



# IP over DWDM

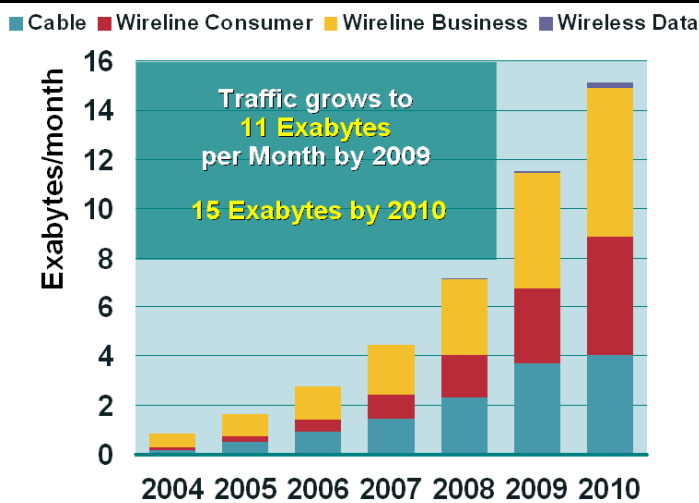
**Tim Pennell**  
**WW SP Technical Operations**

# Outline

- The case for IP optimized transport
- Changes to the architecture of the network
- Cisco solution and direction
- Network Management
- Summary

# Overall Traffic Growth Is Straining All Known Network Architectures

## Global IP Traffic—By Segment



### For Perspective:

1 Exabyte = 5 X All the World's Printed Matter

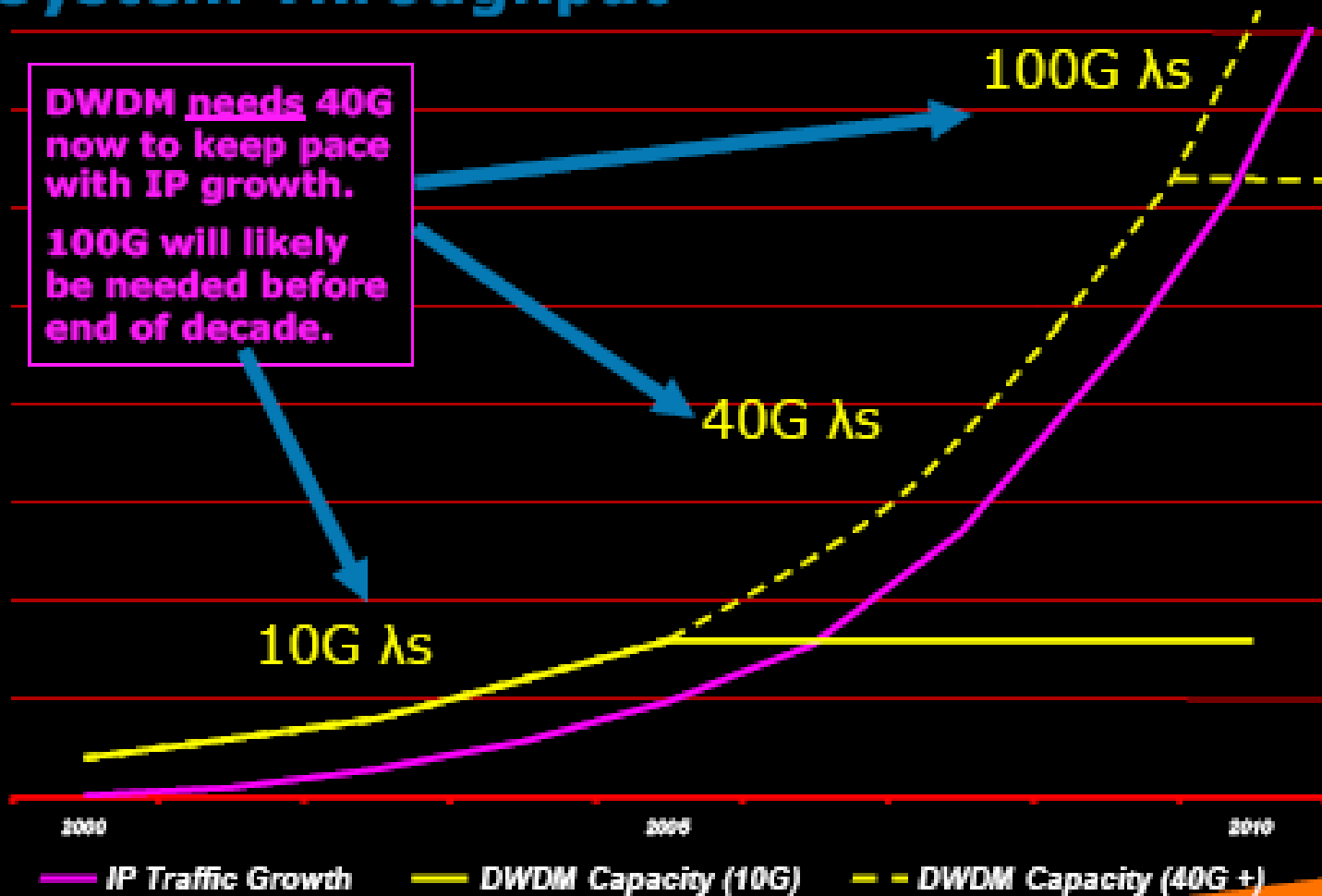
5 Exabytes = All Words ever Spoken

- Legacy applications moving to IP
  - Video – SD, HD, Broadcast Cable
  - Voice
- New applications almost exclusively IP
  - Video - On Demand, DVRs, Switched Digital, Video conferencing ...
  - Audio – Streaming audio, Internet radio, Digital juke boxes, etc....
  - High-Speed Data, Internet
  - Over-the-Top Content providers—i.e., YouTube
- Household Bandwidth Needs in 2010:
  - Applications: HDTV + SDTV + PVRs + HSD + VoIP-Phones

**Twenty such homes would generate more traffic than traveled the entire Internet backbone in 1995**

\*Source: Cisco Estimates, Ovum, Gartner, IDC, Merrill Lynch, MRG, MPA, Public Company Data

