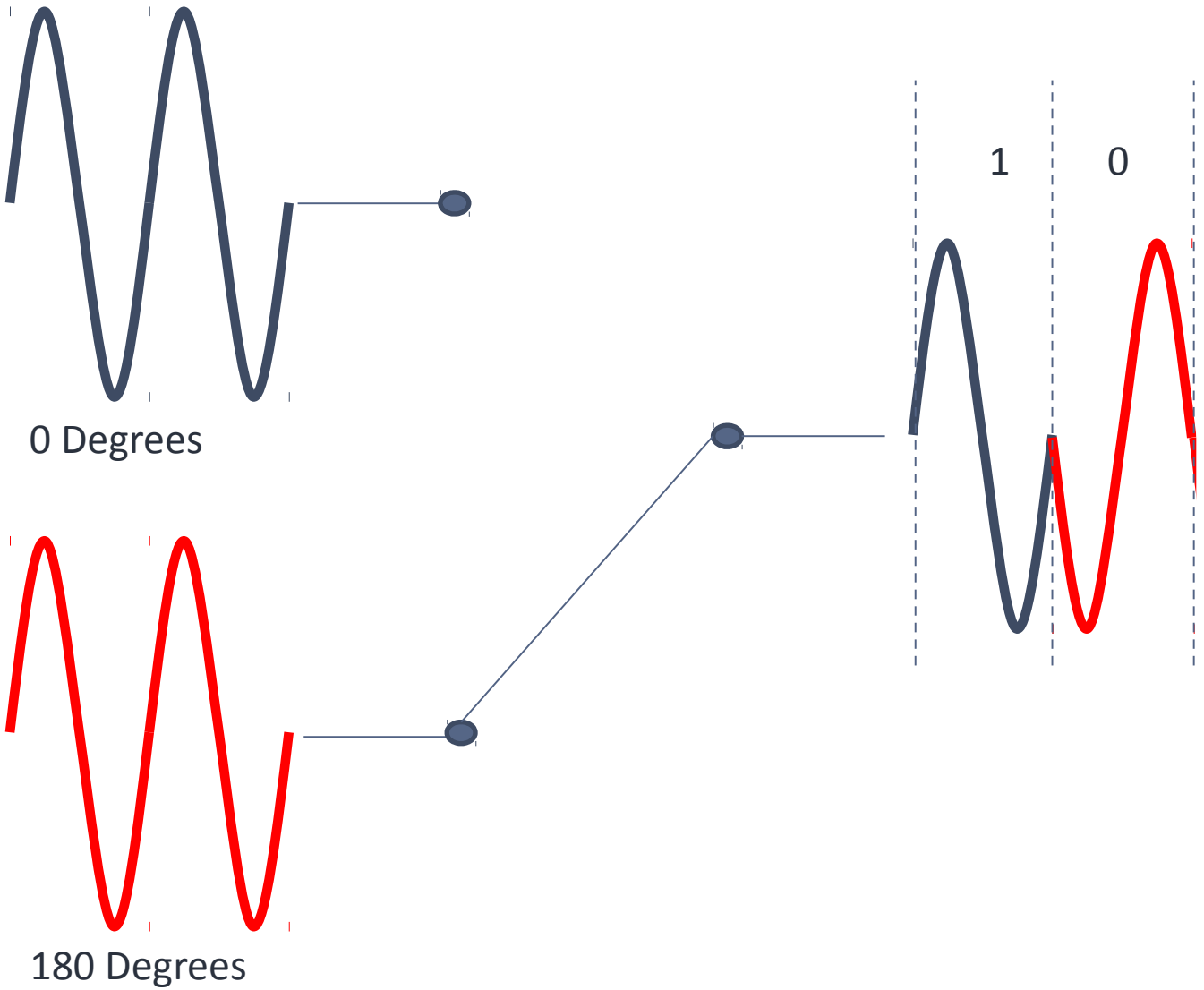
Binary Phase Shift Keying (BPSK)



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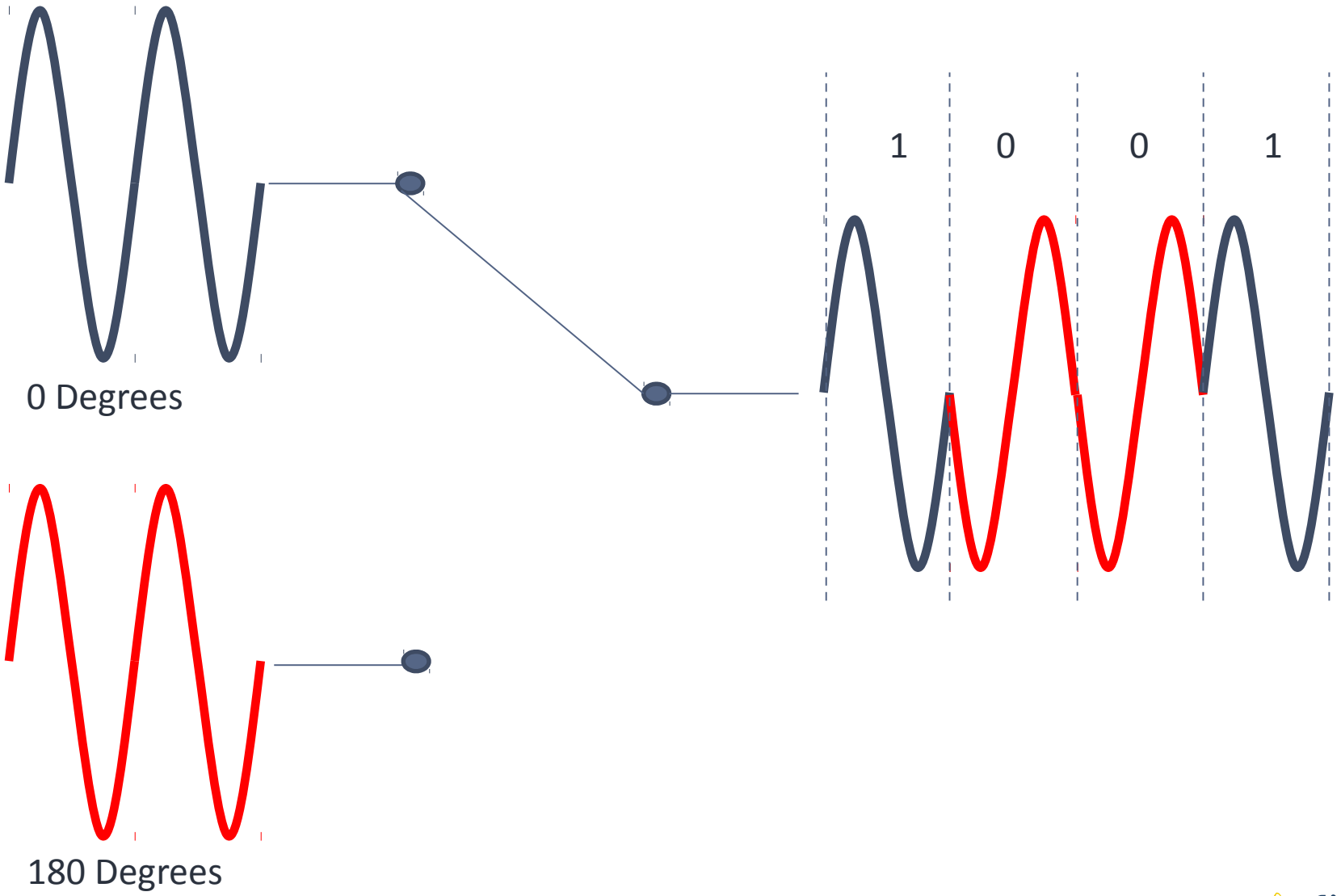
Binary Phase Shift Keying (BPSK)



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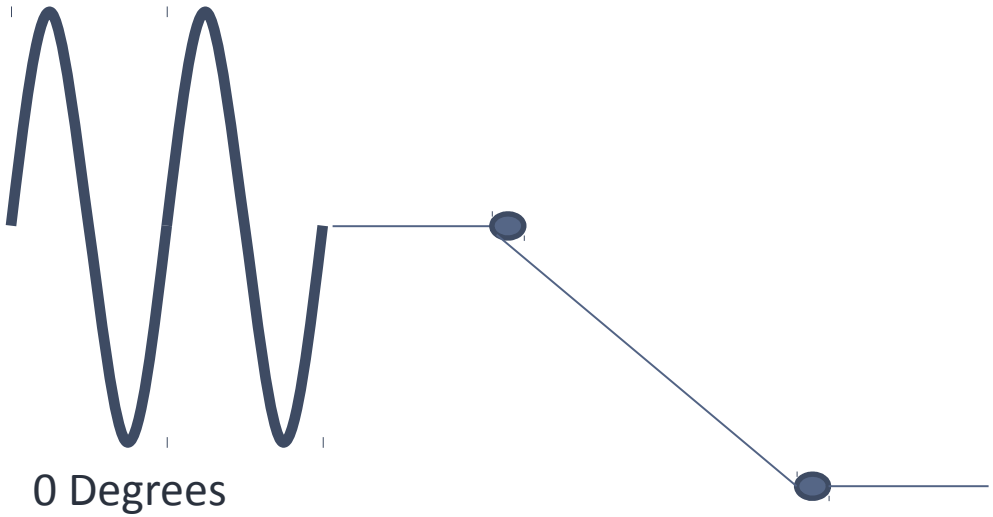
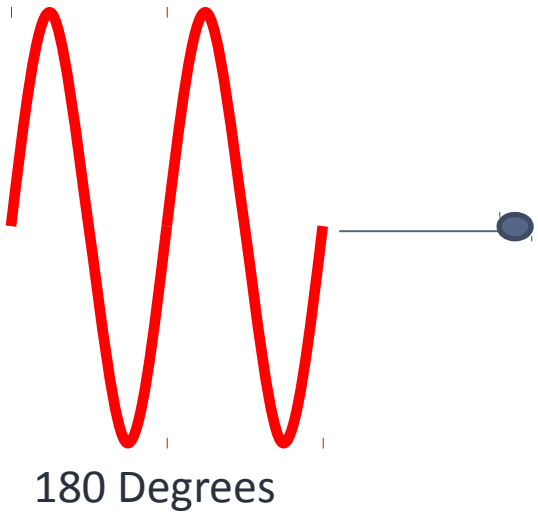
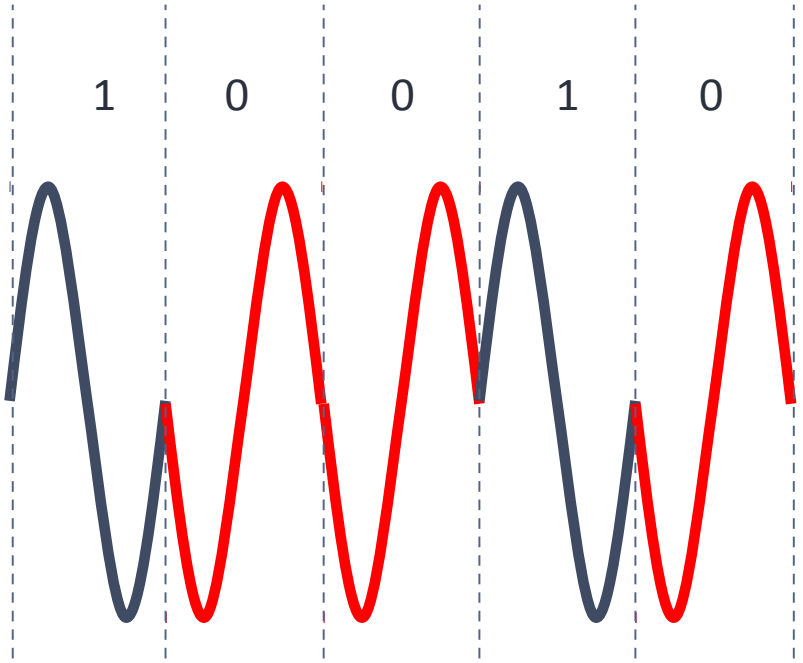
Binary Phase Shift Keying (BPSK)







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OOK vs BPSK

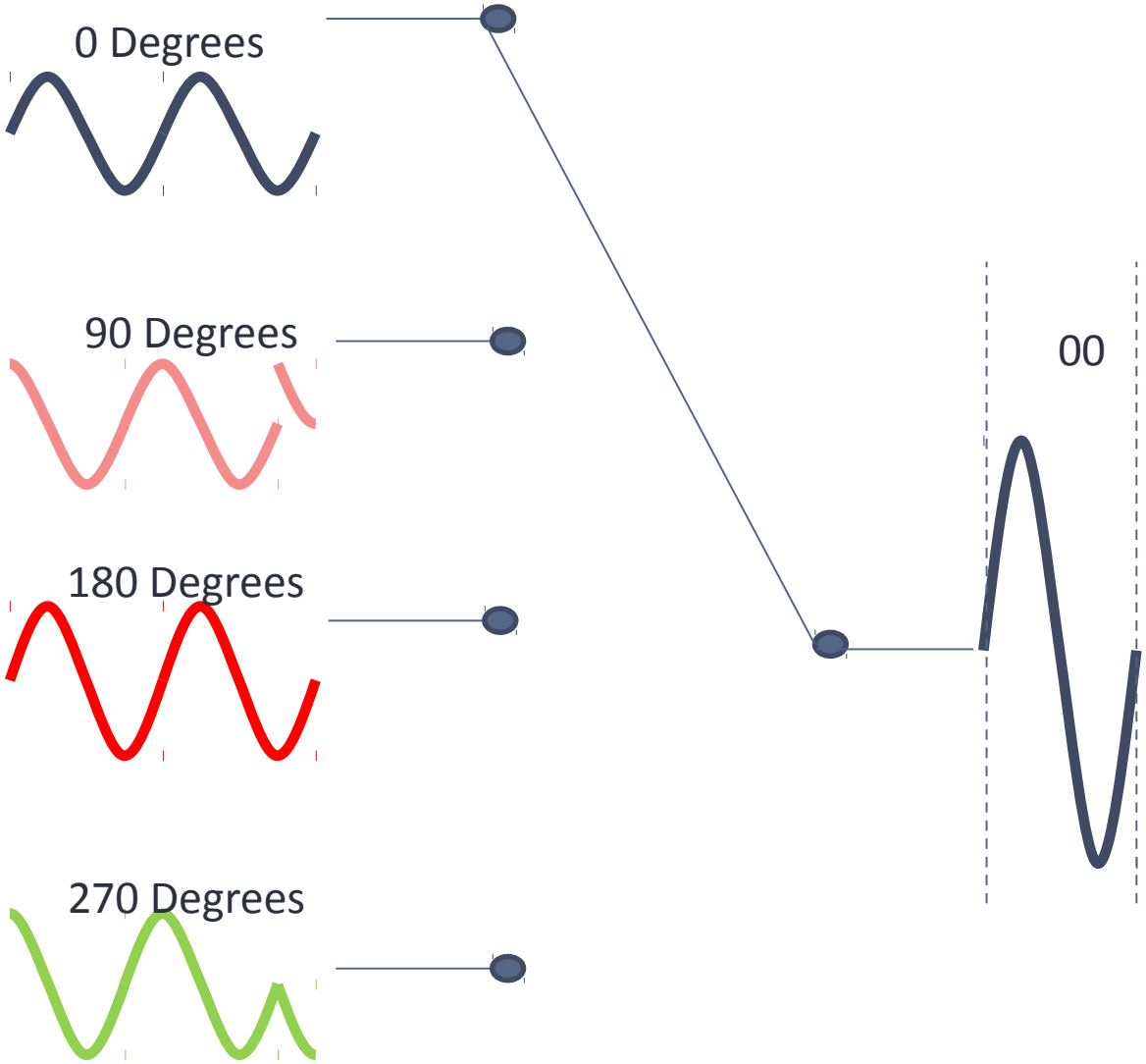
- OOK
  - Rate dependant on change between pulse of frequency and nil signal
- BPSK
  - Rate dependant on change of phase only
- BPSK Benefits
  - Constant signal presence minimizes effects of dispersion

BPSK Essentials

- Signal always being sent
- One phase represents a 1
- A different phase (180^0 represents a 0)

- Frequency stays the same
- Only Phase changes

Quadrature Phase Shift Keying



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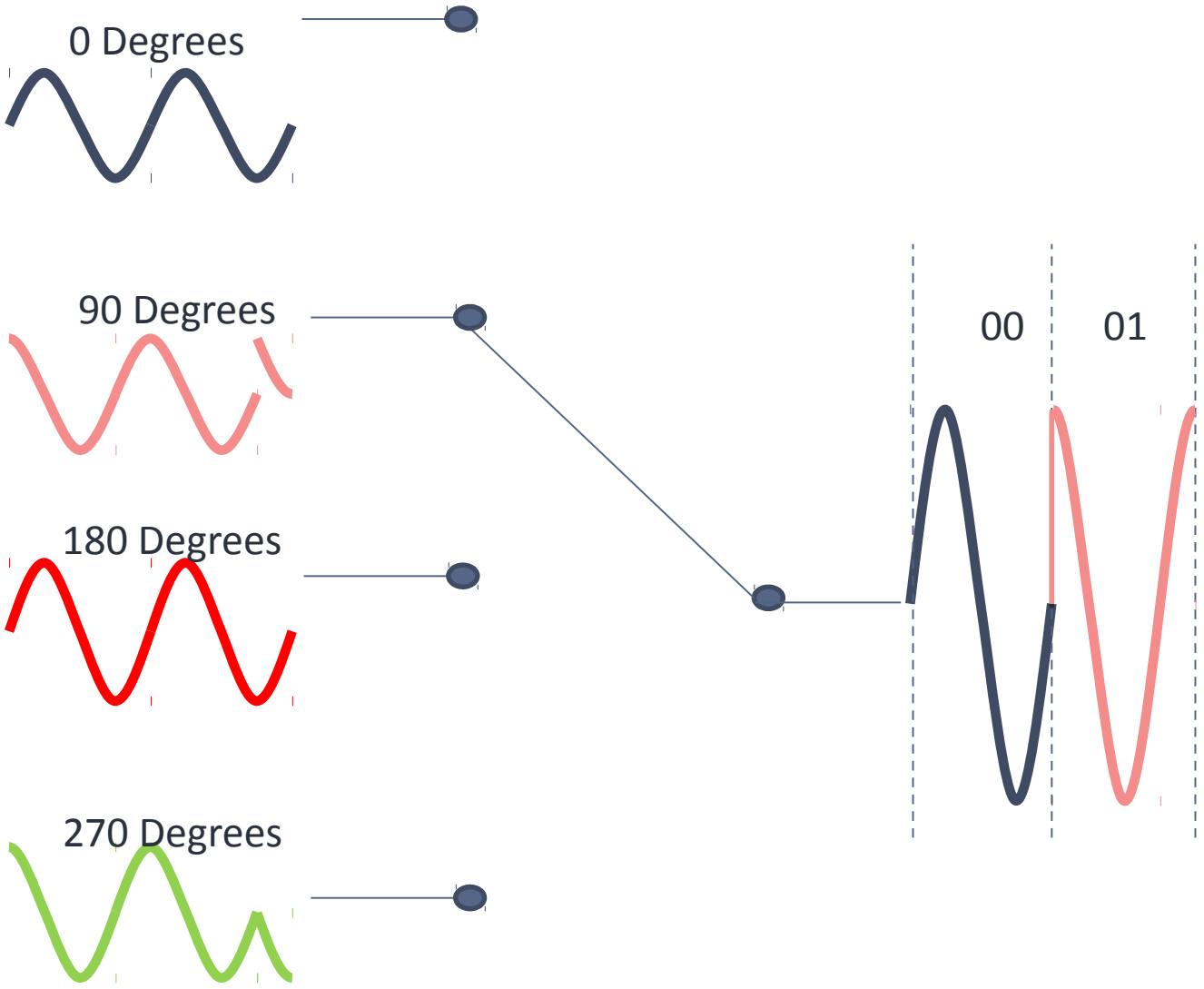
Quadrature Phase Shift Keying



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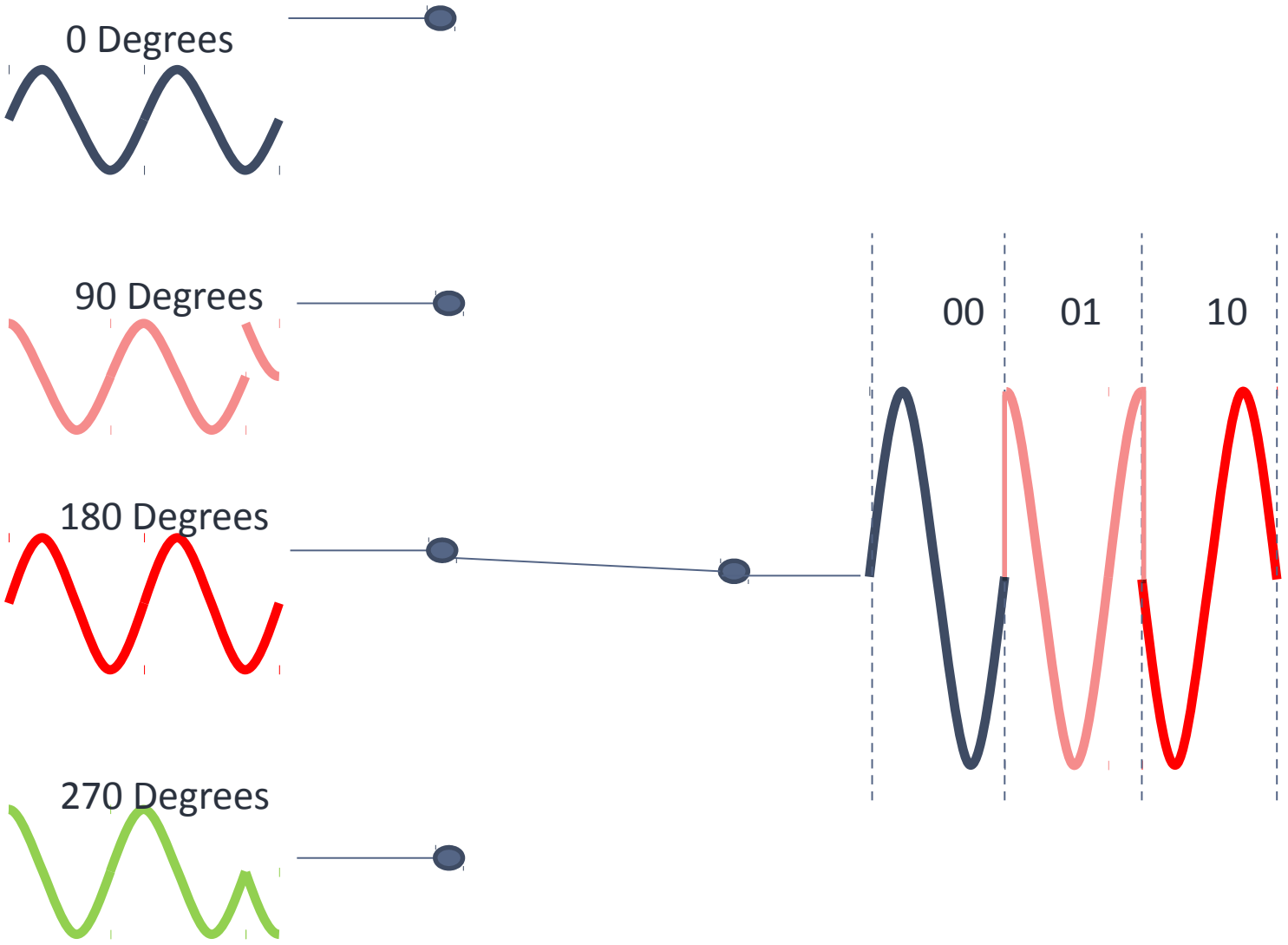
Quadrature Phase Shift Keying



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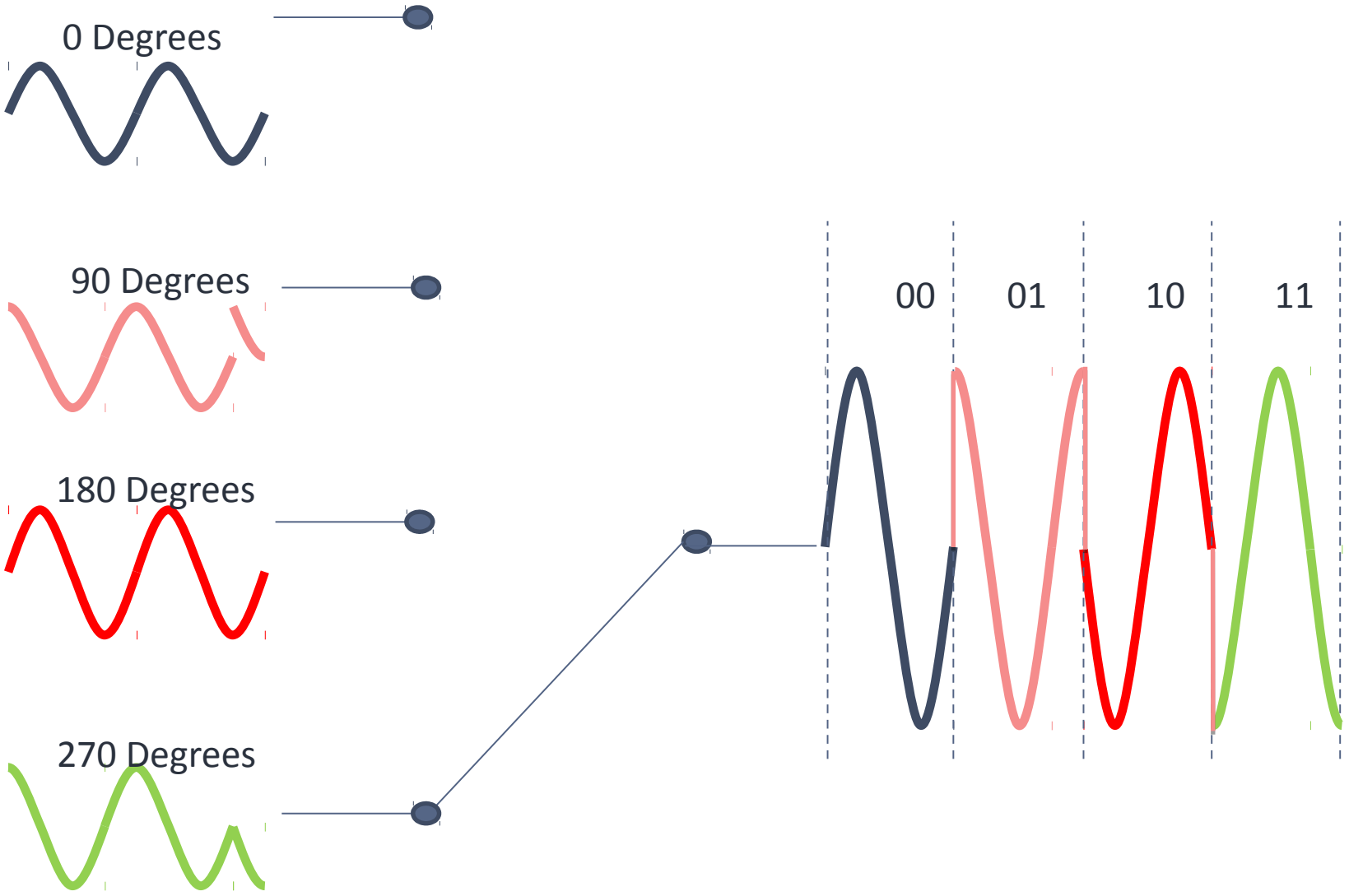
Quadrature Phase Shift Keying



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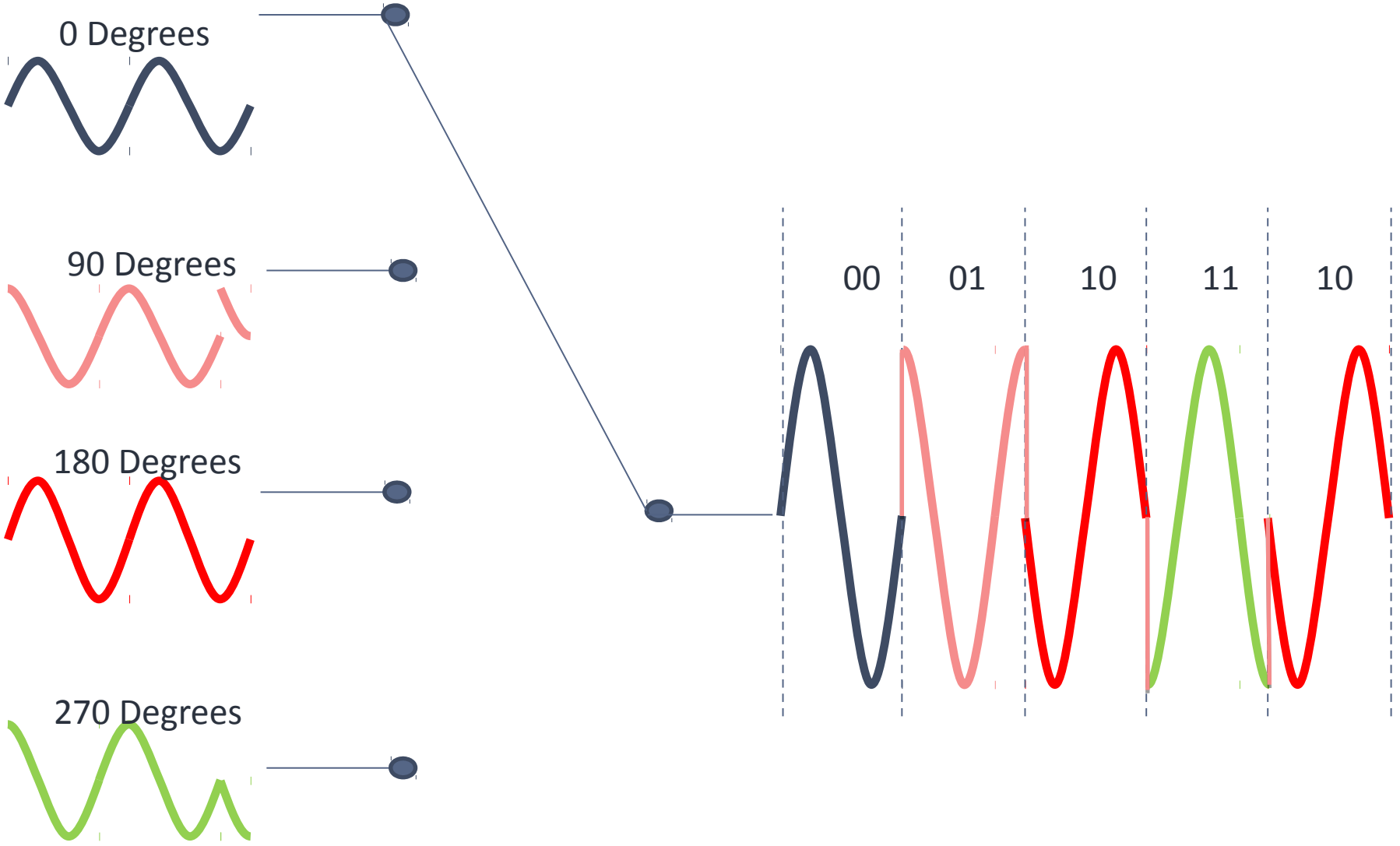
Quadrature Phase Shift Keying



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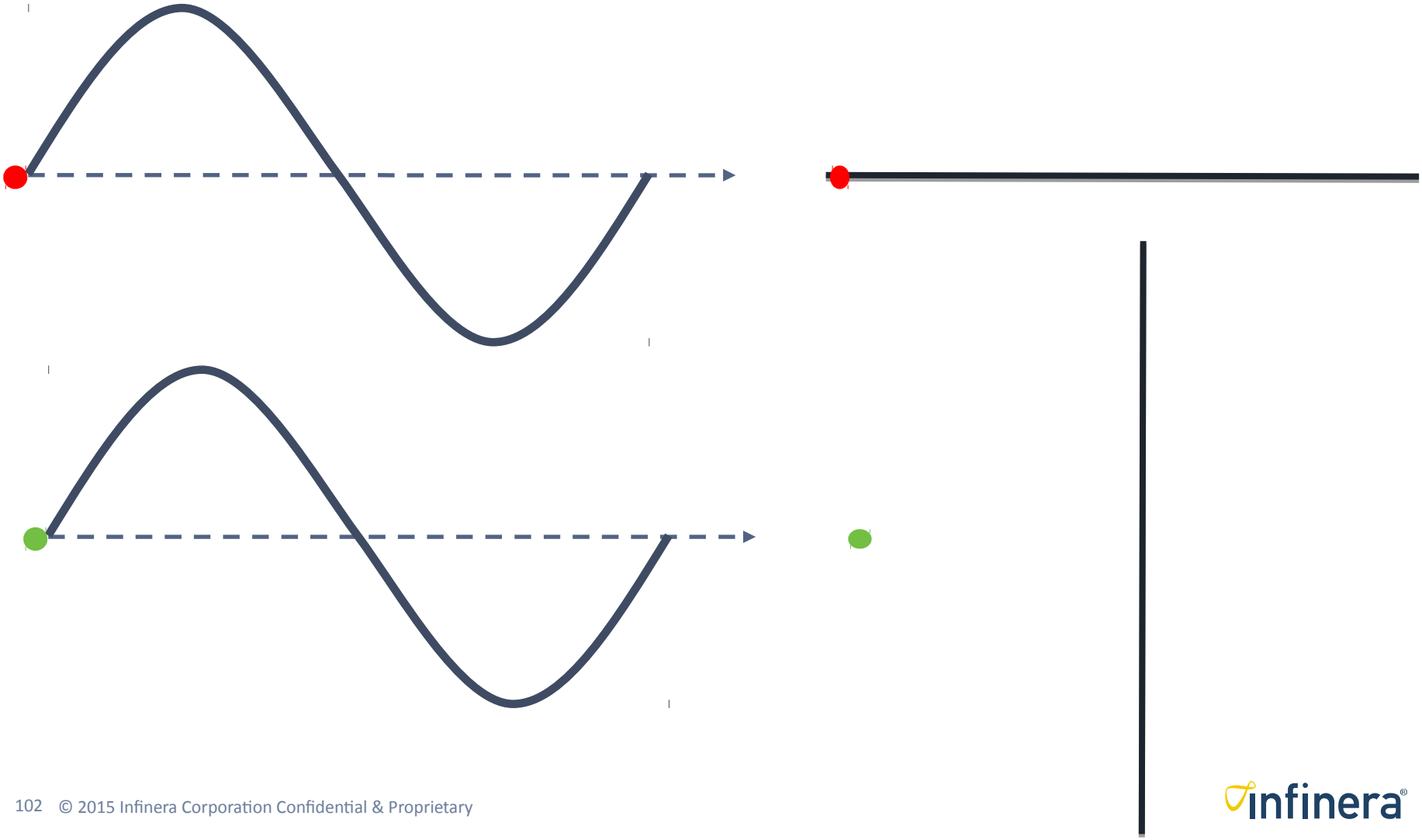
QPSK Essentials

