IPoDWDM

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Agenda

- IPoDWDM Architecture
- Advanced IPoDWDM Features
- IPoDWDM Management
- 40G/100G Design Considerations
  - Optical Impairments
  - Modulation Schemes
- 40G/100G Deployment considerations in 10G Optical networks
- Case Study
- 100G - where we are today?
- Summary

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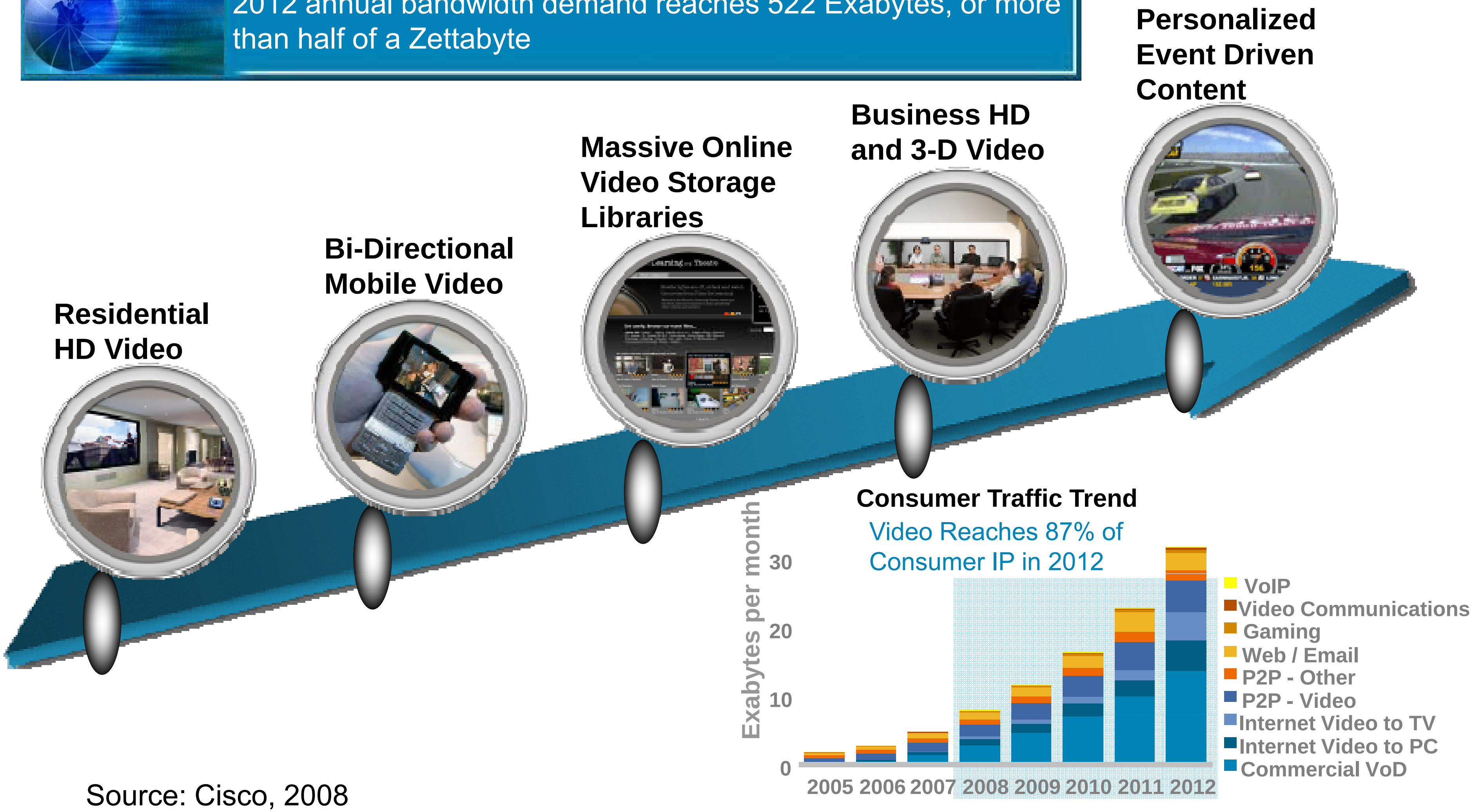
IPoDWDM Architecture

Network Focus: Increasingly Bandwidth Intensive and Complex

44 Exabytes per month **Total Traffic** by 2012

2012 annual bandwidth demand reaches 522 Exabytes, or more than half of a Zettabyte



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Traffic Trend

- Services converging on IP
  - Peer to peer
  - Carrier built broadcast and VoD
  - Over the top providers
  - Video conferencing
  - High impact data movement
- Traffic is no longer predictable
  - Flash crowds
- Requires advanced protection mechanism
  - Must meet stringent SLAs
- Reduced revenue per bit
  - Everyone wants more and more bandwidth, but not willing to pay more and more

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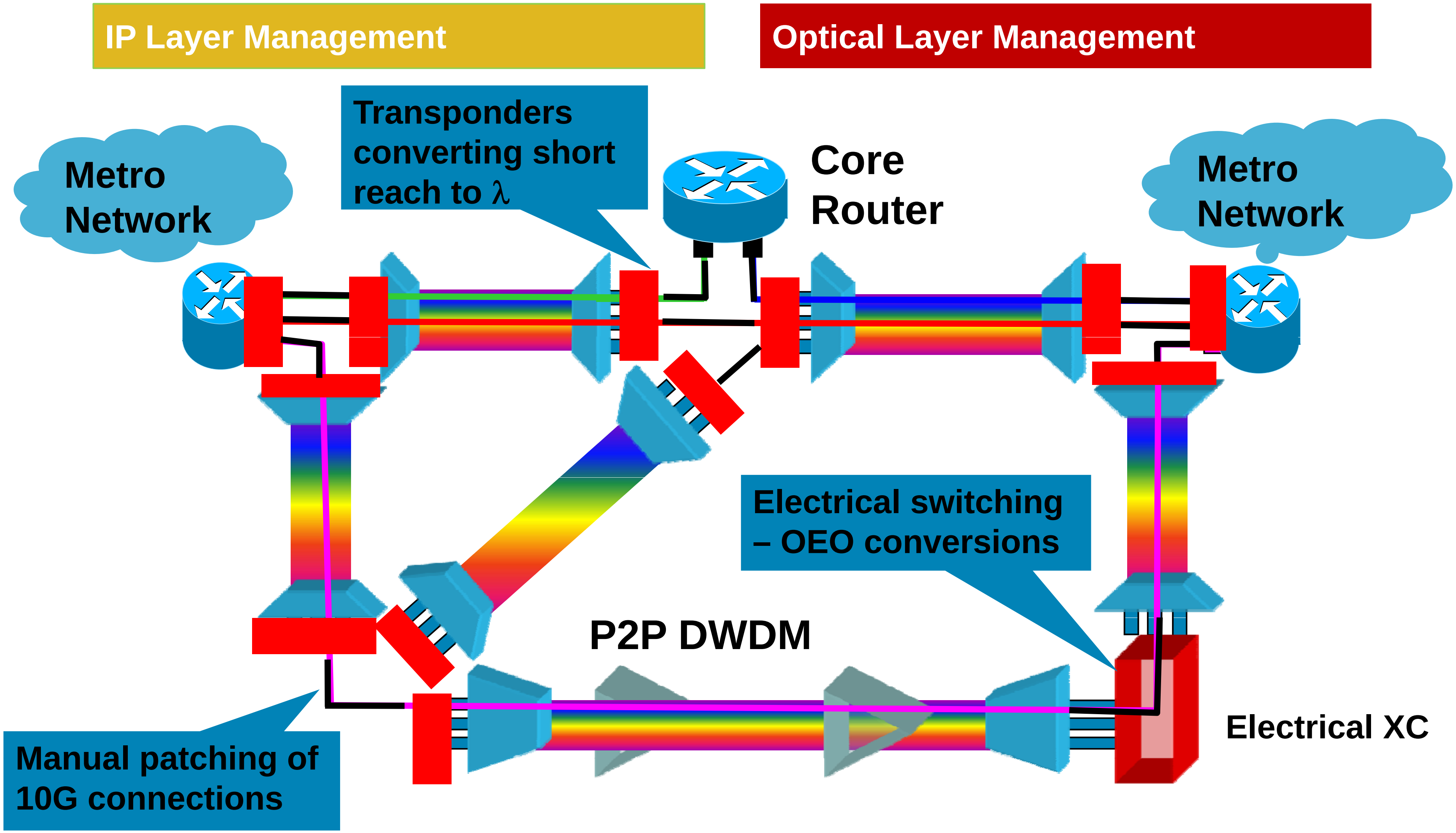
Today's IP Network + Optical Network



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Where Does This Take Us?

- **Higher bandwidths** are needed to address this growth:
  - **10 Gig Networks** beginning to feel the **strain**
    - Cannot rely on L2/L3 aggregation: **LAG 4 X 10G ≠ 40G**
    - Cannot rely on L1 aggregation: DWDM ports are not unlimited
  - **Increase wavelength** capacity as soon as viable:
    - Move to higher data rates per lambda, i.e. 40G and 100G
    - But must operate over existing infrastructure
    - And ideally with equivalent performance to 10G
    - Requires advanced optical modulation schemes
- **Remove** all unnecessary network layers leaving only:
  - **Service layer (IP)**
  - **Transport layer (DWDM)**
- **Integrate** DWDM technology on Router: IPoDWDM

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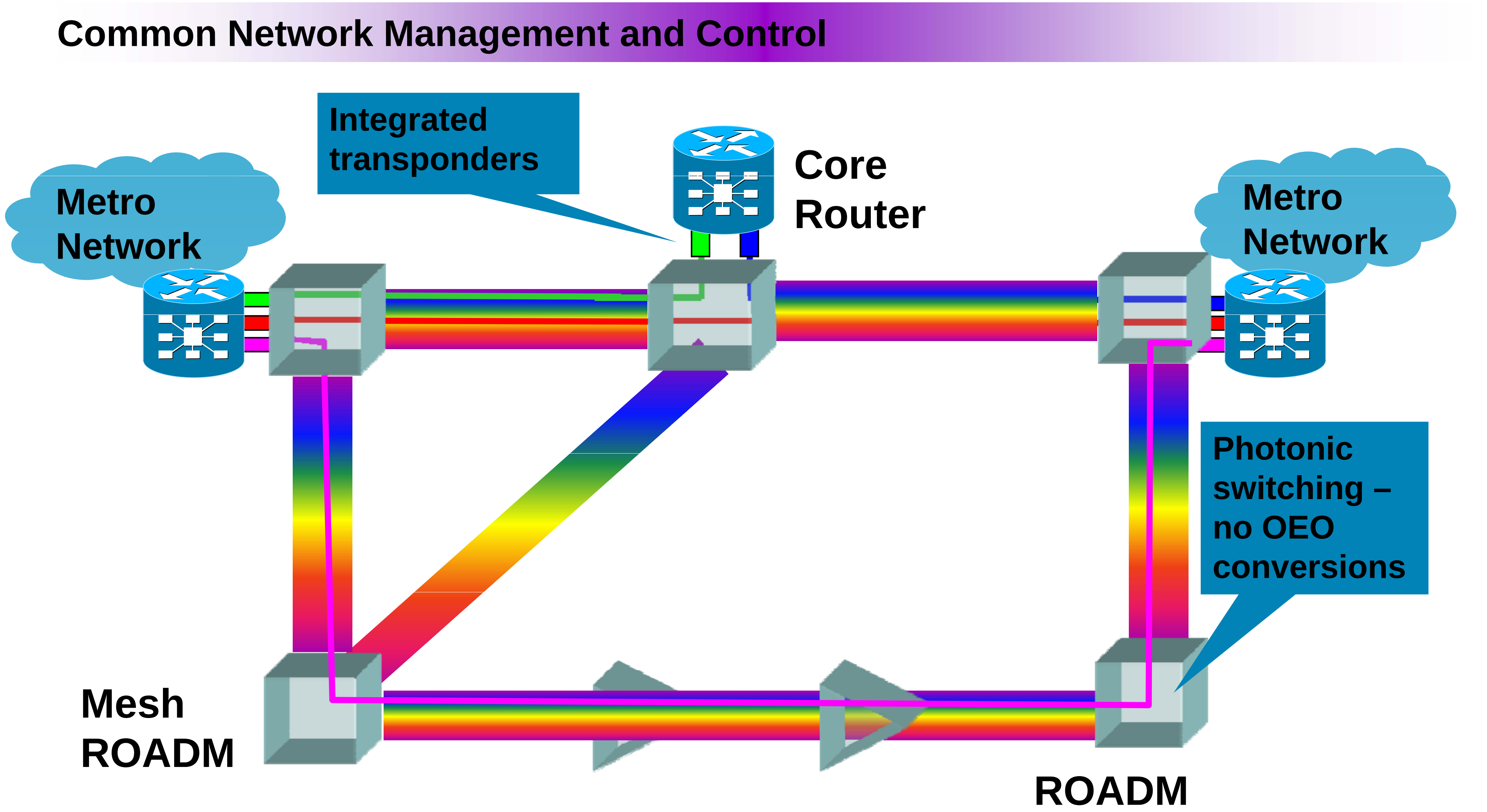
New Cisco IPoDWDM Architecture