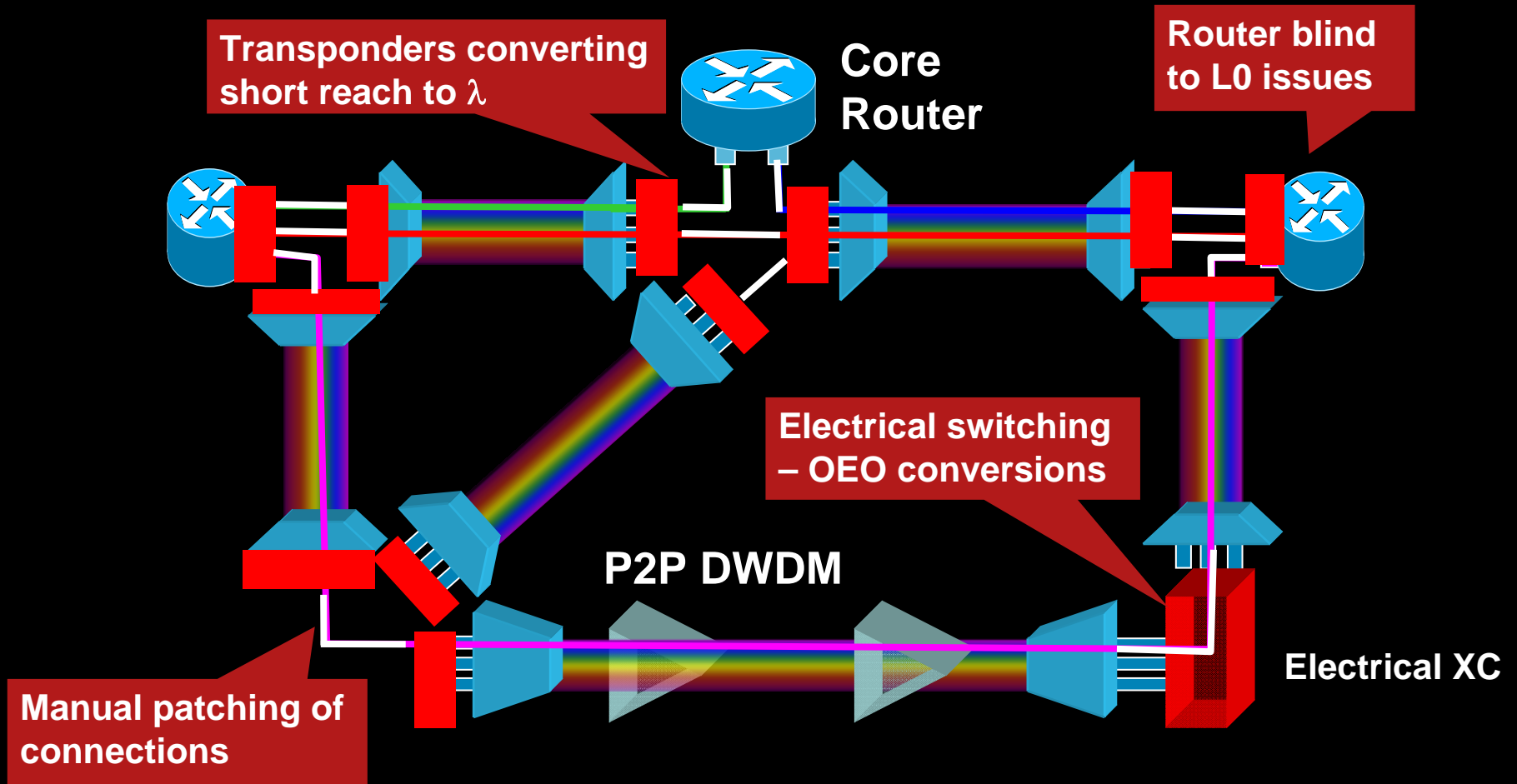
# Growth Trends in IP Traffic and DWDM System Throughput



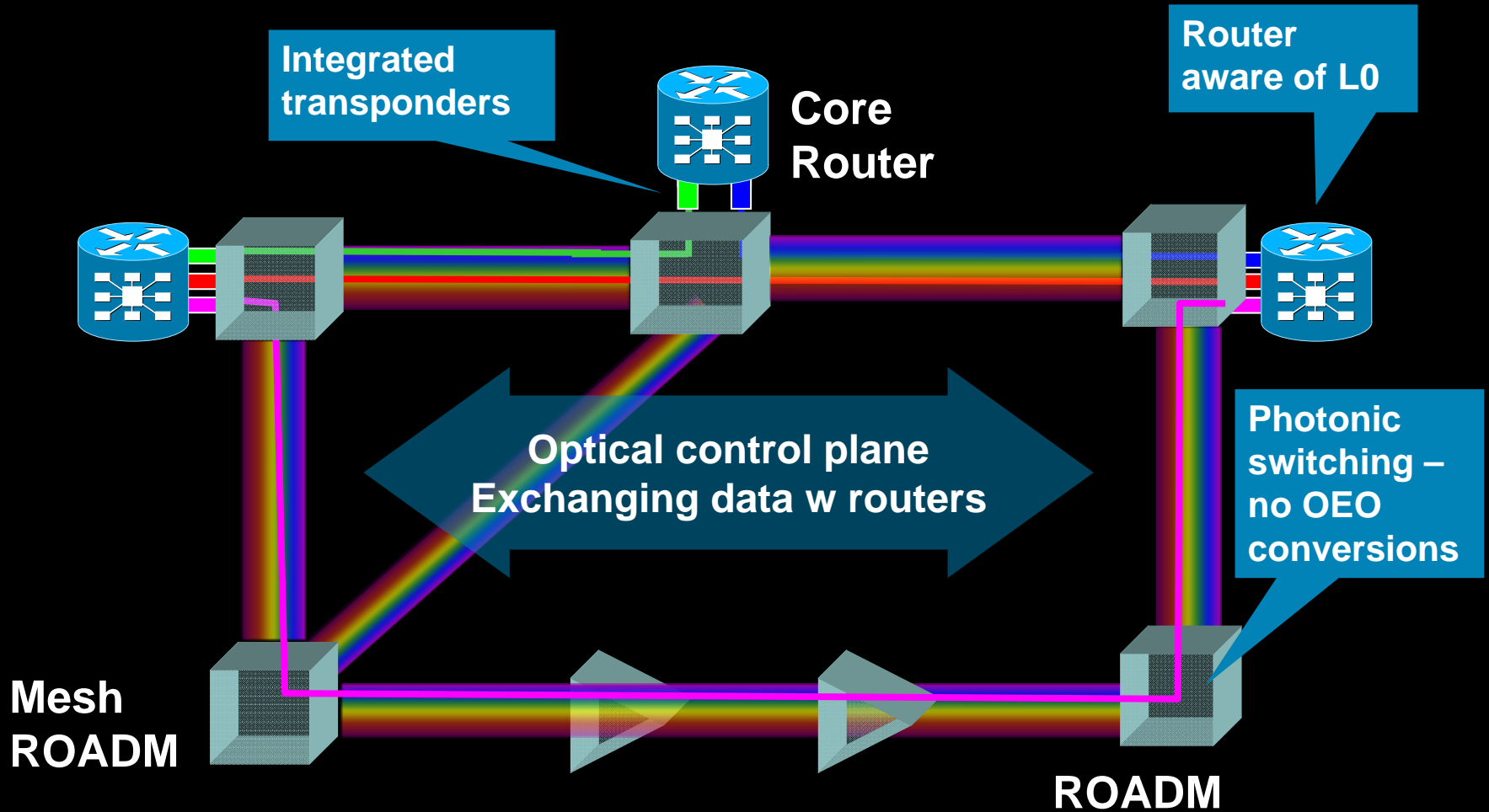
# Where does this take us ?