- Signal always being sent
- One phase represents two bits
  - 00
  - 01
  - 10
  - 11
- Frequency stays the same
- Only Phase changes

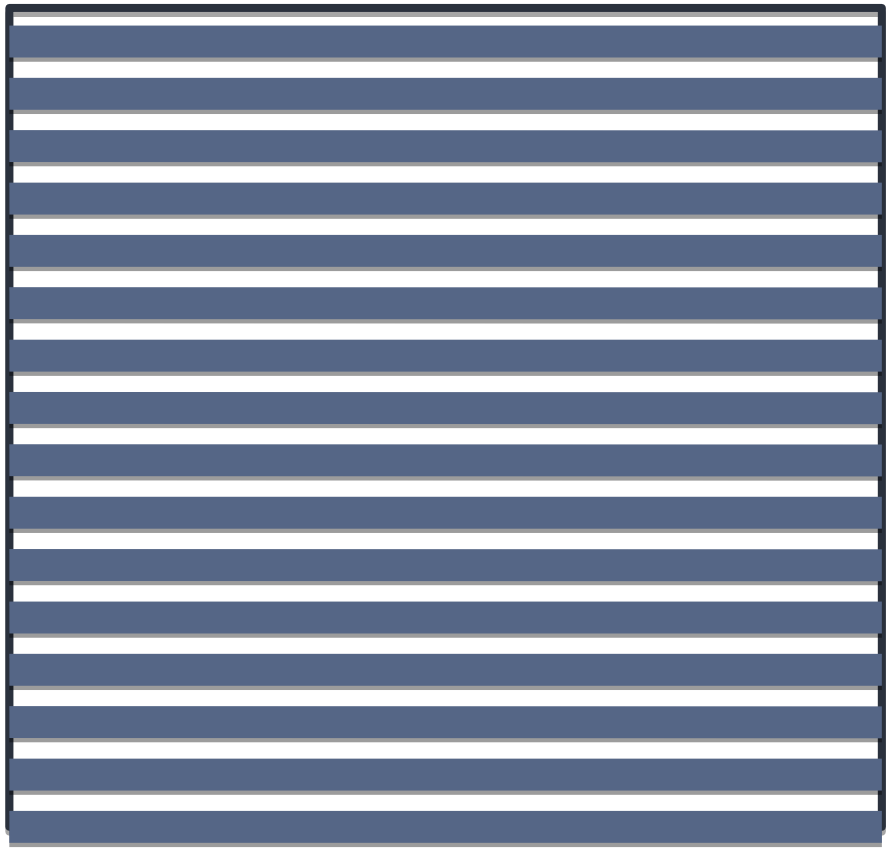
Polarization Modulation

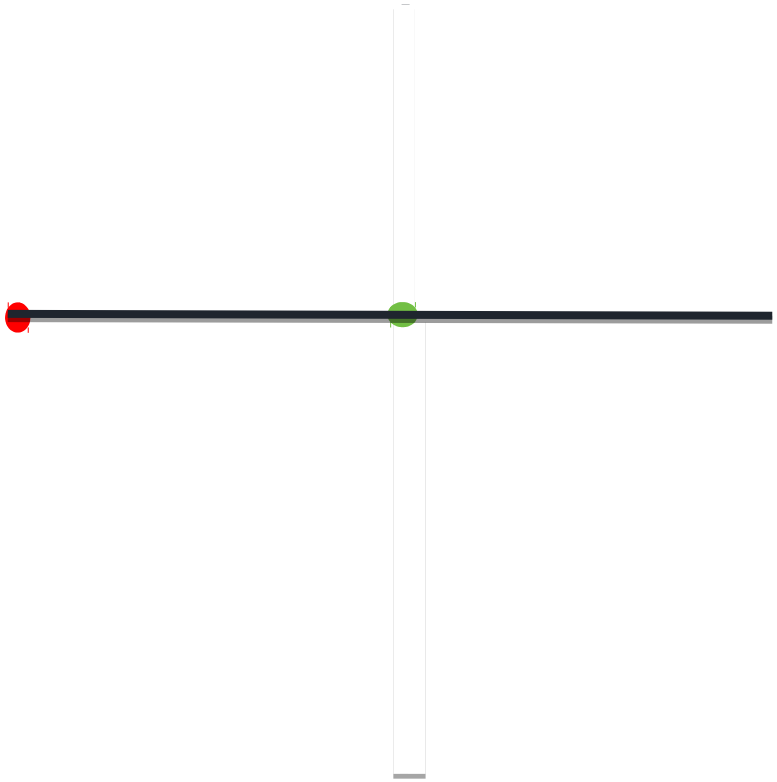
Sideways View

“Coming at you” View



Polarization Modulation (Horizontal)





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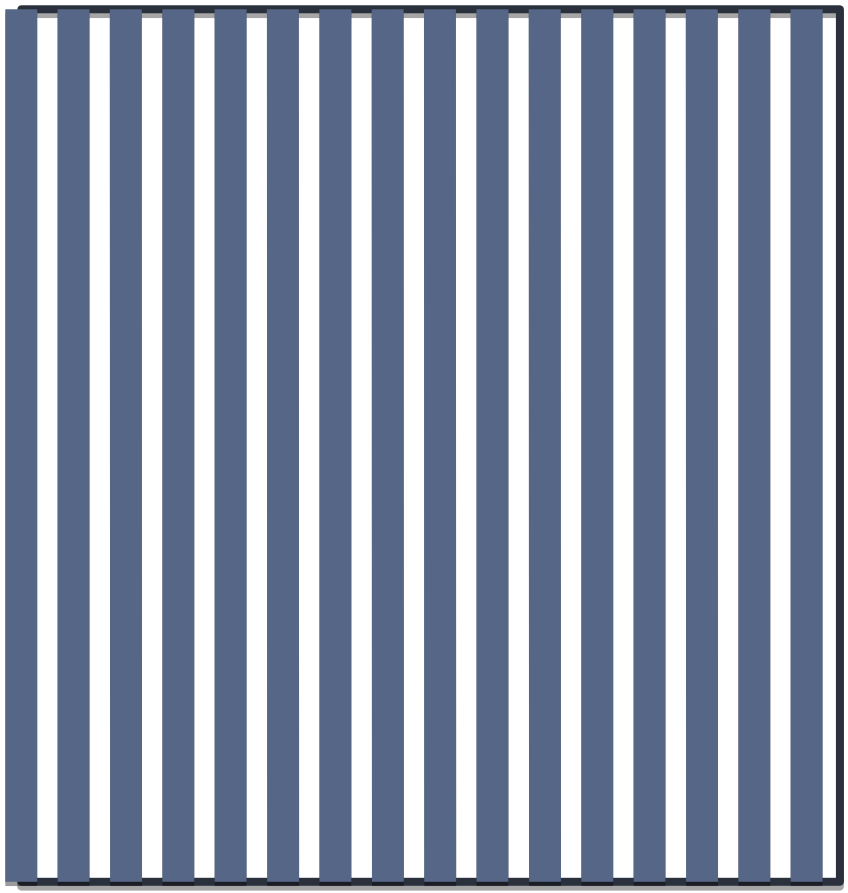
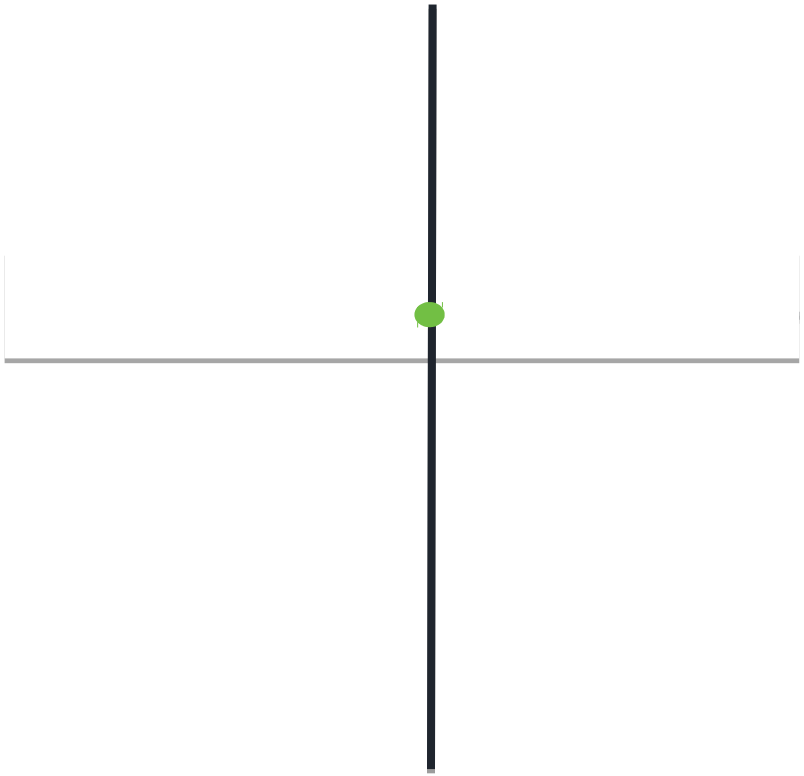
Polarization Modulation (Vertical)





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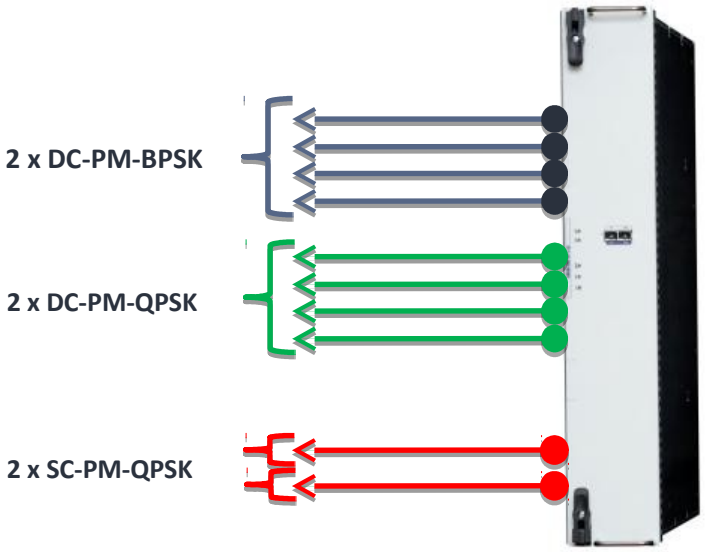
OTN Line Module Rates

- PM – QPSK
  - 10 x 50Gbps Optical Channels
  - 500Gbps per OCG
  - 5 x OTU4 (100G) Dual Carrier
  - 10 x OTU3i+ (50G) Single Carrier
- PM – BPSK
  - 10 x 25Gbps Optical Channels
  - 250Gbps
  - 5 x OTU3i+ (50G) Dual Carrier

Mixed Modulation on AOLx2/SOLx2 (SD-FEC)



Mixed modulation on AOFx/SOFx will be in R16.1

- Ability to configure BPSK and QPSK on the same SD-FEC Line Module
- QPSK: SC-PM-QPSK and DC-PM-QPSK modes
- BPSK: DC-PM-BPSK
- Channel pairing similar to HD-FEC modules
- Provisioning rules and capability
  - Same as AOLX (HD-FEC) support
- Features
  - GMPLS support
  - GCC0 in-band management support
  - Support for all service types

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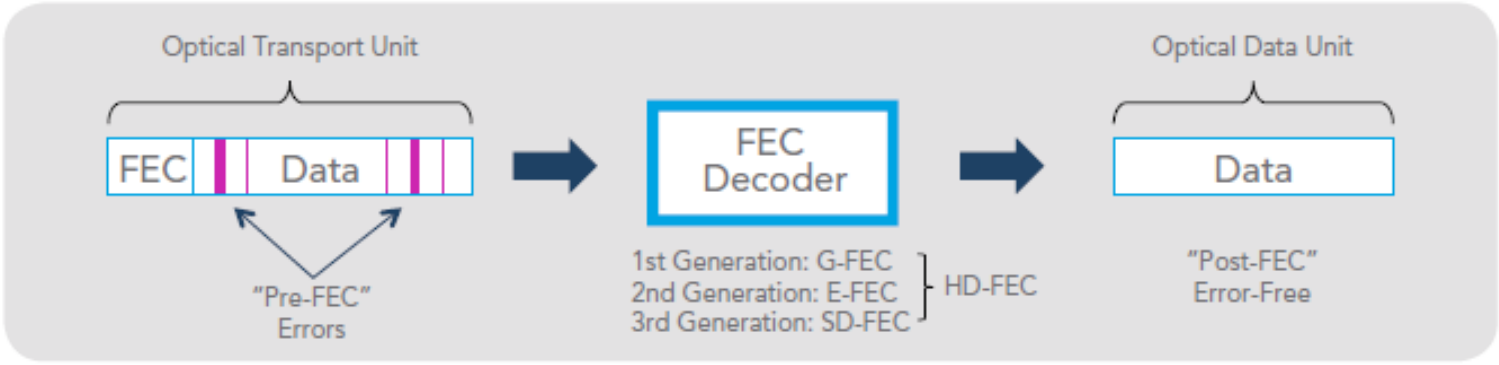
Forward Error Correction (FEC)

- FEC principle:
  - Red lines show some Pre-FEC errors
  - Signal goes through FEC decoder
    - Digital processing of signal to deliver error free Post-FEC data
    - As FEC algorithms become more complex more powerful digital processing is required
  - This is Hard Decision FEC (HD-FEC)



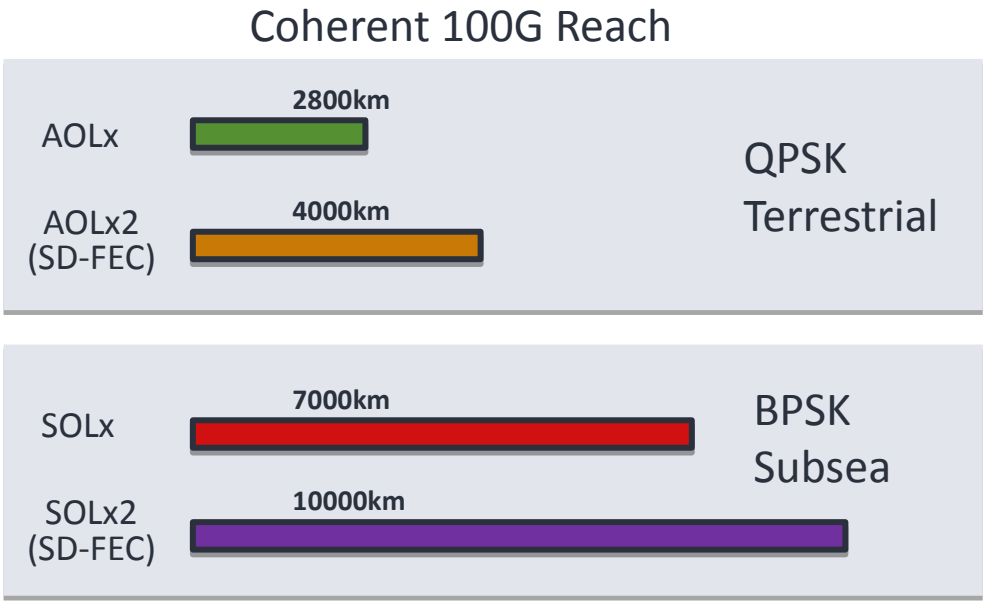
Soft Decision Forward Error Correction (SD-FEC)

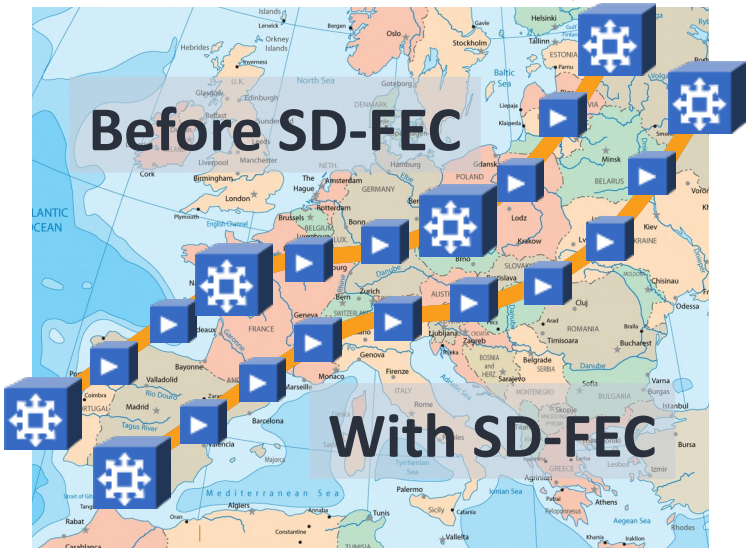
- Why SD-FEC?
  - By increasing data rates OSNR is reduced therefore more regen required
    - More cost
    - Not always possible i.e submarine networks
- SD-FEC:
  - Allows greater optical capacity
  - Almost doubles optical reach
  - Improves tolerance to noise

HD and SD-FEC

- SD and HD comparison:
  - HD: Bit errors are detected using a hard, binary decision
    - Anything above the threshold is a 1, anything below is a 0
  - SD: Decoder can provide a more soft or granular report if a bit should be a 1 or 0 and make a decision based on how confident it is
    - Multiple FEC decodes are done in parallel
    - Result with lowest error count is selected

SD-FEC benefits





- 20–40% more Reach
- Trans-continental reach
- Trans-pacific reach

- Eliminates regens
- Better optical express
- New architectures:
  - More express traffic
  - Landing station skipping

Reduces Need For Regens Enabling Cheaper Networks/More Margin

Progress Check

- What is the benefit of SD-FEC?

a) Allows more regen sites and reports more digital PM data?

b) Improves reach and reduces regen sites?

c) Allows ALS to be activated?

d) Enables muxing and de-muxing of OCGs?

DTN-X 100G Line Modules

Advanced OTN FlexChannel Module 100G (AOFM-100)

Advanced OTN FlexChannel Switching Module 100G (AOFX-100)

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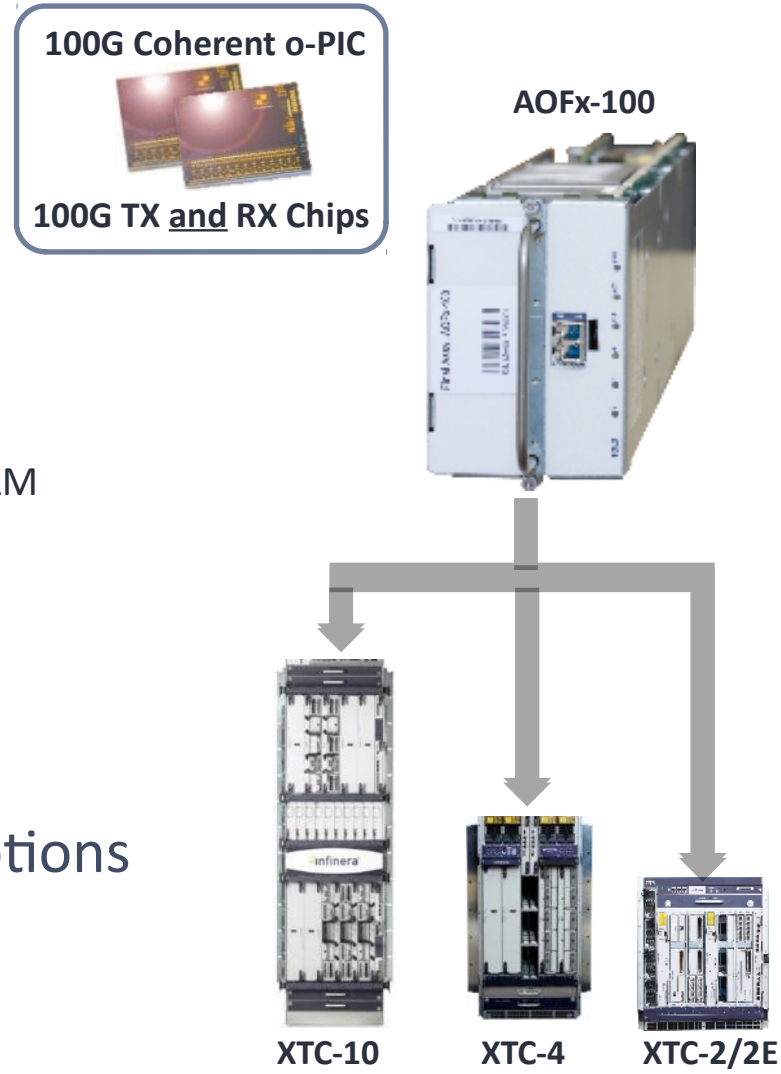
what THE NETWORK will be

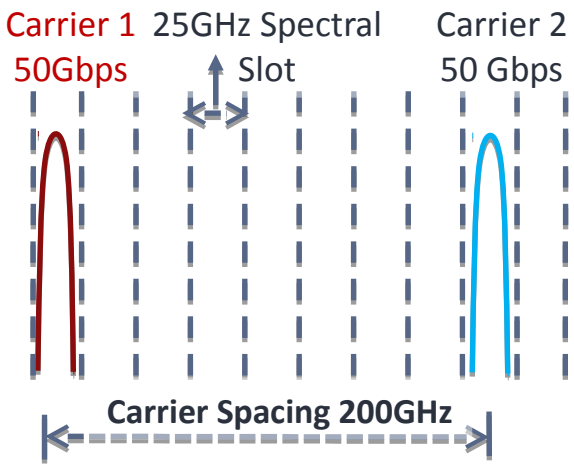
AOFX-100 with Next-Gen Infinera 100G Coherent PIC

- AOFx-100
  - 100G WDM Line Module
  - Next-gen 100G Coherent PIC
  - ITU-T and OCG channel plans
- Modulation Formats
  - FlexCoherent PM-QPSK, PM-BPSK, PM-3QAM
- Density per OTxM-x00
  - Fits into 2 sub-slots: double-wide
  - Up to 5 x AOFx-100 per OTMx-500
  - Up to 6 x AOFx-100 per OTxM-600
- Multiple performance/reach options
  - C3/C5: Metro Core/Regional
  - C6: Long-Haul
  - C8: ULH



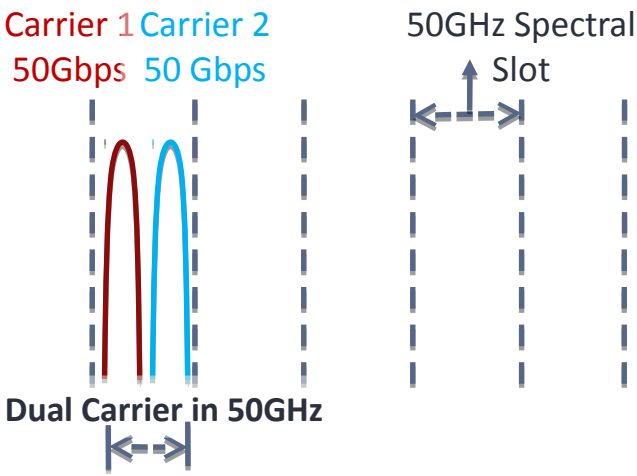
AOFx-100 Channel Plans

Infinera OCG Channel Plan



- Covers C-band
- Up to 7.2Tbps per fiber

Infinera Flex-grid Channel Plan



- Covers extended C-band
- Up to 9.6Tbps per fiber

* Blue-band OCG channels 3 and 4 not supported with 3 PONs. Addition of a 4th PON would extend capacity to 8Tbps. Check Infinera roadmap for availability

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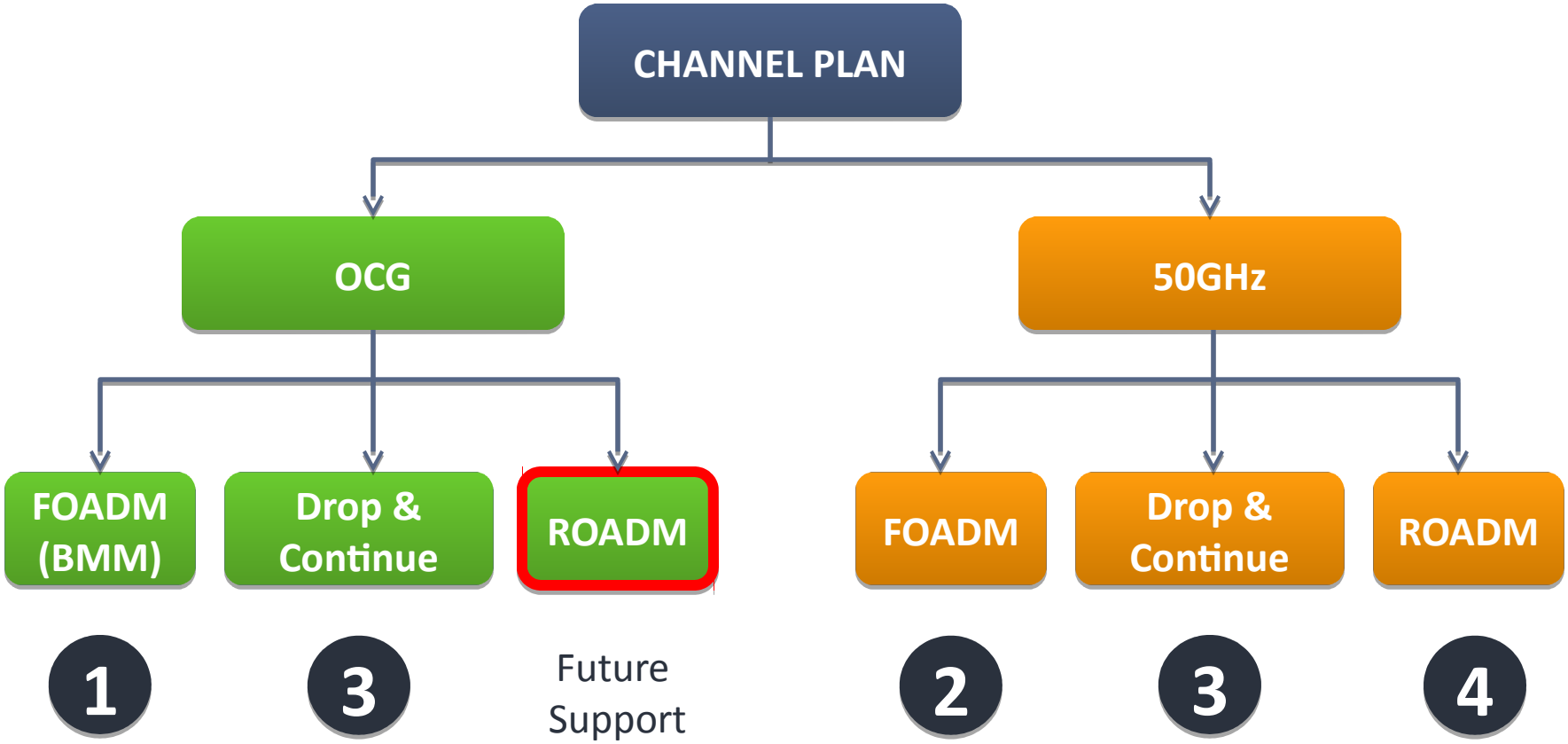
Muxing Option Taxonomy



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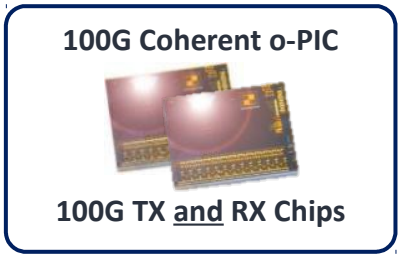
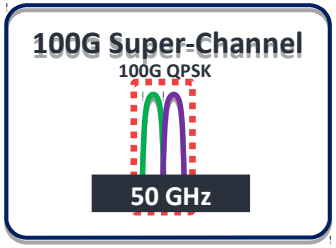
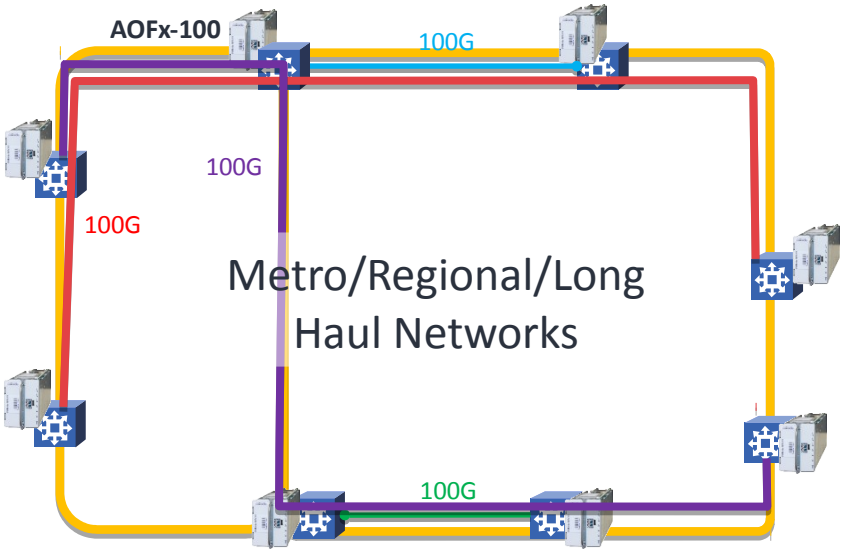
AOFx-100 Overview







- 100G DWDM Line Module
  - Dual-wide TIM supported in all XTC chassis
  - Incorporates 100G coherent optimized PIC
- Up to 9.6Tbps in extended C-band using Flex-grid channel plan
- Supports Infinera's OCG channel plan
- Tunable over a wide range: only 3 modules required to cover extended C-band
- Switching and terminal application optimized:
  - AOFM-100 –terminal/100% add-drop only
  - AOFX-100 – multi-degree and mesh applications
- Supports metro, regional and long haul applications
  - Enables an optimized solution for lower-capacity add/drop sites and thin routes
  - Initial support for QPSK modulation with 4000km reach
  - HW supports BPSK and 3QAM

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Packet Switching Module (PXM)

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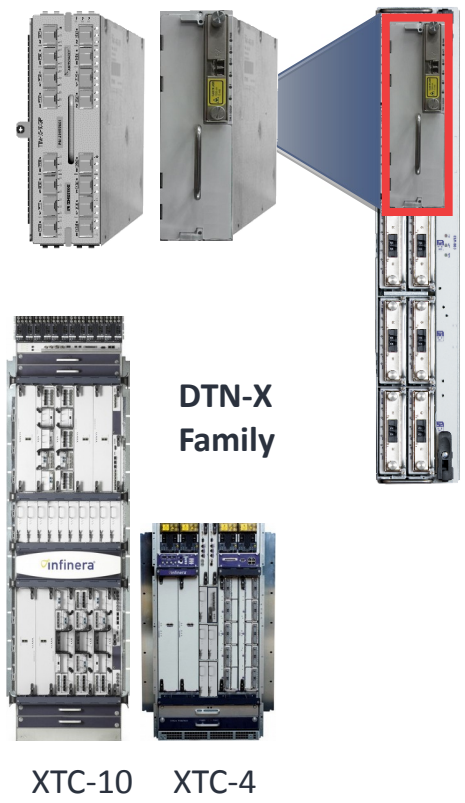
what THE NETWORK will be

Packet Switching Module (PXM)



- Packet Switching Module
  - 16 x 10GbE (PXM-16-10GE)
  - 1 x 100GbE (PXM-1-100GE)
- Double wide/double height module fits into OTM2
- Built-In 200G Packet Switch
  - Enables QoS, Traffic Management, Bandwidth Profiles, Packet Classification and more
- Fits DTN-X: XTC-4 & XTC-10

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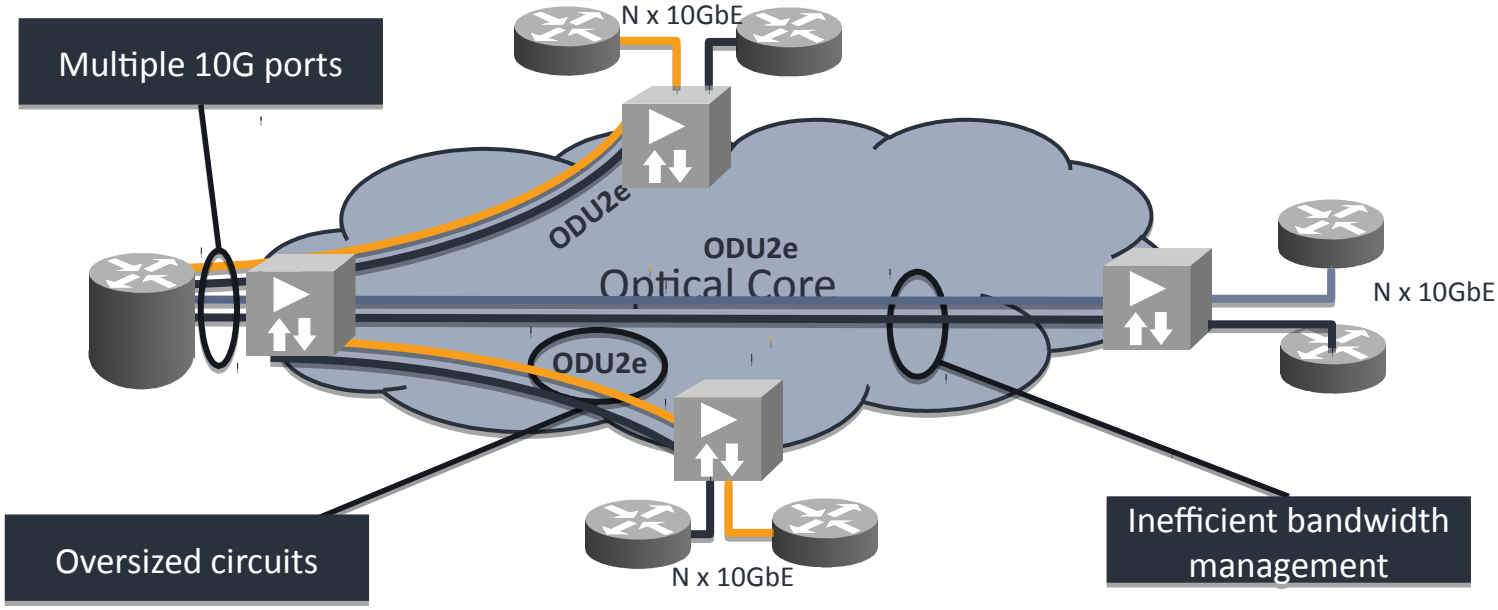
Drawbacks of pure transport solution.