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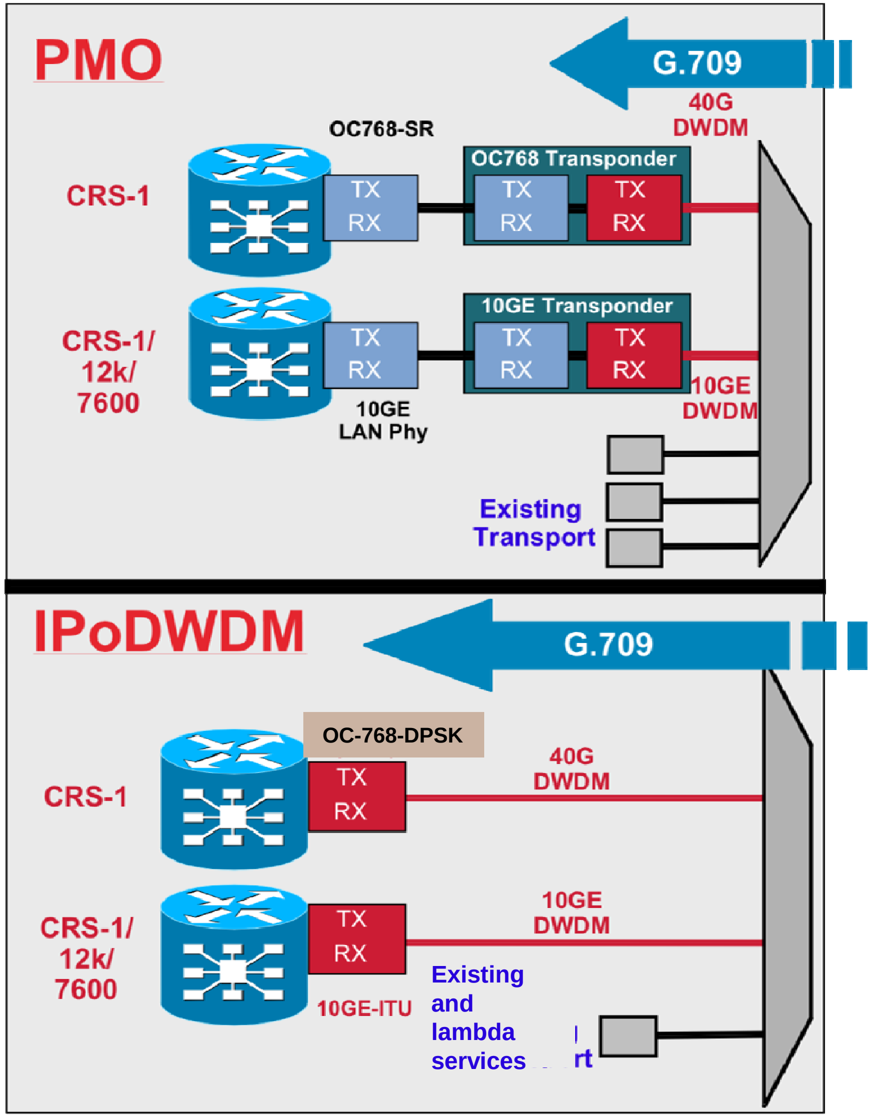
Cisco IPoDWDM Benefits

- 1/3 the number of Opto Electronic Components
- Less common cards
- ½ the number of patch cables
  - Less operational issues at turn up
- Less Shelves
- Less Racks
  - Less Real Estate
  - Less COLOC fees
- Less Power
  - Reduced Power costs
  - No new Power plant requirements
- G.709 terminates on router
  - L1 awareness
  - Enhanced troubleshooting features
  - Enhanced protection features
- 40 Gbps over optical network designed for 10Gbps
  - Additional bandwidth with no network outages
  - Upgrade/Add one lambda at a time
- Leverage current CRS-1 network



Present Mode of Operations vs. IPoDWDM Architecture

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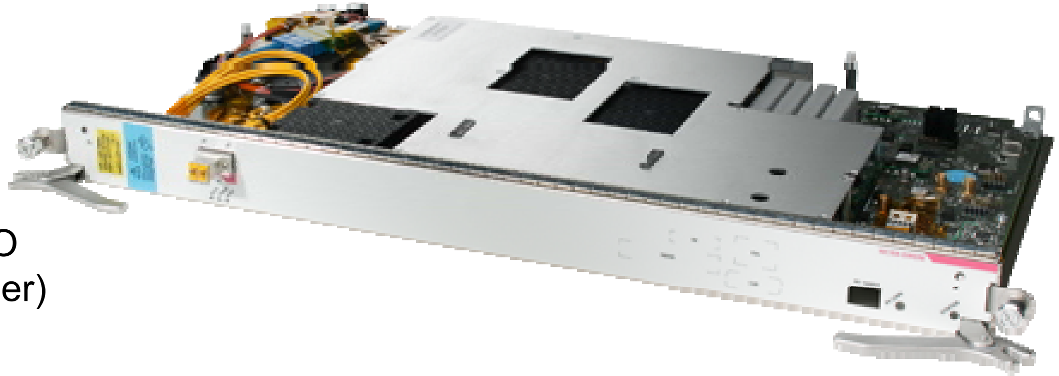
OC-768 DWDM PLIM on the CRS-1



Chassis Support:
All CRS chassis

Hardware:
OC768-DPSK/C and 1OC768-DPSK/C-O
CRS-MSC-40G-B (requires 3.6.x or higher)

General Feature Support:
All features supported on the OC768 PLIM

- 89 configurable wavelengths on OC768-DPSK and OC768-DPSK/C-O combined
- Must run G.709 and E.FEC (on by default)
- Performance Monitoring over time (15 min or 24 hours)
- Alarm and Transceiver Monitoring
- Loopback Line and Loopback Internal for troubleshooting support
- Compatible with 10GigE DWDM systems
- Open Architecture

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An Open DWDM Layer – not as Hard as it Seems…

- Public references:
  - MSTP
  - Nortel CPL
  - Ciena CoreStream
  - Alcatel
  - Padtec
  - Lucent OLS400
  - Siemens SURPASS hiT7550
  - Tellabs TITAN 7100
- Other trials:
  - Fuji
  - Huawei
  - Ericsson MHL-3000

Not a technical issue – a political one

CENIC, USA

Netia, Poland

eThekwini, South Africa

Qatar Foundation

Kuwait Information Network

TENET, South Africa

Bulgarian Telecommunication Company

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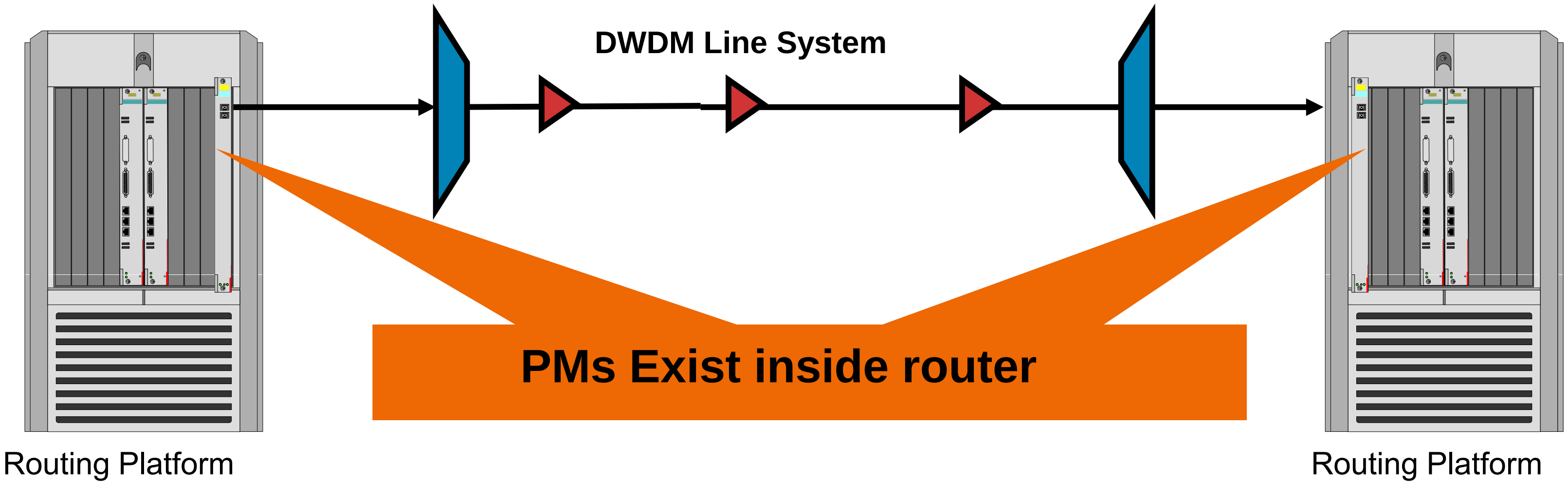
IPoDWDM Architecture Advantages



With IPoDWDM, The Routing Layer Is Now Aware of Optical Layer Performance

- Optical PMs Exist in Router
- G.709 PMs Exist in Router

Giving way to Advanced Features

IPoDWDM is an Architecture built around optimizing the network and providing CAP and OP Ex reductions and simplifications

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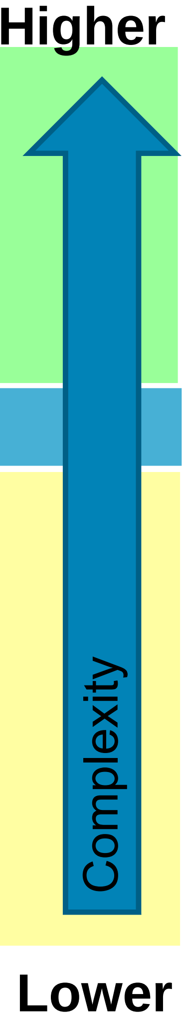
Advanced IPoDWDM Features

Advanced IPoDWDM Features

- Combined Restoration/Optimization
- Optical Auto BW
- CLI driven Optical BW
- Colorless, Omni-Directional and Advanced DWDM Control Plane
- Shared Risk Link Groups – L0 to L3
- Coordinated Maintenance
- LMP and Alarm Correlation
- Proactive Protection



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Advanced IPoDWDM Features
- Proactive Protection

Proactive Protection

- Measures the Bit Error Rate at the receiver before the Forward Error Correcting code (FEC) is applied
- When a user-defined threshold is crossed, an indication is sent upstream
- Head-end then triggers re-convergence
- This will protect against the most common failure modes in DWDM networks with near-zero packet loss.
- Can not be achieved with any other technology but IPoDWDM

Why can we do this?

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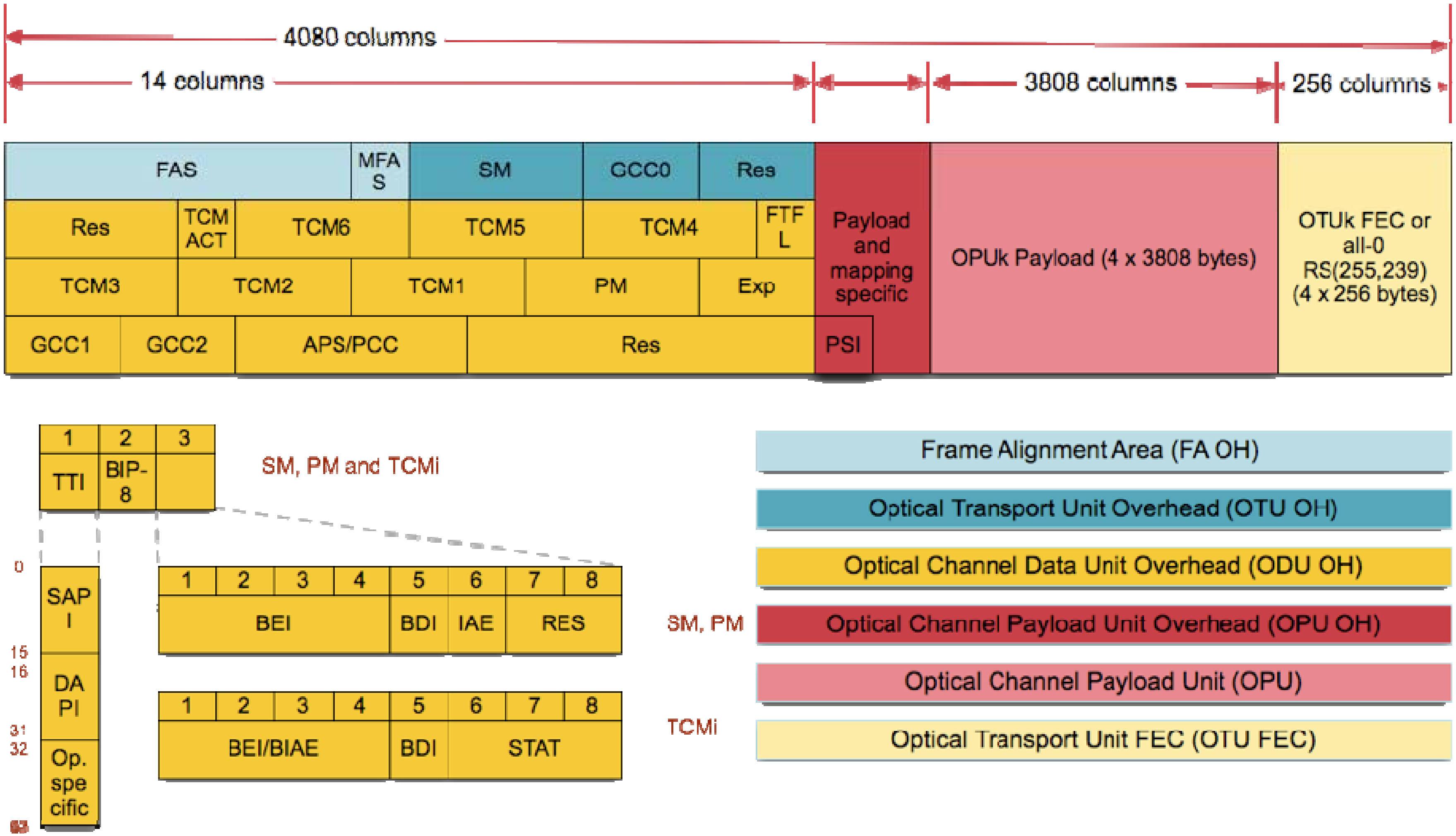
Structure of Optical Transport Unit (OTU) Per ITU-T G.709