- **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  $\neq$  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

# Typical IP Network + Optical Network



# Cisco IPoDWDM Architecture



# Cisco IPoDWDM Strategy

- **Element Integration**

Integrate transponder functionality onto routing platforms (10GE, 40G, G.709, EFEC)

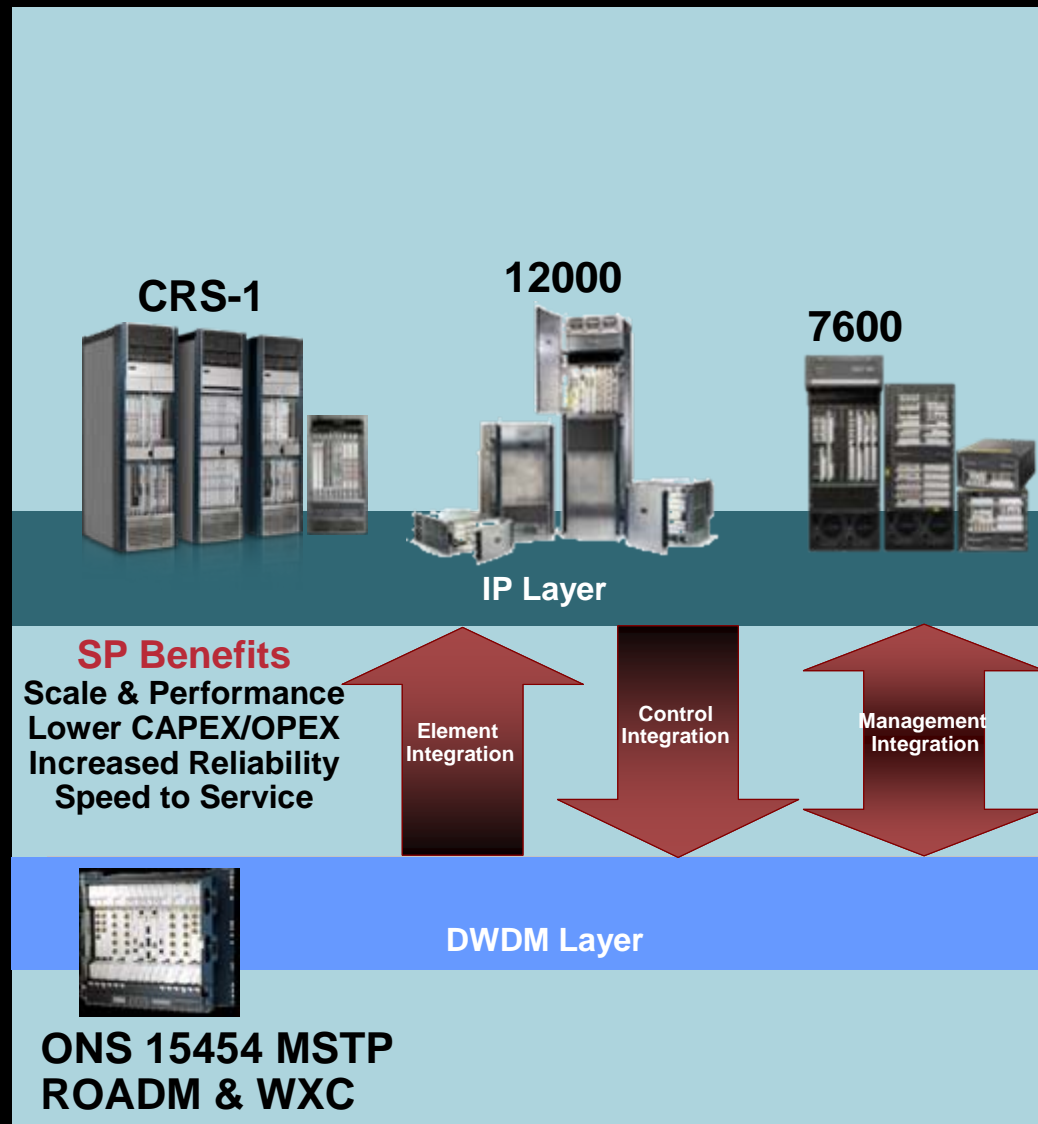
Integrating photonic switching into DWDM platforms (ROADM / WXC)

- **Control Integration**

DWDM aware GMPLS for provisioning of lambdas driven by IP control plane  
Coordination between layers (e.g. SRLG, NLAC)

- **Management Integration**

Separate or integrated management

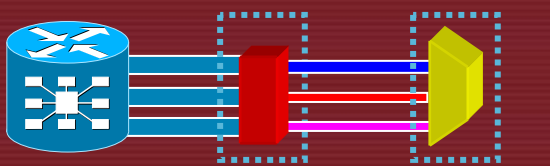


# Immediate Benefits of IPoDWDM solution

Before



Router Transponder ROADM

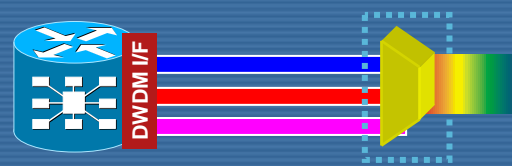


WDM Transponders  
Integrated into Router



Router

ROADM



- **Lower CapEx**  
Elimination of OEOs
- **Lower OpEx**  
Space, power, management
- **Enhanced resiliency**  
Fewer active components
- **Investment protection**  
40G and beyond, interoperability over *existing* 10G systems

# Replacing TDM layer functions

1. Easy operations (OAM&P)
  - G.709 overheads mimic SONET/SDH functions
  - GMPLS allows optical layer visibility into hard to detect failures
  - Integrated optics allows for low cost optical monitoring
2. Fast protection
  - Control plane provides fast failure indications to optical switches
  - Router based fast reroute (FRR) can be more economical and as fast/reliable as transport layer protection
3. Sub-wavelength grooming & aggregation
  - Not needed if router trunks can fill 10G wavelengths
  - Manage bandwidth at the wavelength level using optical switches

# MSTP: Leveraging the Intelligent WDM layer

## Open WDM Architecture:

### ✓ Transparent Transmission

High-performance (EFEC, adv. mod.)