Inefficient Port usage

- Single port per destination
- Complex fiber & port configurations
- Inefficient Router use

Transport Inefficiency

- Fixed circuit capacity
- Fixed destination
- Inefficient circuit use

No Stat-Mux

- Inefficient circuit fill
- Wasted bandwidth
- No flow routing /QoS

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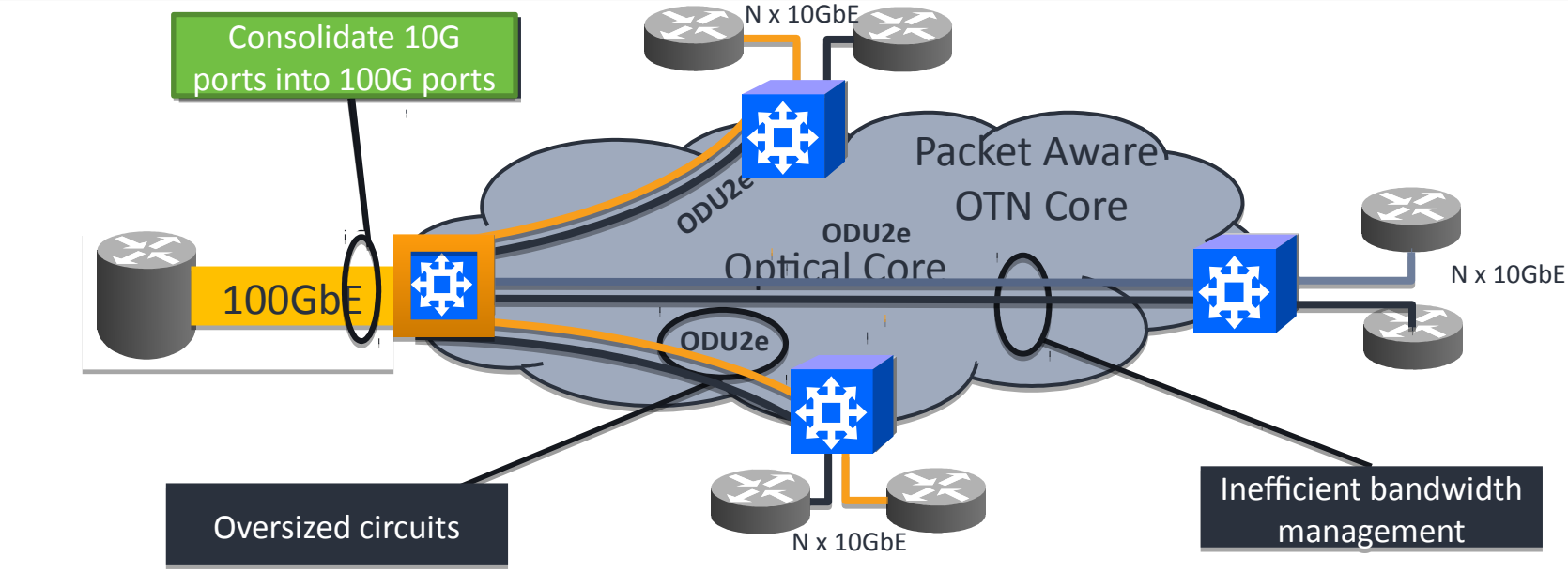
Port Consolidation Improves Router Efficiency



Inefficient Port usage

Port Consolidation

- Combine multiple 10G ports into fewer 100G ports
- Reduce fiber & port counts
- Simplify & improve router efficiency & reliability

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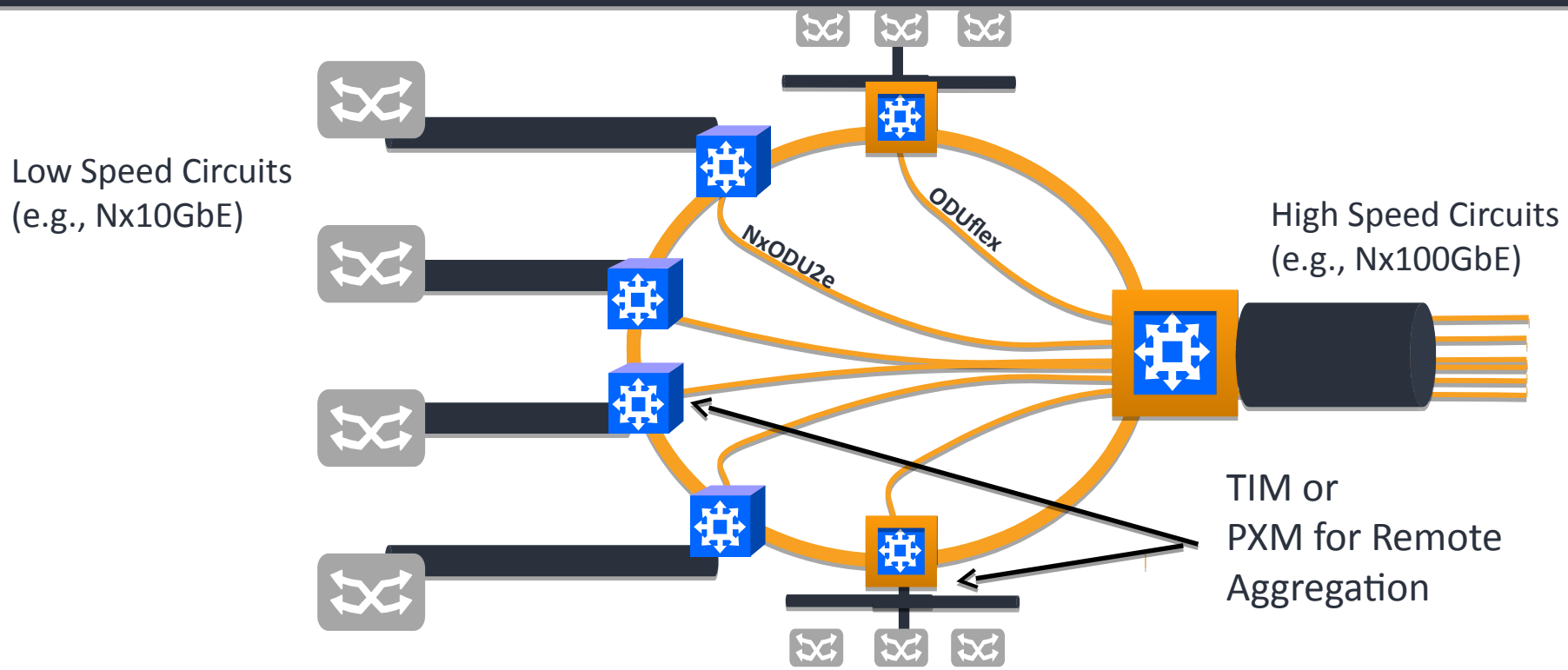
Packet Aggregation (Key Customer Application)



Aggregation is simply grooming packets onto higher speed ports

- Feeders may originate on TIM or PXM
- All TIM sites must be ODU2e or nxODU2e
- VLAN ID's are used to map at aggregation PXM site
- Further traffic processing can be done at PXM sites

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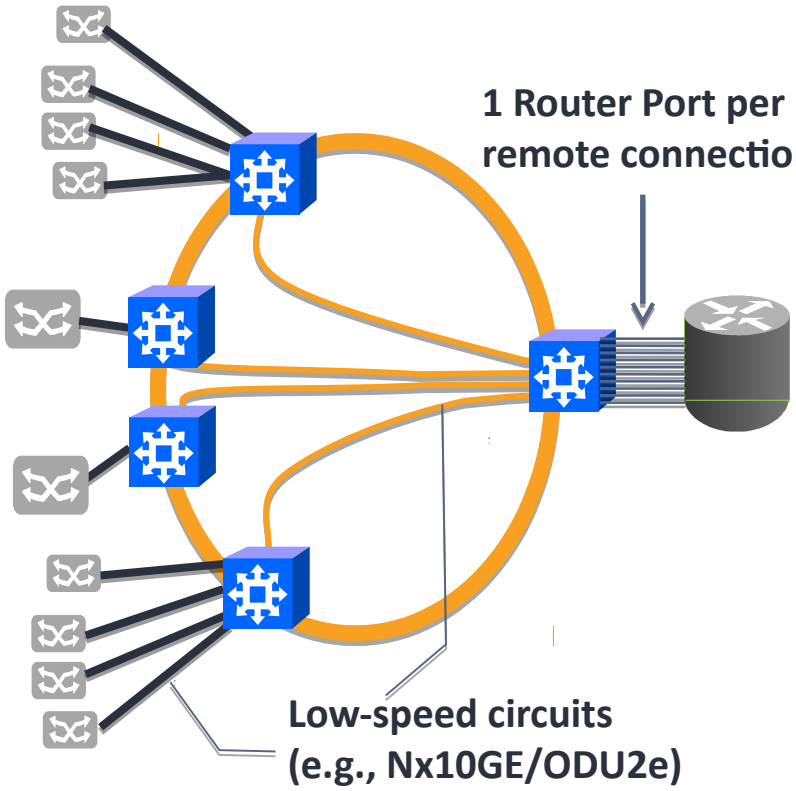
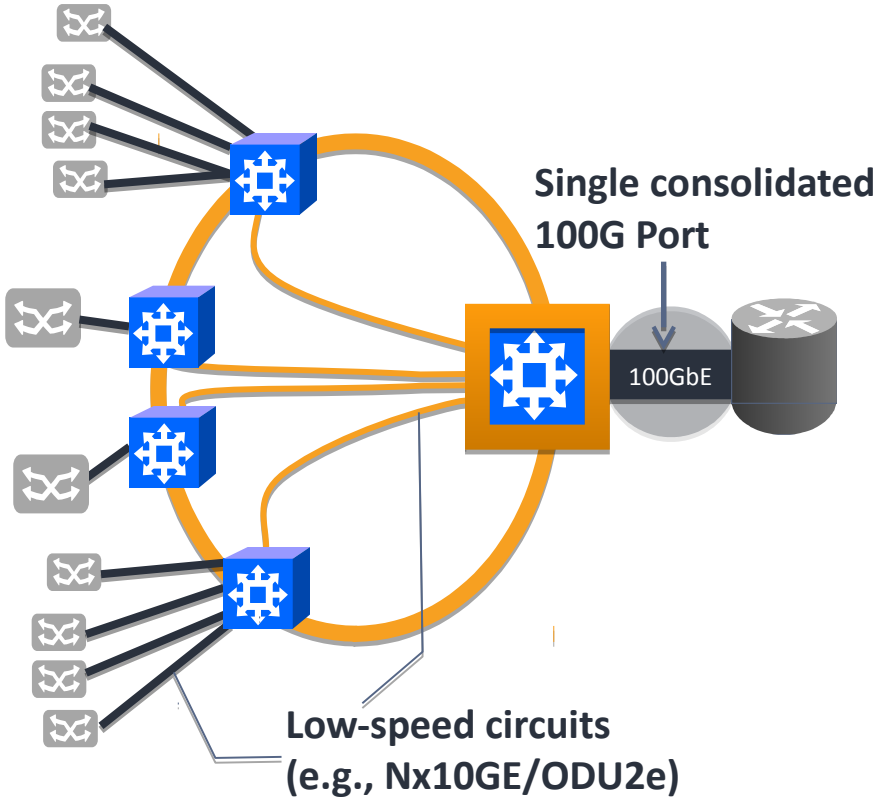
Application: Shared Router Interconnect





Traditional Method

- Single port per destination
- Complex fiber & port configurations
- Inefficient Router use

PXM Port Consolidation

- Consolidate 10G into fewer 100G ports
- Reduce fiber & port counts
- Simplify/improve router efficiency/reliability

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Flex ILS

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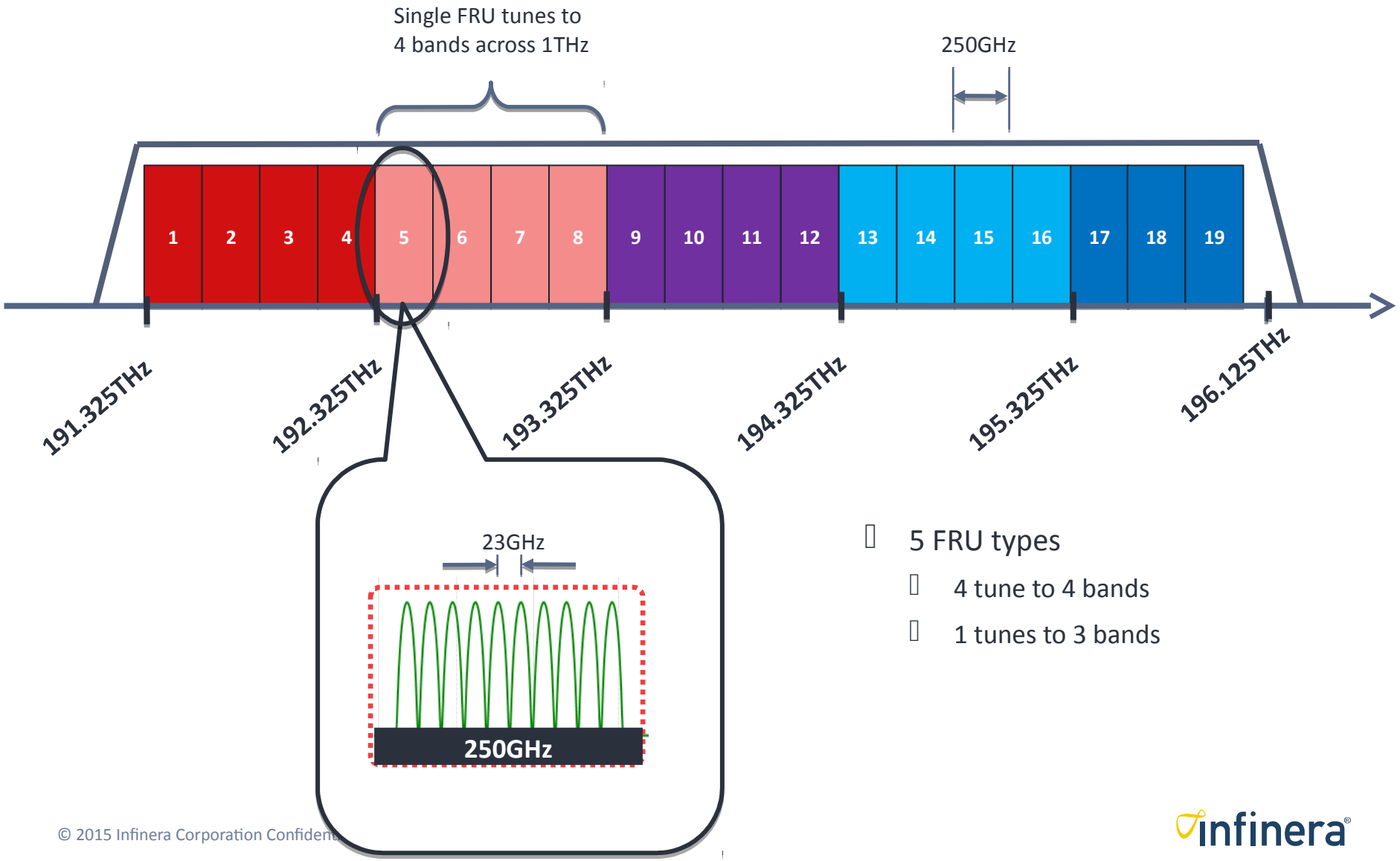
what THE NETWORK will be

AOFx-500/SOFx-500 Banded Super-Channel Plan

Uses 19 250GHz Frequency Slots Across 4.8THz



- 5 FRU types
  - 4 tune to 4 bands
  - 1 tunes to 3 bands

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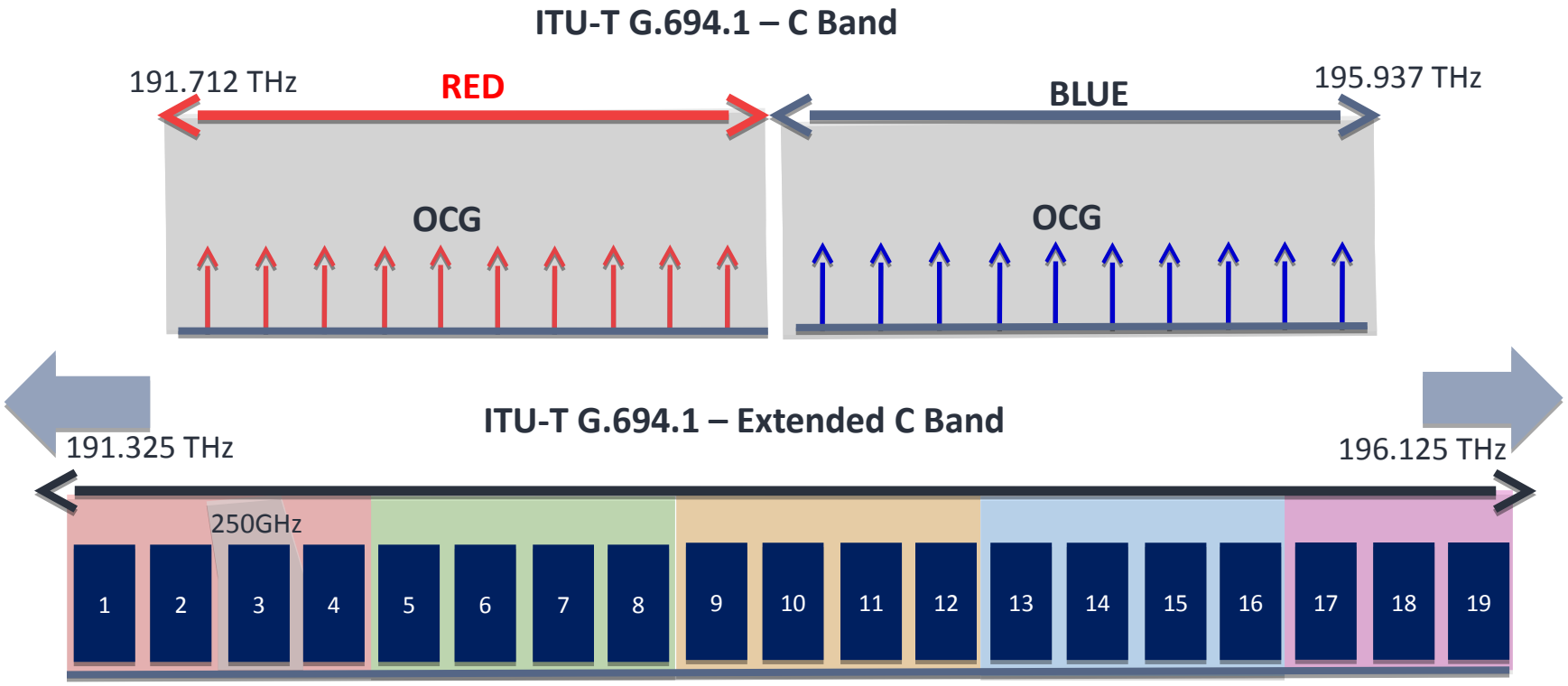
Flex-Grid Super-Channels

FlexChannels



- Optical Carrier Group (OCG) Super-Channel
  - A group of 10 DWDM channels
  - 200GHz spacing between channels
- 16 OCGs in C-band
  - Channel plan with up to 25GHz spacing
  - Tunable across 4 OCGs
- FlexChannel: Contiguous spectrum-optimized Super-channel
  - A group of 10 DWDM channels in 250 GHz
  - Can be placed anywhere in the spectrum
- 19 Super-Channels in Extended C Band
  - Tunable across 1 THz window

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C-ROADM

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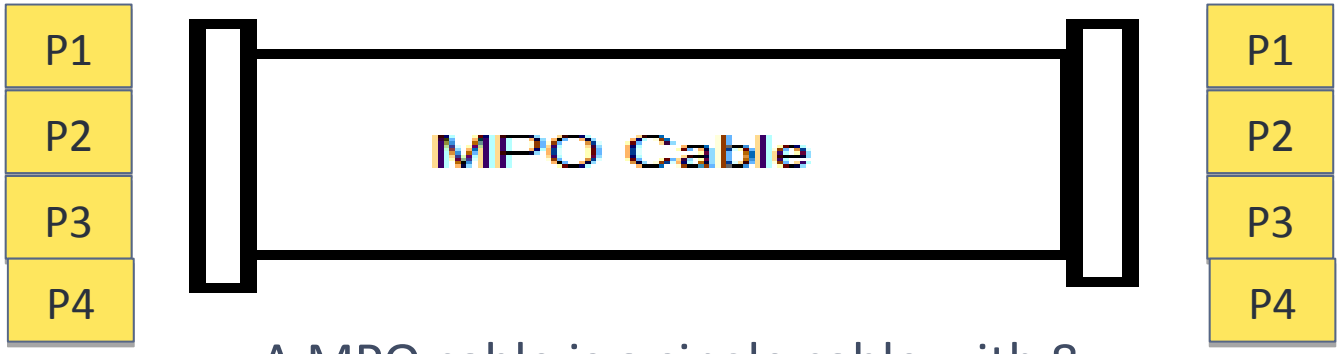
what THE NETWORK will be

MPO

The MPO connector is a single connector but has 4 logical ports. In GNM or DNA you will see the 4 ports. These 4 ports are connected by physical fibers.

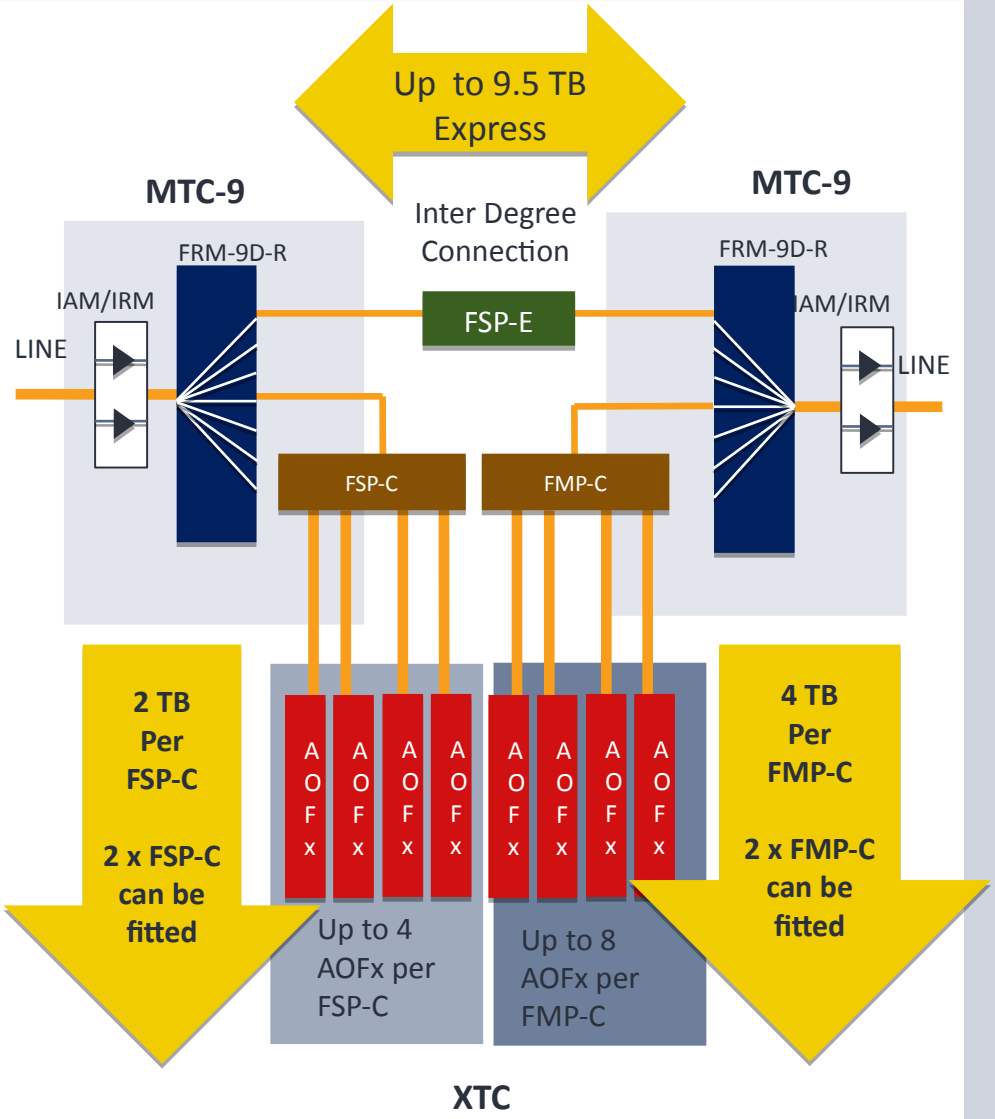


A MPO cable is a single cable with 8 fibers or 4 fiber pairs inside

Fiber Cleaning

- Remember: always clean all fibers and connectors
- You are familiar with cleaning wipes, cletops and how to use them
- However, MPO requires a different cleaner:

Direct Connect Colorless ROADM with FSP-C or FMP-C



- Direct Connect: AOFx-500 connects directly to FRM-9D
- Low cost add/drop option
  - No channel mux needed(FMM-F/C)
  - FSP-C (passive) can connect to 4 AOFx-500 line modules
  - Enables “pay as you play” deployment of channel mux for high-degree/high add-drop applications
- Direction specific Add/Drop
  - Add/drop ports connect to direction-specific FRM module
- FSP-E is used for express connections between FRM-9D
- Supports auto-discovery from AOFx-500 to FRM

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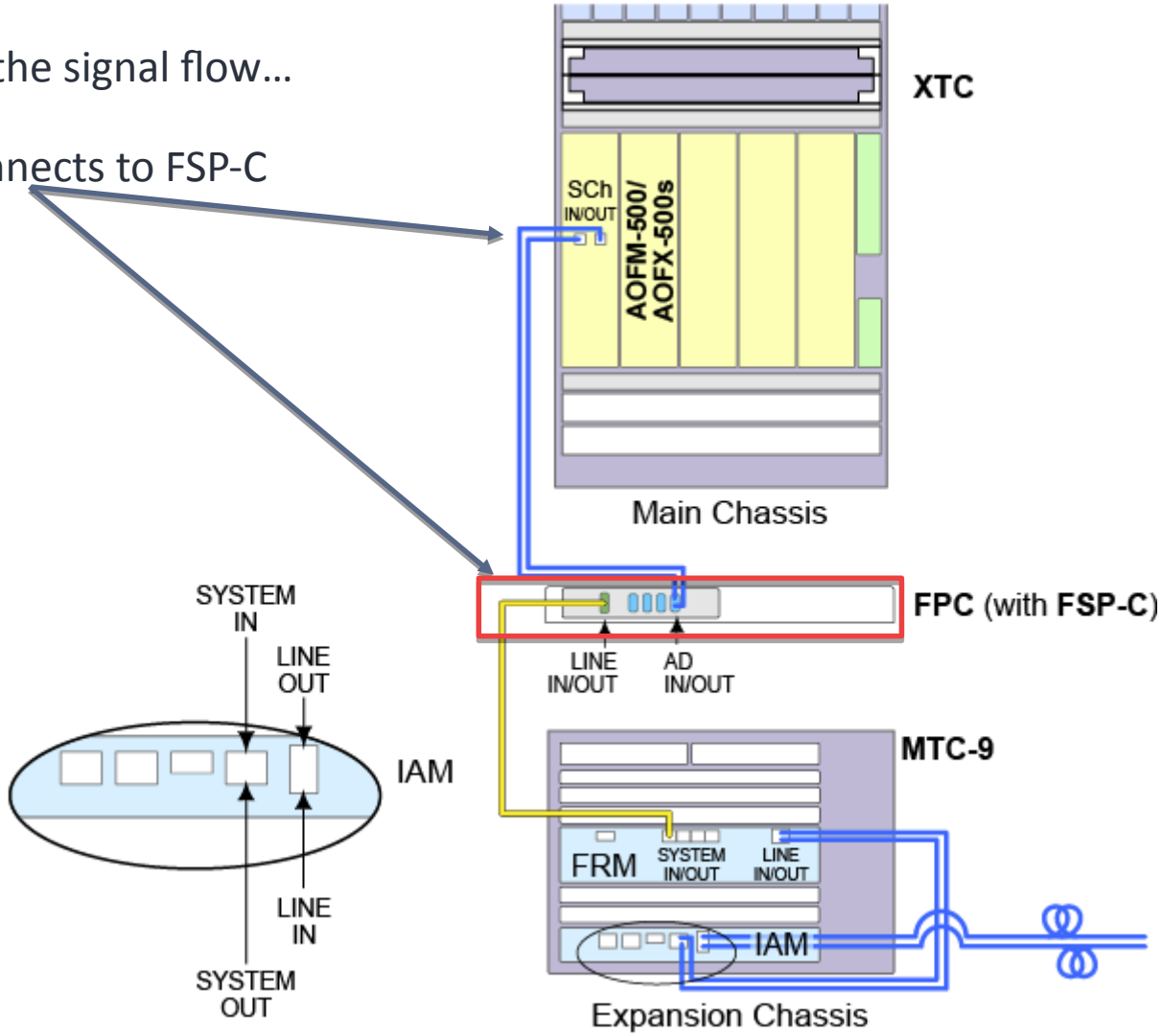
Example Configuration of a DTN-X Colorless ROADM

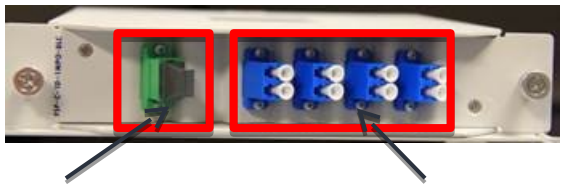
Let's follow the signal flow…

AOFM/X connects to FSP-C



Colorless Add/Drop Shuffle Panel (FSP-C)

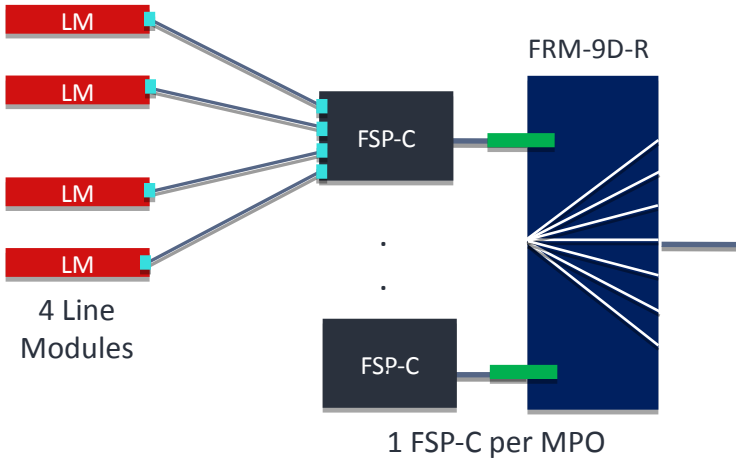
FSP-C



MPO Connector to FRM-9D

LC Connector to line modules

FSP-C Connectivity with FRM-9D-R



- Enables direct connect FlexROADM config with FRM
  - Connect line module to FRM without any active MUX modules
- Convert MPO to duplex LC
  - 1 MPO to 4 add/drop ports
- Enables direction specific add/drop
  - 12 line module add/drop for up to 5D
  - 8 line module add/drop for 6D to 9D
- Passive module
  - Fit 2 in 1 RU FPC-1 (19”, 600mm, 23” rack mounting)
  - Supports auto-discovery from line module to FRM