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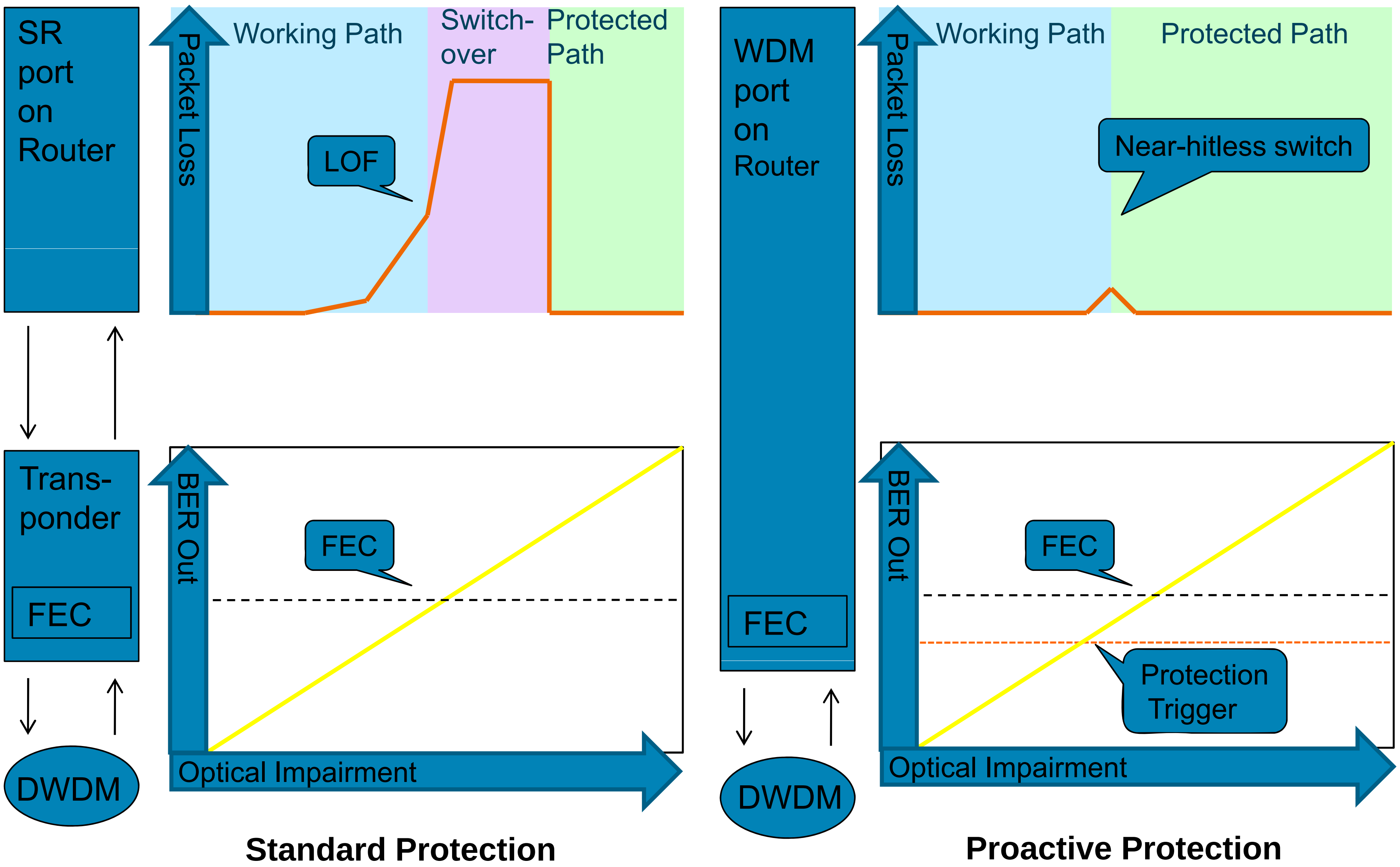
Standard vs. Proactive Protection



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Maintenance mode for DWDM interface

- Proactive protection is also used to switch traffic away due to a maintenance activity
- When the state of a DWDM port is put in out of service – maint (OOS-MT), by a mgmt tool (e.g., CTC) or manually (via CLI), proactive protection will be used
- Proactive protection will bidirectionally switch away from the line once one of the ports is put in OOS-MT mode. It will re-enable use of the line only when both ends are back in service
- Note: this behavior is active irrespective if proactive protection is enabled or disabled – the "no enable" command disables automatic triggering of protection but not maintenance triggers

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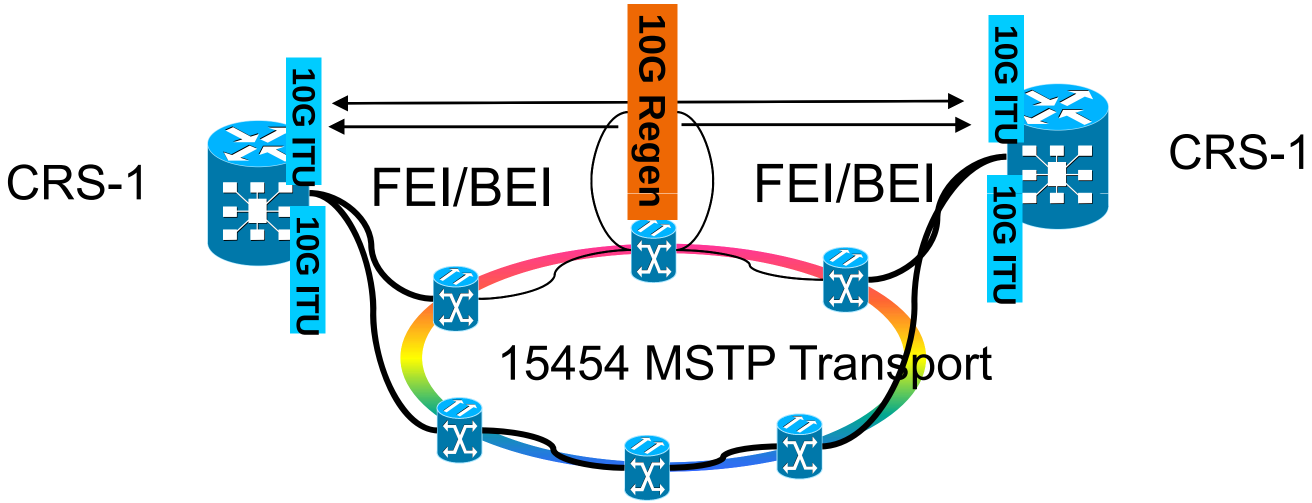
Regeneration aware Proactive Protection

A-Z Provisioning of pre-FEC thresholds



Cisco unique “Regeneration aware” Proactive Protection
Assure business continuity and mission critical connection

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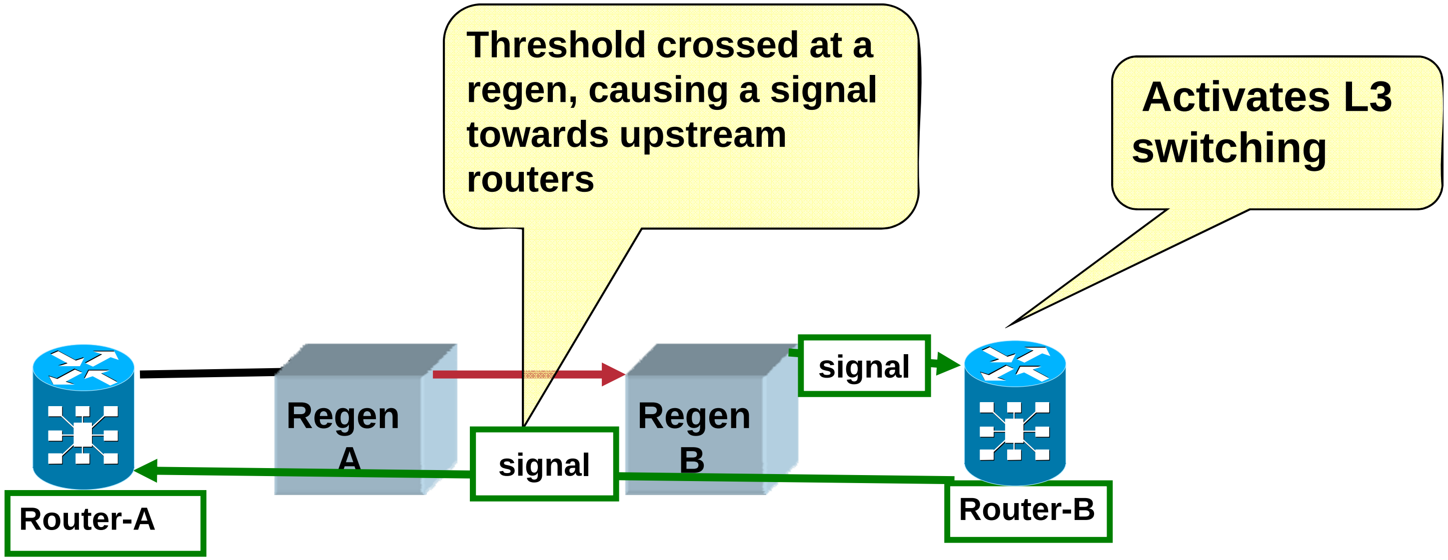
How does it work



1. A-Z Provisioning sets congruent threshold for pre-FEC BER
2. Whenever a degrade is detected, i.e. the BER pre-FEC threshold is crossed at REGEN, REGEN propagates a Degrade indication forward and backward
3. FRR detects the degrade indication and switch

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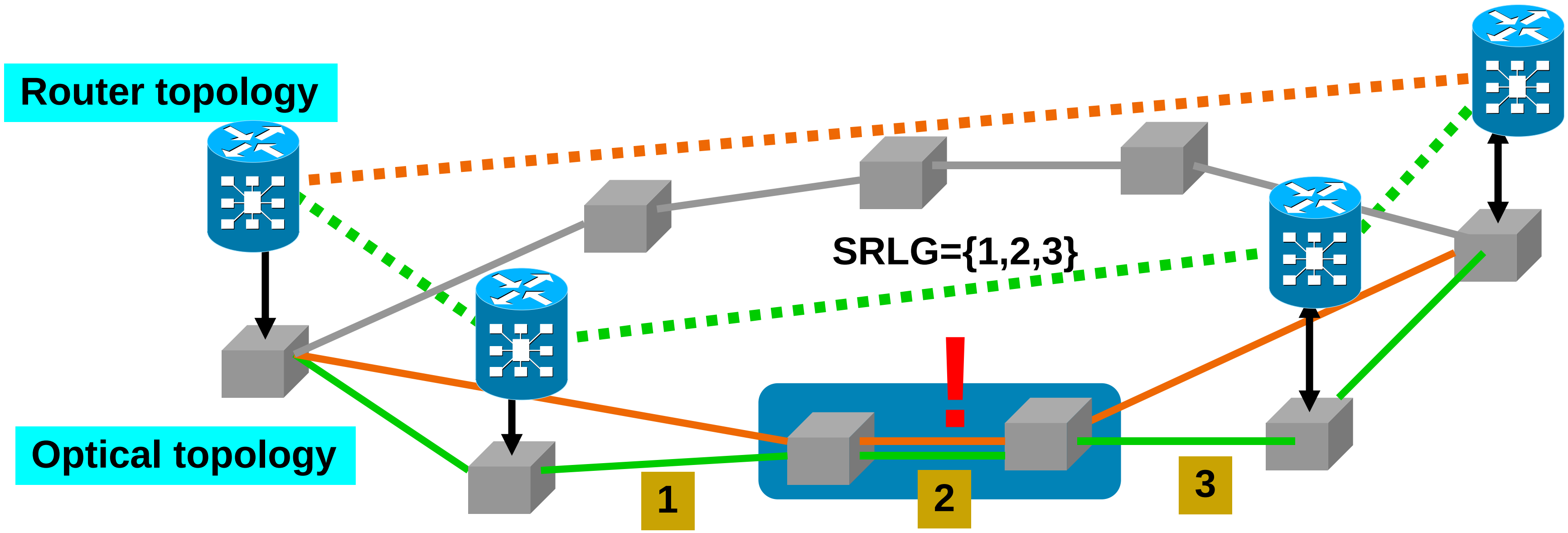
Advanced IPoDWDM Features
- Shared Risk Link Groups (SRLG)

Share Risk Data Between Layers to Ensure True Diversity for FRR



– FRR decides protection path ahead of a failure
– Can be wrong w/o SRLG data
  What appears diverse in L2/L3 may not be diverse in L1
– Manual SRLG entry is error prone and not up to date
– SRLGs can be mined from the Optical layer and fed to IP layer