Bit-rate Independent

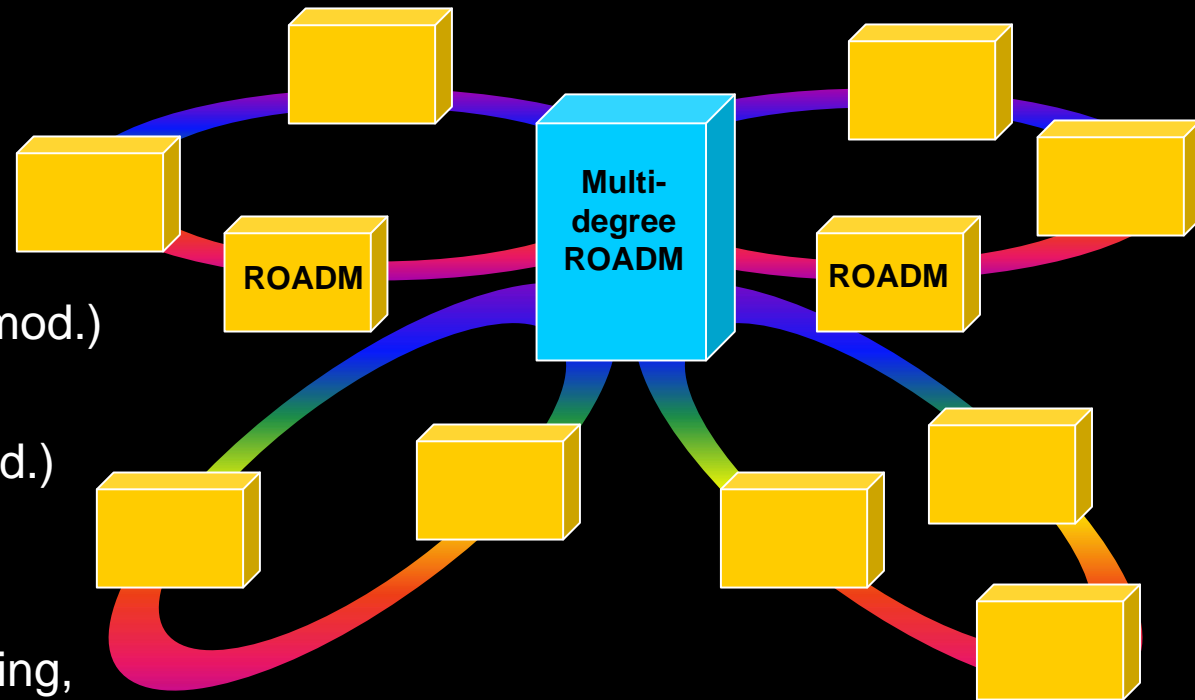
'Alien-Wavelength' (emerging std.)

### ✓ Operations Friendly

G.709 OAMP, tunability, monitoring,  
GMPLS

### ✓ Network planning flexibility

ROADM, Planning tools



## IPoDWDM interoperability:

- State-of-the-art performance over MSTP
- Field tested 'Alien-Wavelength' over existing (3<sup>rd</sup> party) WDM Systems

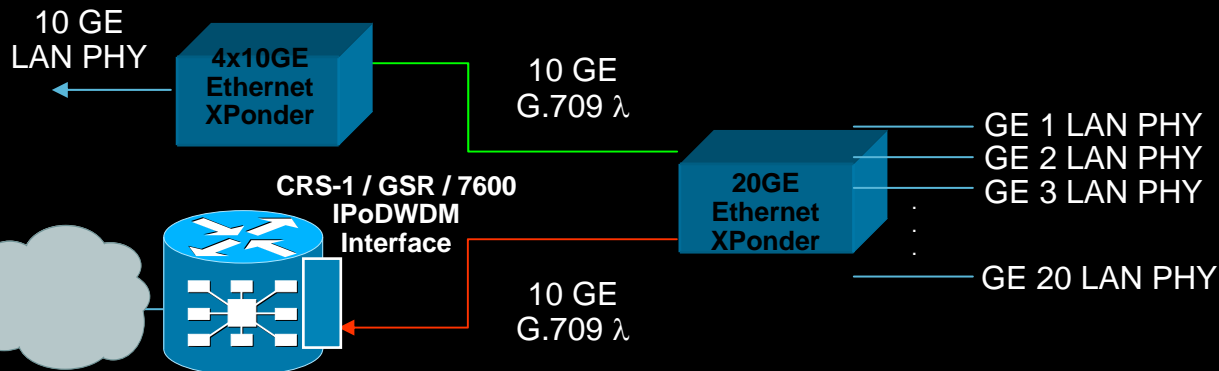
# MSTP: Industry First Ethernet Aggregation Integrated into DWDM



- Introducing Ethernet XPonders (pronounced “Cross-Ponder”)
- Single card for Ethernet Add-Drop, muxponder and transponder
- Innovations:

Layer-2 Ethernet aggregation of NxGE into 10GE  
 Sub-wavelength add/drop and drop and continue  
 50 ms resiliency

G.709 (WDMPHY): OAMP, EFEC



# MSTP: An Open DWDM Layer

## Not as hard as it seems

- Public references:
  - Cisco ONS1545 MSTP
  - Nortel CPL (Comcast)
  - Alcatel 1626LM (Embratel)
  - Padtec MetroPad (Embratel)
  - Lucent OLS400 (Dreamhack)
  - Siemens SURPASS hiT7550 (indirectly via SL OEM)
  - Tellabs TITAN 7100 (via published Stratalight interop)
- Other trials:
  - Fujitsu Flashwave (Comcast metro)
  - Ciena CoreStream (Sprint)
  - Huawei 80CH DWDM (China Telecom)
  - Ericsson MHL-3000 (DT)

**Not generally a technical barrier – more a political one**

# Mama Network 40G IPoDWDM over Ciena LH DWDM

**40Gig, Plug and Play Circuit Turn Up**  
“The most difficult part of the whole project was installing Windows on Sigbritt’s PC,” said Hafsteinn Jonsson of Karlstad Stadsnat.