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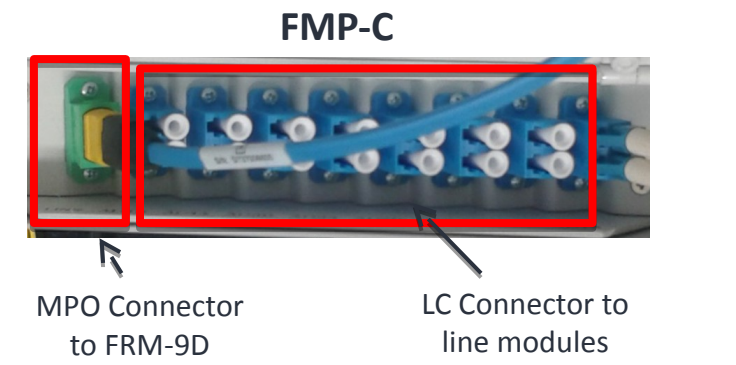
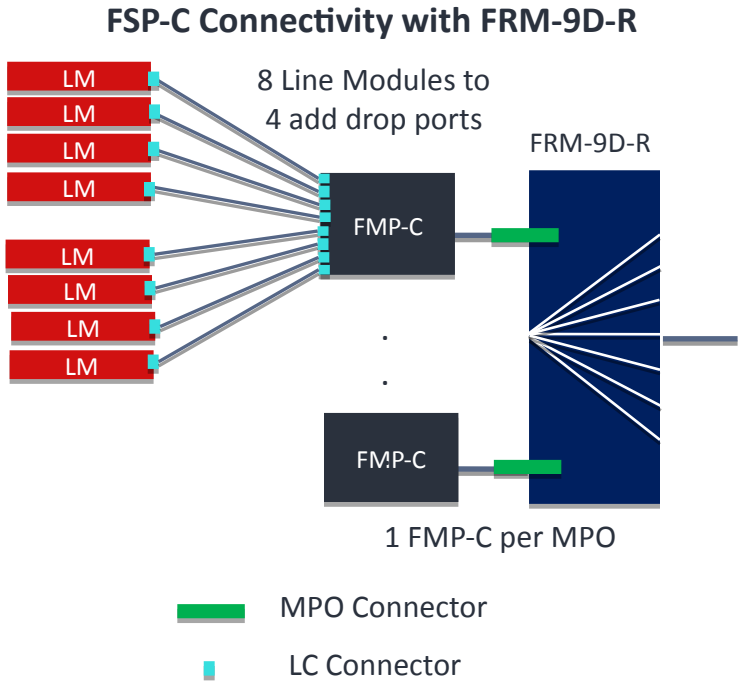
Colorless Add/Drop Multiplexer Panel (FMP-C)





- Enables direct connect FlexROADM config with FRM
  - Connect line module to FRM without any active MUX modules
- Convert MPO to duplex LC
  - 1 MPO to 4 add/drop ports
  - 2 LM per pair of fibers
- Enables direction specific add/drop
  - 12 line module add/drop for up to 5D
  - 8 line module add/drop for 6D to 9D
- Passive module
  - Fit 2 in 1 RU FPC-1 (19”, 600mm, 23” rack mounting)
  - Supports auto-discovery from line module to FRM

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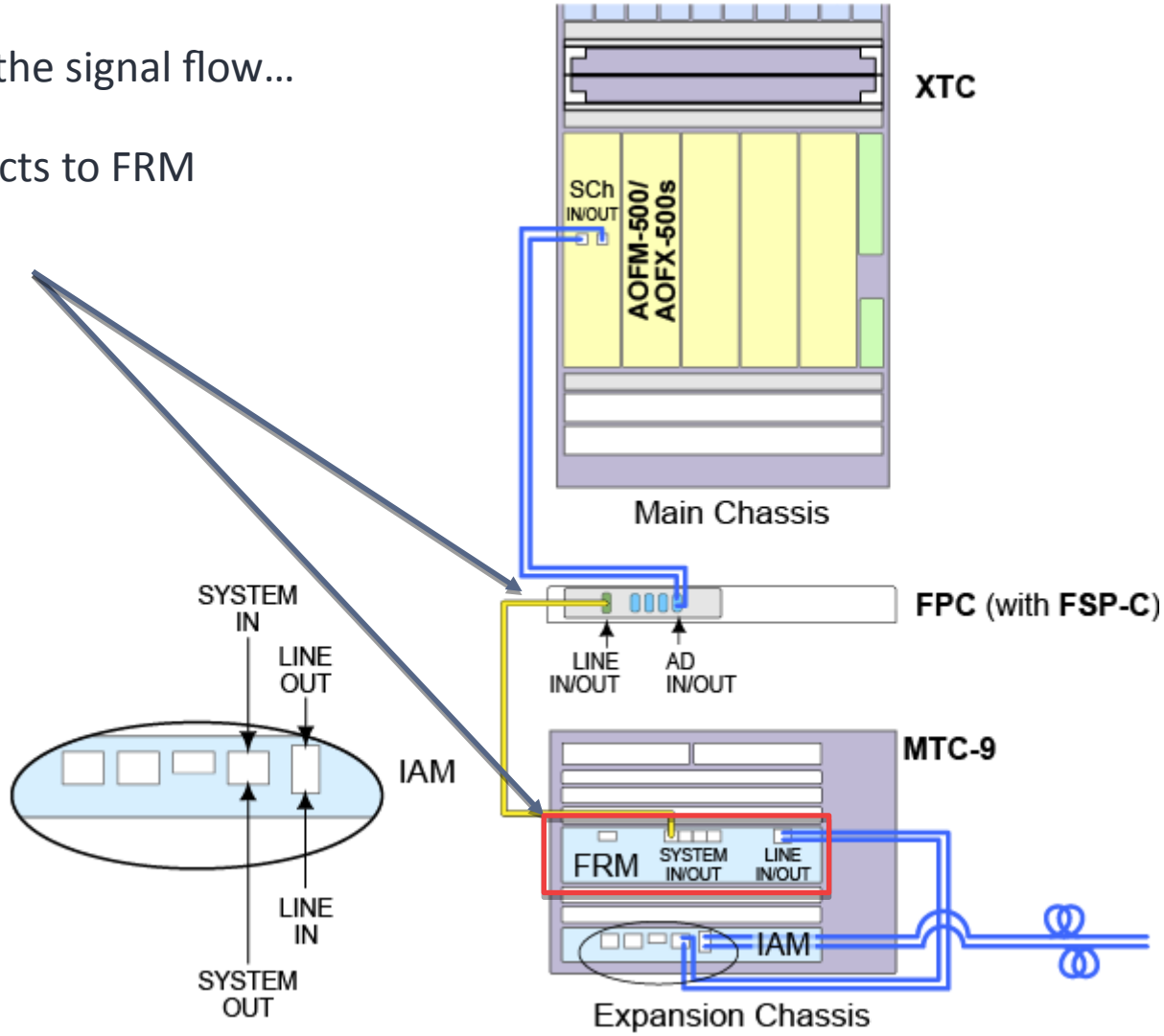
Example Configuration of a DTN-X Colorless ROADM

Let's follow the signal flow…

FSP-C connects to FRM



Flex ROADM Module (FRM-9D-R-8-EC)

FRM can add/drop up to 16 Super Channel Groups (SCGs)

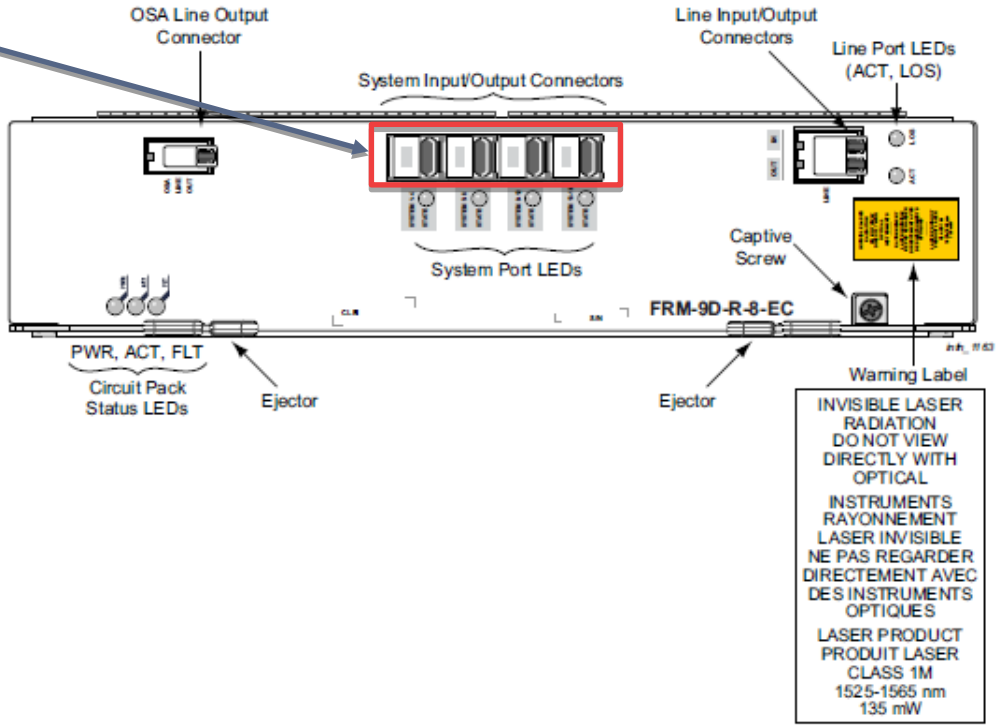
Express up to 19 SCGs

FSP-C or FMP-C connects to 1st or 2nd System Ports (3rd and 4th port is for express)

A software association is made manually between the FSP-C or FMP-C and the FRM System Port

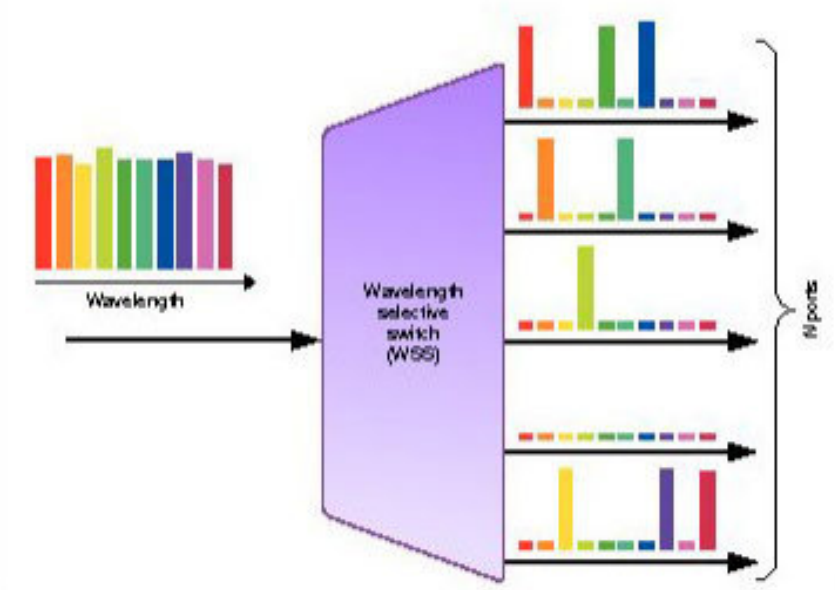
WSS in FRM is configured to add/drop the selected Super Channel Group (SCG)

Figure 3-19 FRM Faceplate



What is WSS?

- WSS = Wavelength Selective Switch
- WSS is the central heart of FRM9D
- WSS allows any wavelength of incoming light to be switched to any output port
- Variable attenuation can be added for each individual wavelength in WSS for channel power control and equalization



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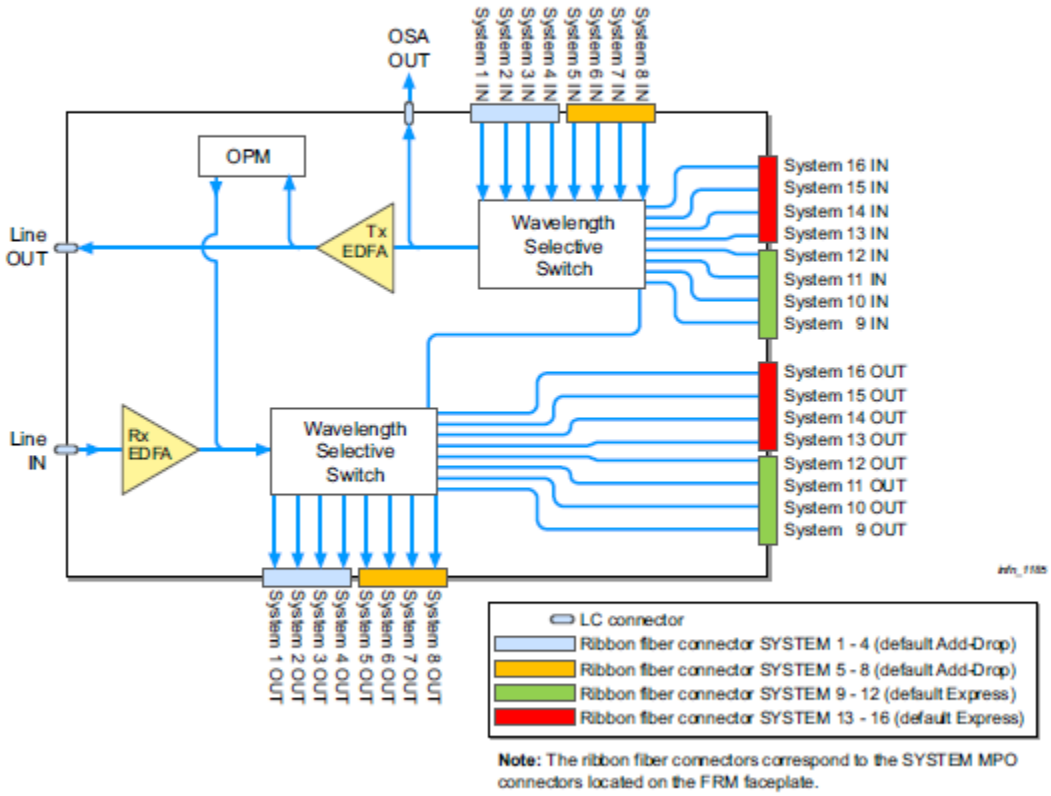
Flex ROADM Module (FRM-9D-R-8-EC)

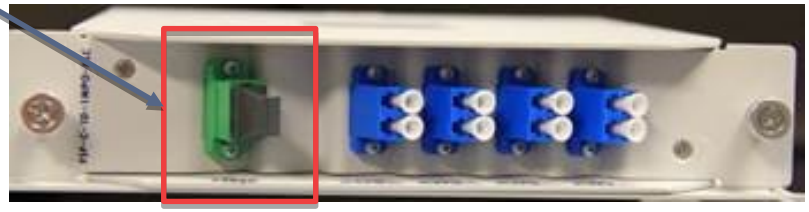
Figure 3-18 FRM Data Plane Block Diagram



Note: The ribbon fiber connectors correspond to the SYSTEM MPO connectors located on the FRM faceplate.

Associate FSP-C to FRM

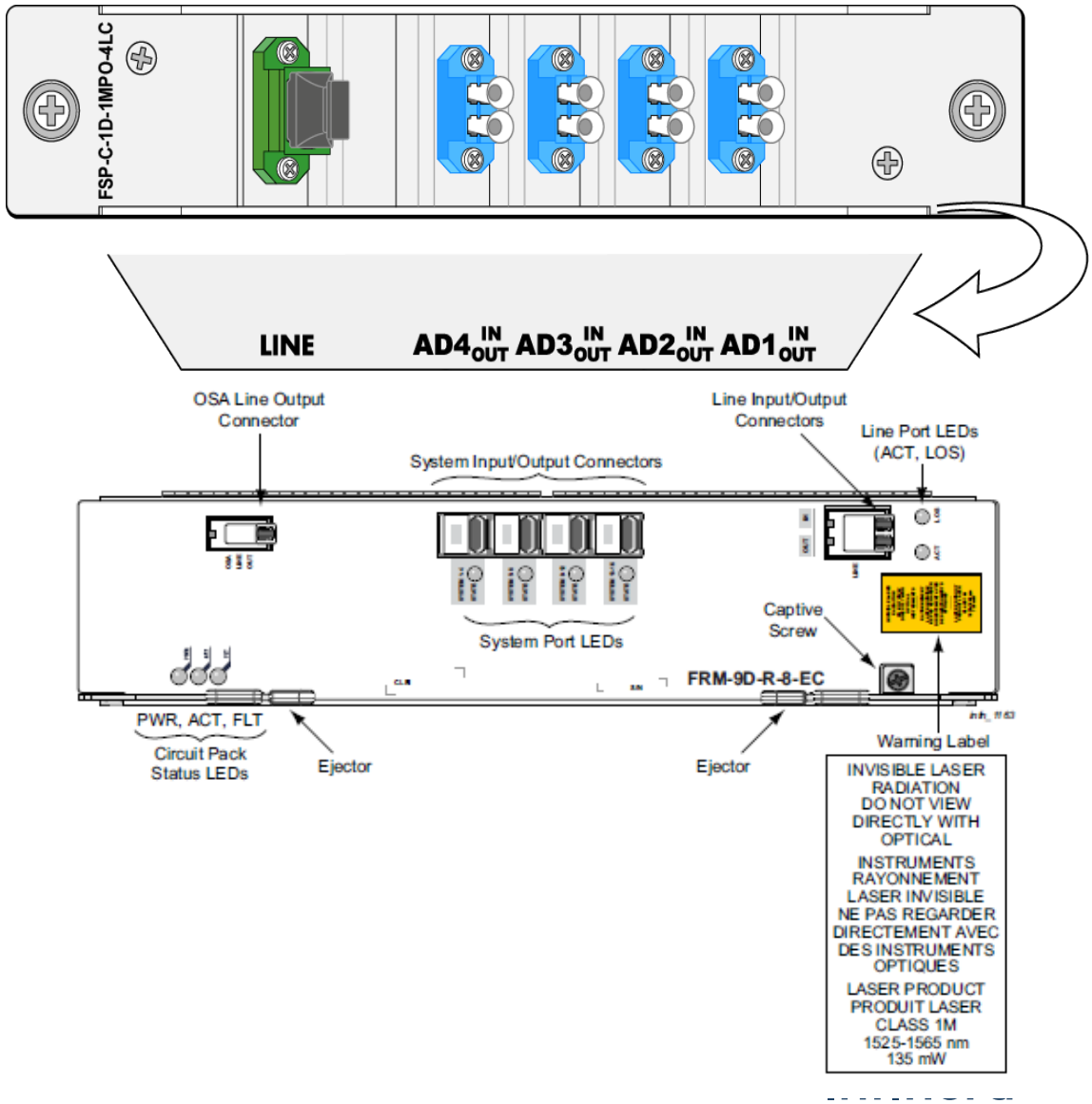
Each MPO port is 4 fibers/connections from an FSP-C
From left to right:
System 1-4 is S1 (add/drop)
System 5-8 is S5 (add/drop)
System 9-12 is S9 (Express)
System 13-16 is S13 (Express)



Associate FSP-C to FRM

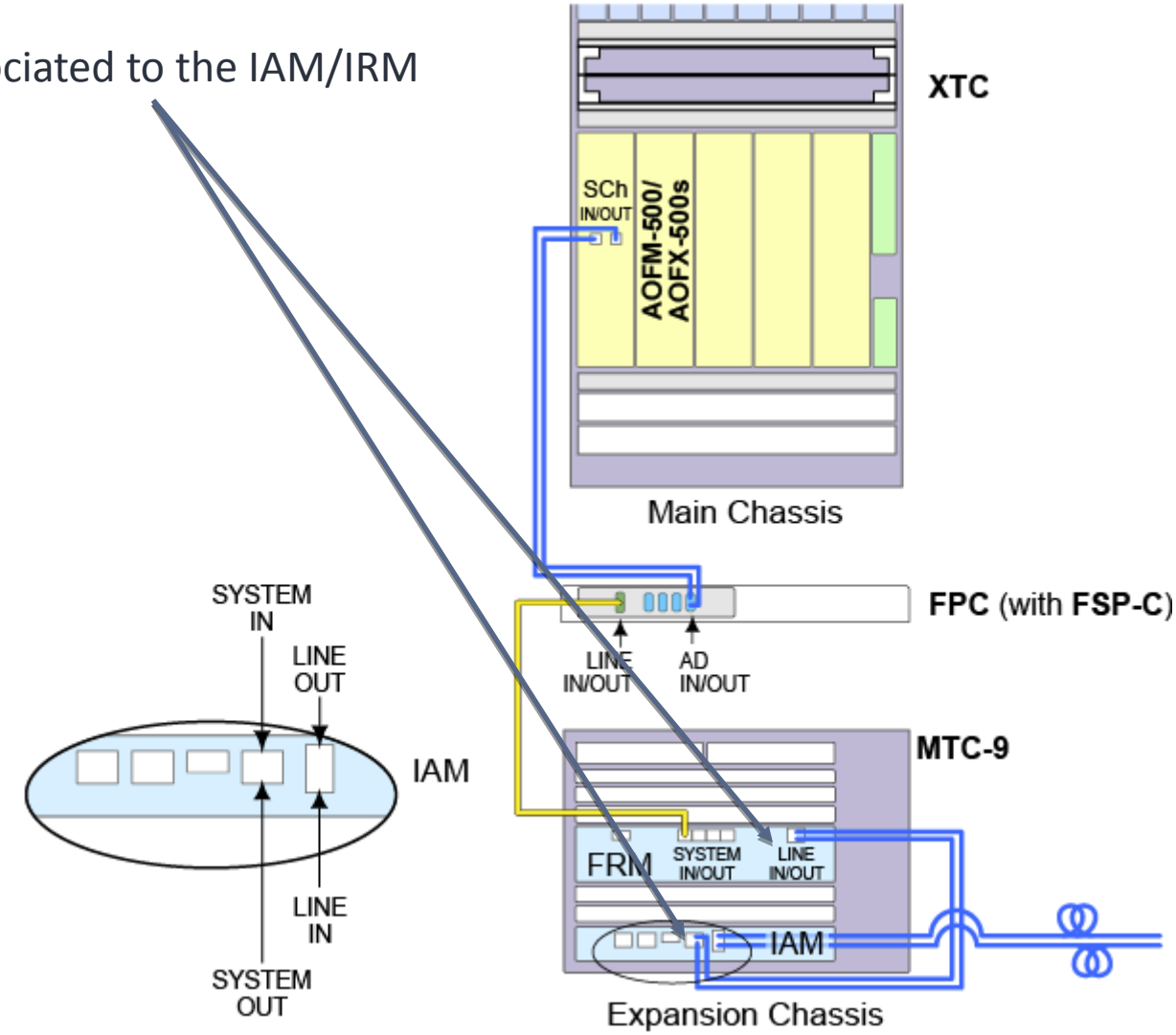
If you associate the FSP-C with S1 then:
AD1 will be S1
AD2 will be S2
AD3 will be S3
AD4 will be S4

If you associate the FSP-C with S5 then:
AD1 will be S5
AD2 will be S6
AD3 will be S7
AD4 will be S8



Associate FRM to IAM/IRM

FRM is associated to the IAM/IRM

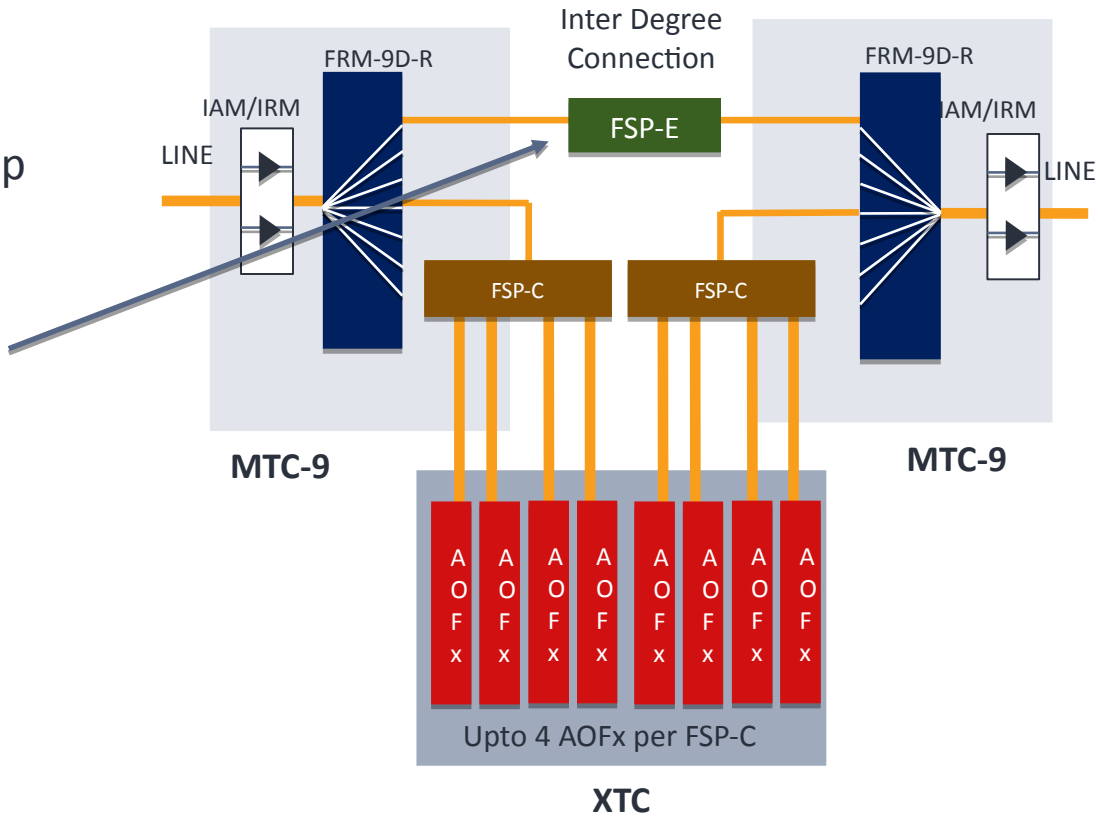


DTN-X C-ROADM Turn up and Test

This completes the process for one add/drop direction. Repeat for all other add/drop directions.

What about express traffic?

We will look at that in the next section '*FlexILS Turn up and Test*'



Flex ILS ROADM

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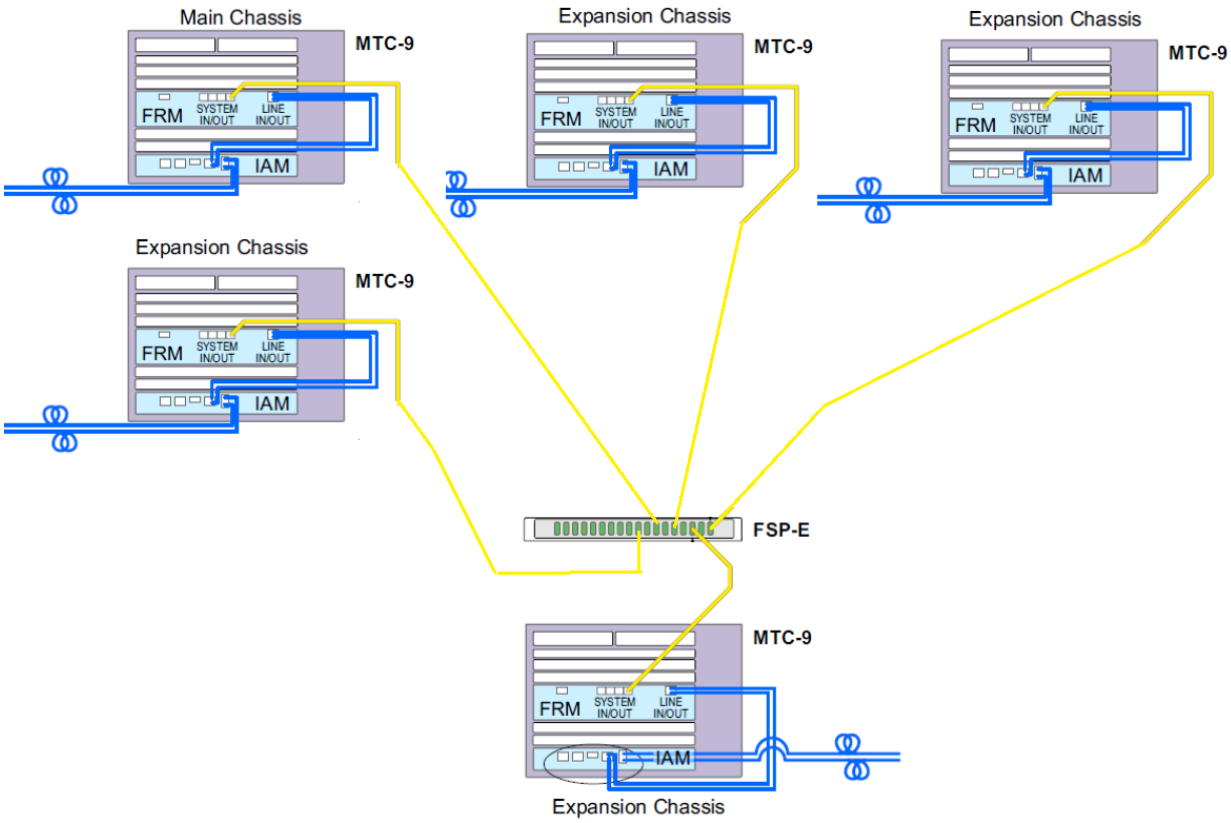
Flex ILS ROADM Turn up and Test

This diagram shows an MTC-9 as a main chassis in a FlexILS configuration.

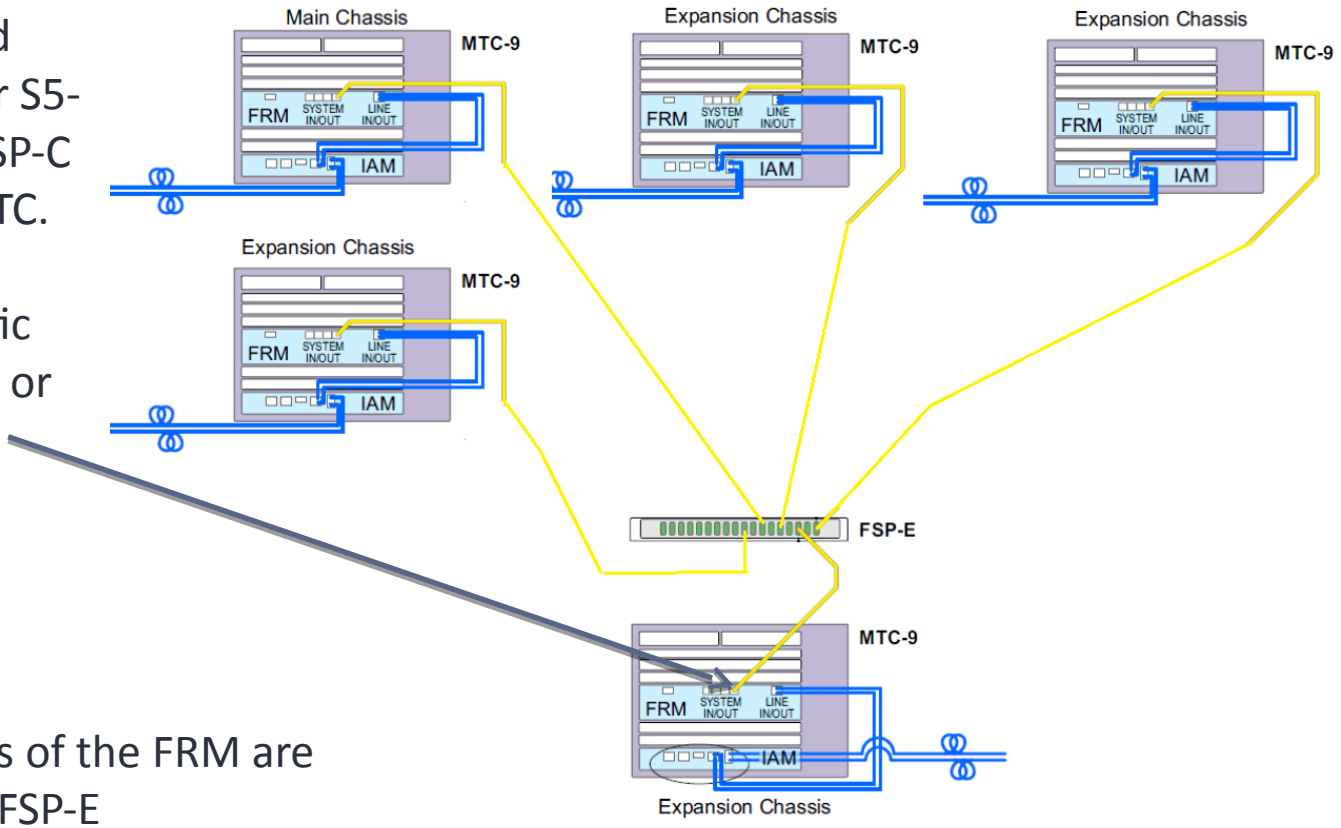
The express connections showing 4D



Flex ILS ROADM Turn up and Test

As the signal comes in to the IAM it is amplified. Add/drop traffic would transmit out of S1-4 or S5-8 and connect to an FSP-C and then to AOFx in XTC.