Enhance network resilience w/o error-prone manual work

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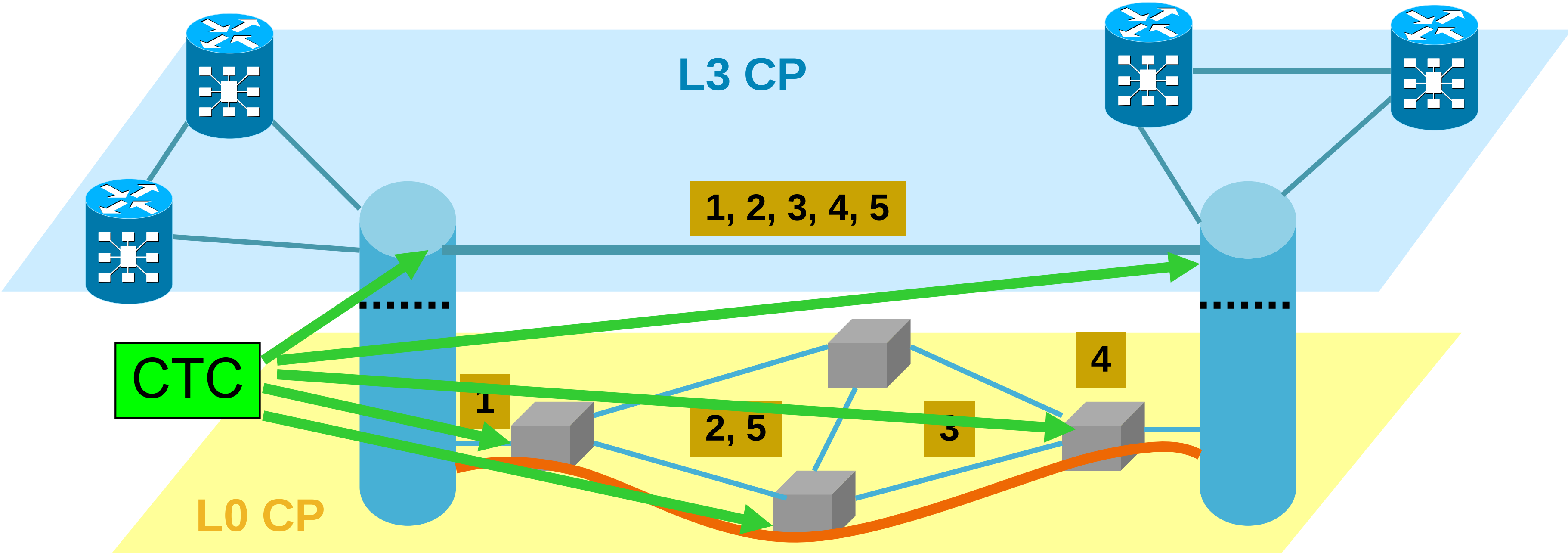
SRLG sharing details



1. Provision L0 SRLGs into nodes via CTC
2. Collect risks when setting up e2e path via CTC
3. Provision into router by CTC (Virtual Transponder)
4. Use by planning tools and L3 apps (e.g., FRR)

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IPoDWDM Management

Simple Configuration

Ensure you are user of user group in proper task group

Configure DWDM controller using CLI:

```
controller dwdm0/15/0/0
 admin-state in-service
 wavelength 7
```

Configure L3 interface same as before

* Additional optional commands exist

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Managing a WDM Interface on a Router

On par or better than advanced transponders

show controllers dwdm 0/15/0/0

```
Port dwdm0/15/0/0
Controller State: up
Loopback: None
```

```
G709 Status
OTU
      LOS  = 0      LOF  = 0      LOM  = 0
      BDI  = 0      IAE  = 0      BIP  = 0
      BEI  = 0      TIM  = 0

ODU
      AIS  = 0      BDI  = 0      OCI  = 0
      LCK  = 0      BIP  = 0      BEI  = 0
      PTIM = 0      TIM  = 0

FEC Mode: Enhanced FEC(default)
      EC(current second) = 4063      EC   = 74084864668  UC   = 0
      pre-FEC BER = 9.53E-8      Q  = 5.26      Q Margin = 5.49

Remote FEC Mode: Unknown
      FECMISMATCH = 0
```

Line Card State

ITU-T G.709

Performance Monitoring

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Managing a WDM Interface on a Router

On par or better than advanced transponders

show controllers dwdm 0/15/0/0 (cont)

Port dwdm0/15/0/0

```
Detected Alarms: None
Asserted Alarms: None

Alarm Reporting Enabled for: LOS LOF LOM IAE OTU-BDI OTU-TIM OTU_SF_BER OTU_SD_BER
ODU-AIS ODU-BDI OCI LCK PTIM ODU-TIM FECMISMATCH
BER Thresholds: OTU-SF = 10e-3  OTU-SD = 10e-6

OTU TTI Sent     String ASCII: Tx TTI Not Configured
OTU TTI Received String ASCII: Rx TTI Not Recieved
OTU TTI Expected String ASCII: Exp TTI Not Configured

ODU TTI Sent     String ASCII: Tx TTI Not Configured
ODU TTI Received String ASCII: Rx TTI Not Recieved
ODU TTI Expected String ASCII: Exp TTI Not Configured

Optics Status

      Optics Type:  DWDM
      Wavelength Info: C-Band, MSA ITU Channel=15, Frequency=195.40THz, Wavelength=1534.250nm
      TX Power = 1.04 dBm
      RX Power = -5.33 dBm
      RX LOS Threshold = -16.00 dBm
TDC Info
      TDC Not Supported on the Plim or
TDC Info
      Operational Mode: AUTO
      Status :        LOCKED
      Dispersion Setting : 0 ps/nm
```

Optical Alarms
Trace & Performance Monitoring

On-Board TDC included on 2nd Generation

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Managing a WDM Interface on a Router

On par or better than advanced transponders

show controllers dwdm 0/15/0/0 pm history fec

Port dwdm0/15/0/0

```
g709 FEC in the current interval [ 1:30:00 - 01:31:21 Mon Jun 28 2010]
    EC-BITS   : 238922        Threshold : 0        TCA(enable)  : NO
    UC-WORDS  : 0             Threshold : 0        TCA(enable)  : NO

g709 FEC in interval 1 [ 1:15:00 -  1:30:00 Mon Jun 28 2010]
    EC-BITS   : 2254454        UC-WORDS  : 0

g709 FEC in interval 2 [ 1:00:00 -  1:15:00 Mon Jun 28 2010]
  EC-BITS   : 2143773        UC-WORDS  : 0

g709 FEC in interval 3 [ 0:45:00 -  1:00:00 Mon Jun 28 2010]
   EC-BITS   : 2312558        UC-WORDS  : 0

g709 FEC in interval 4 [ 0:30:00 -  0:45:00 Mon Jun 28 2010]
    EC-BITS   : 2249076        UC-WORDS  : 0

g709 FEC in interval 5 [ 0:15:00 -  0:30:00 Mon Jun 28 2010]
    EC-BITS   : 2548391        UC-WORDS  : 0
```

Performance Monitoring
Current Interval

Past Intervals

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Managing the SP “walls”: Virtual Transponders

- The major objection against IPoDWDM: the transport people want to manage “their” transponders
- The data/network people don’t want the transport people to touch “their” routers
- Virtual Transponders address this issue

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What does the Virtual Transponder do?

- Exposes the DWDM aspects of an IPoDWDM interface
- Integrate into DWDM EMS using XML
- Allows for segmented management of the transmission and IP networks

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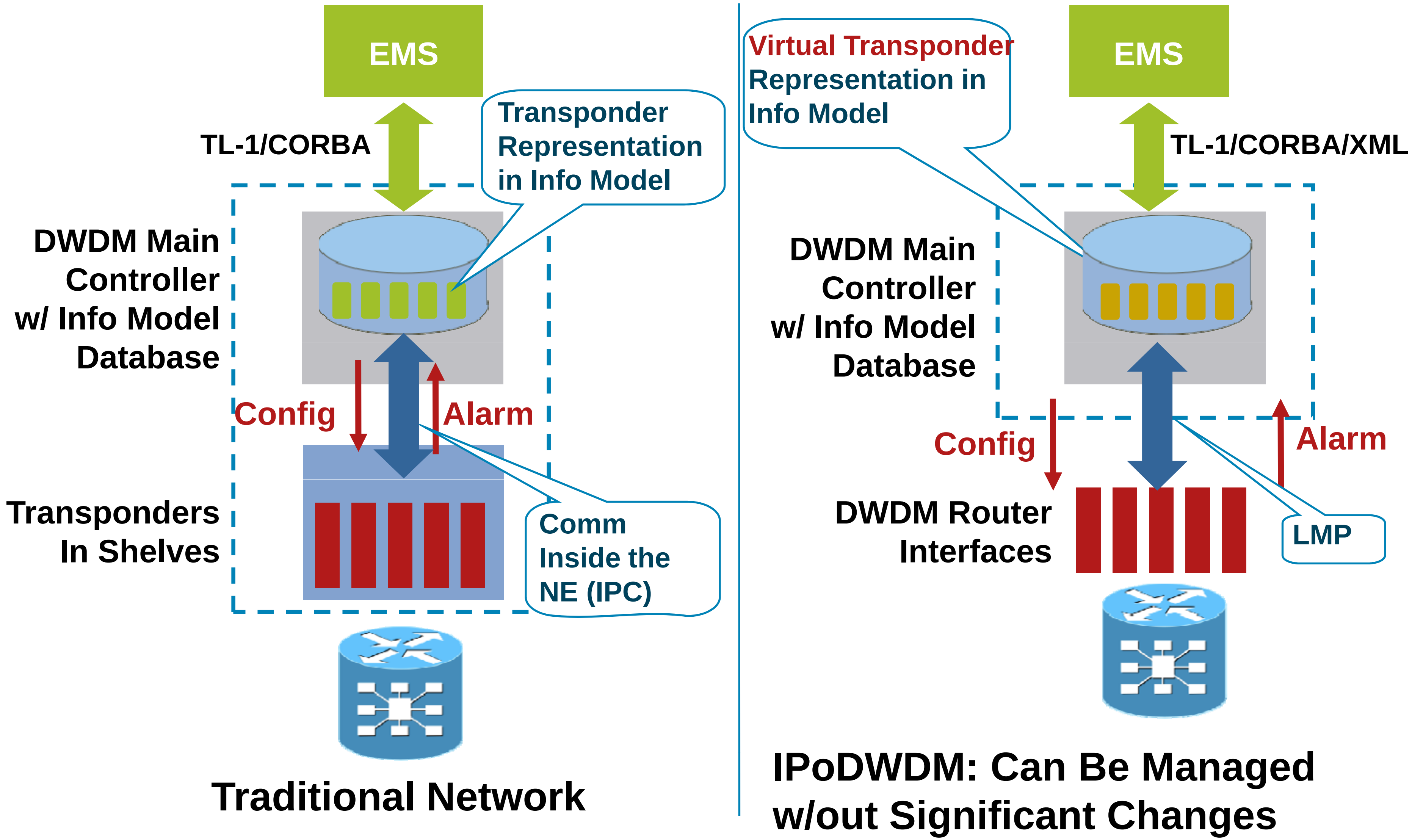
Virtual Transponder: How to Manage IPoDWDM from a Legacy DWDM EMS



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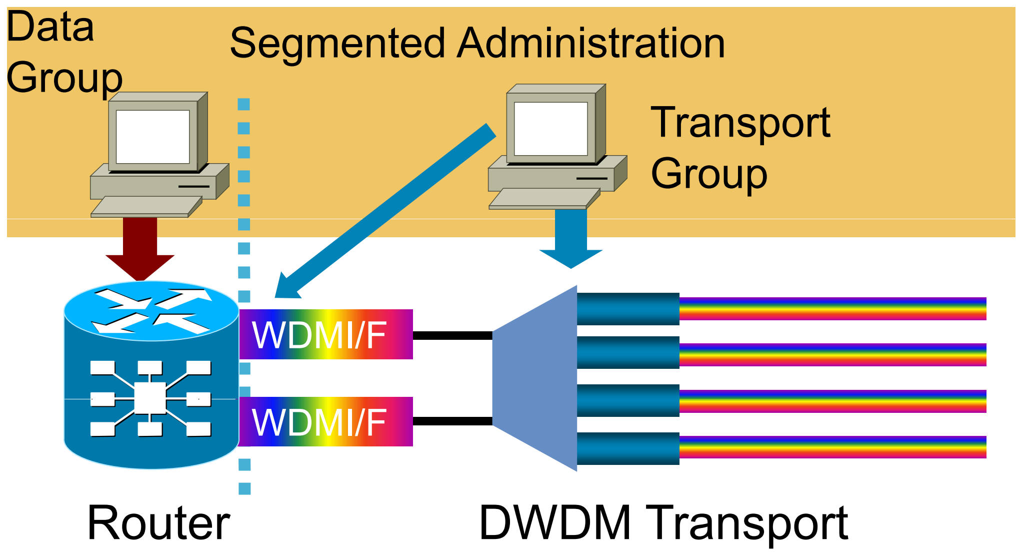
Segmented Administration

- Respect organization boundaries
- Data/transport group separation
- Restrict users



IOS-XR Side

- Each command is associated with a Task ID
- Task IDs are grouped together in task groups
- Users inherit allowed Task IDs through group membership
- TACACS and Radius also supported