# Recent Trends Towards IPoDWDM

## Other Router Vendors Following Cisco's Lead

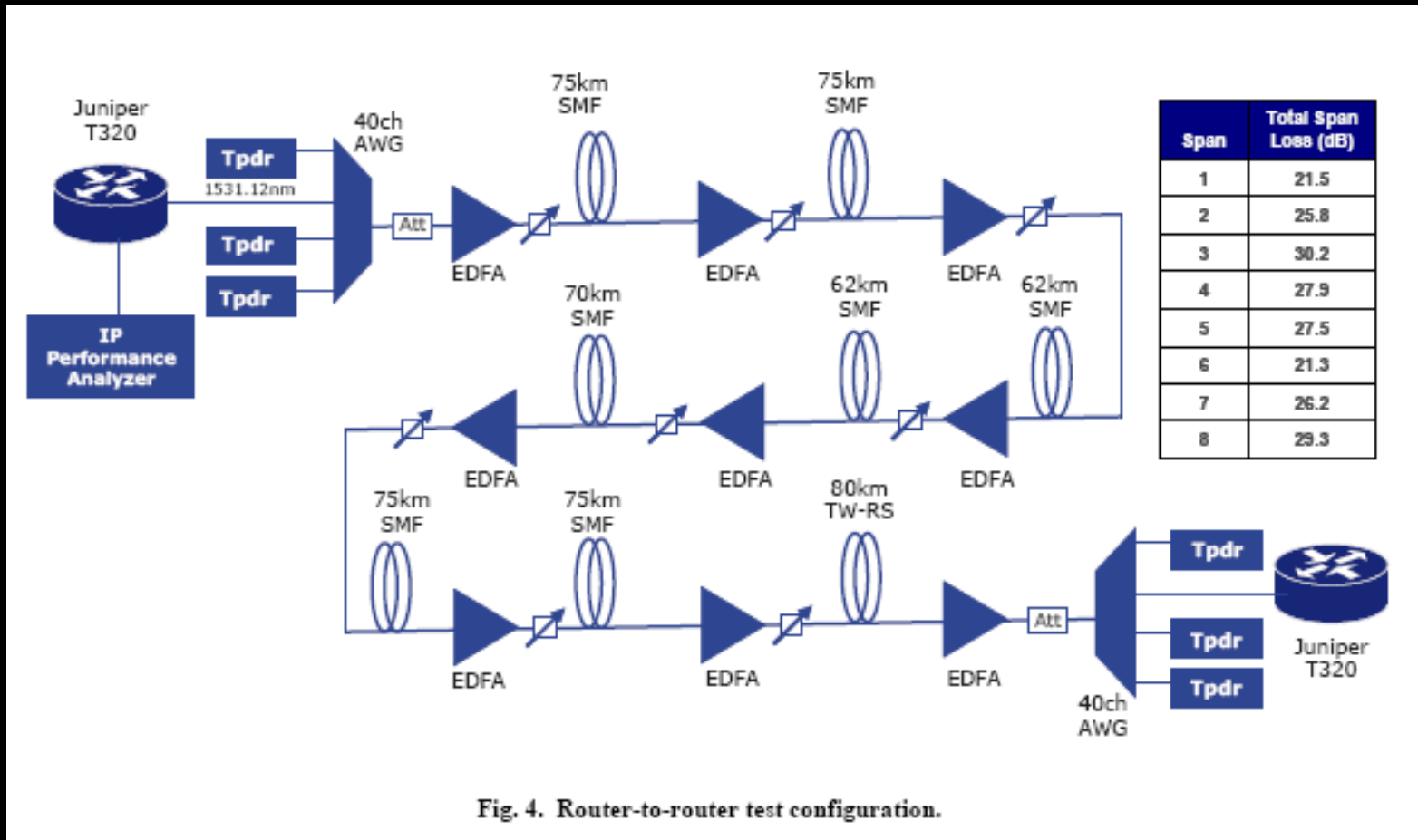
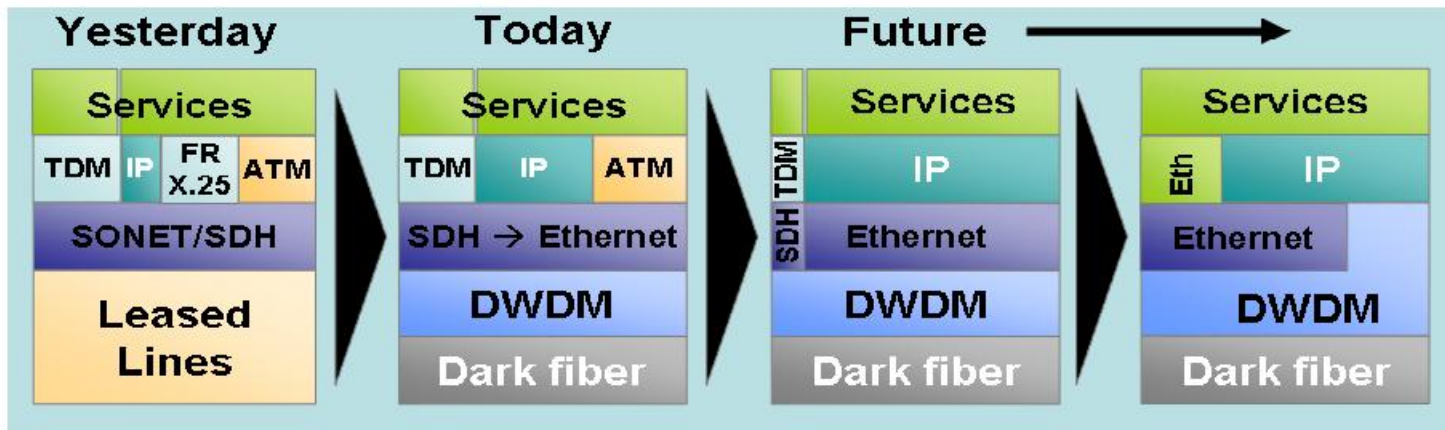


Fig. 4. Router-to-router test configuration.

10GE WDM PHY demo from Juniper/Adva [OFC08 NME4]

# Other vendors also believe this is the Future

## Ethernet (IP) Over Optics (WDM) Technology Enables Cost-Efficient Terabit Connection



- Optical transport (and access) will jointly evolve with class of e2e services
- Carrier Ethernet transport will over time substitute Sonet/SDH-based TDM services with improved service features & significant opex savings
- Cross-layer optimization will continue to improve overall cost efficiencies
- IP-over-WDM technologies, along with packetized optical networks, will serve the new Internet connectivity infrastructure for both fixed & mobile communities