However, express traffic transmits out of S9-12 or S13-16

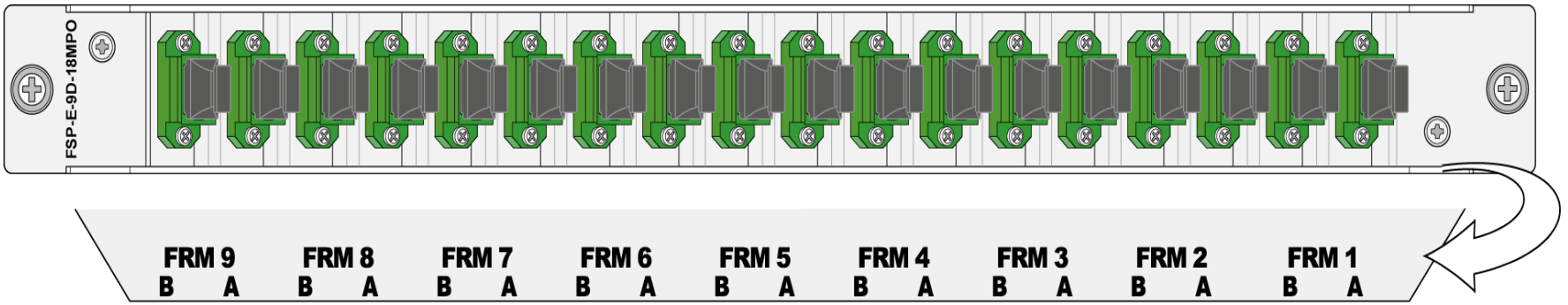


The Express ports of the FRM are connected to an FSP-E

Flex ILS ROADM Turn up and Test

Express traffic transmits out of S9-12 or S13-16

FSP-E-9D-18MPO



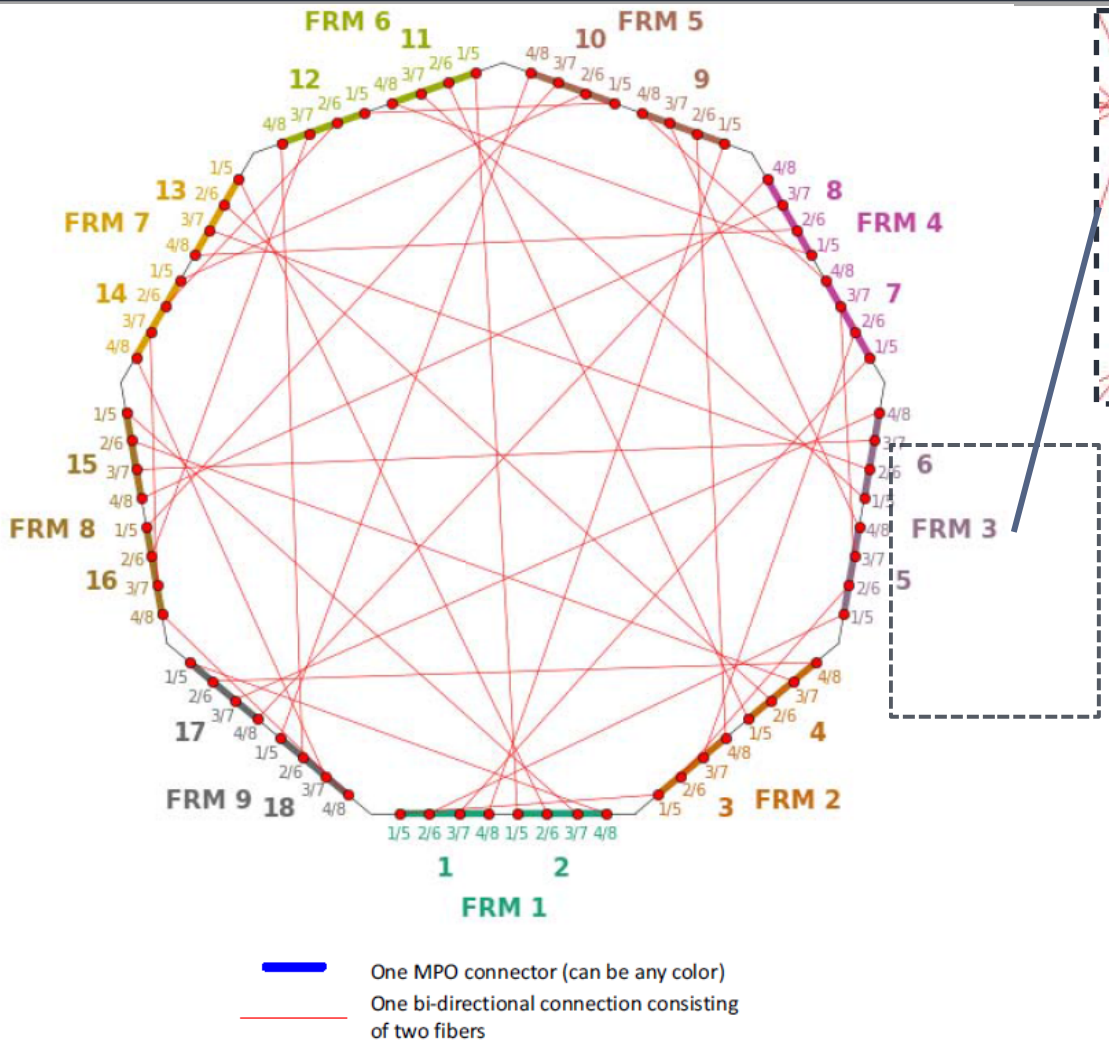
infn_1192

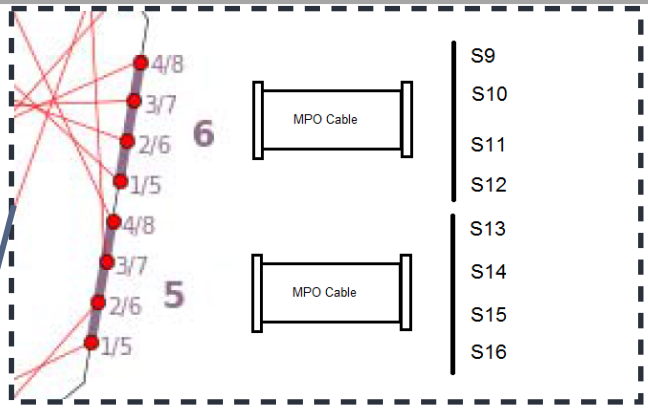
Each port is connected to 4 other ports to allow for 4 degree switching

Table on right shows port connectivity i.e. 1A is connected to 2A, 3A, 4A and 5A

	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B
1A																		
1B																		
2A																		
2B																		
3A																		
3B																		
4A																		
4B																		
5A																		
5B																		
6A																		
6B																		
7A																		
7B																		
8A																		
8B																		
9A																		
9B																		

FSP-E-9D-18MPO logical connectivity





MPO connected to 1A and using S13 - S16, the ports it would connect to is

S13 → 5A S15
S14 → 4A S15
S15 → 3A S15
S16 → 2A S16

MPO connected to 2A and using S13 - S16, the ports it would connect to is

S13 → 5A S16
S14 → 4A S16
S15 → 3A S16
S16 → 1A S16

Note: First port number on one end goes to the last port number on the other end (MPO cables are internally cross connected/swapped)

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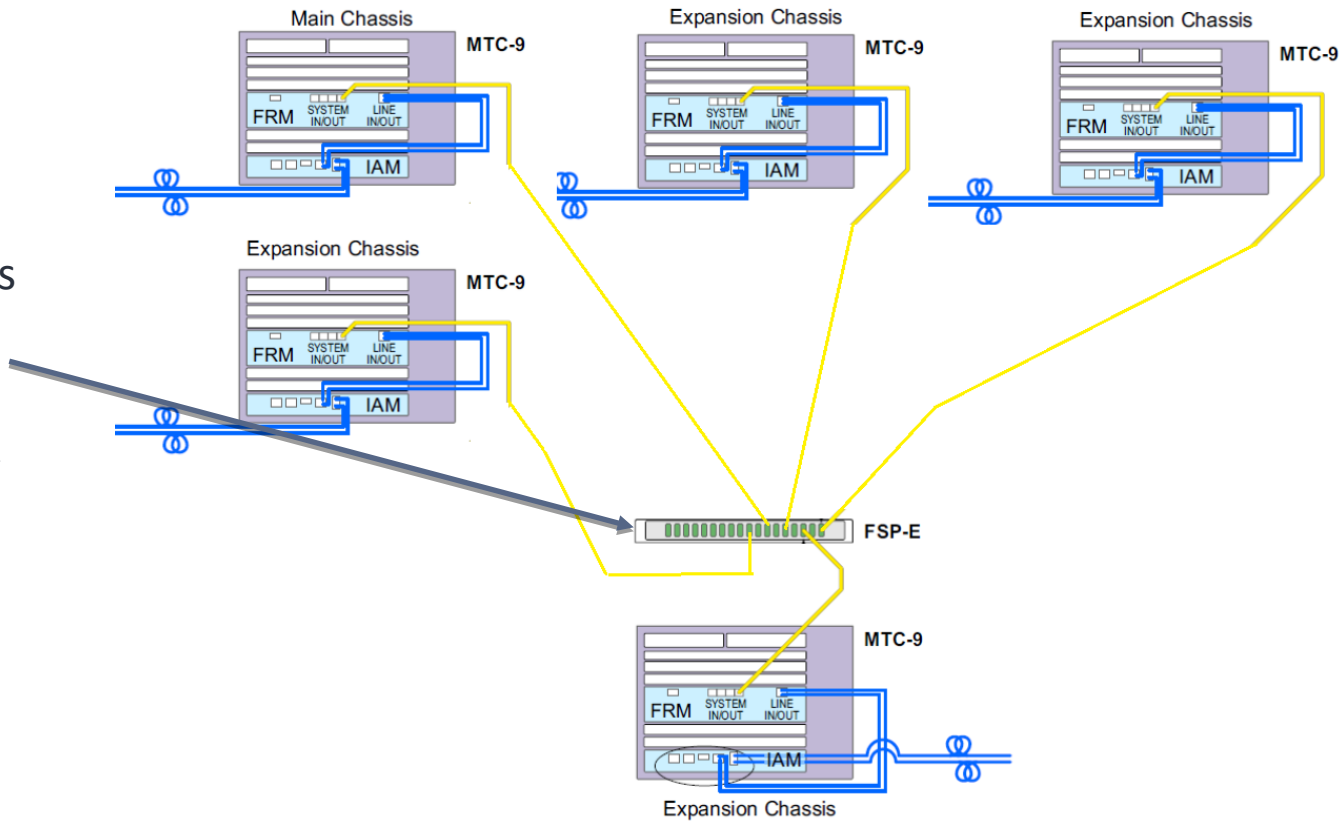
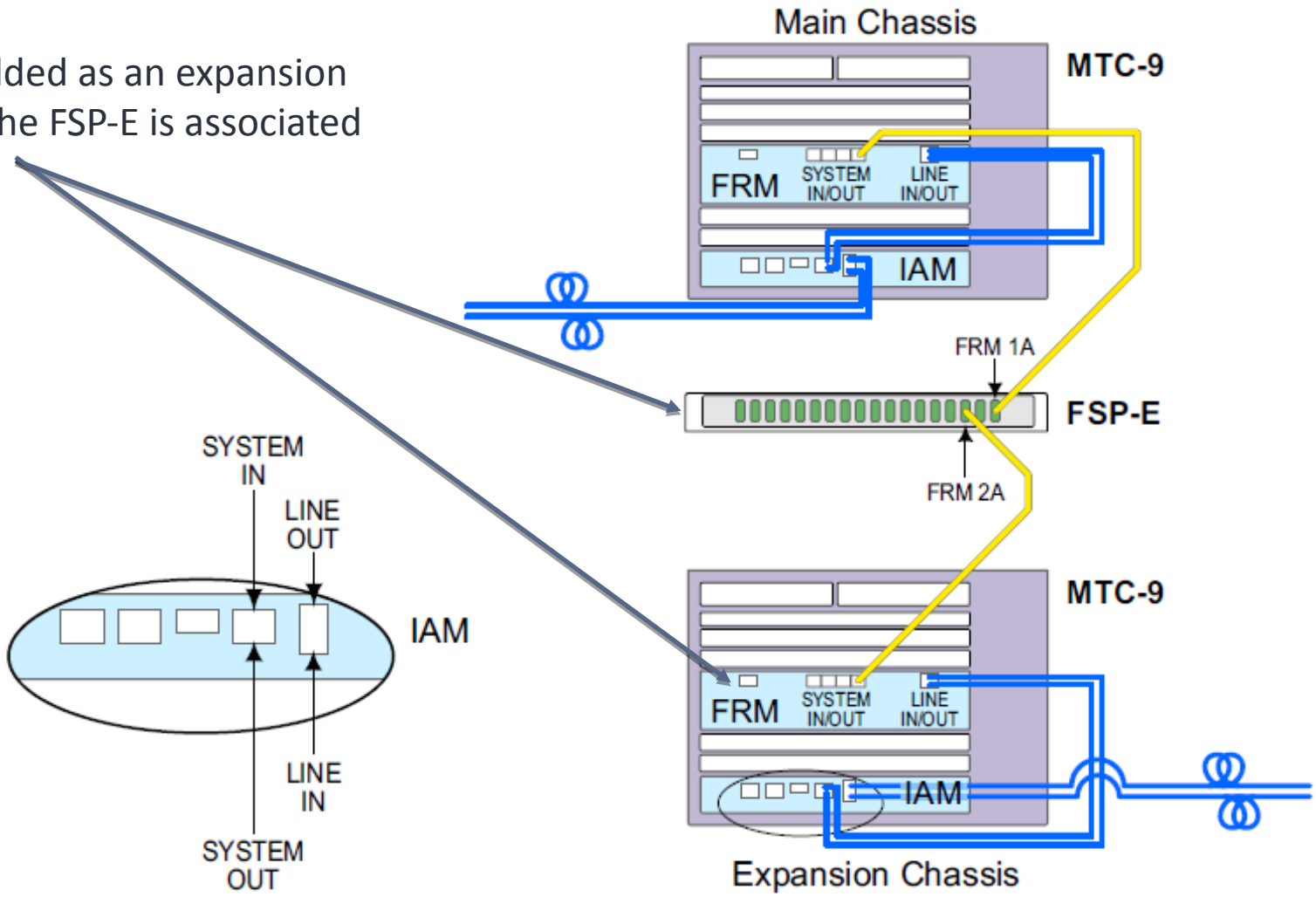
Flex ILS ROADM Turn up and Test

Additional FRMs are connected to the same FSP-E.
Provided FRMs are connected correctly to the FSP-E then they can switch SCG's between FRMs.
In this case, FSP-E ports 1A , 2A, 3A, 4A and 5A
are connected



Add FPC and associate FSP-E to FRM

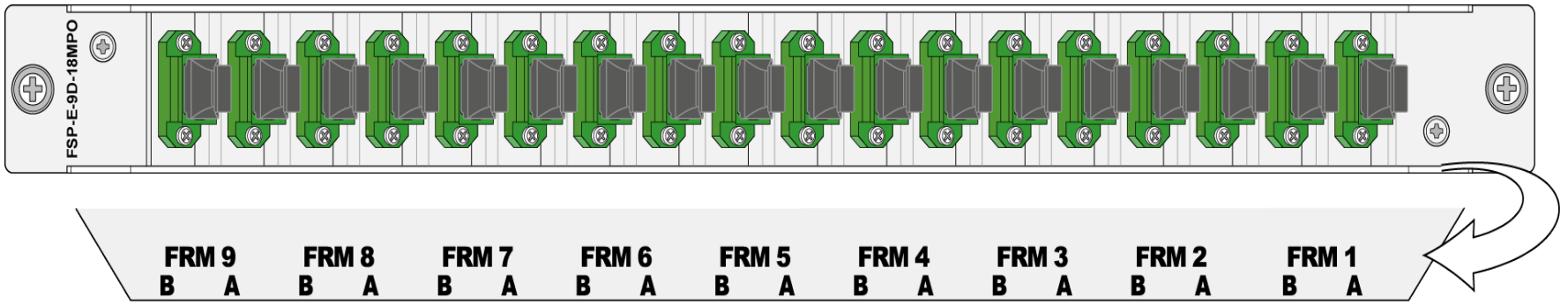
The FPC is added as an expansion chassis and the FSP-E is associated to the FRM



FRM Ports

Each MPO port is 4 fibers/connections from an FSP-E
From left to right:
System 1-4 is S1 (add/drop)
System 5-8 is S5 (add/drop)
System 9-12 is S9 (Express)
System 13-16 is S13 (Express)

FSP-E



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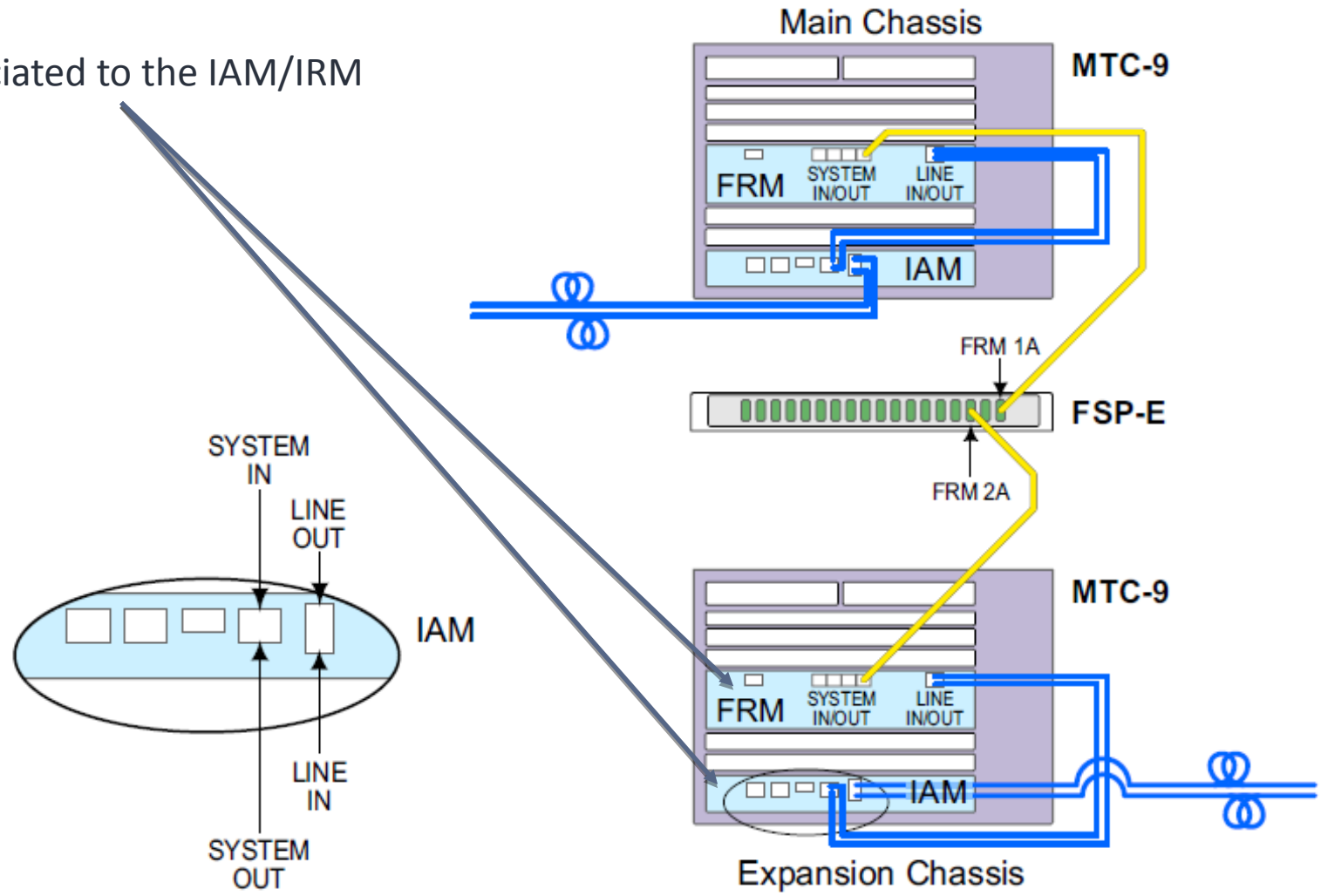
Note that the labelling of the FSP-E is from right to left
BUT in the GUI is from left to right…

Associate FRM to IAM/IRM

FRM is associated to the IAM/IRM



CDC-ROADM

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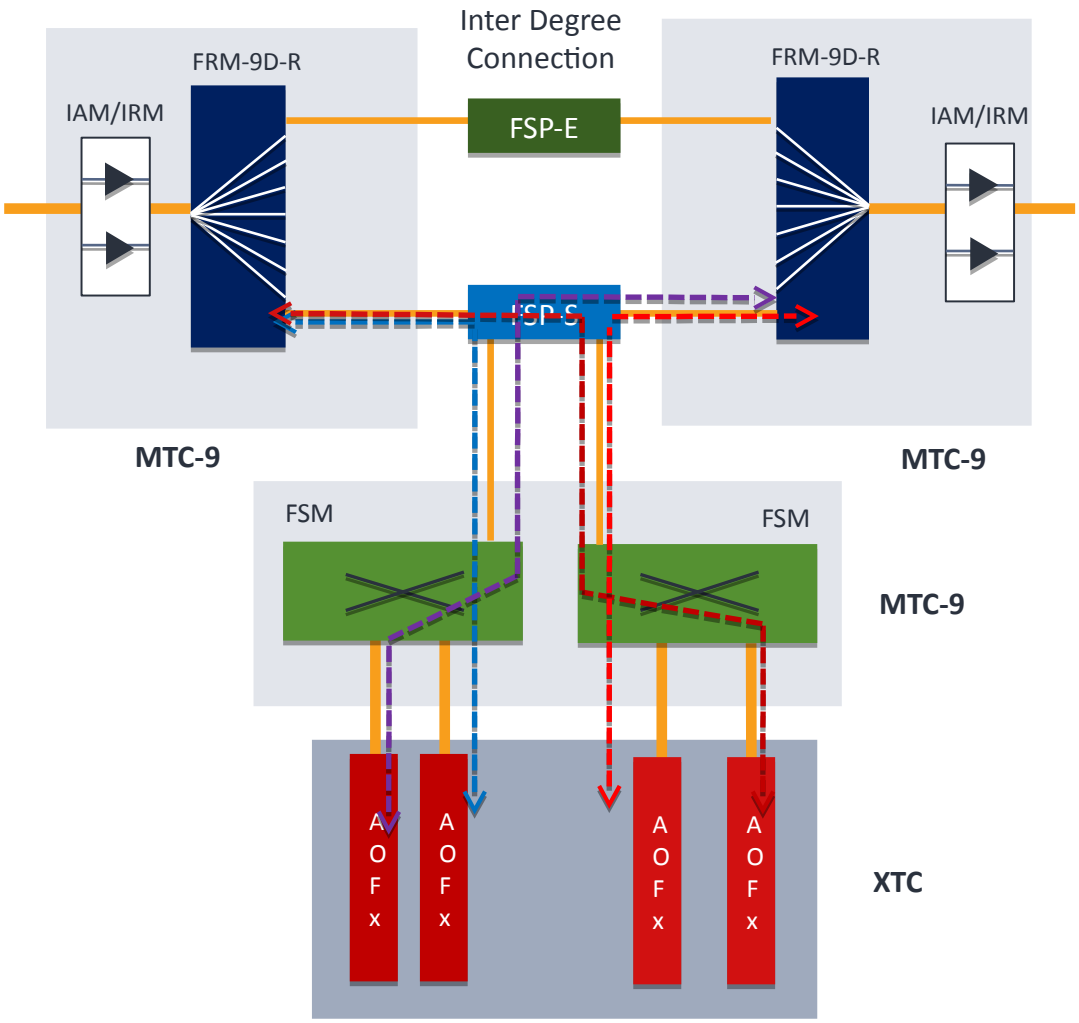
CDC ROADM



- Super-Channel CDC FlexROADM
  - Up to 8 Degrees
  - 19 500G Super-Channels add/drop per degree
- FSM provides CDC functionality
  - 12 add/drop ports and 8 line ports
  - Up to 8 FSMs per node
- Shuffle panels for fiber management
  - FSP-E for express connectivity among FRM-9D-R
  - FSP-S for add/drop using FSM
- Benefits:
  - Fully flexible and un-constrained multi-direction photonic switching

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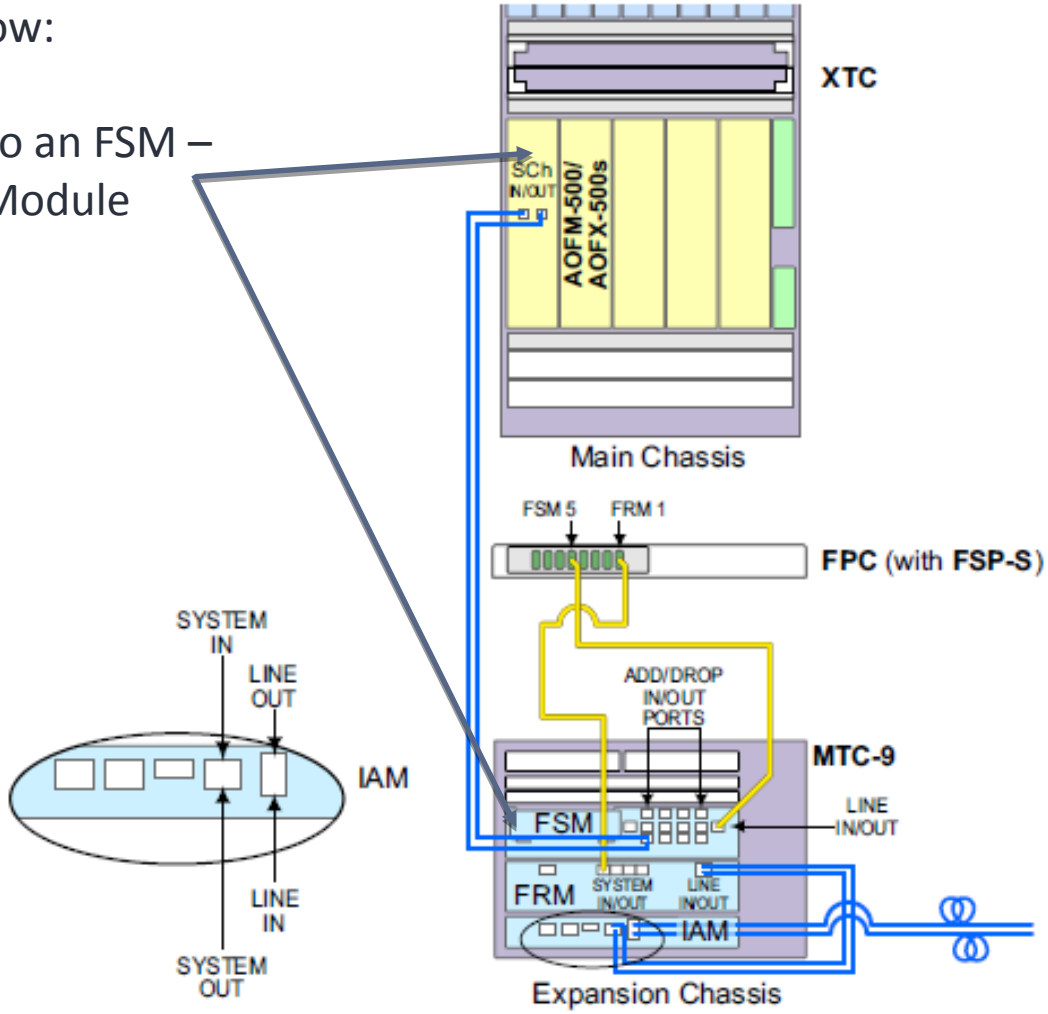
Example Configuration of a DTN-X CDC ROADM

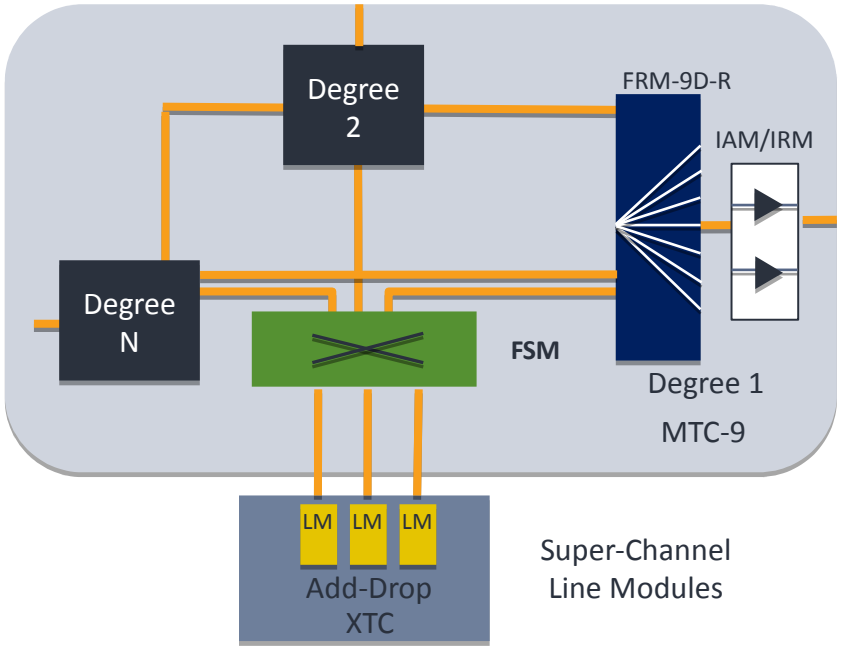
Let's follow the signal flow:

AOFx connects directly to an FSM – Flex ROADM Switching Module

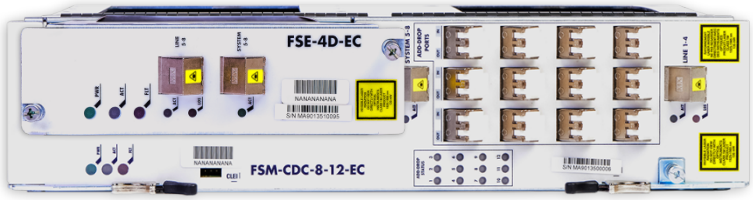


FSM (FlexROADM Switching Module) Overview

CDC FlexROADM Node



FSM Faceplate



- Provides CDC functionality along with FRM-9D-R
  - Multiples of same λ can be add/drop to same FSM
  - Can be connected to multiple FRM-9D-R (directions)
- Direction independent add/drop
  - Mux/Demux and switching of 12 channels to 8 directions
  - Up to 8D CDC FlexROADM Node
- Supports OCGs and alien wavelengths (in future)
- 3 slots in MTC-9

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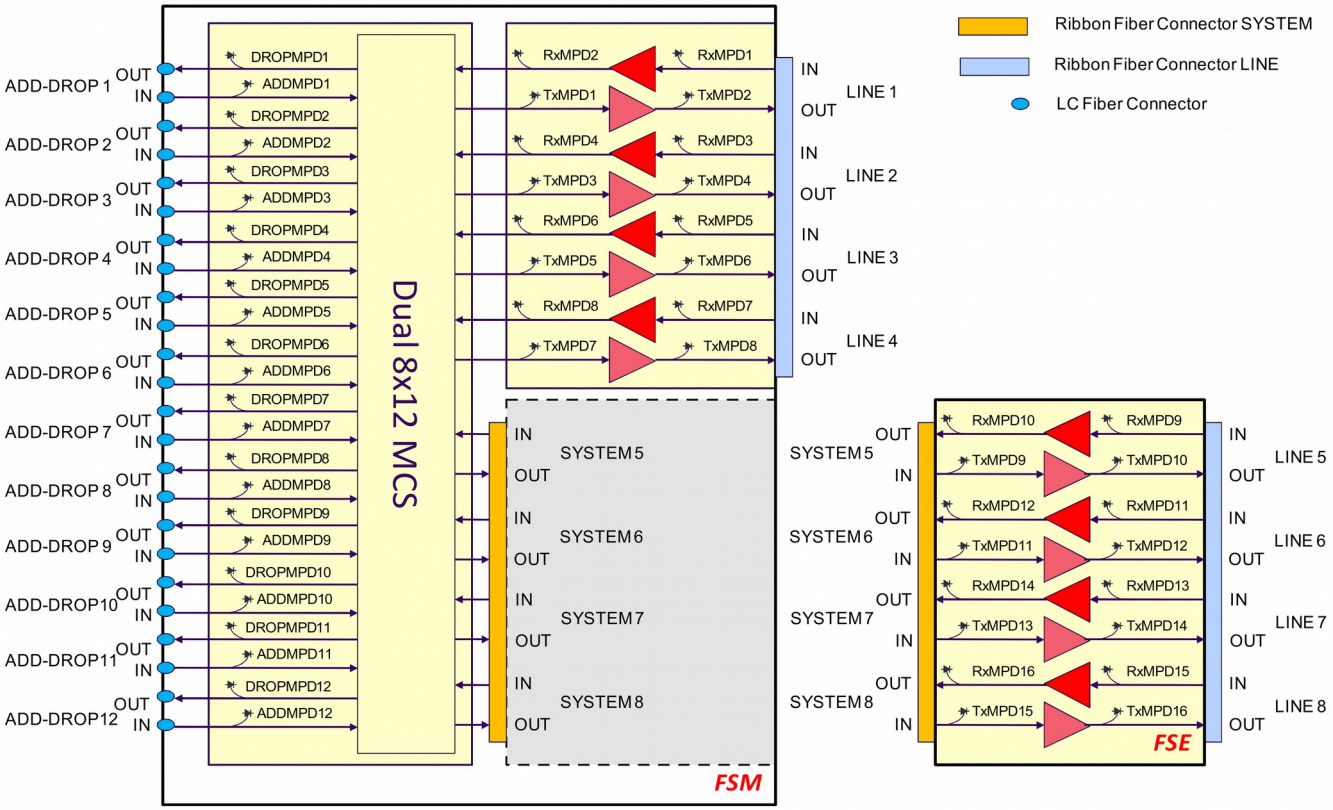
FSM-CDC-8D-12-EC Overview

Up to 12 SCGs can be connected to the FSM directly from the AOFx and be cross-connected to any of the 4 line ports. All 12 SCGs can go out of the same Line Port if desired.