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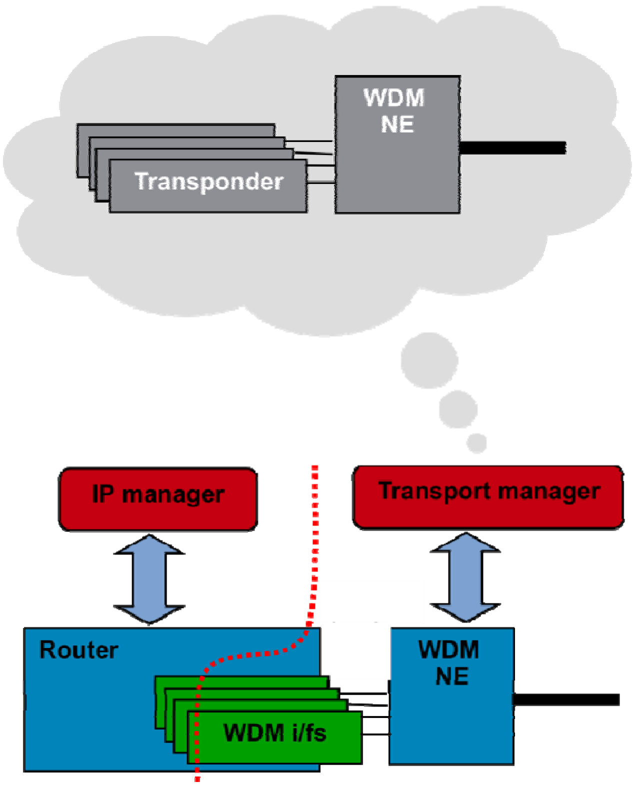
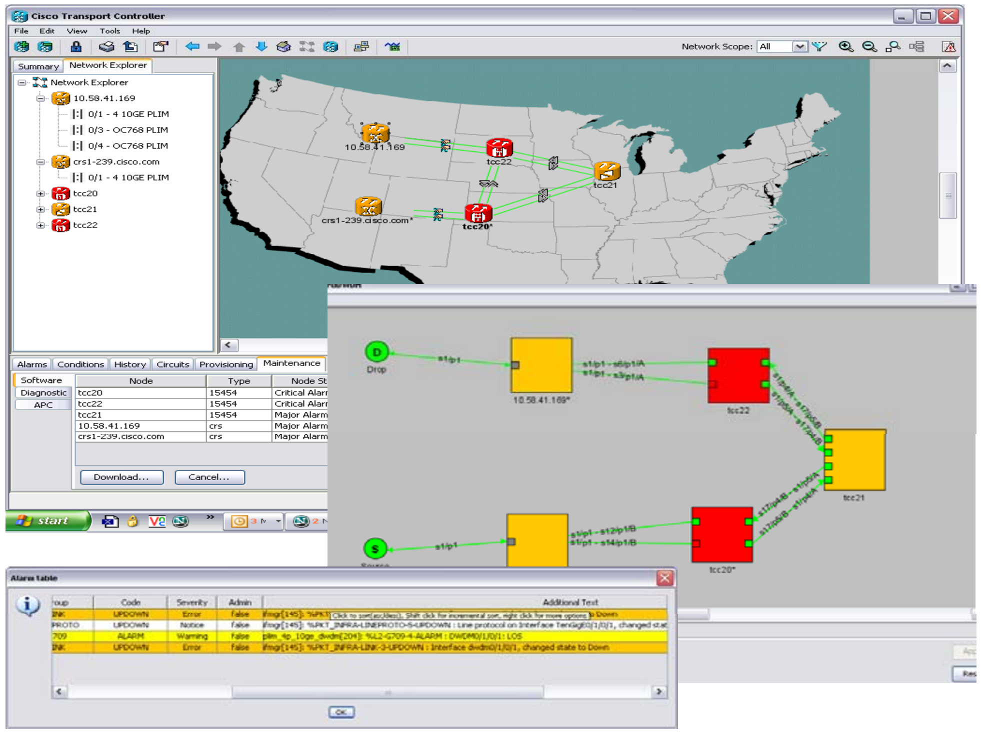
Example: Managing DWDM Interfaces on Routers as part of the DWDM Layer





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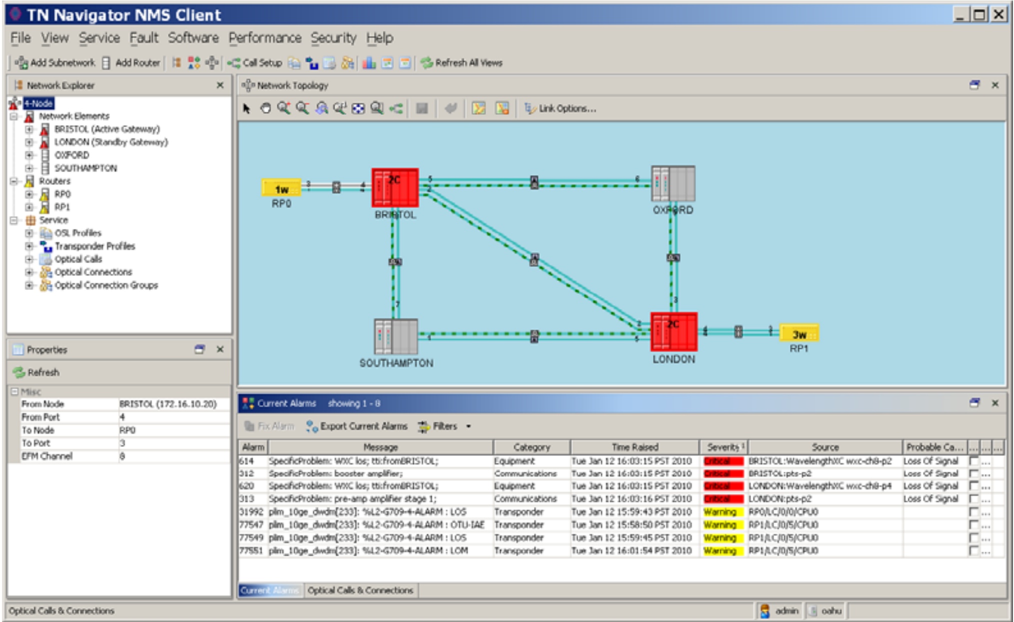
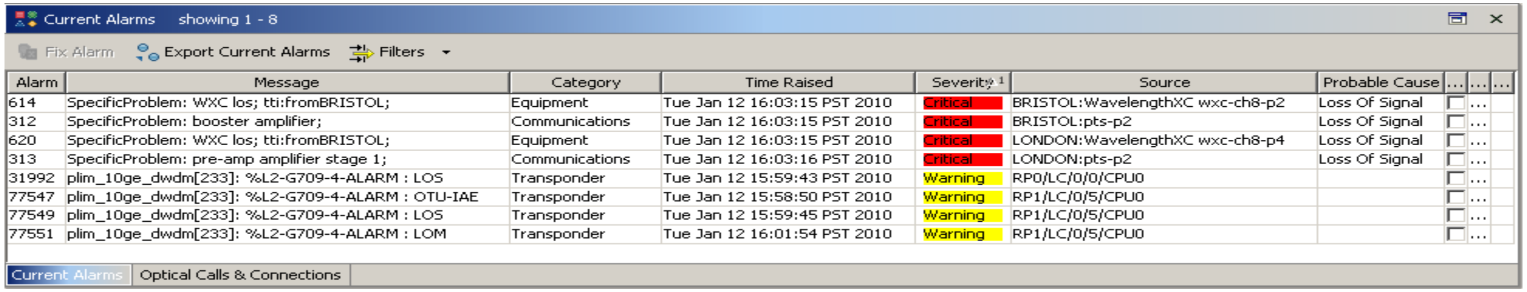
Third Party VTXP integration

Cisco opens it's XML schemas to a Third Party DWDM vendor whom integrates into management plane of DWDM platform





Alarm	Message	Category	Time Raised	Severity	Source	Probable Cause
614	SpecificProblem: WXC los; tti:fromBRISTOL;	Equipment	Tue Jan 12 16:03:15 PST 2010	Critical	BRISTOL:WavelengthXC wxc-ch8-p2	Loss Of Signal
312	SpecificProblem: booster amplifier;	Communications	Tue Jan 12 16:03:15 PST 2010	Critical	BRISTOL:pts-p2	Loss Of Signal
620	SpecificProblem: WXC los; tti:fromBRISTOL;	Equipment	Tue Jan 12 16:03:15 PST 2010	Critical	LONDON:WavelengthXC wxc-ch8-p4	Loss Of Signal
313	SpecificProblem: pre-amp amplifier stage 1;	Communications	Tue Jan 12 16:03:16 PST 2010	Critical	LONDON:pts-p2	Loss Of Signal
31992	plim_10ge_dwdm[233]: %L2-G709-4-ALARM : LOS	Transponder	Tue Jan 12 15:59:43 PST 2010	Warning	RP0/LC/0/0/CPU0	
77547	plim_10ge_dwdm[233]: %L2-G709-4-ALARM : OTU-IAE	Transponder	Tue Jan 12 15:58:50 PST 2010	Warning	RP1/LC/0/5/CPU0	
77549	plim_10ge_dwdm[233]: %L2-G709-4-ALARM : LOS	Transponder	Tue Jan 12 15:59:45 PST 2010	Warning	RP1/LC/0/5/CPU0	
77551	plim_10ge_dwdm[233]: %L2-G709-4-ALARM : LOM	Transponder	Tue Jan 12 16:01:54 PST 2010	Warning	RP1/LC/0/5/CPU0	

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40G/ 100G Design Considerations

Higher Data Rates
Minimum Requirements

- 40 Gig and above rates must meet minimum requirements:

  Target 10 Gig distances—1500 Km reach

  Not simply a Greenfield technology, but plug and play over existing 10Gig networks

  Must be as open as possible, operate over third party DWDM networks

  Must operate over both 100GHz as well as 50GHz spacings

  Must be at a competitive cost point

  Power and footprint must be reasonable, can not redesign Router/transport shelf due to blade

- To achieve must leverage/control:

  1. Optical Impairments

  2. Modulations schemes

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Optical Impairments

Optical Impairments
Acronyms

- Chromatic Dispersion (CD)
- Attenuation
- Optical Signal to Noise Ratio (OSNR)
- Compensate for low S/N using FEC
- Polarization Mode Dispersion (PMD)
- Four Photon Mixing (FPM) or Four Wave Mixing (FWM)
- Cross Phase Modulations (XPM)

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Optical Impairments

Chromatic Dispersion (CD)

The refractive index of fiber has a wavelength dependence. This causes the higher frequencies to travel faster then lower frequencies causing a pulse broadening effect. Measured in ps/nm*km, threshold / limit measured in ps/nm.

Confusion, do I want it or not? Is it good or bad?

- Reducing Dispersion will increase distance and performance
- Reducing/eliminating Dispersion will also increase nonlinear effects thus limiting distance/performance

Counter Measure: Dispersion Compensating Unit (DCU)

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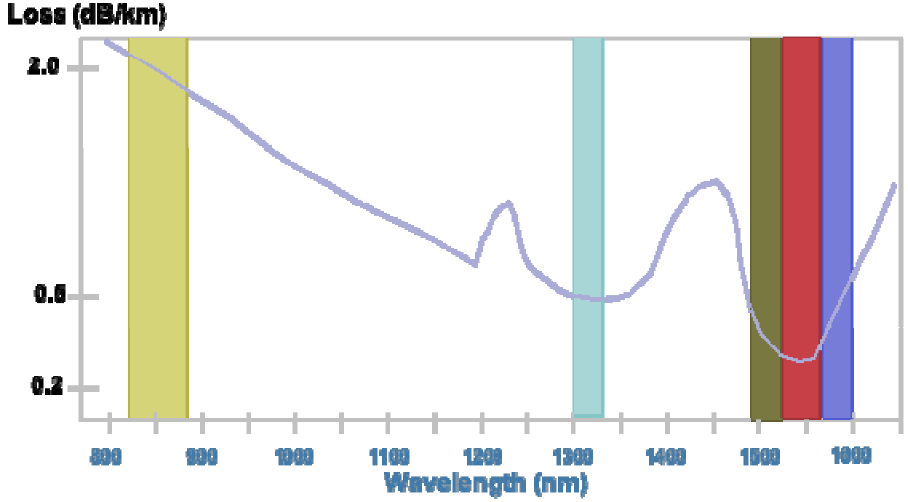
Optical Impairments

Attenuation



Loss of signal strength

Limits transmission distance

SMF28 - approx 0.25dB/km

Counter Measure: Optical amplifier

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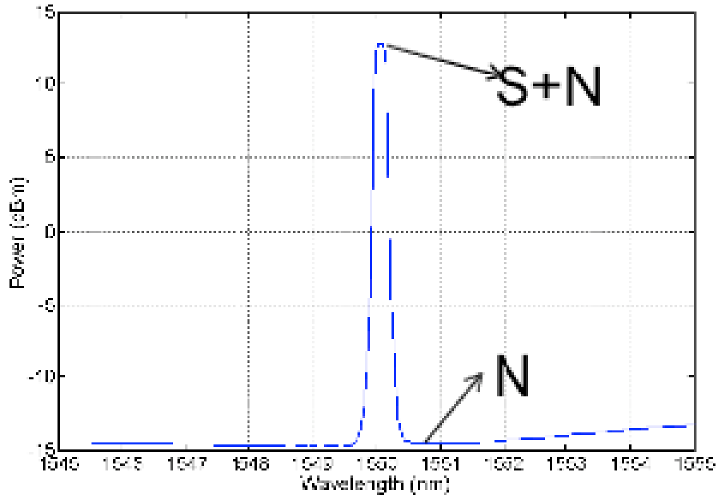
Optical Impairments

Optical Signal to Noise Ratio (OSNR)



- Noise introduced by optical amplifiers
- Function of data rate-rule of thumb, 2X data rate = 3 dB higher OSNR
- Limits number of amps hence distance
- **Counter Measure: Regen/Forward error correction**