Alcatel-Lucent

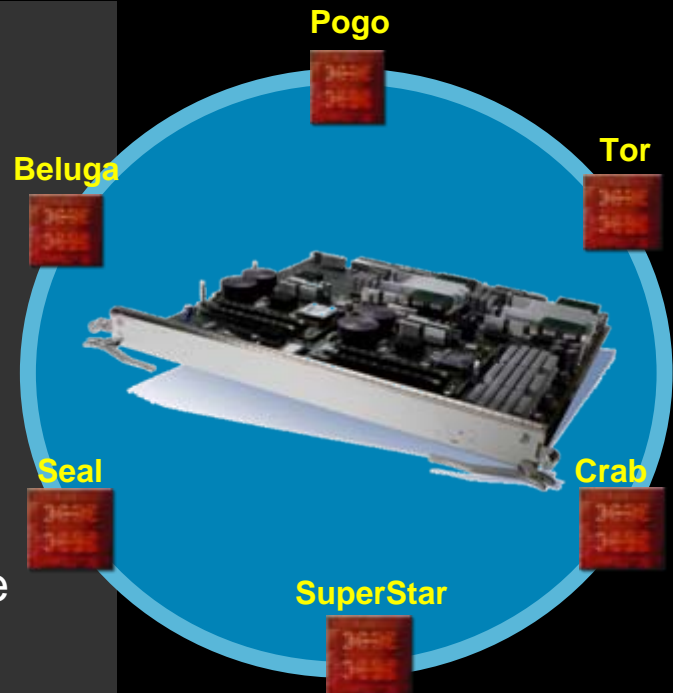


# Cisco Commitment to IPoDWDM Innovation

## ■ Interface speed

- Cisco 1<sup>st</sup> to productize 40G
- Leading 100G effort in IEEE (HSSG)
- 100G development work in progress

- 100Gbps Switch Fabric, MSC and PLIMs
- 10G, 40G, 100G interfaces
- Target for existing CRS-1 chassis with no power/cooling upgrades
- **Reduction of power/G by a factor of 2.5**
- Increased line card scale & new feature development
  - Prefixes, policers, queues, VLANs...
- Ability to run in lower performance and/or bandwidth mode to save power - Green Mode
  - 8% to 15%



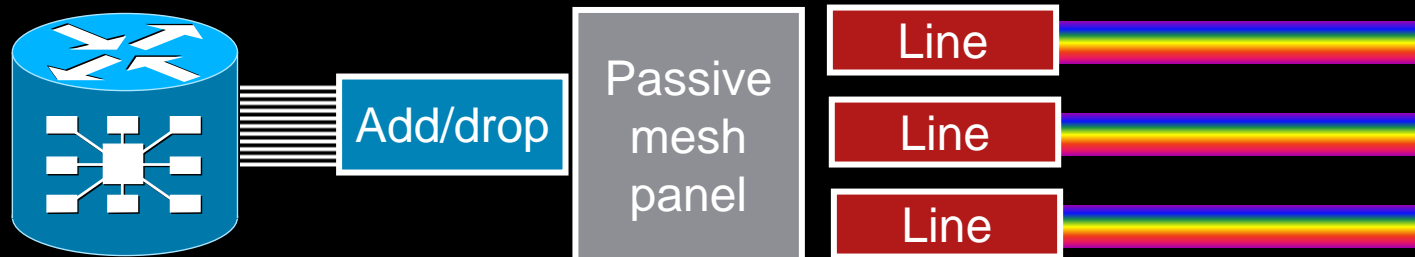
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- **Optical switching capability**

- Cisco is leading ROADM market
- Innovative, operationally friendly, mesh ROADMs
- Early to provide configurable add/drop switching



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- **Control plane**

- Introduced partial control plane (OSPF, NLAC)
- Experimenting with DWDM impairment aware GMPLS

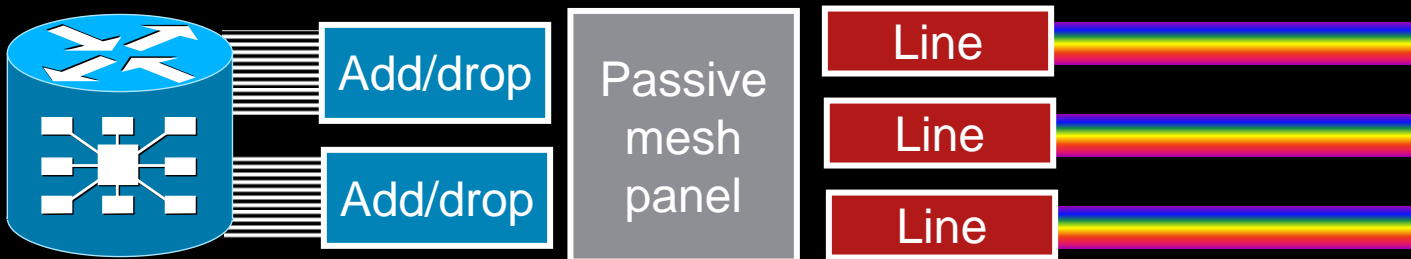
# Careful DWDM layer design with the future in mind

- **Future proof grid**

- Must accommodate a variety of possible future modulation formats for 100Gbps and beyond
- Flex Spectrum instead of a fixed grid
- In the mean time sticking to 100GHz grid is safest

- **In-service upgradeable optical switching nodes**

- MSTP architecture easy to upgrade as more DWDM links added and more add/drop is needed



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- **Open DWDM layer**

- Full support for alien wavelengths in MSTP
- Working to extend GMPLS to support 3<sup>rd</sup> party Tx/Rx
- No need to restrict Tx/Rx innovation to Transport vendor roadmap