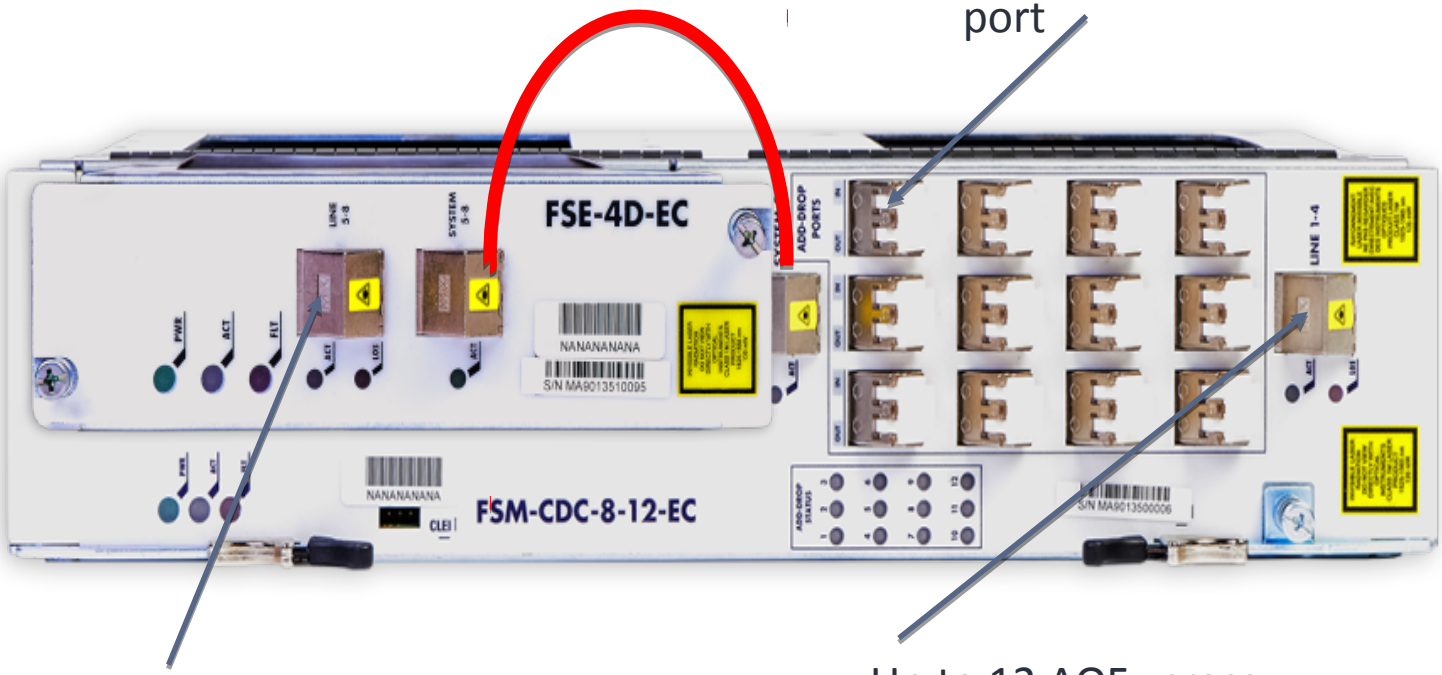
FSE (Expansion Module) provides another 4 ports



FSM-CDC-8D-12-EC

MPO cable must be fitted to use Line 5-8

1 x AOFx connects to an Add/Drop port

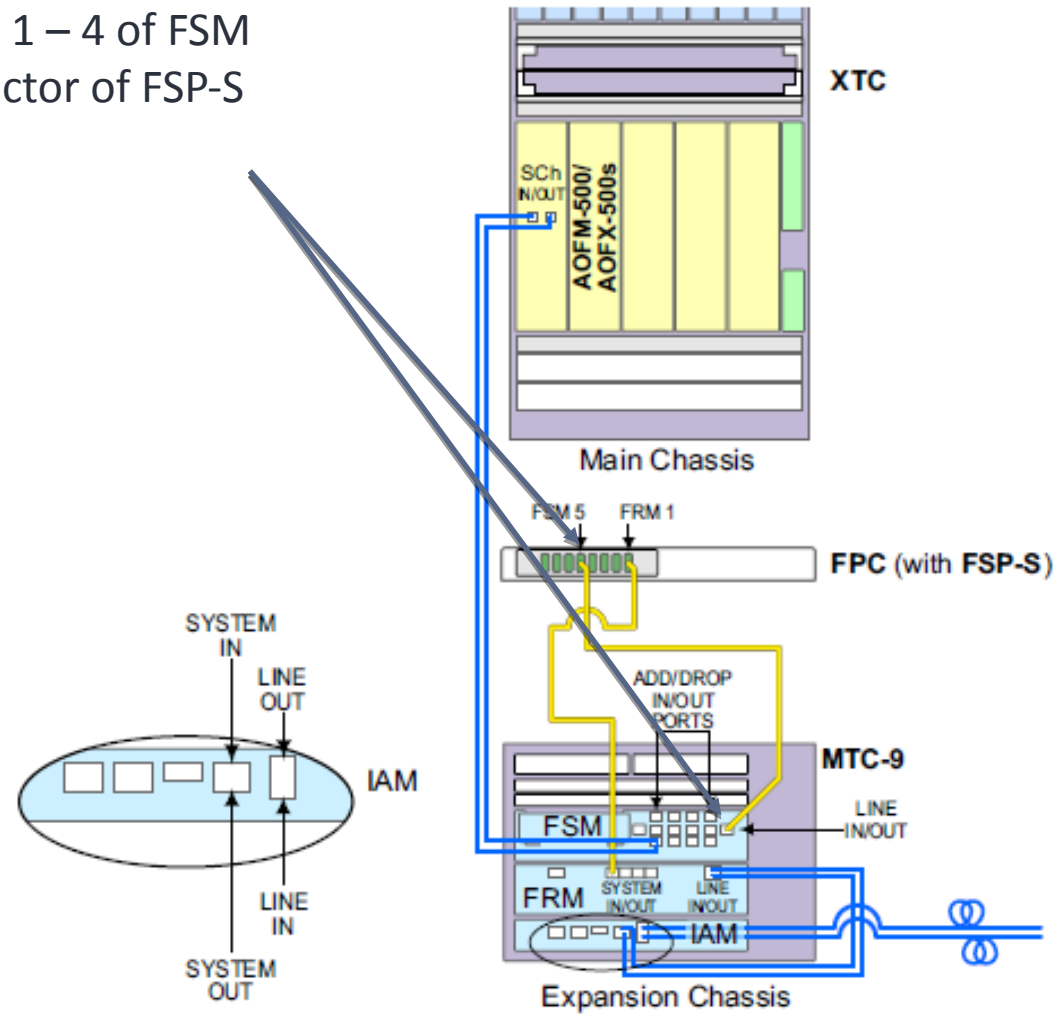


With Extender Card fitted up to 12 AOFx cross connect to Line 1 to 4 and Line 5 to 8 (MPO connectors) up to 8D

Up to 12 AOFx cross connect to Line 1 to 4 (MPO connector) up to 4D

Example Configuration of a DTN-X CDC ROADM

MPO connector for Line 1 – 4 of FSM connects to MPO connector of FSP-S



FSP-S-4D-8MPO

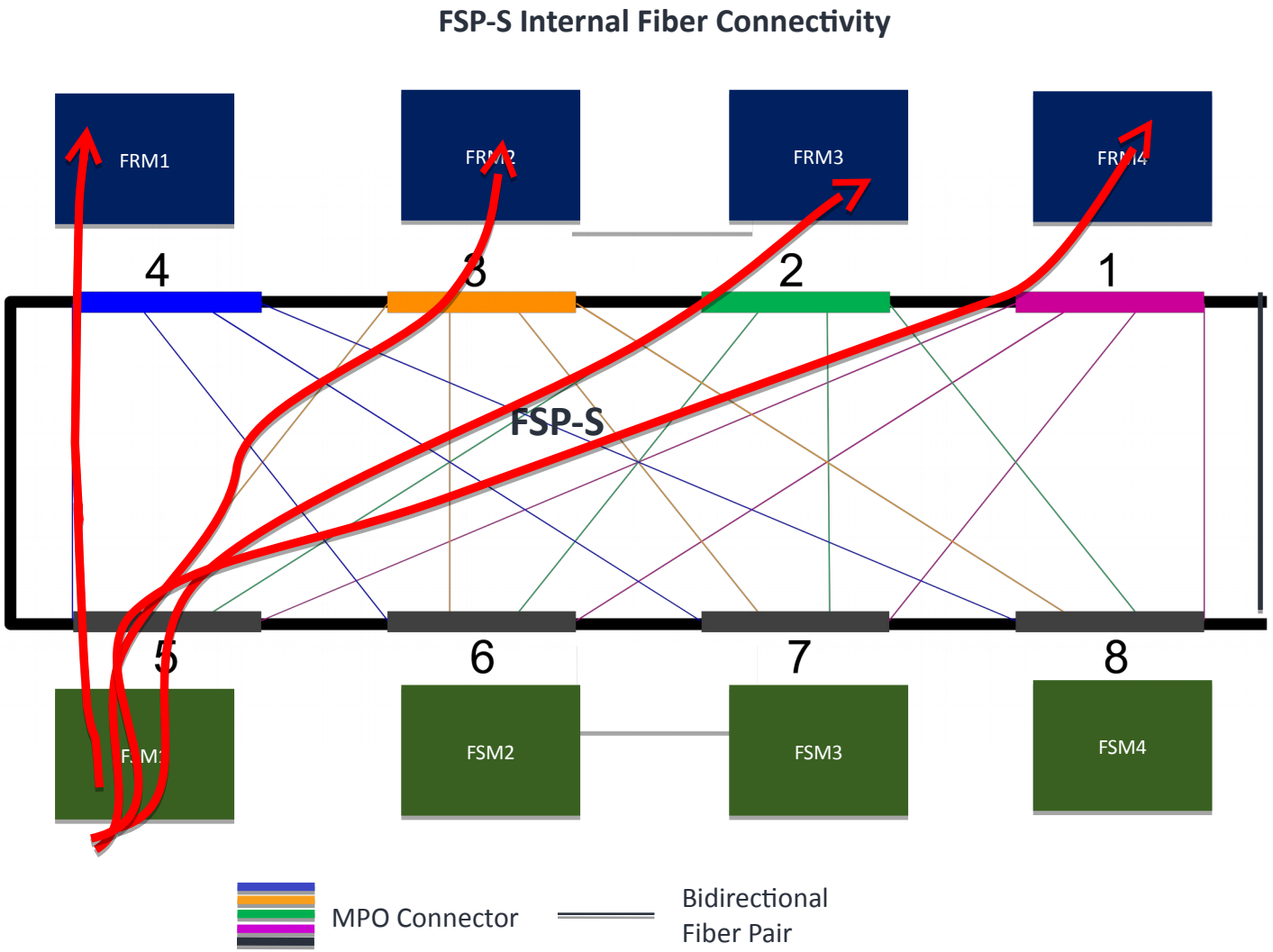
Ports are labelled, from left to right, 1 to 8

- CDC add/drop shuffle panel
- Enables connectivity between FSM and FRM-9D-R for CDC FlexROADM configuration
  - Connect to MPOs from 4 FRMs and 4 FSMs
  - Breakout MPO cables such that each FRM-9D-R connect to different FSM
- Passive Module,
  - Half-width FRU - fits 2 in 1 RU FPC-1(19”, 600mm, 23” rack mounting)
- Modular Architecture
  - Number of FSP-S depends upon number of degrees (FRM) and add/drop capacity(FSM)

CDC Add/Drop Shuffle Panel (FSP-S)

FSM must connect to port 5, 6, 7 or 8. Line 1 – 4 of FSM MPO is then sent to port 1 to 4. (line 1 to port 1, line 2 to port 2 etc)

FRM then receives up to 4 Lines, 1 from each FRM



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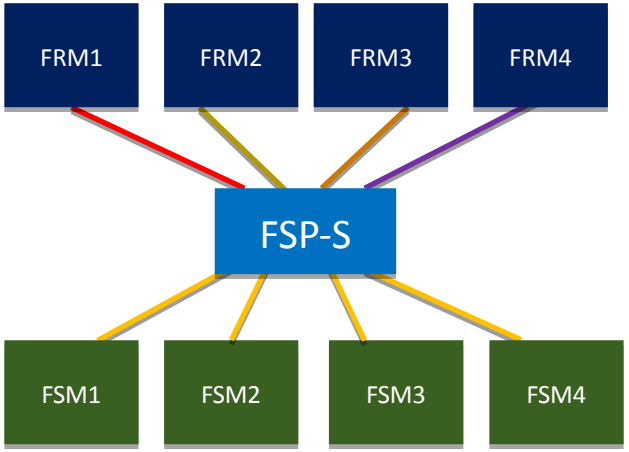
Deployment Scenario of FSP-S

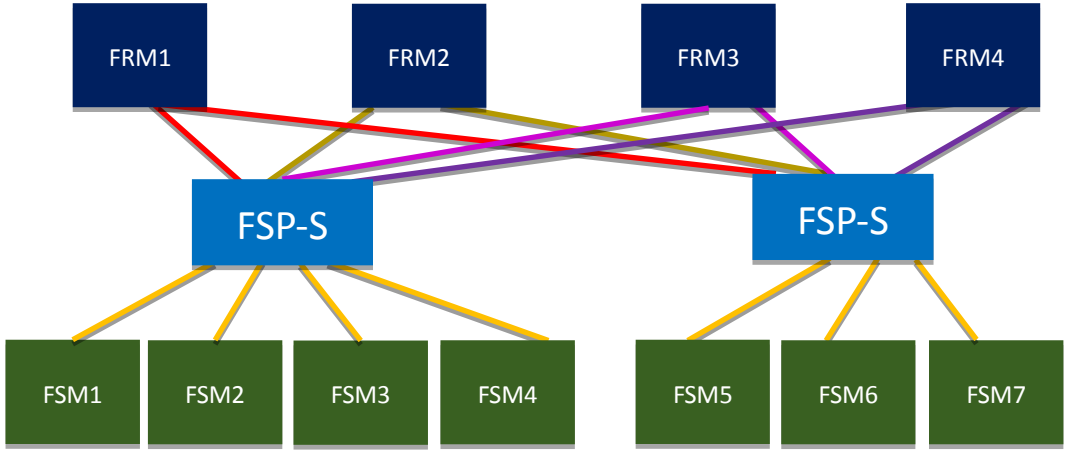
4 Degree CDC ROADM Node

4D CDC ROADM with 4 FSM
(63% Add/drop capacity)



- 1 MPO from each FRM gets connected to FSP-S
- 1 MPO from each FSM gets connected to FSP-S

4D CDC ROADM with 7 FSM
(100% Add/Drop capacity)



- 2 MPO from each FRM gets connected to two different FSP-S
- 1 MPO from each FSM gets connected to FSP-S

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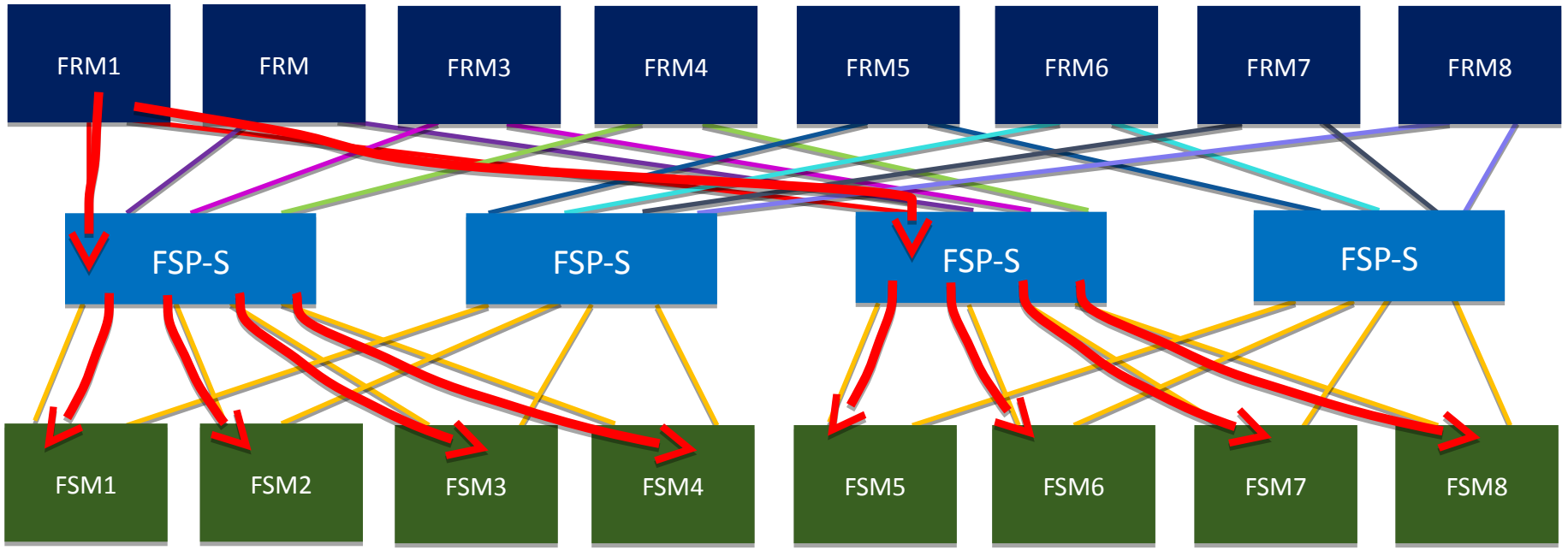
Deployment Scenario of FSP-S

8 Degree CDC ROADM Node

8D CDC ROADM with 8 FSM
(63% Add/drop capacity)



In the Drop direction every FRM is connected to every FSM through two FSP-S cards, each FSP-S has an expansion card fitted.
Also in the Add direction every FSM is connected to every FRM through the FSP-S cards.

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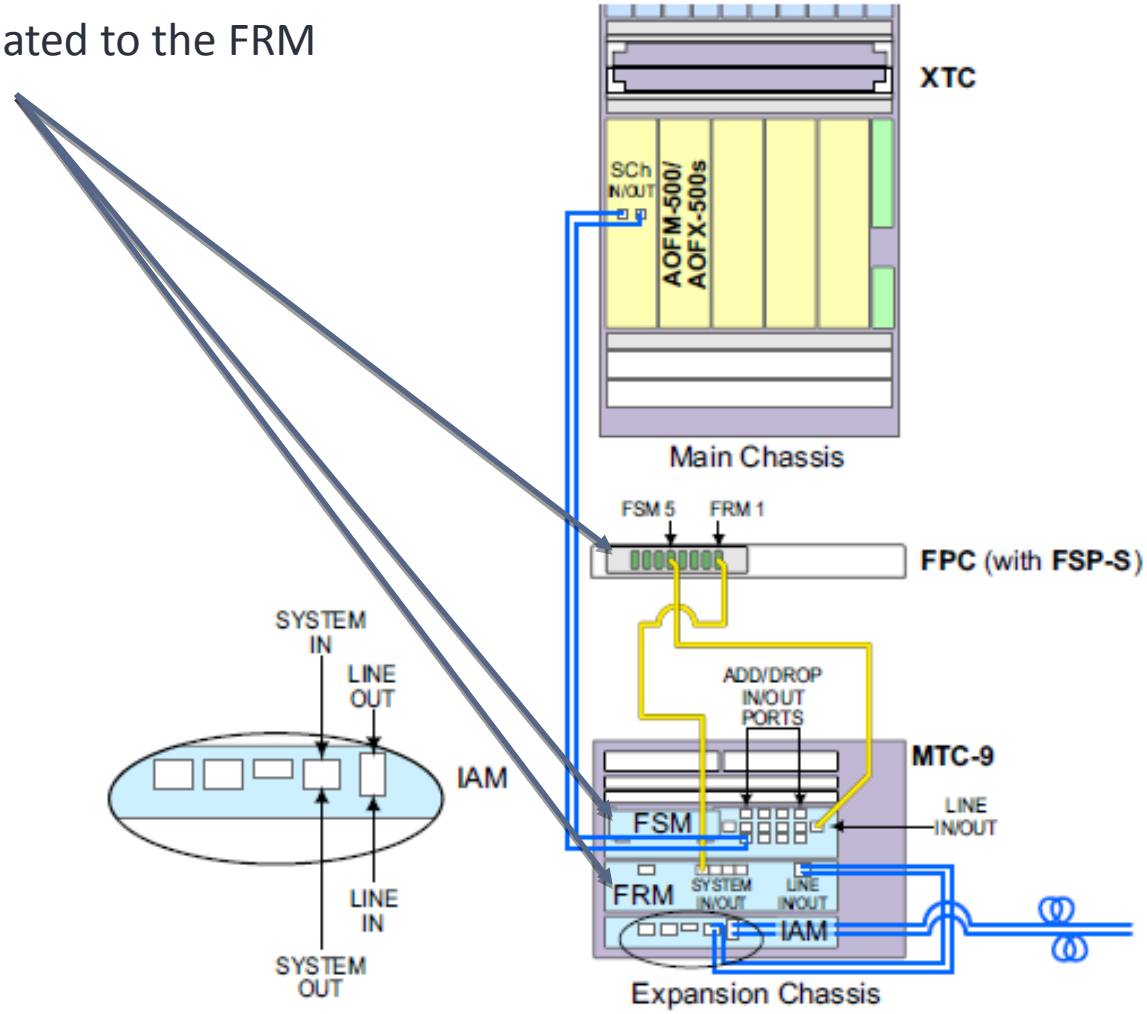
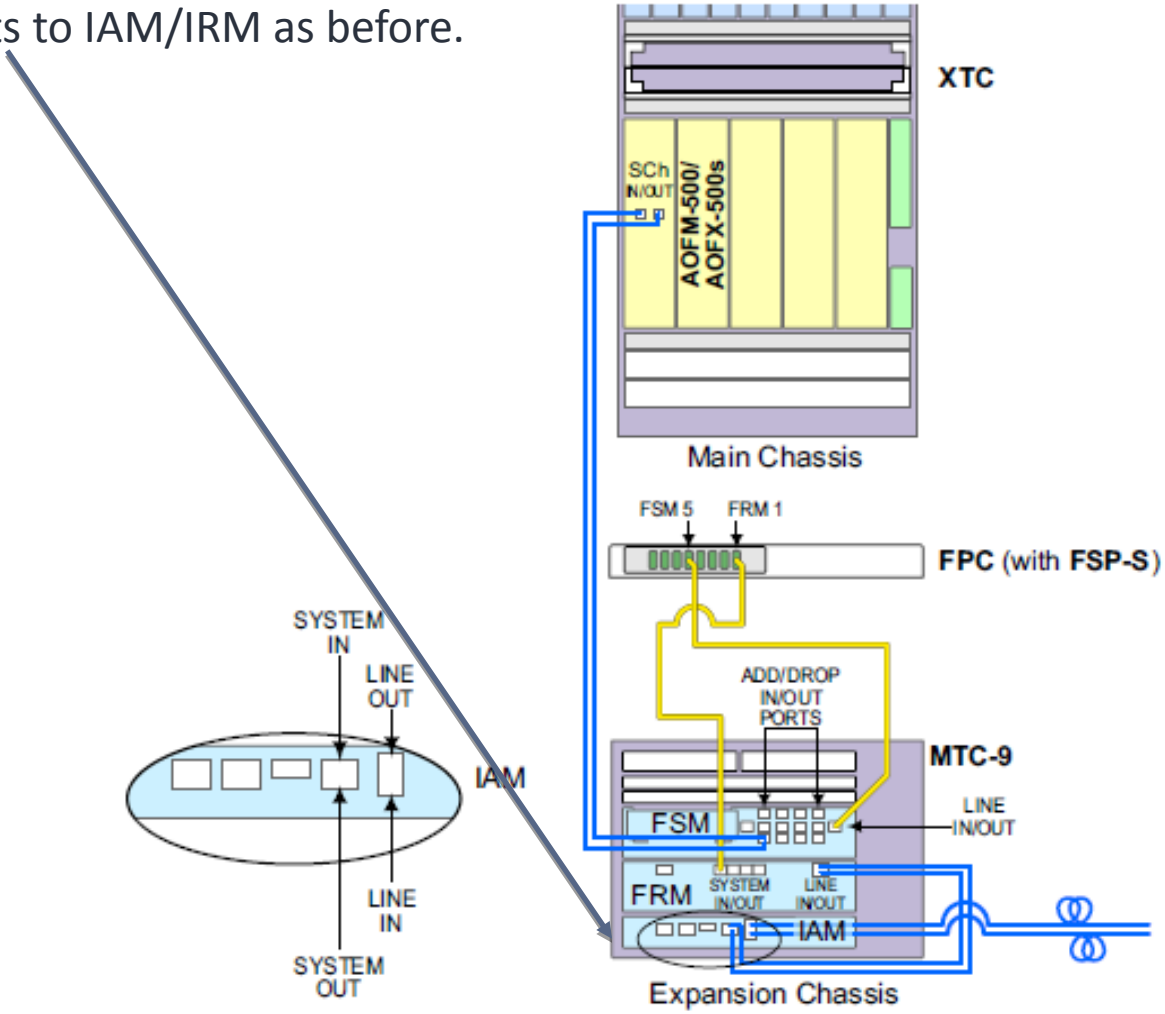
FSP-S connects to FRM and FSM

The FSP-S is associated to the FRM and FSM

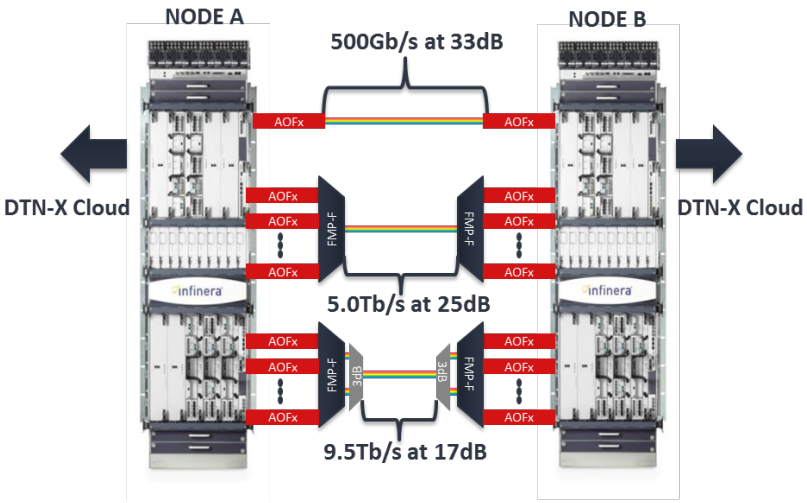


Example Configuration of a DTN-X CDC ROADM

FRM then connects to IAM/IRM as before.



Open Wave on AOFx/SOFx



- Directly connect AOFx/SOFx pair (no FRM or intermediate Amps)
- Enable GCC0 channel between AOFx/SOFx pair
- End-to-end GMPLS provisioning and restoration supported

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Flex ILS Amplifier and Raman

Turn up and Test

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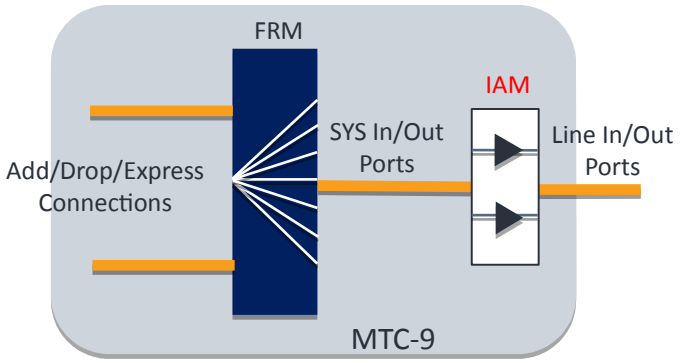
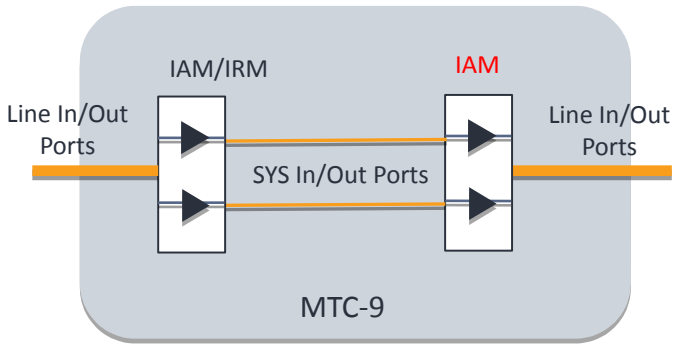
ILS Amplifier Module (IAM) Overview

IAM in ROADM Node



IAM in OLA Node



- Variable gain EDFA
- Optimized for Coherent Waves
  - No DCM required
- Extended C Band Support
- Integrated 1510nm OSC
- Serve line in/out ports of same fiber degree
  - One module per degree
- 2 Slots in MTC-9

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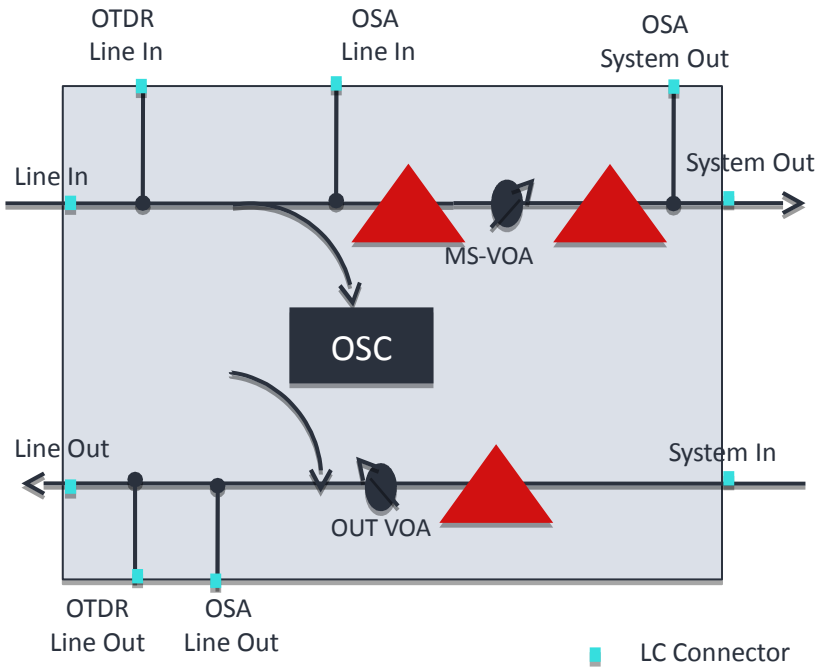
IAM Detailed Description

IAM2 HW Block Diagram



IAM2 Faceplate

- OSC terminated/generated per fiber direction
- High output power (21.5dBm)
- Multiple Variants
  - IAM2 – R10
    - Support for 0-28dB spans
    - Two stage EDFA with mid-stage VOA
    - Pre-amplifier and booster amplifier
    - OSA & OTDR ports
  - IAM1 – R11
    - Support for 0-20dB spans
    - Pre-amplifier only, no EDFA in Tx direction
    - No OTDR ports

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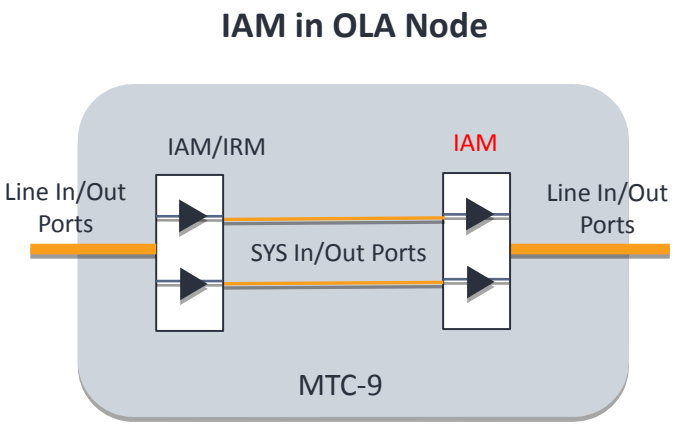
IAM Fibering

IAM/IRM system ports are fibered together in OLA node



Management

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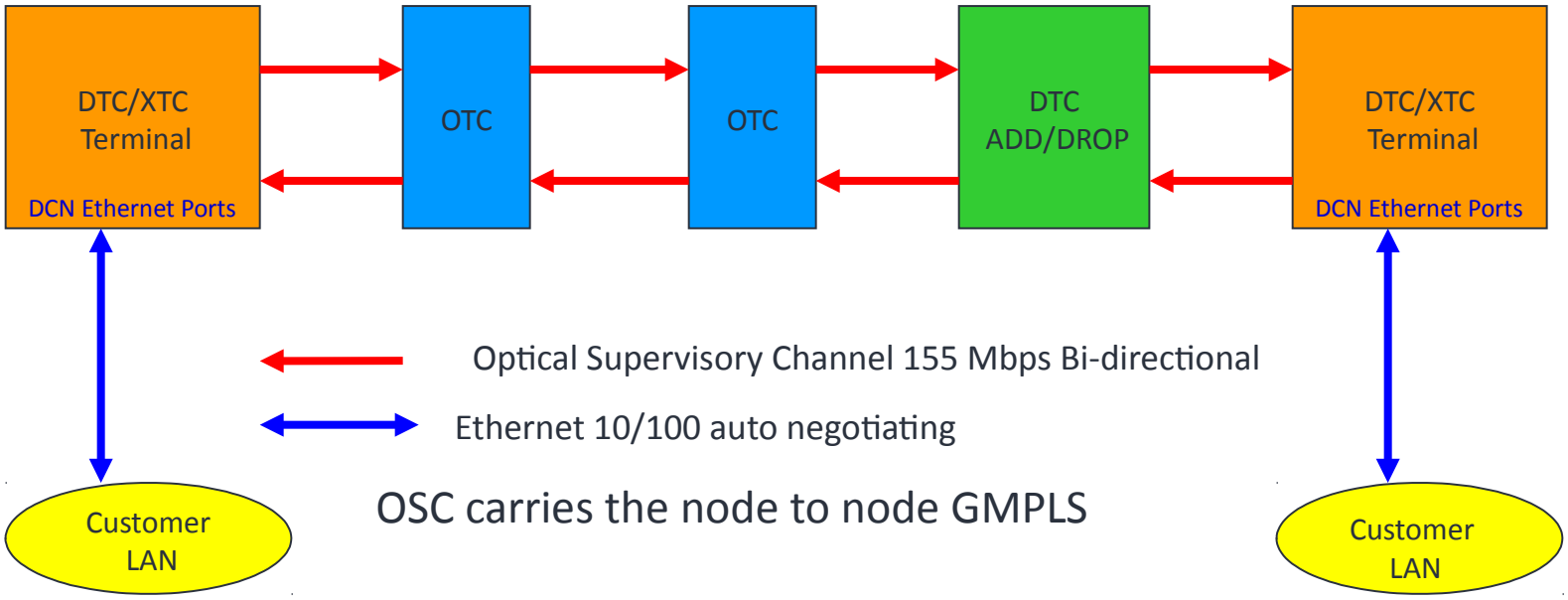
Network Management