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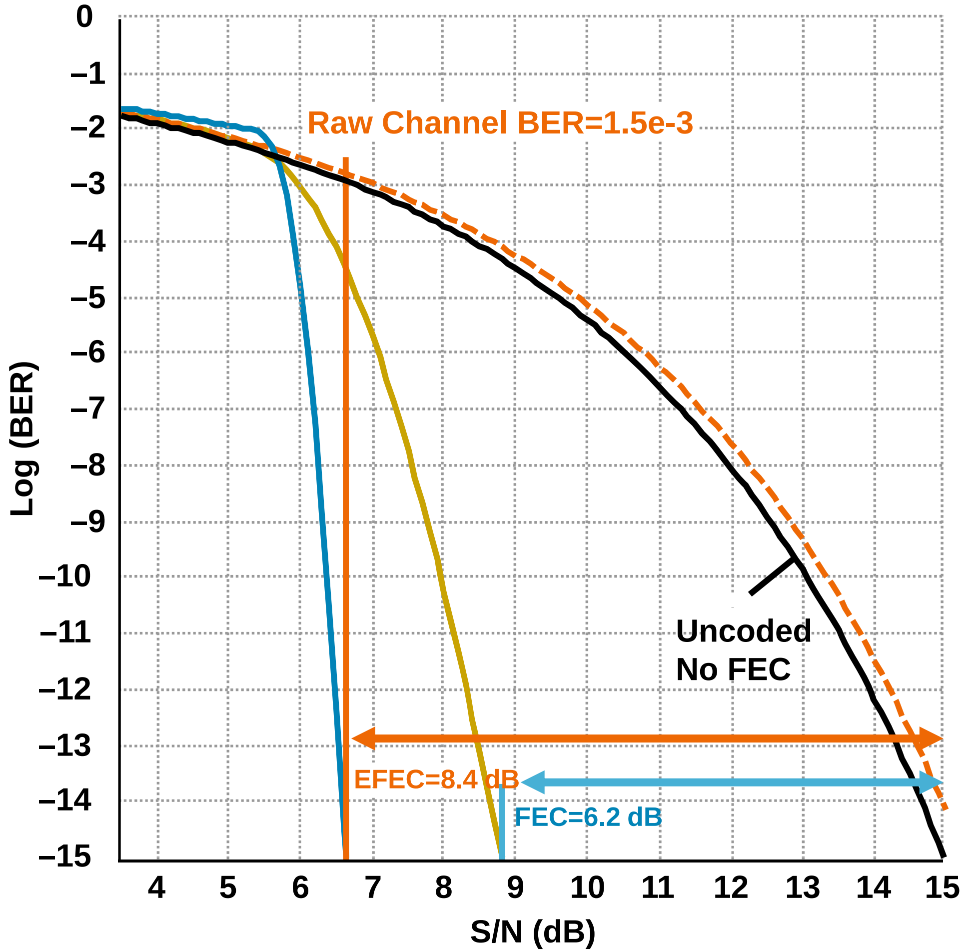
Optical Impairments
Compensate for low S/N using FEC

- FEC extends reach and design flexibility, at “silicon cost”
- G.709 standard improves OSNR tolerance by 6.2 dB (at 10^{-15} BER)
- Offers intrinsic performance monitoring (error statistics)
- Higher gains (8.4dB) possible by enhanced FEC (with same G.709 overhead)



Benefit: FEC/EFEC Extends Reach and Offers 10^{-15} BER

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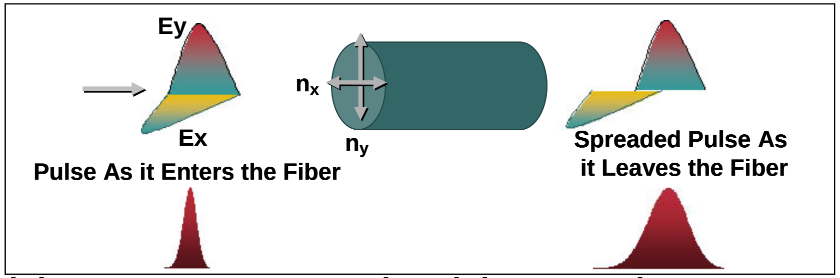
Optical Impairments

Polarization Mode Dispersion (PMD)

Since fiber cores are not perfectly symmetrical, the light will travel down the X and Y axis at different rates leading to a pulse broadening effect. This is a function of a coefficient multiplied by the square root of the total distance measured in ps/km1/2



Function of bit rate, greater the bit rate the greater the dependence on PMD

PMD is statistical in nature, one must account for mean value rather then instantaneous

Counter Measure: PMD compensators are available

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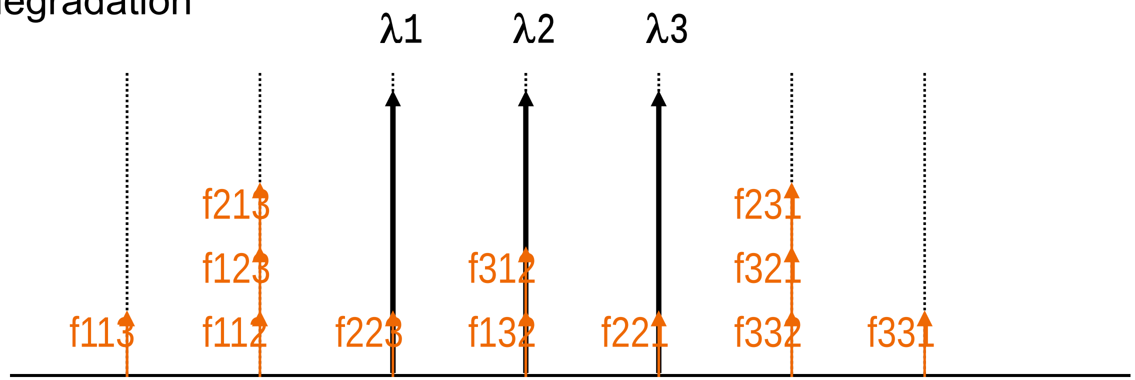
Optical Impairments

Four Photon Mixing or Four Wave Mixing (FPM or FWM)

- Beating between two channels at their difference frequency, modulates the phase at that frequency generating new tones as side bands. These new products interfere with other channels
- BER degradation



Total Beats = N(N-1)^2

Counter measures:

- Unequal channel spacing
- Increase channel spacing
- Chromatic Dispersion, waves alternate in and out of phase, reducing mixing efficiency

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Optical Impairments

Cross Phase Modulation (XPM)

This arises due to the weak dependence of the refractive index on intensity: $n=n_0 + n_2*I$. Here the nonlinear refractive index modulates one of the carriers onto the other.

Pulse broadening gets exaggerated with Chromatic Dispersion

Counter measures:

Chromatic Dispersion, the group velocity causes the interfering pulse to walk thru the other

Larger spacing between carriers

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Modulation Schemes

40/100G Is Much Harder than 10G

	100G vs. 10G	100G vs. 40G
OSNR Requirement	10 dB higher	4 dB higher
CD tolerance	100 X less	6.25 X less
DGD tolerance	10 X less	2.5 X less
PMD limited distance	100 X less	6.25 X less
Optical BW	10 X	2.5 X

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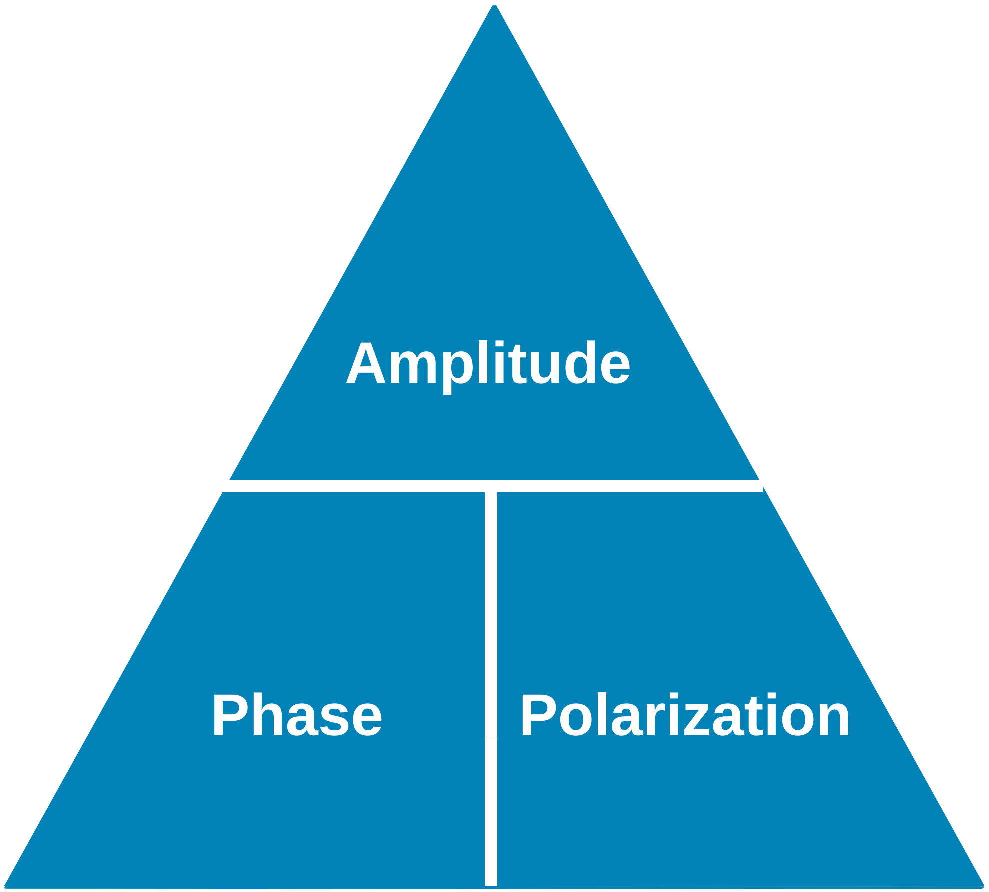
Modulation Schemes



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Modulation Schemes

Acronyms

- (N)RZ—(Non) Return to Zero
- PSBT—Phase Shaped Binary Transmission
- CS-RZ—Carrier Suppressed Return to Zero
- DPSK—Differential Phase Shift Keying
- DQPSK—Differential Quadature Phase Shift Keying
- ODB—Optical Duo Binary
- QPSK—Quadature Phase Shift Keying
- PM-’X’—Polarization Multiplexing

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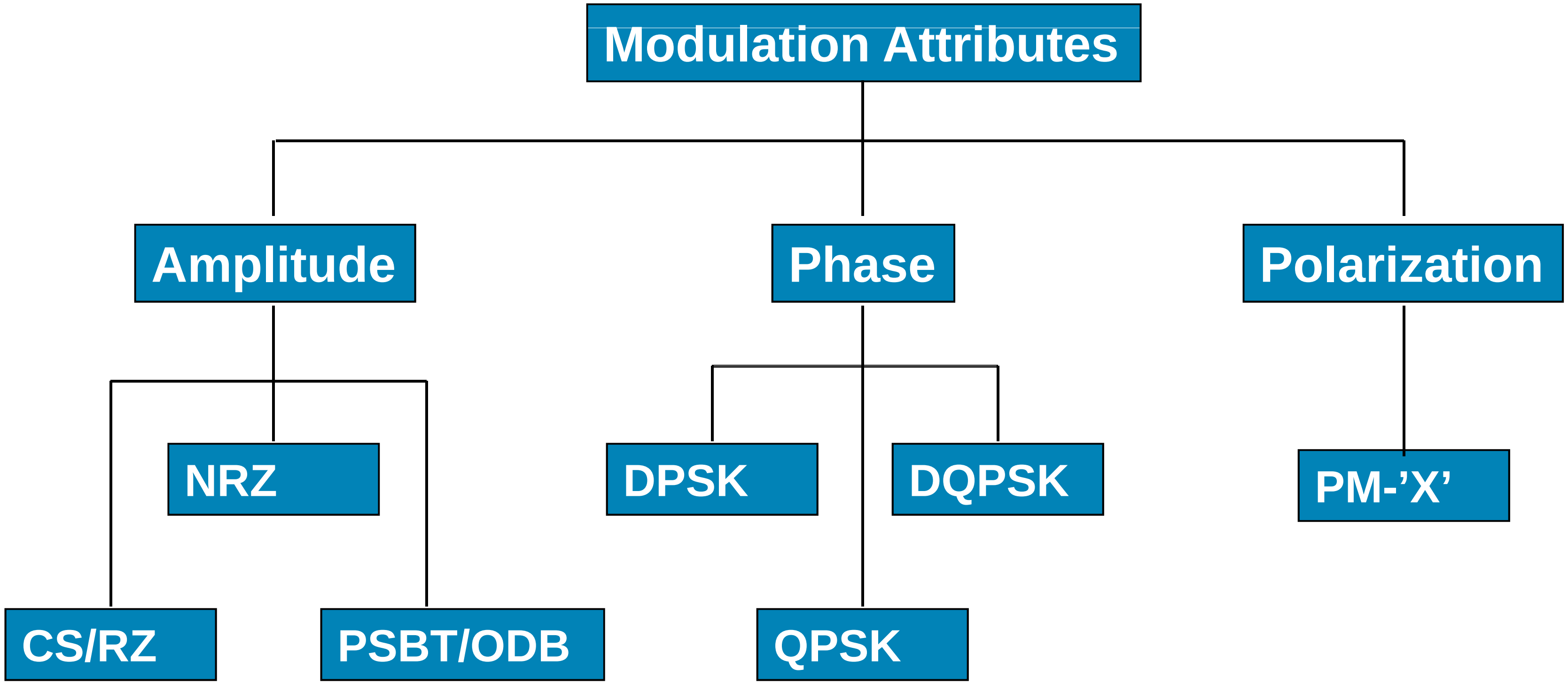
Modulation Schemes