# DWDM Layer Evolution must be Closely Tied to IP Layer Evolution

**Proactive protection** → demonstrated, working toward product

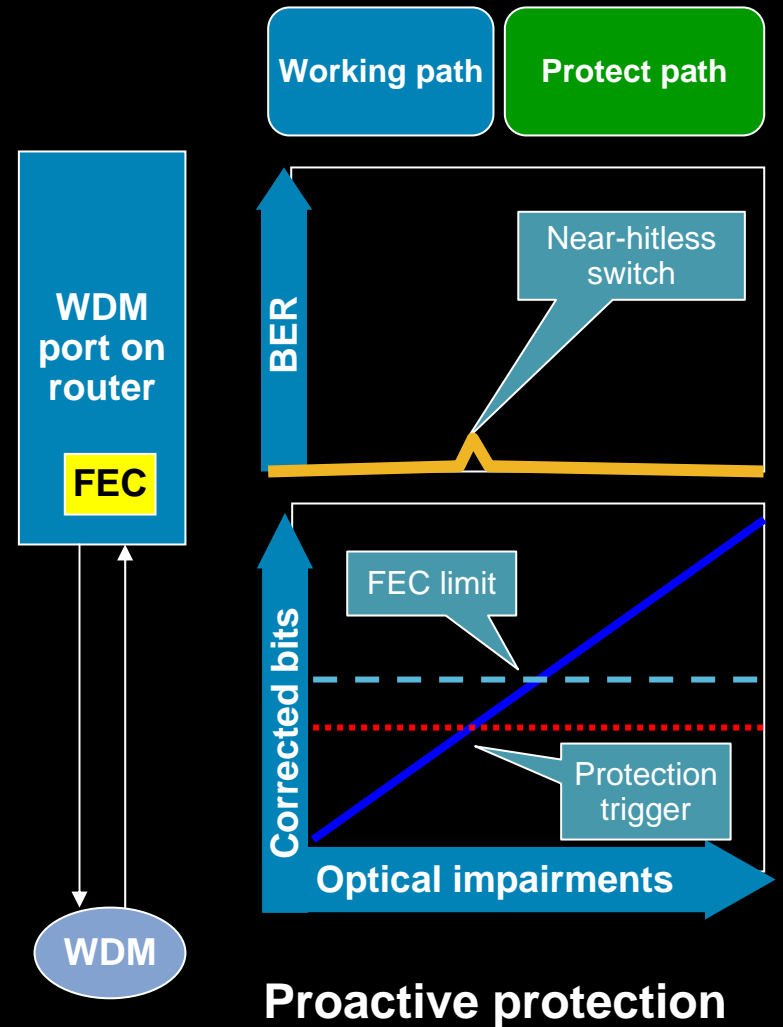
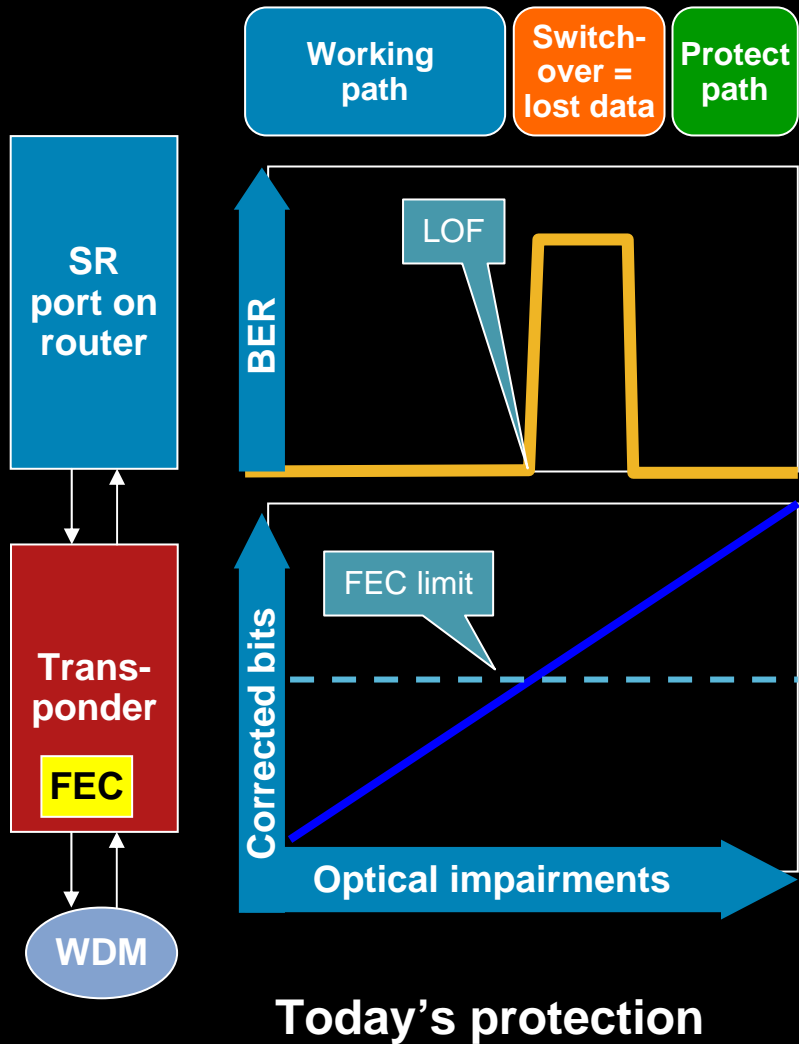
**SRLG sharing** → working toward product

**Coordinated maintenance** → working toward product

**Flexible bit rate** → trade-off bit rate for regeneration;  
investigating

**Optical auto bandwidth** → investigating

# Proactive Protection



# Pre-FEC Preliminary results

- Tested manual/fast cuts, slow OSNR and PMD degradations
- Tested MPLS FRR, IP FRR, ISIS convergence
- In all cases, achieve near zero outage for slow failures

Protection Type	Fault	Packet Loss (ms)		
		Highest	Lowest	Average
Proactive	Optical-switch (25ms)	11.48	10.99	11.24
Proactive	Noise-injection	0.12	0	0.05
Proactive	Fibre-pull	14.97	0	4.97
Standard	Optical-switch (25ms)	11.61	11.16	11.32
Standard	Noise-injection	2852	2602	2727
Standard	Fibre-pull	83.43	13.49	37.63

Noise injection 0.1 ~ 1dB / 1000ms



# HEAVY READING

*Heavy Reading* – Independent quantitative research and competitive analysis of next-generation hardware and software solutions for service providers and vendors

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## Long-Haul DWDM: Market & Technology Outlook

### Core DWDM Architectures & Operations

#### "Alien Wavelengths" & the Integration of WDM Optics on Client Equipment

One of the most interesting changes in the DWDM market over the past three years has been the development and positioning of architectures and solutions that support "alien wavelengths" – or the implementation of DWDM optics on clients of the DWDM network. The goal of this architecture is network simplicity and capex reduction, as it reduces a set of transponders in each network connection by placing DWDM optics on a router, switch, or multiservice provisioning platform (MSPP), which then interfaces passively to the DWDM network. The DWDM network, in the logical extreme of this architecture, is made up of passive mux/demux units, managed optical amplifiers, wavelength switches, and signal-conditioning equipment.

# Core DWDM Architectures & Operations

## Value of Integrating DWDM Optics on Client Equipment

DO YOU SEE VALUE IN INTEGRATING DWDM OPTICS ON ROUTERS AND SWITCHES TO REDUCE TRANSPONDERS IN A DWDM NETWORK?	NUMBER OF RESPONSES	PERCENT OF TOTAL
Yes	54	62%
No	7	8%
Not sure	26	30%
Total	87	