- Communications to and from Gateway Network Elements (GNEs) utilizes the DCN port(s)
- Communications to and from Subtending Network Elements (SNEs) utilizes the OSC channel(s)
- The MCM/OMM routes communications sent or received to the appropriate DCN/OSC port

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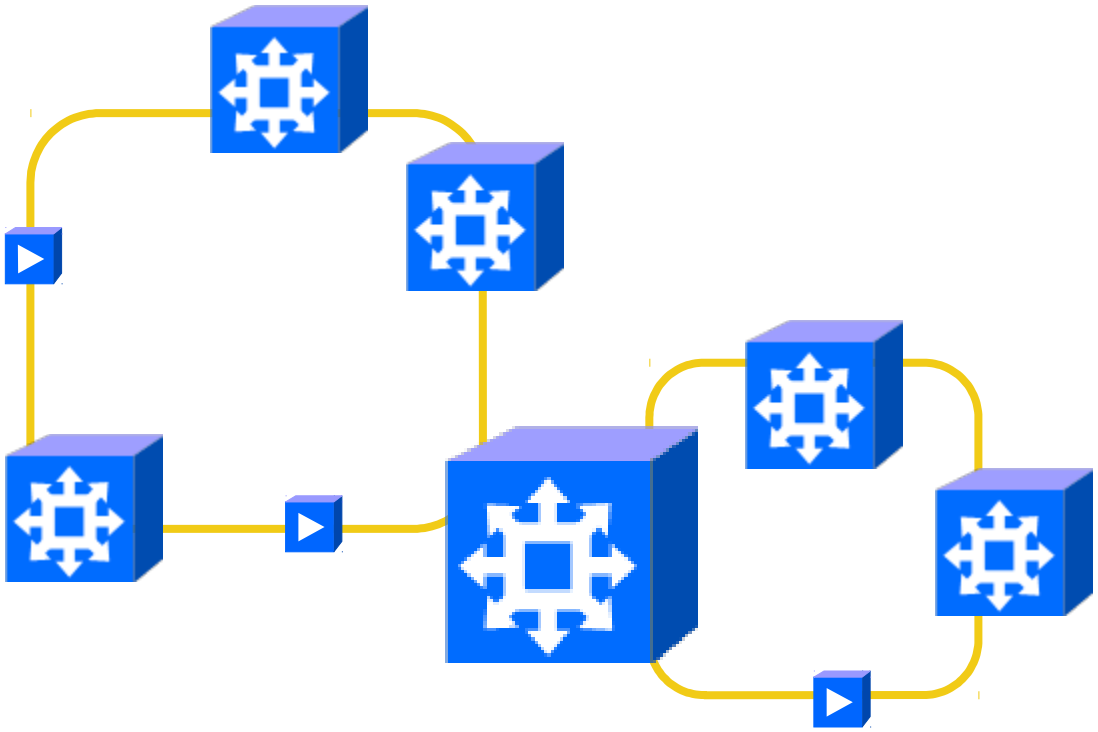
Example Network



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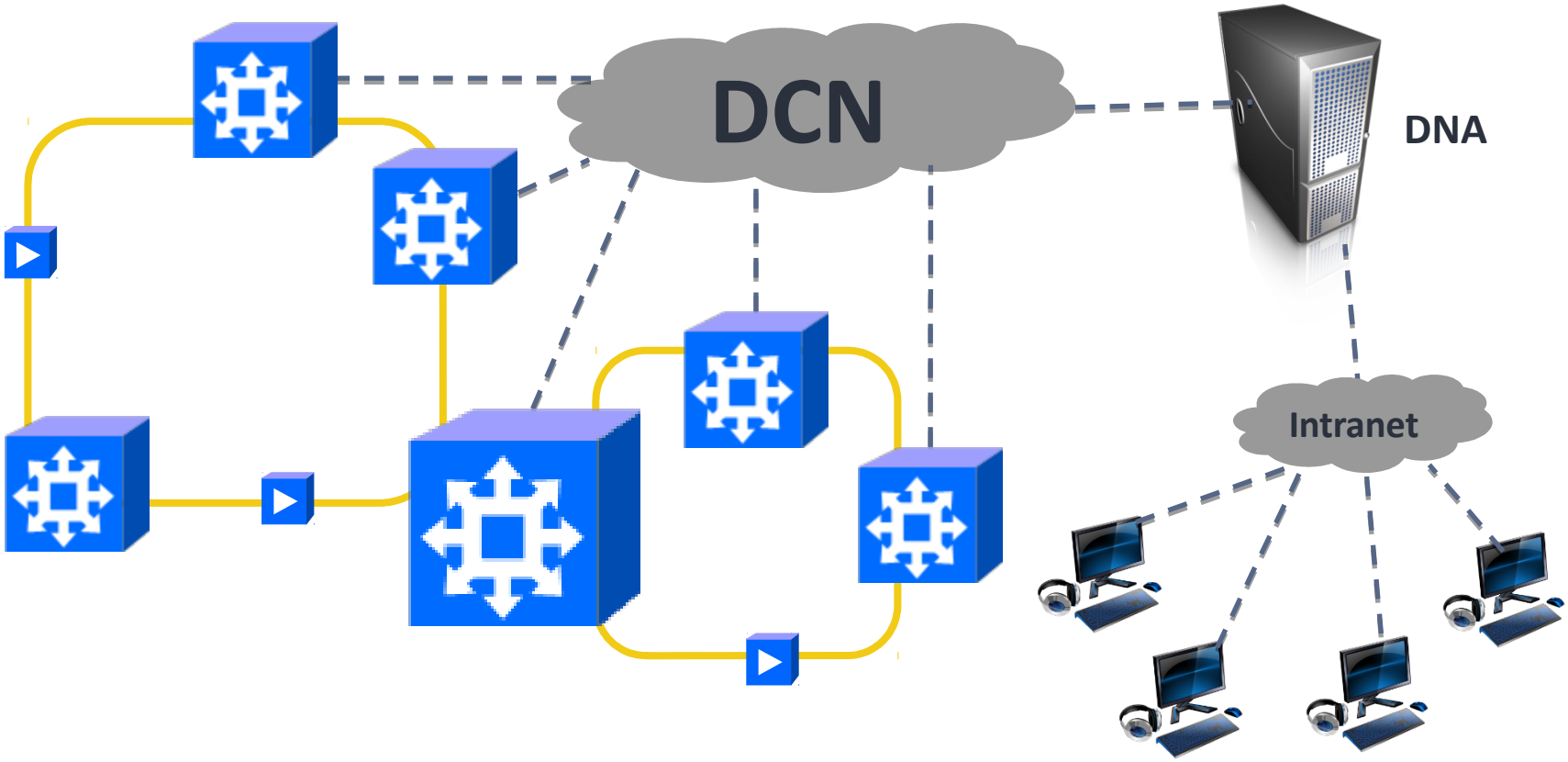
DCN Connectivity



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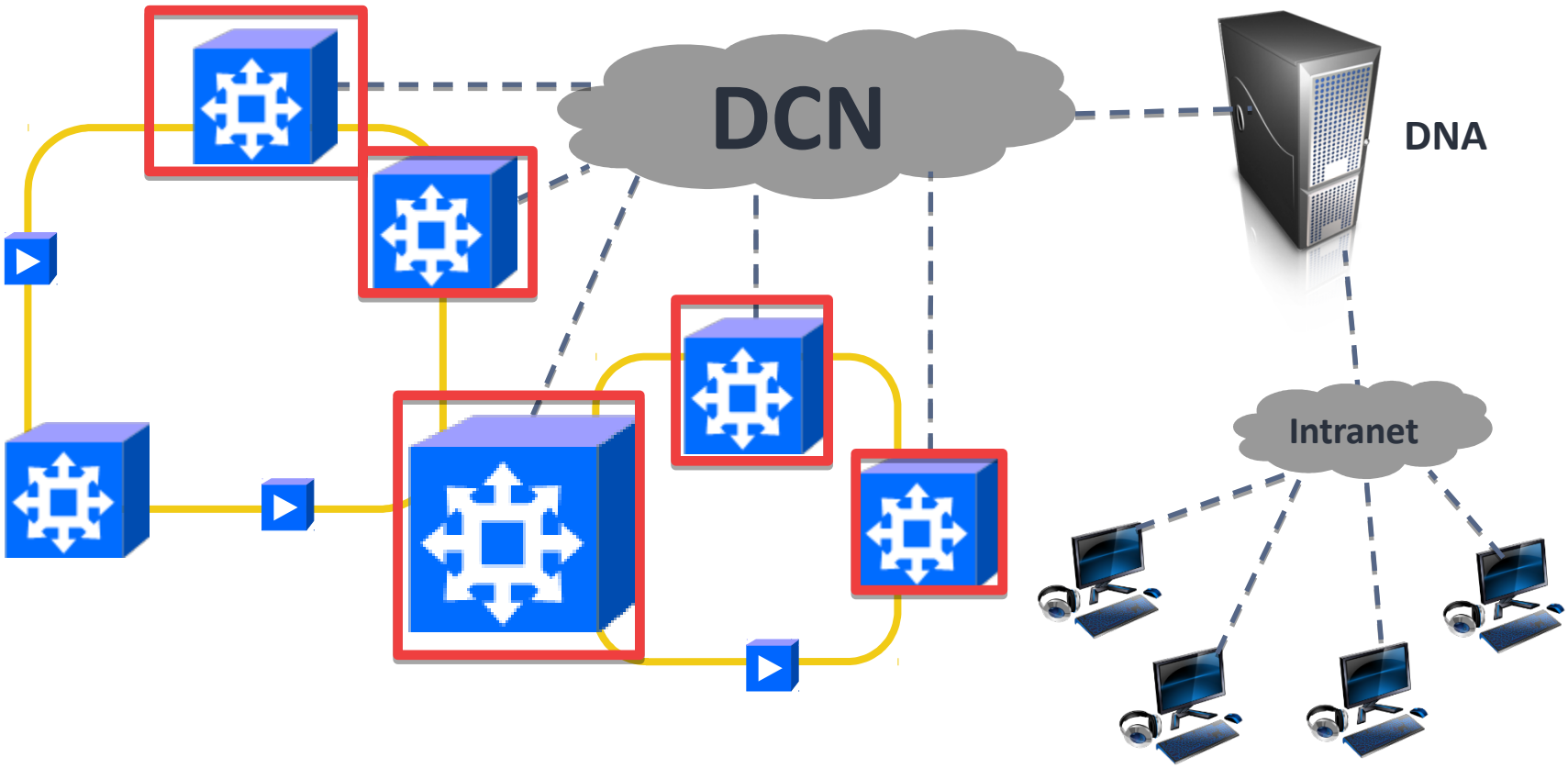
Gateway Network Element (GNE)



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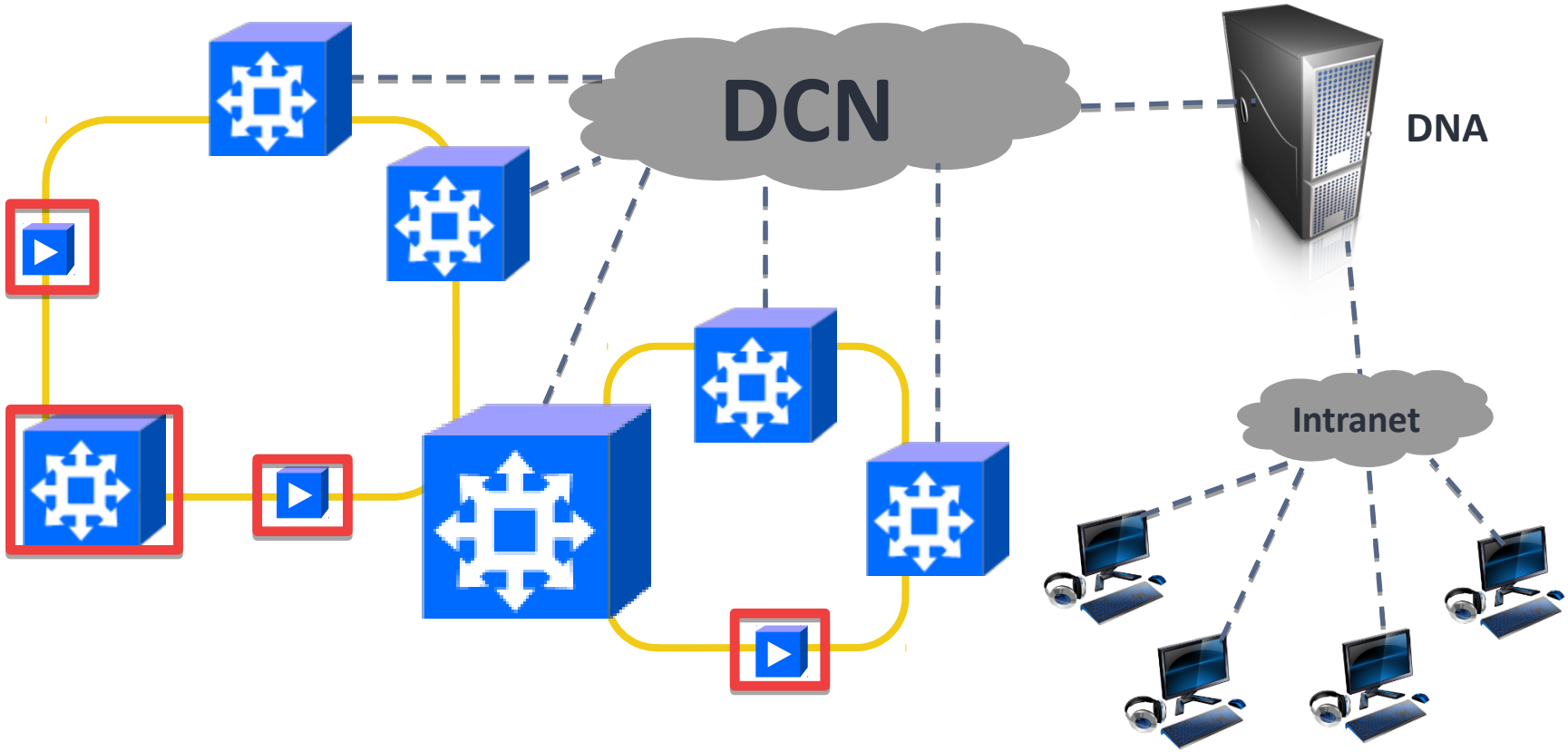
Subtending Network Element (SNE)



SNEs managed via OSC

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Optical Supervisory Channel (OSC)

- 1510nm
- OC-3 Ethernet Over Sonet (100mbps)
- OSC laser can be disabled
  - By changing admin state to lock
  - i.e. for fiber splicing

Automatic Laser Shutdown (ALS)

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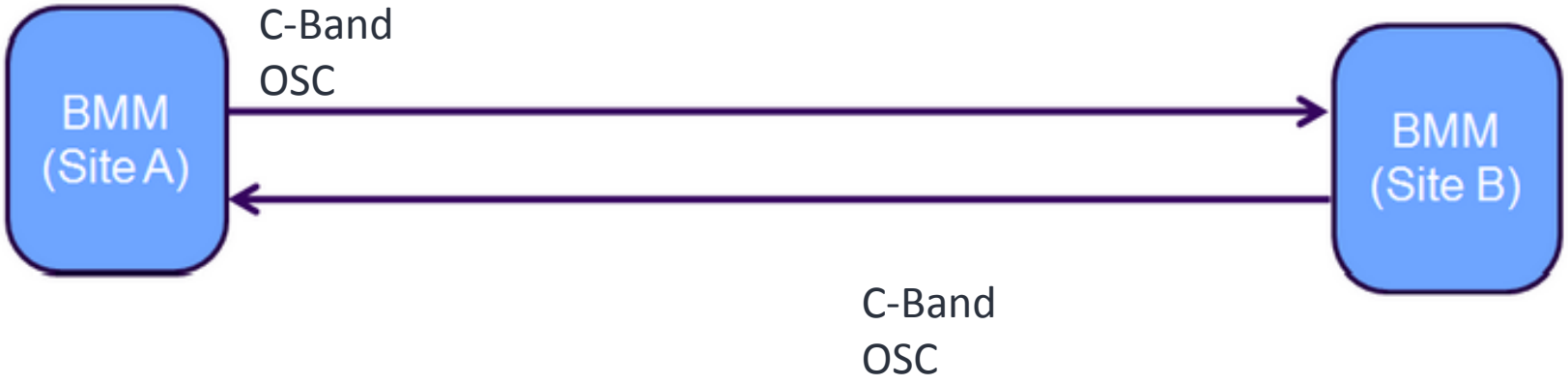
Automatic Laser Shutdown (ALS)

- All BMMs support ALS feature
  - Isolates and contains a fiber cut on a digital link
  - Shuts down C-Band in both directions
  - Can be disabled via management interface (not recommended)

BMM Automatic Laser Shutdown (ALS)



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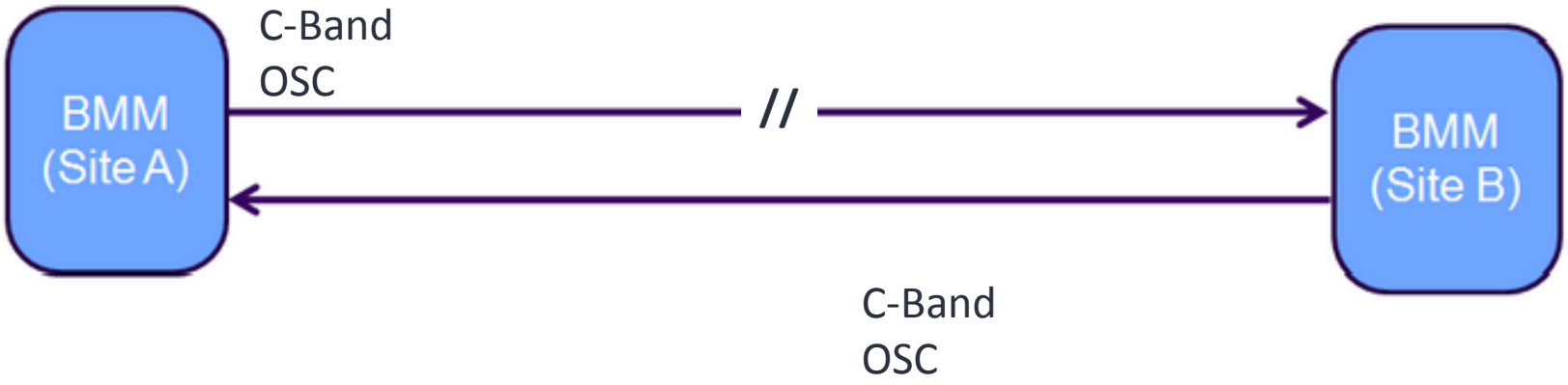
Span Connectivity Failure



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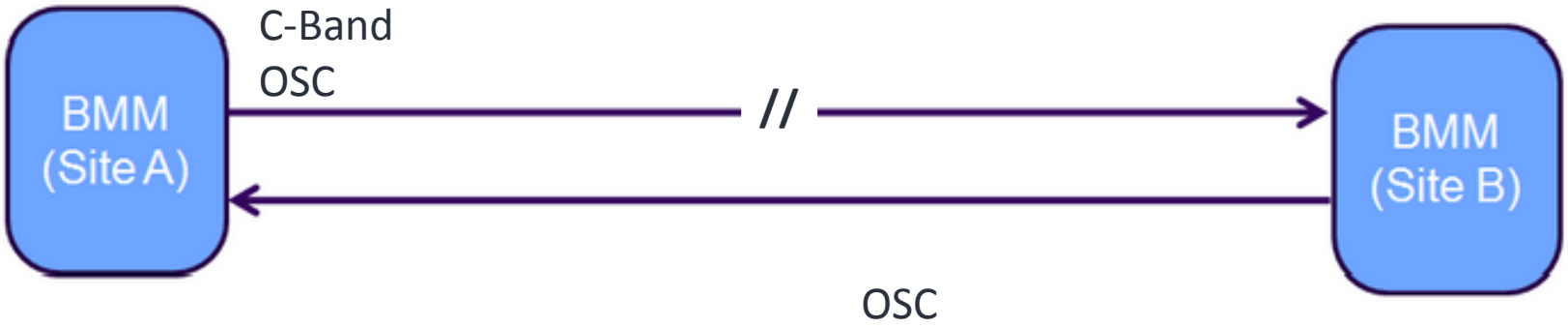
C-Band turned off



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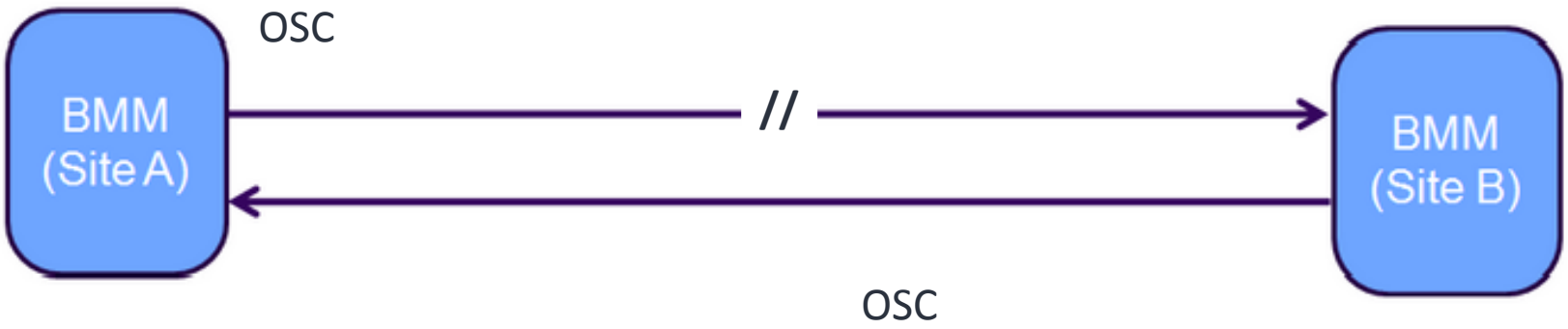
C-Band turned off



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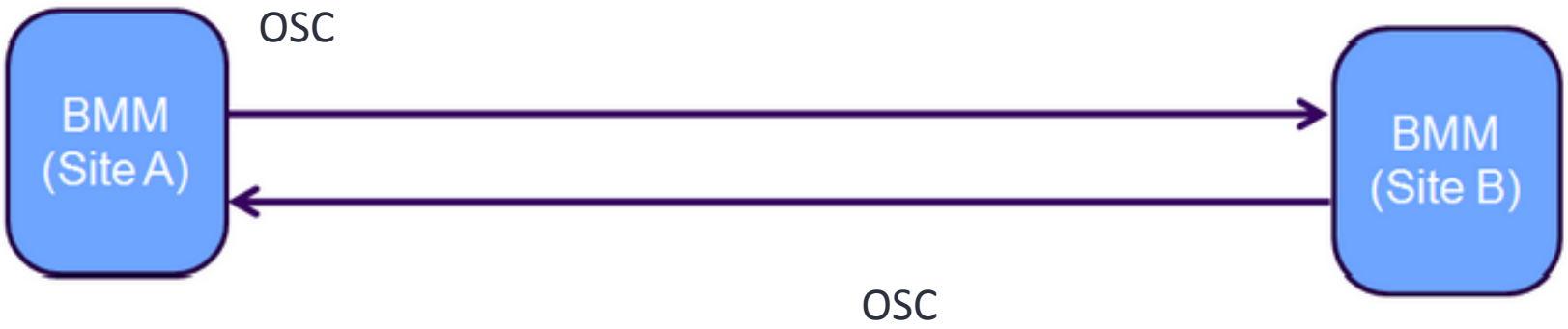
Span re-connected



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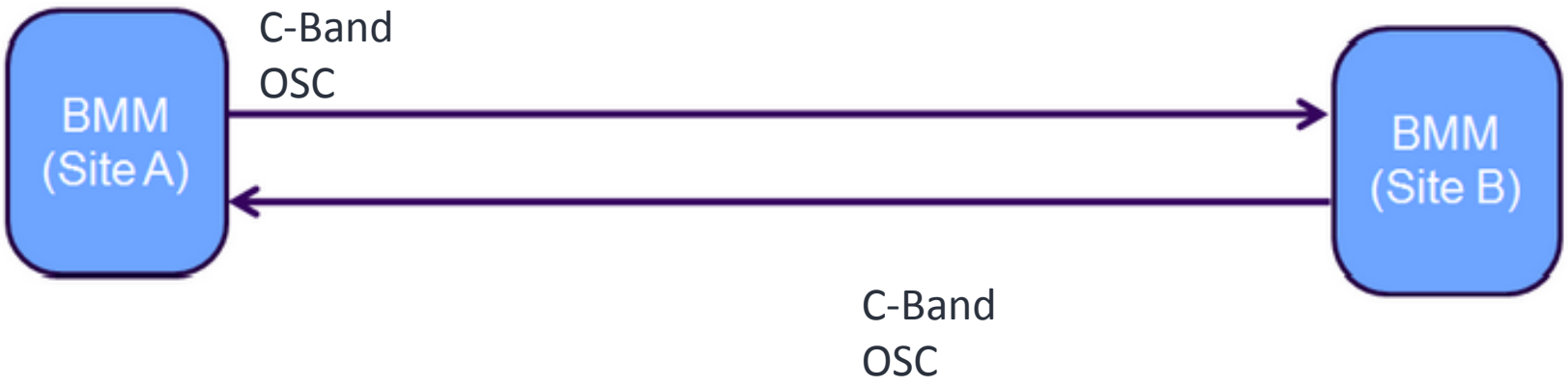
C-Band re-activate



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Protection Schemes

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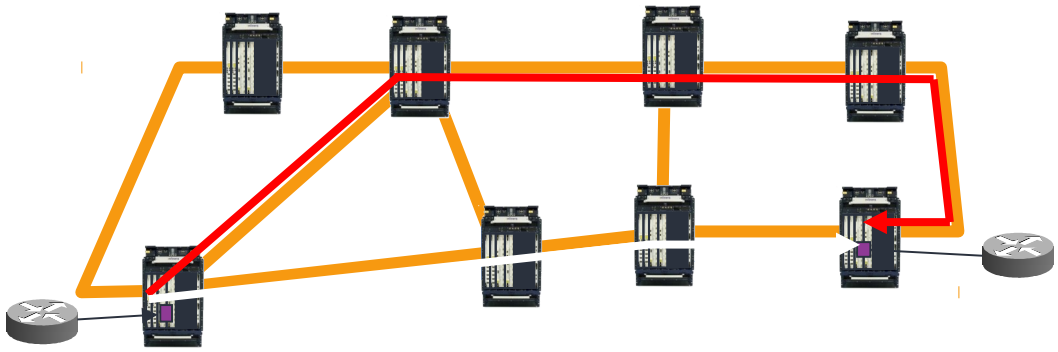
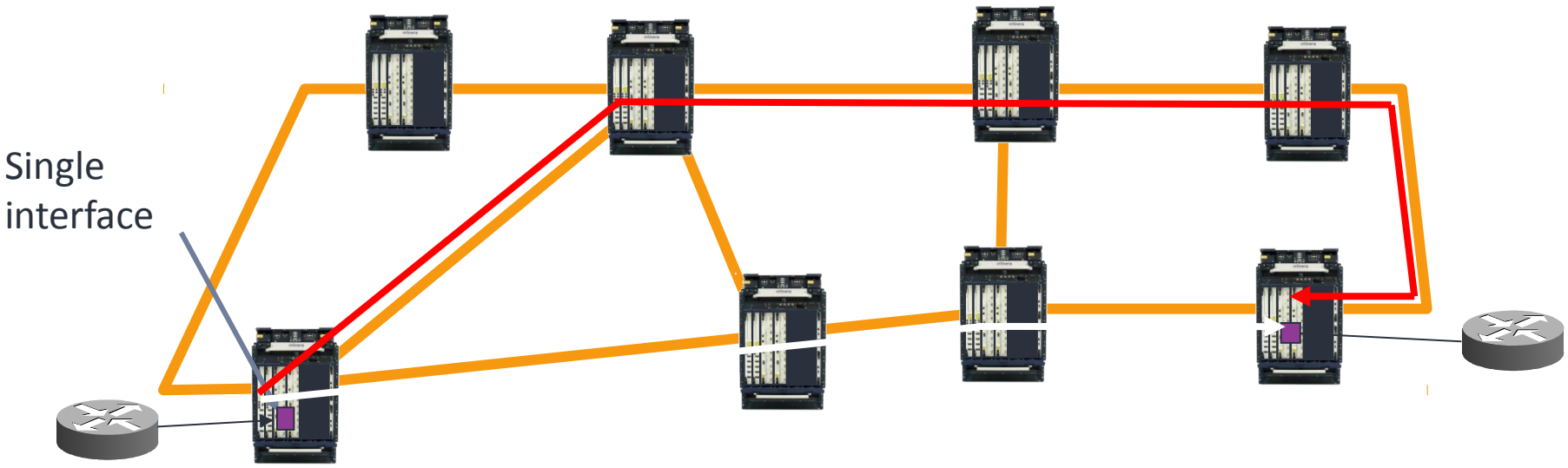
Service Types

- Unprotected
- 1 Port D-SNCP
- 2 Port D-SNCP
- Unidirectional
- GMPLS Restoration



D-SNCP: Digital Subnetwork Connection Protection

Dedicated Protection - 1 Port DSNCP Network View



- Protects digital paths against facility and BMM failures
  - Dedicated diverse 1+1 protection paths
  - Client equipment interfaces to 1 client port on the DTN (no client Y-cables)
- Enhanced Digital Wrapper monitors quality of signals
  - Both working and protect signals monitored
  - Switching based on SDH/SONET-style SF thresholds
- Can be Revertive or Nonrevertive

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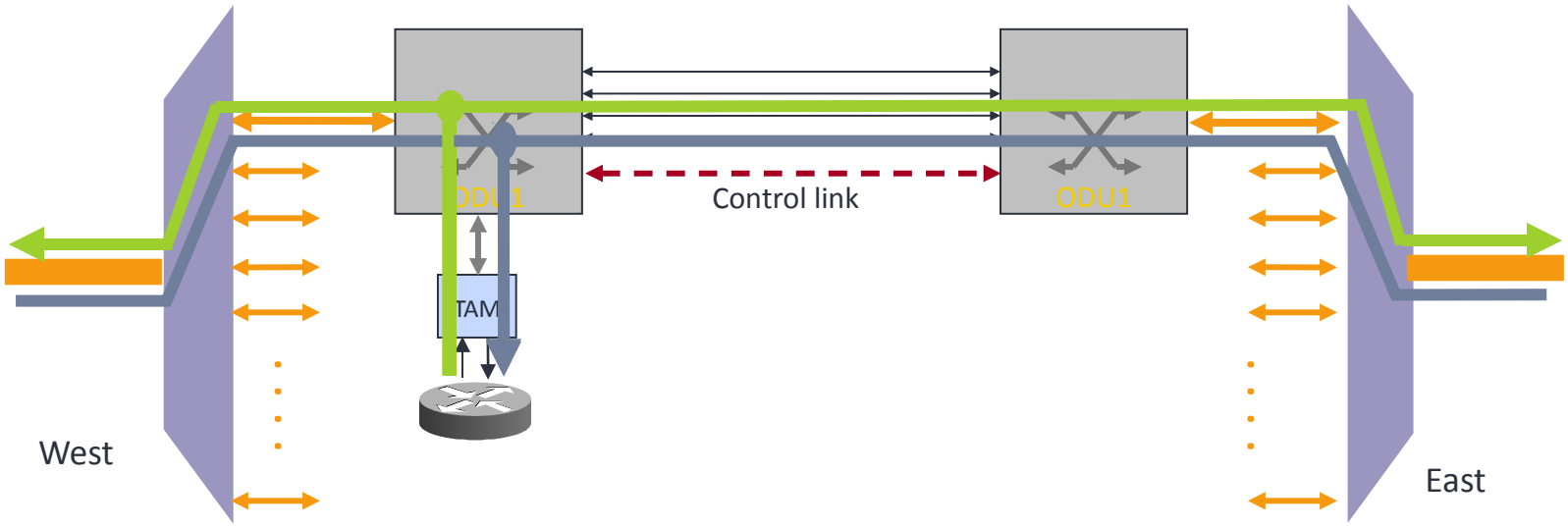
Dedicated Protection - 1 Port DSNCP

Node View



- Client signal transmitted on diverse paths to egress DTN
  - Client signal multicast electronically
- Manual and Lockout switching supported
- Supports both line & client side triggers
  - Trib & line-side failures (LOS/LOF)
  - Digital service failure (SF BER)

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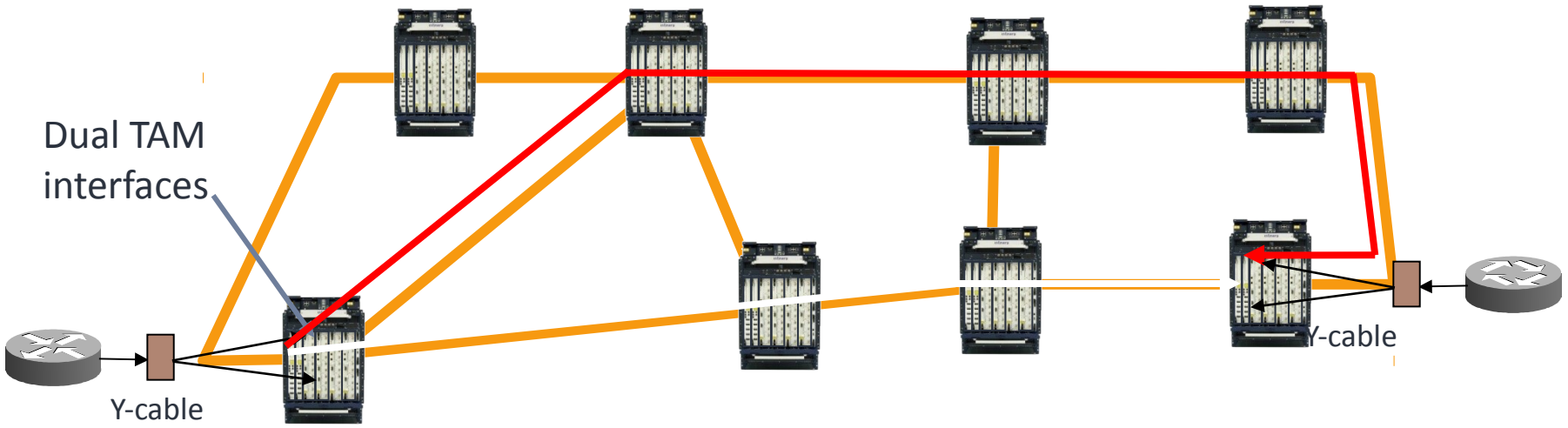
Dedicated Protection - 2 Port DSNCP