Where 'X' Can Be DPSK, DQPSK, QPSK, etc. …

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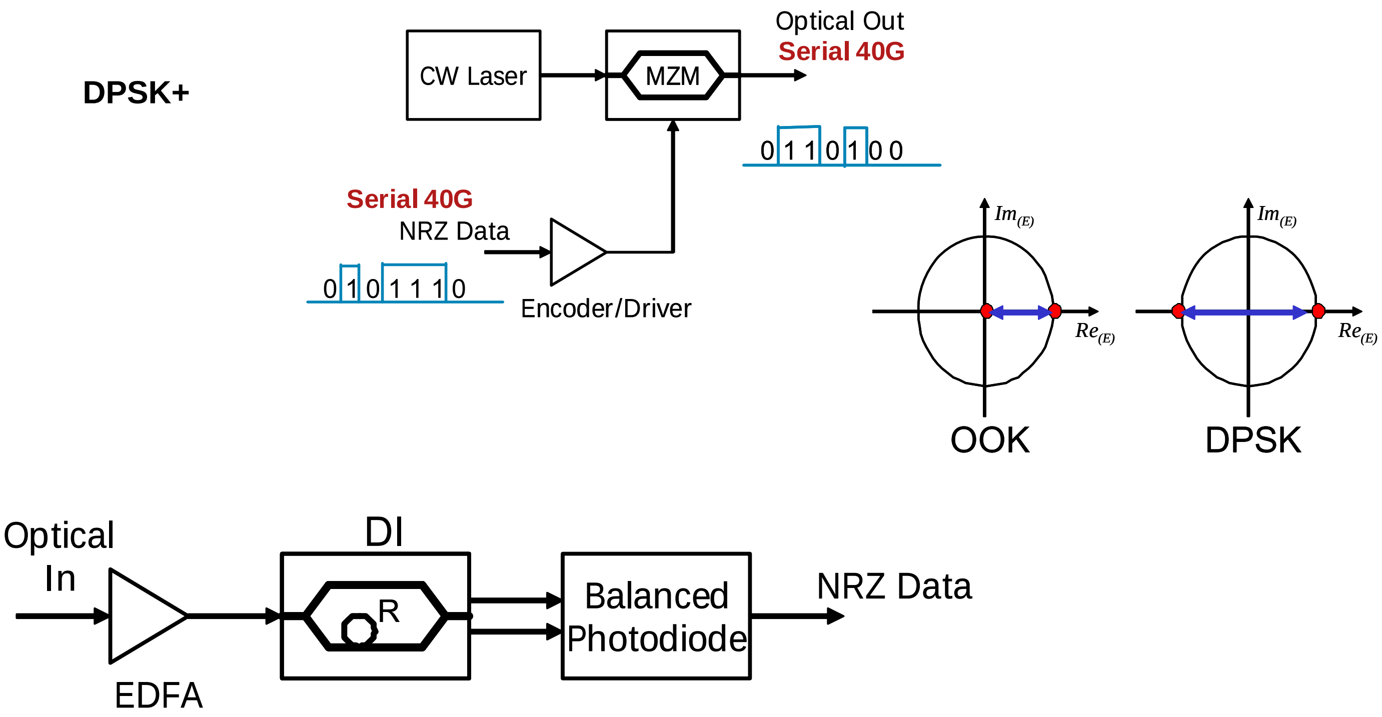
40 G Modulation Scheme – DPSK+



40Gig Phase 2

- DPSK – Differential Phase Shift Keying
- Increase distances utilizing Enhanced FEC
- Cisco chose DPSK best overall for 40Gig although find PM-QPSK very interesting and viable for higher data rates

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100G – Need to address

- Transmitter
  - Increasing speed means
    - Complex Optics = Complex Electronics = $$$$$$
    - More Optical Impairments
- Receiver
  - Address impairments
    - Optical compensation vs. Electrical compensation
  - Coherent vs. Direct detection
- Forward Error Correction (FEC)
  - Hard Decision FEC
    - Standard FEC – 6dB Coding Gain
    - Enhanced FEC – 8+dB Coding Gain
    - Newer FECs – 9+dB Coding Gains
  - Soft Decision FEC
- Each of the above FECs can be used for any of the options

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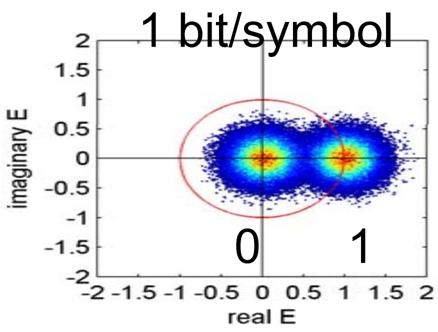
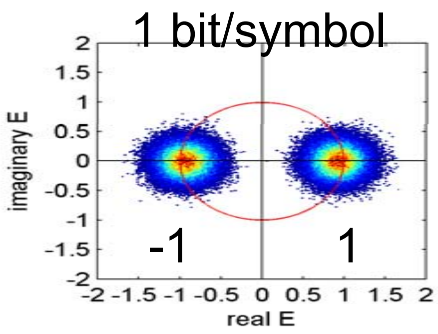
100G – The Transmitter

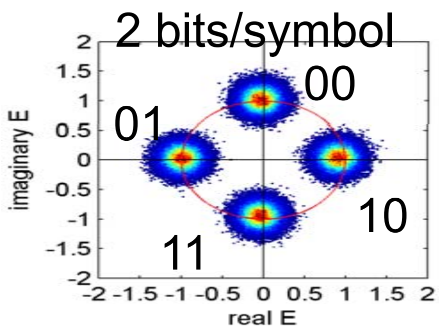
- Need to go slower
  - Optical impairments are directly related to signaling rates
- Need to increase modulation efficiency
  - Signaling speed decreases & Information Rate increases
  - NRZ to ODB to (D)PSK to (D)QPSK
- Need to increase optical efficiency
  - Split signal over two polarizations (PM – Mod Scheme)



NRZ



PSK



QPSK

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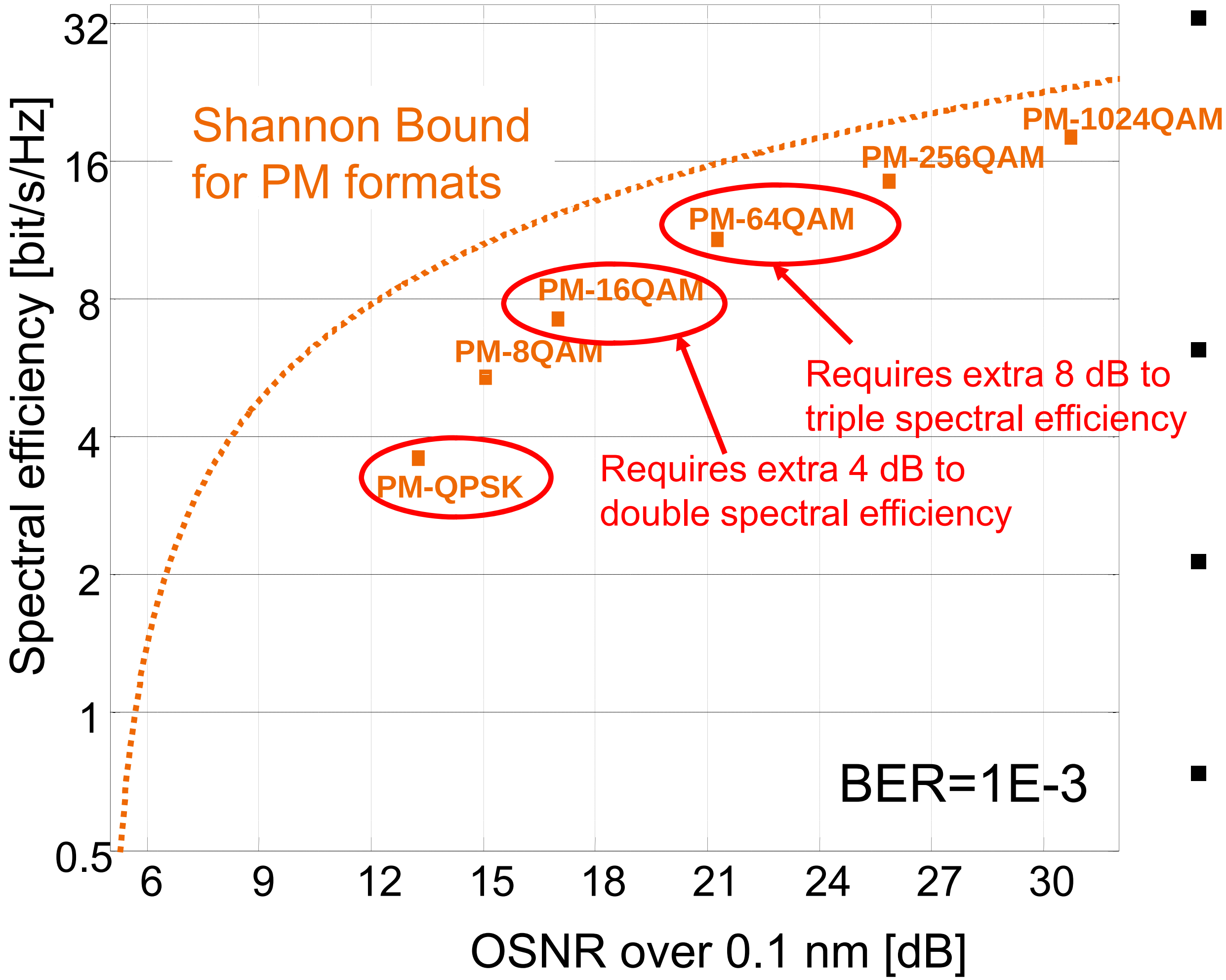
OSNR Required at 111 Gb/s



- Higher level modulation formats require increasingly higher OSNR even at constant bit rate
- PM-16QAM requires 4 dB more than PM-QPSK
- PM-64QAM requires 8 dB more than PM-QPSK
- PM-256QAM would require 13 dB more than PM-QPSK!

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Cisco 100Gig DWDM Technology Update

- Multiple technology options are being examining in the industry today

  PM-DQPSK – Direct detection, Hard decision FEC

  Co-FDM Multiple Carrier – two 50G carriers in a 50GHz channel

  Coherent PM-QPSK – Hard decision FEC

  Coherent PM-QPSK – Advanced FEC

- Cisco Approach

  One solution, best-in-class performance:

  • PM-QPSK – Advanced FEC

  • Min of 2dB (~1.5x) better performance then other options above

  • Optimal Reach – up to 2,000Km

  • Part of a Cisco End-to-End Solution

Cisco strategic decision: Get it right the first time. No one can afford to iterate through multiple generations

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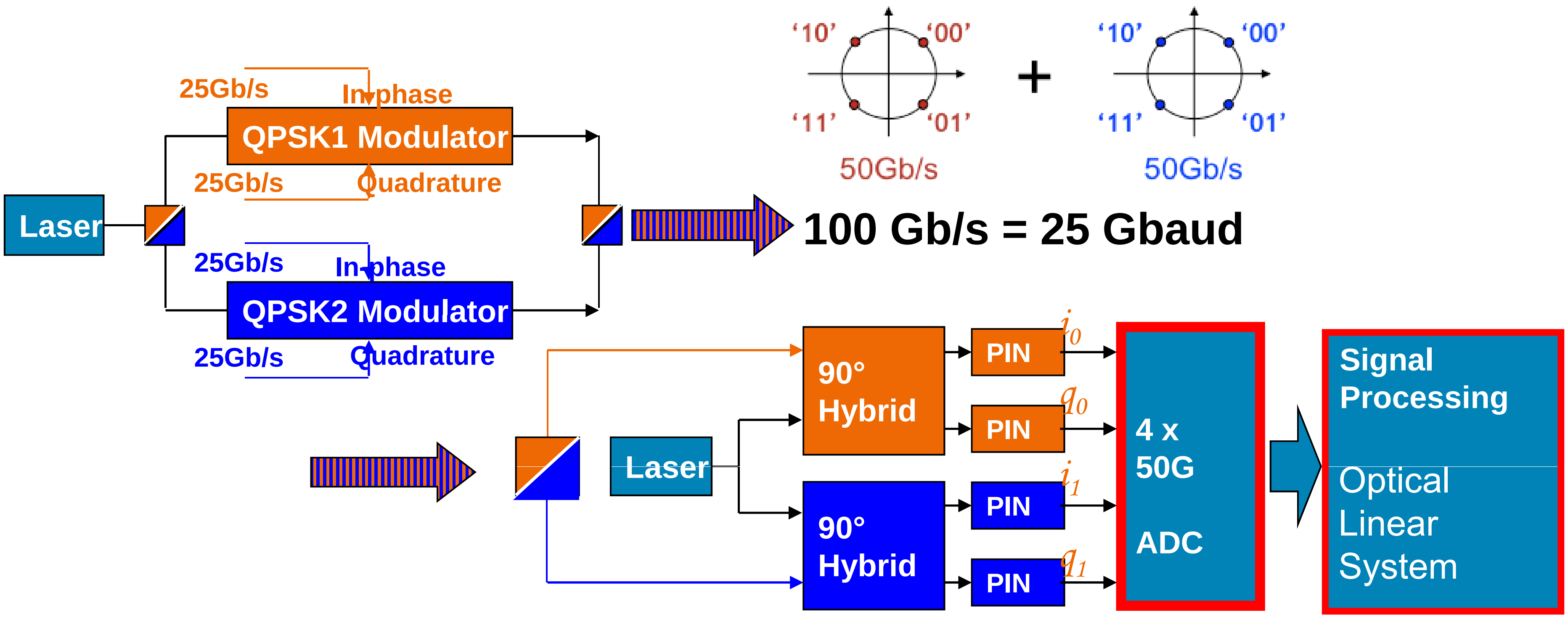
Cisco View of 100GigE Transmission



- PM – QPSK – Polarization Multiplexed Quadrature Phase Shift Keying
- Increase distances utilizing Cisco Advanced FEC
- Advanced signal processing to address:
  - CD Compensation
  - PMD Mitigation
  - Single Channel Non-linear impairment mitigation
- To be implemented on both router interfaces and transport NEs

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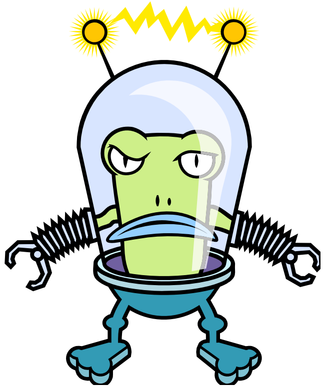
40G/100G Deployment Considerations in 10G Optical Networks

Operating on 3rd party DWDM System

3rd PARTY DWDM SYSTEM MUST SUPPORT ALIEN WAVELENGTHS!



-> Alien/foreign wavelength is any 3rd party ITU wavelength operating over an existing DWDM infrastructure.

-> G698.2 – Standard for “Alien/Foreign waves” defines:

properties for signal sources and sinks

properties for DWDM links for “black links” (i.e. alien wavelengths)

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Network Architecture

Design Considerations

Noise and Impairment Limits

- 40G receiver differs from 10G

	40G IPoDWDM Transponder (DPSK+)	10G Transponder
Launch Powers	0 dBm	0 dBm
Rx Windows	5 to –18 dBm	0 to –23 dBm
OSNR (.1nm)	~ 14.5 dB	~ 15 dB
CD	+/- 750ps/nm	+/- 2000ps/nm
PMD	2.5ps	10ps

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What to take into consideration ?
Basics that you should start with

- Fiber Type
- OSNR
- Chromatic Dispersion
- Polarization Mode Dispersion
- Spectrum Allocation
- Channel Spacing
- Design Margin

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Basics that you should start with (cont'd)

- **Check end-to-end OSNR**.
  Determine if your network is within DWDM cards margin

  •**Watch out how OSNR is given**. For 10Gb/s DWDM it is common to provide OSNR with Bandwidth Resolution = 0.1nm
  IPoDWDM cards has results given with RBW = 0.5 nm usually.

$$\mathbf{OSNR_{(0.1nm)}} = \mathbf{OSNR_{(0.5nm)}} + 10\log(0.5nm/0.1)$$

$$\mathbf{OSNR_{(0.1nm)}} = \mathbf{OSNR_{(0.5nm)}} + 7dB$$

- **Check end-to-end CD**
- **Check end-to-end PMD**
- **Check Rx power (attenuation)**

MSTP has tool to do these calculations for you!

Cisco Transport Planner

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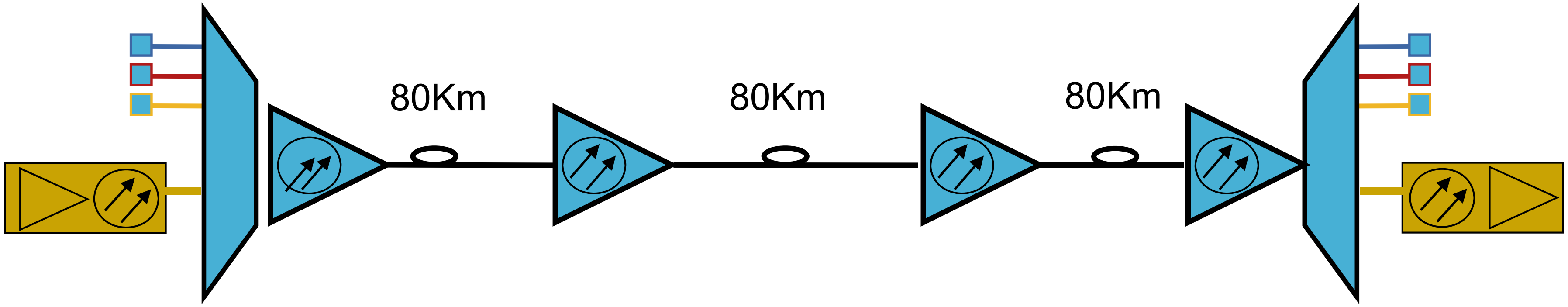
Sample Calculations – basics



Attenuation = α * L

α = Attenuation coef

L = Distance (km)

Chromatic Dispersion = D * L

D = Dispersion coef

L= Distance (km)

DGD = PMD X SQRT(L)

DGD – Differential Group Delay

PMD= PMD coefficient

OSNR = 58 + Pin – NF – 10*log(#CH) – 10*log(#Amp Cas)*

* assuming all amps the same

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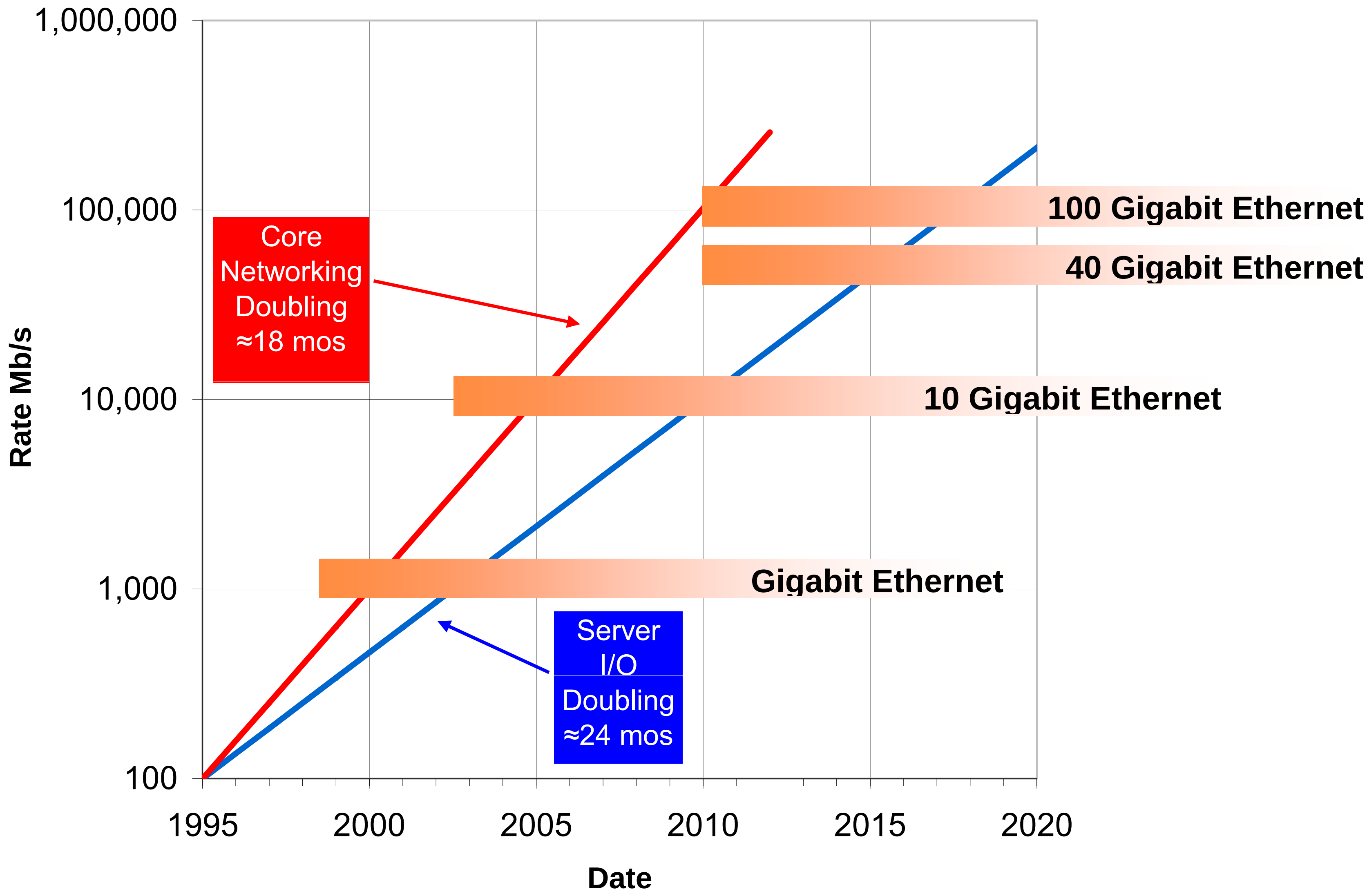
100G: Where are we today?

40GbE and 100GbE: Computing and Networking



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Industry Efforts for 40/100G

- IEEE 802.3ba 40Gb/s and 100Gb/s
  - Defined client interface for 40GigE and 100GigE
  - Ratified June 17, 2010
- ITU Study Group 15, Next Generation Optical and Transport Networks
  - ODU3E and ODU4 defined and completed
- OIF, 100G Long-distance DWDM Transmission
  - address the historically fragmented DWDM market space
  - drive commonality of design, specification and operation
    - at both component and system level
  - 100G PM-QPSK agreed upon

Cisco Taking an Active Leadership Role in All of the Above

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Key Takeaways

- 100GE and 40GE have been ratified June 17, 2010
- 100GE demand is high from SP customers to address networking and aggregation issues
- Cisco is taking a strong leadership role:
  - Both LAN and WAN technologies
  - Industry standards
  - Components and sub-components and obviously in 100G IP forwarding!
- Cisco launched the industry's first 100GE interface!!
  - June 2008 – client side
  - March 2010 – 100GigE on CRS-3 – live AT&T

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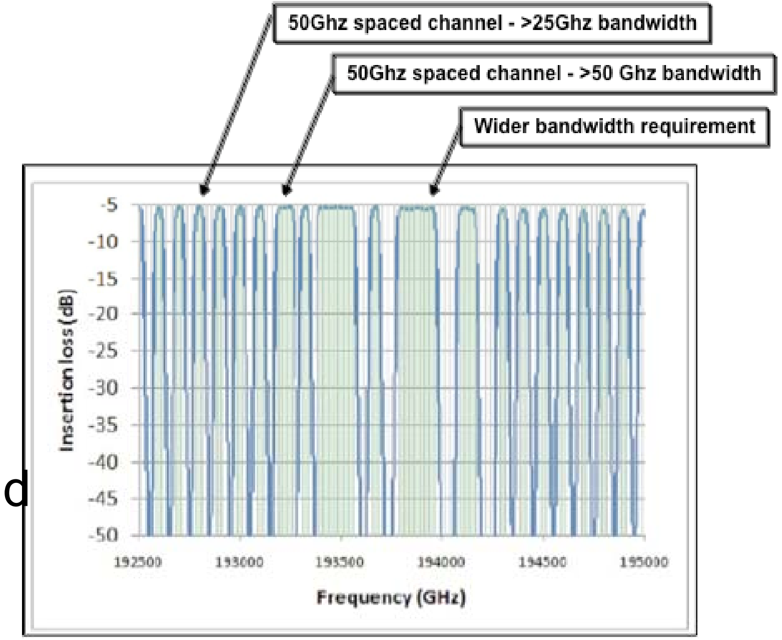
What Comes After 100Gig?

- Higher data rates
  200Gig, 400Gig, 1T?
- Need to investigate other modulation techniques
  PM-16QAM, PM-64QAM, …. or CO-OFDM ?
- Need deeper look at FEC
  Advanced FEC
  What other algorithms are there
- Need of intelligent DWDM layer
  Flex spectrum
  Control plane
  Advanced operations, troubleshooting and protection mechanisms



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Summary

Cisco IPoDWDM Summary and Benefits

- IP traffic continues to grow
  - 24 Exabytes per month by 2012
  - Driven by application service convergence on IP
- Optical layer must be open
  - Optical layer needs to be in place for 5–10 year minimum
  - Cannot afford to tie transmission rate innovation to DWDM vendor's roadmap
  - Encourages innovation by maintaining competition
- New services converging on IP need more robustness
  - IPoDWDM delivers robustness, reliability and cost savings
    - Fewer shelves—less CO space, less power, less gear improving reliability
    - Fewer Opto electronic components—increased reliability
    - Half number of patch cable—dirty connectors and miss connection account for majority of problems in field
    - G.709 PMs to the interface not masked by transponder—improved network resiliency
    - Enable advanced features
    - 40G over current 10G optical network
- Investigation underway in 1 Tbps

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Acronyms

- BER – Bit Error Rate
- CD – Chromatic Dispersion
- CTC – Cisco Transport Planner
- DGD – Differential Group Delay
- DWDM – Dense Wave Division Multiplexing
- FEC- Forward Error Correction
- FRR – Fast Re-Route
- FPM – Four Photon Mixing
- FWM – Four Wave Mixing
- GMPLS – General Multiprotocol Label Switching
- IEEE – Institute of Electrical and Electronics Engineers
- ITU – International Telecommunication Union
- LMP – Link Management Protocol
- MAC- Media Access Control
- MMF – Multi Mode Fiber
- OIF – Optical Internetworking Forum
- OSNR – Optical Signal to Noise Ratio
- PM – Performance Monitoring
- PMD – Polarization Mode Dispersion
- PMO – Present Mode of Operations
- QAM – Quadrature Amplitude Modulation
- ROADM – Reprogrammable Optical Add/Drop Multiplexer
- SLA – Service Level Agreement
- SMF – Single Mode Fiber
- SR- Short Reach
- SRLG – Shared Risk Link Groups
- VOD – Video on Demand
- VTXP – Virtual Transponder
- XPM – Cross Phase Modulation

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Q&A

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