Network View



- Protects digital paths against equipment failures
  - Dedicated diverse 1+1 protection paths
  - Client equipment interfaces to 2 client ports on the DTN with Y-cables
- Enhanced Digital Wrapper monitors quality of signals
  - Both working and protect signals monitored
  - Switching based on SDH/SONET-style SF thresholds
- Can be Revertive or Nonrevertive
- 2 Port DSCNP can include auto restoration in addition to the 1+1 protection

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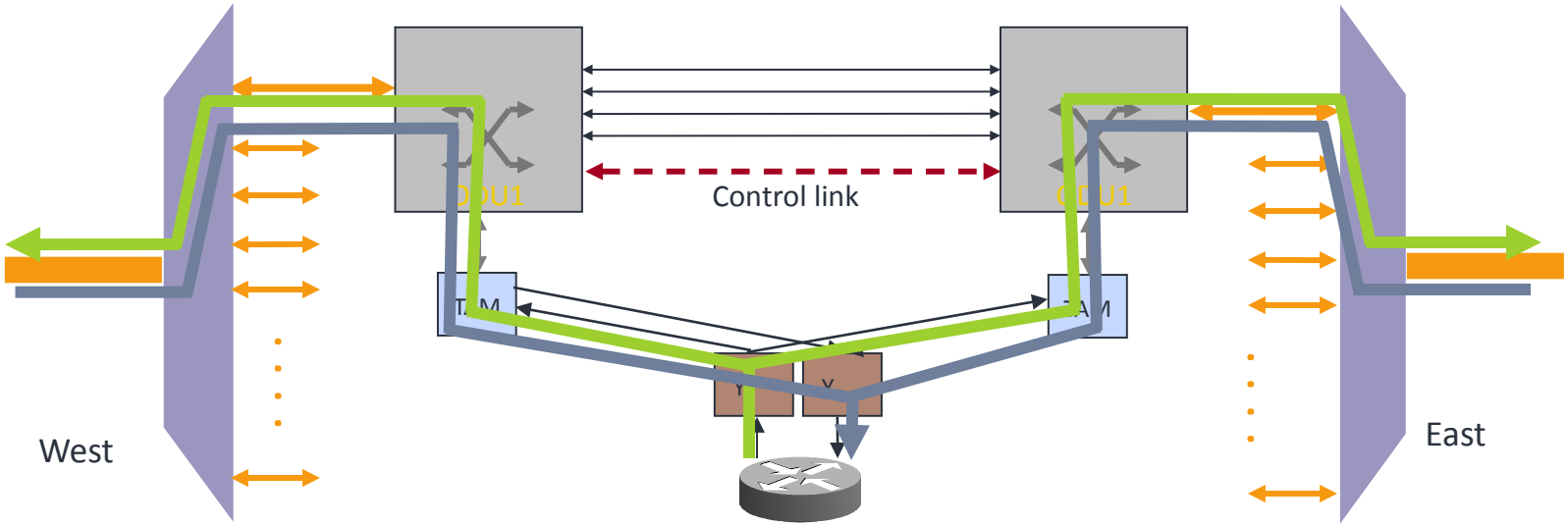
Dedicated Protection - 2 Port DSNCP

Node View



- Client signal transmitted on diverse paths to egress DTN
  - Client signal dual cast using Y-cable optical splitter
- Hardware control link between Line Modules at egress DTN coordinates TX to optical splitter
- Manual and Lockout switching supported
- Supports both line & client side switching triggers
  - Trib & line-side failures (LOS/LOF)
  - Digital service failure (SF BER)

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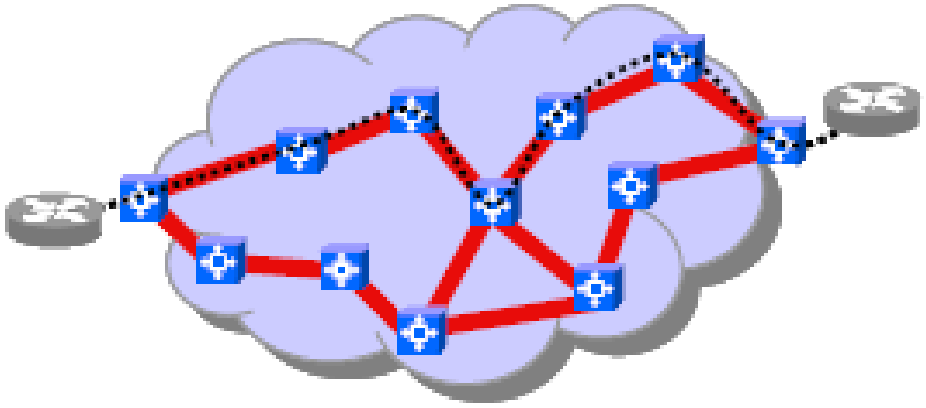
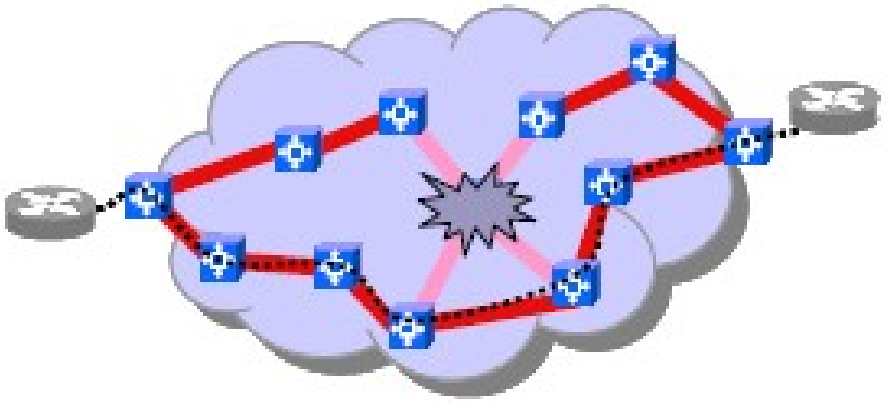
GMPLS Restoration

Dynamic GMPLS Circuit Restoration

- Topologies Supported
  - Linear
  - Ring
  - Mesh
- Restoration activity
  - Determines alternate path bandwidth availability
  - Reroutes SNCs utilizing available bandwidth
  - Preferred restoration path can be provisioned
- Can be Revertive or Nonrevertive

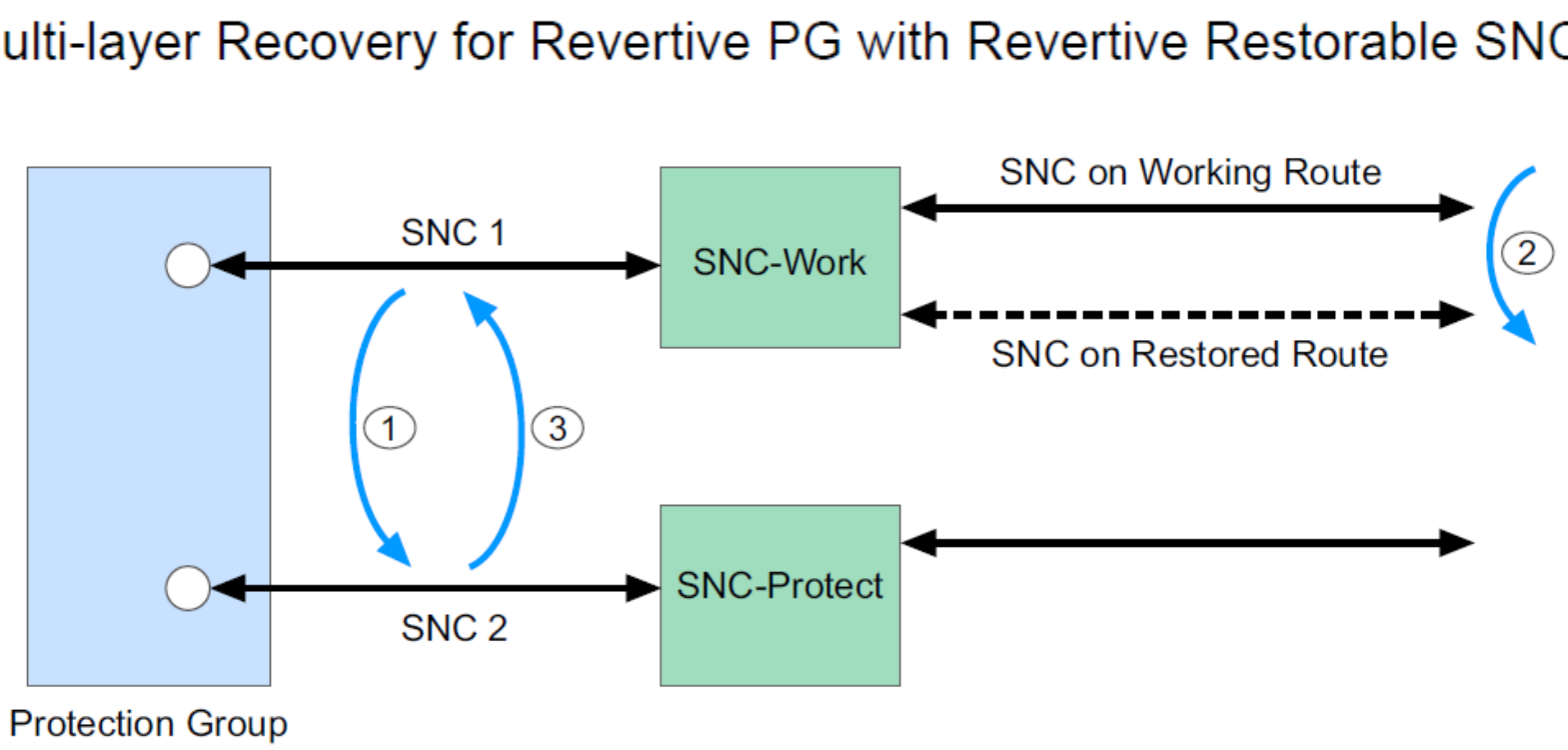


Data Path Before Network Outage



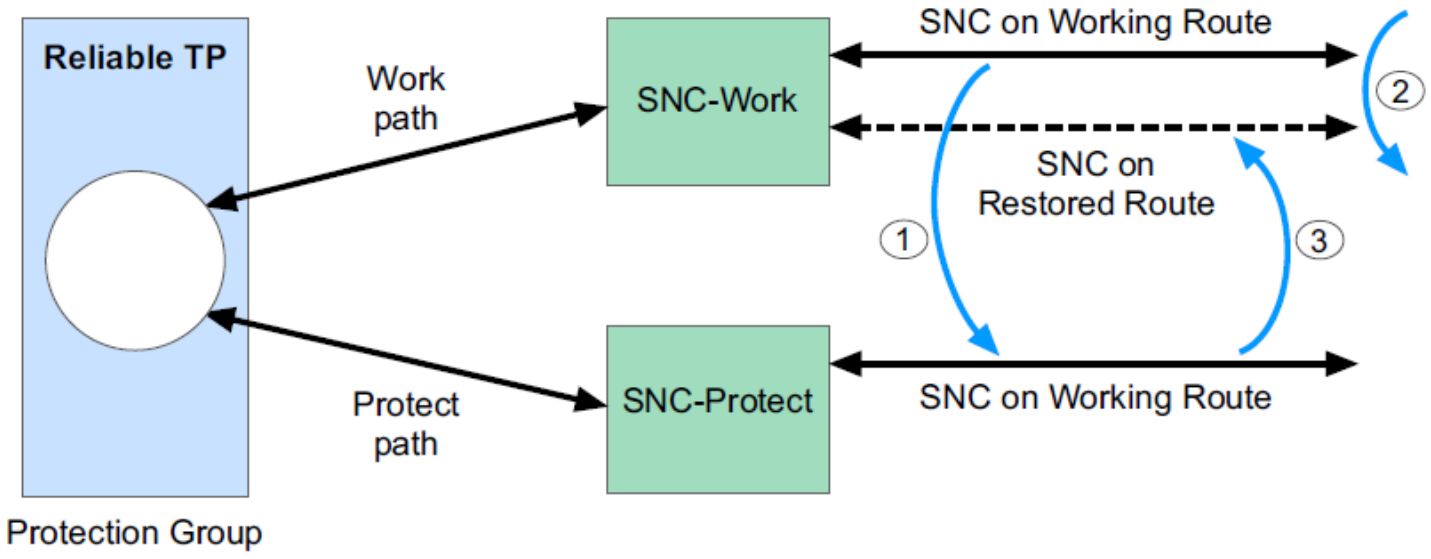
Rerouted path on Outage

Multi-Layer Recovery (MLR)

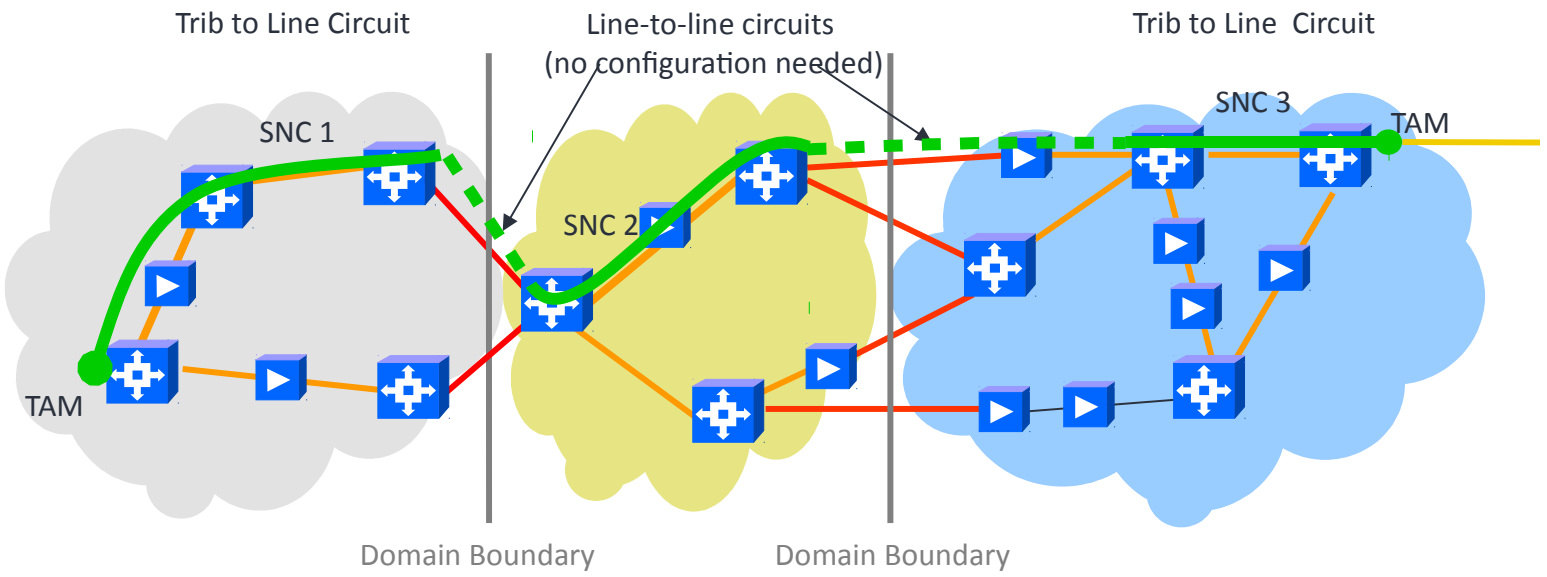


Multi-Layer Recovery (MLR)

- D-SNCP and GMPLS restoration (DTN only)
  - 1P or 2P D-SNCP combined with GMPLS restoration
  - Fault causes Protection path to become active
  - Working path then restores itself
  - If Protection path fails then Working becomes active on restored path
  - All switches are sub 50 ms



Line terminating circuits



- Circuits can be configured with line-side endpoints
  - Trib to Line
  - Line to Line
- Enables the user to create a circuit across GMPLS domains
- A Line Module must be configured for line-side termination (must be done in the software)

FastSMP™

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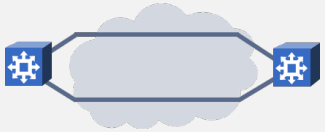
Infinera's FastSMP™

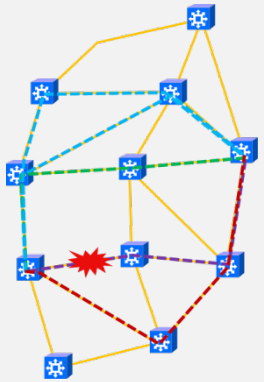
Traditional Optical Protection



1+1 SNCP Protection

- <50 ms switching
- Dedicated protection bandwidth ($$$$)
- Protection for 1 failure

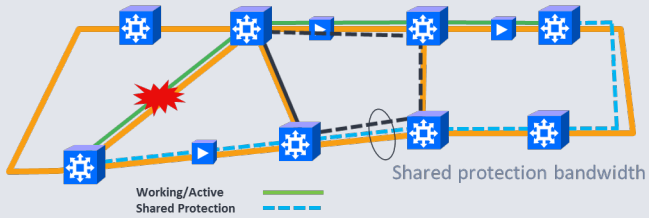
Dynamic Re-routing (circa 2000)



GMPLS Restoration & MPLS FRR

- Dynamic recovery based on available bandwidth
  - Less network cost
- Multiple failure protection
- Variable performance

Infinera's FastSMP™



Provides the advantages of all existing recovery mechanisms

- Hardware assisted sub-50 ms protection switching
- Shared protection bandwidth
  - Better network economics
- Multiple failure protection
- Enables reduction of expensive router ports

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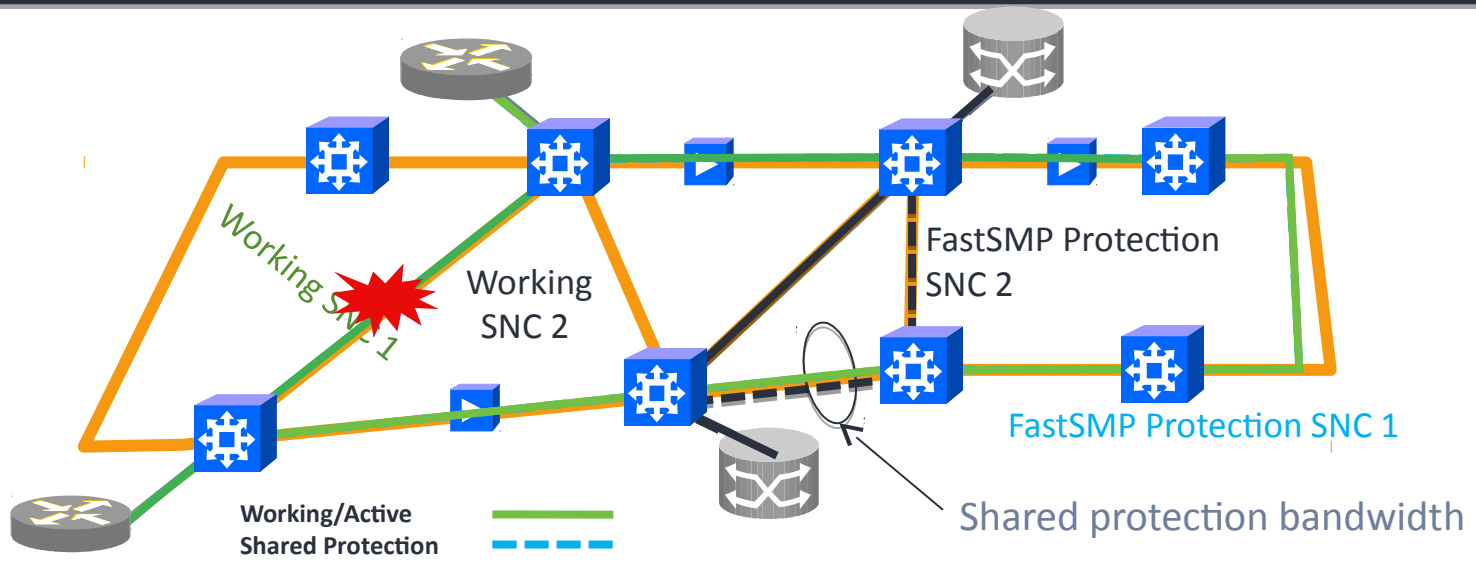
FastSMP™: Shared Protection for a Single Failure



- Logical protection paths
  - Not provisioned, so doesn't actually use resources
  - Planned using reserved protection bandwidth in network
- Up to 10 services can use the same protection resources
  - Disjoint services so that only one affected by the same failure
- Enables up to sizeable reduction in protection resources

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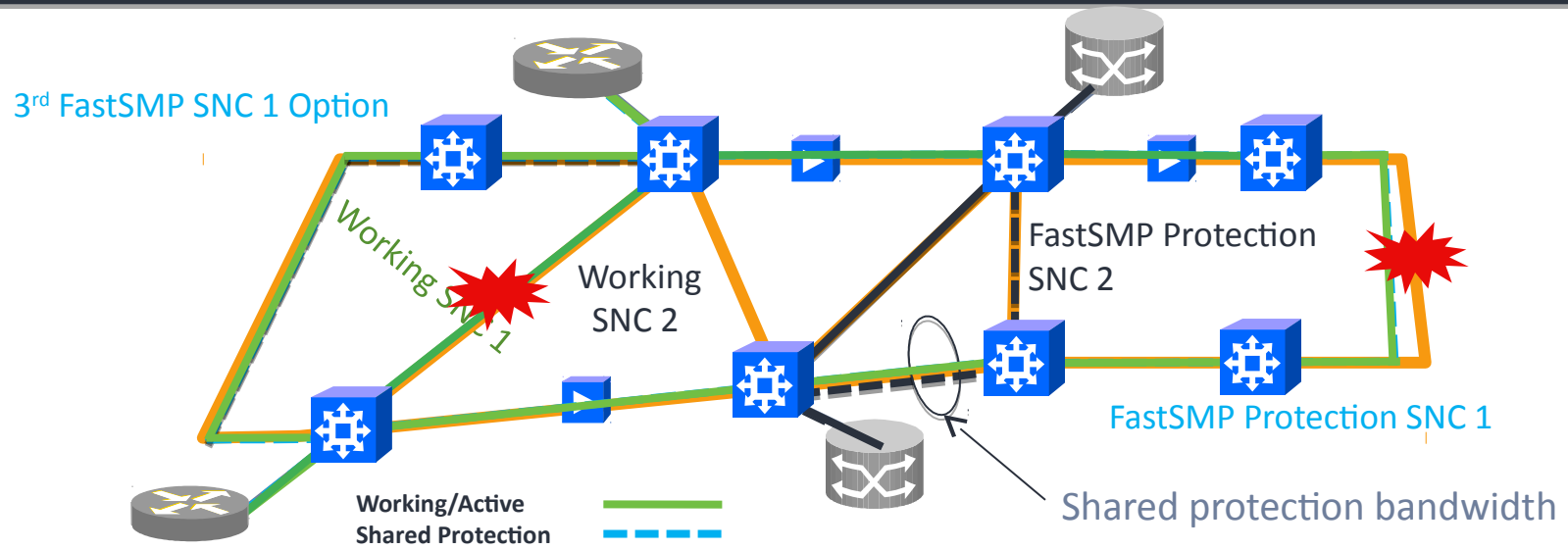
FastSMP™: Multiple Failures



- Services can be protected with multiple logical protections paths
- More options for recovering a service
- Protects against multiple failures

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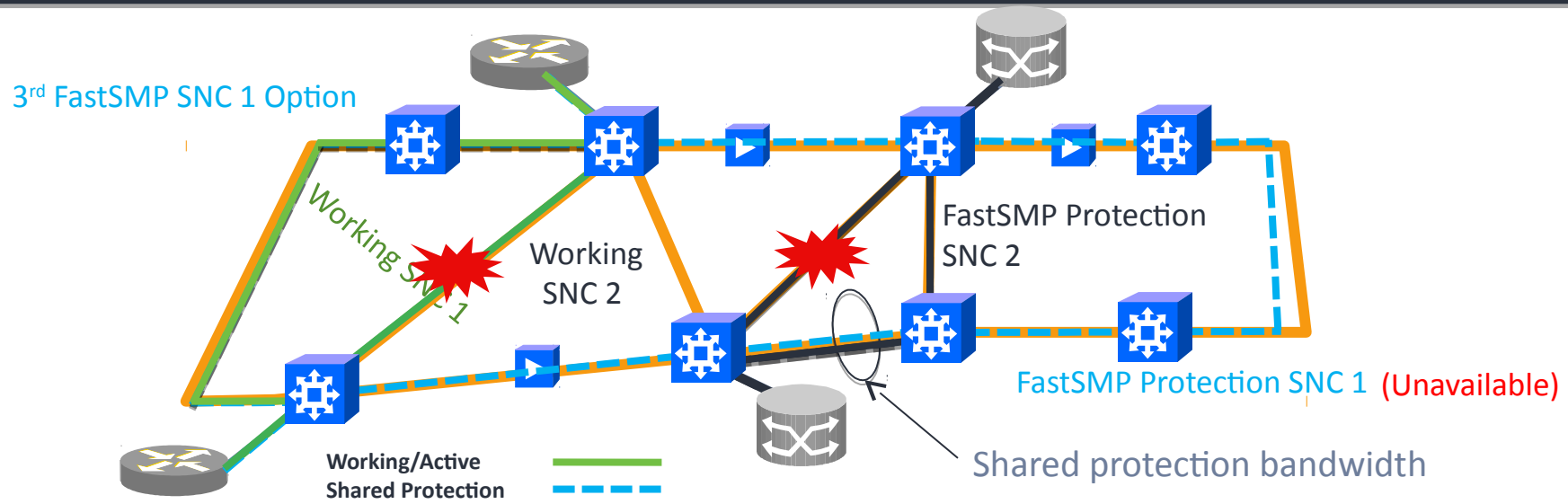
FastSMP™: Topology Updates



- After a failure and protection switch occurs, updated network topology is distributed
  - Failed and used resources are signaled to other nodes as unavailable/used
- Logical protection paths using these resources are marked as unavailable
- When another failure occurs, other logical protection paths are used

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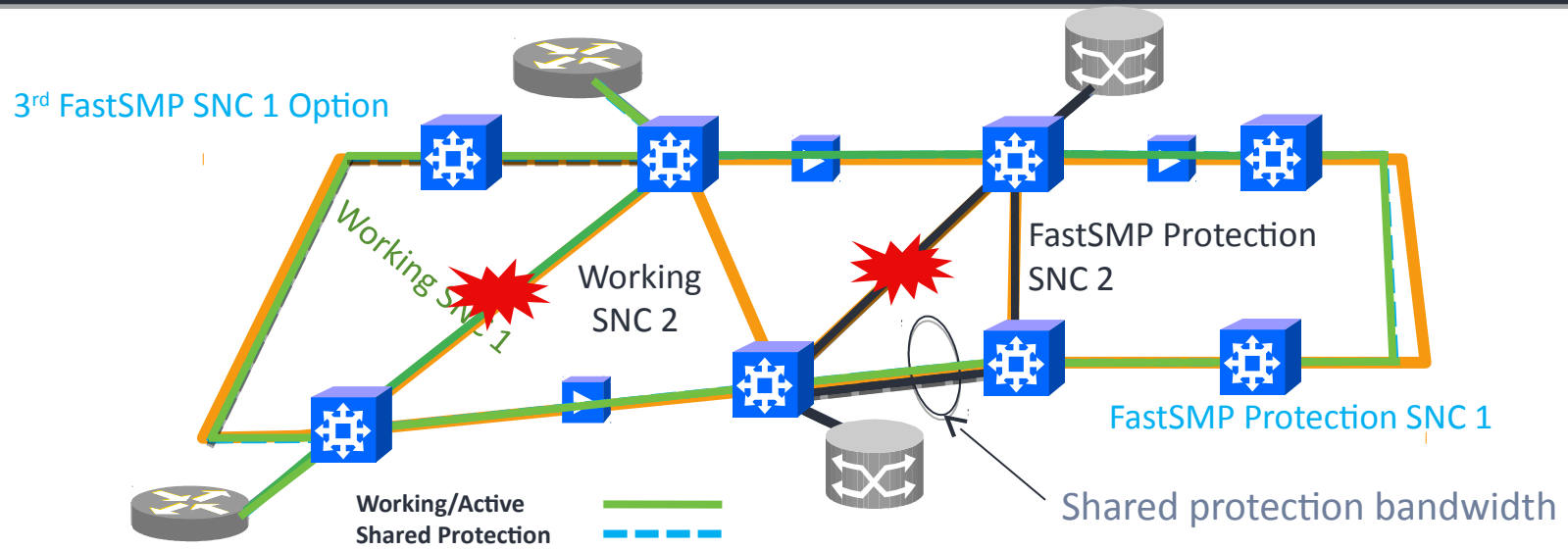
FastSMP™: Priority & Preemption



Preemption example: SNC 2 higher priority than SNC 1

Priority

- FastSMP supports SNC prioritization
- Higher priority SNCs utilize protection resources before lower priority SNCs

Preemption

- Higher priority SNCs preempt lower priority SNC
- High priority get the resources to protect service
- Lower priority SNCs lose the resources

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Licensing

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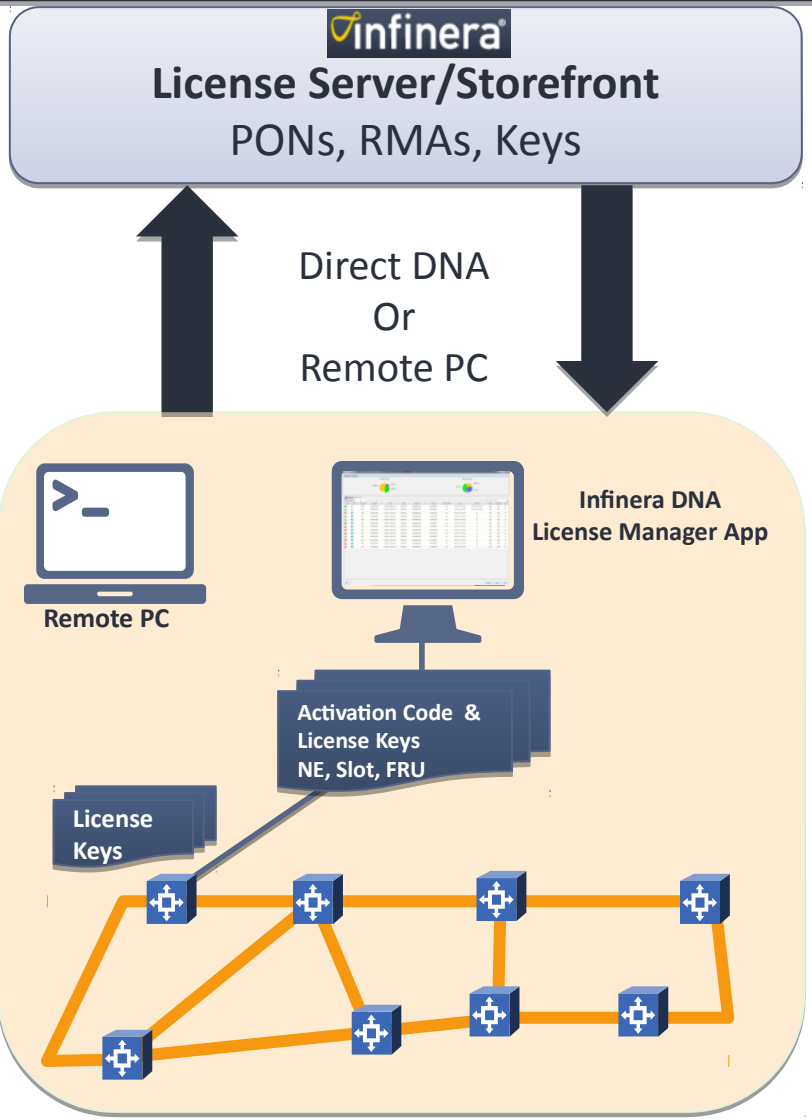
License Management Architecture



- License Server
  - Centralized license key management
  - Inventory, availability
  - Offline connection to DNA
  - High availability & secure access
- DNA – License Manager App
  - License Management & Licensing Rules
  - Activation, Move, Spare & Distribution
  - License mismatch resolution
  - License Inventory
- Network Element
  - License Enforcement, Alarms
  - Licensing Rules

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Objectives

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Objectives review

Upon successful completion of all of the modules contained in this course, the student should be able to describe:

- Optical Transport Networking Fundamentals
  - Optical Channel Payload Unit (OPU)
  - Optical Channel Data Unit (ODU)
  - Optical Channel Transport Unit (OTU)
  - OTN Hierarchy – ODU0, ODU1, ODU2, ODU3, ODU4)
- Photonic Integrated Chip (PIC) functions and benefits
- DTN/DTN-X Node Configurations
- DTN/DTN-X Signal Flow
  - Switching, Line coding (BPSK, QPSK), SD-FEC
- OTxM Configurations
- AOFx-100 Channel Plans and Muxing plans
- Packet Switching Module (PXM)
- FlexILS
- Management
  - OSC, ALS, Protection schemes, licensing