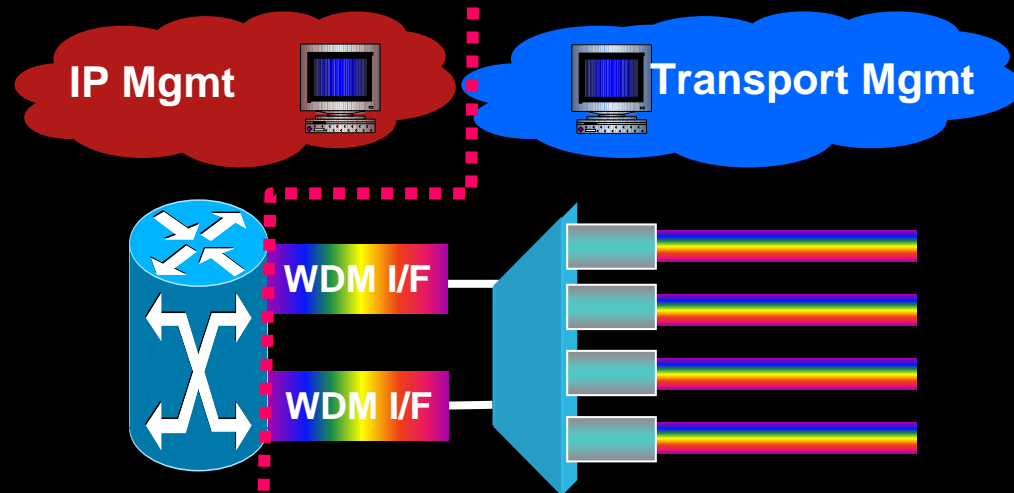
## Concerns About Integrating DWDM Optics on Routers & Switches

WHAT ARE YOUR CHIEF CONCERNS WHEN CONSIDERING INTEGRATING DWDM OPTICS ON ROUTERS AND SWITCHES?	NUMBER OF RESPONSES	PERCENT OF TOTAL
Poor/limited interoperability with DWDM system management	11	13%
Adds complexity to wavelength planning and management	28	33%
Loss of end-end control/management plane information and control	13	15%
Inferior support from router/switch vendors for DWDM transport	15	17%
No opinion/Don't know	19	22%
Total	86	

# IPoDWDM Supports 2 network management models

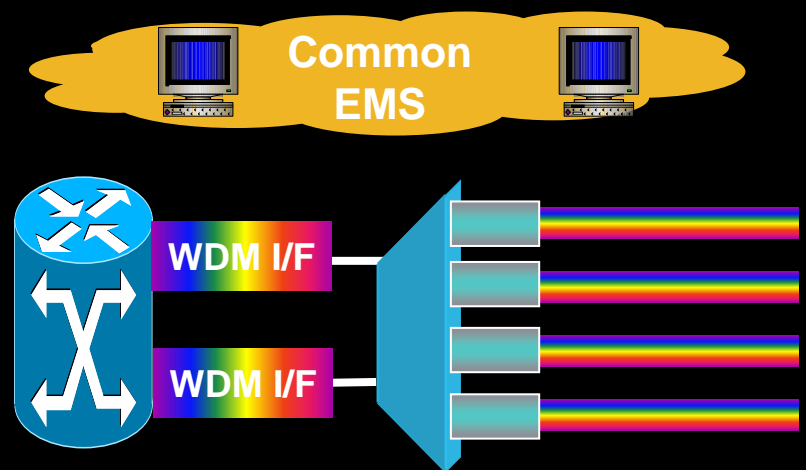
## 1. Segmented Management:

- Retain existing operational model for certain SPs
- Respect boundaries between IP/Transport groups



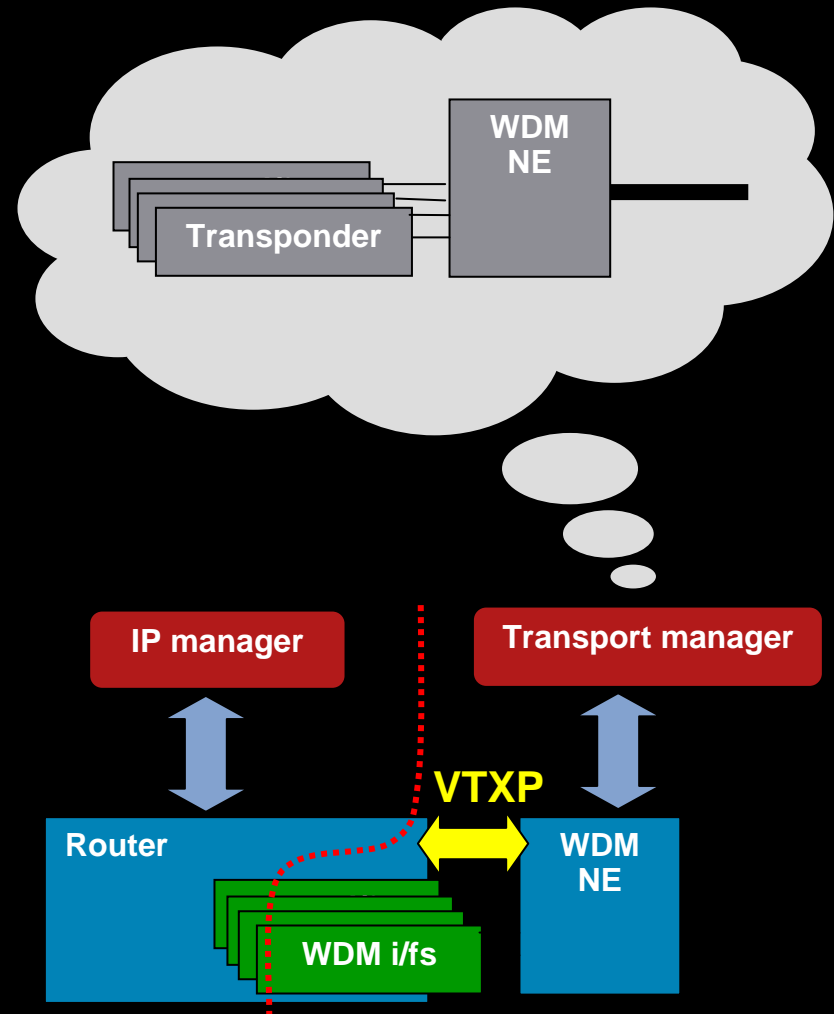
## 2. Integrated management:

- End to end provisioning
- Better trouble shooting
- 1 mgmt system, 1 DB
- Unified look & feel
- Lower OPEX



# The Virtual Transponder (VTXP) Concept

- Virtual transponder protocol
  - Secure session between Router and WDM NE
  - Supports full FCAPS for WDM i/f
  - XML based
- The WDM NE converts VTXP info to its legacy information model to the EMS
  - Router reflected as a transponder shelf
  - WDM i/f reflected as a transponder
- **No change to NMS/OSS**



# Brief Comparison

	Typical IP + DWDM	IPoDWDM
<b>Traffic addition</b>	Labour intensive	Zero touch (mostly)
<b>L0-L3 coordination</b>	Labour intensive: lots of processes	Seamlessly achieved via control plane
<b>Availability</b>	Lower – added OEO	Higher – minimum OEO
	Lower – all outages are traffic affecting	Higher – slow outages are hitless
	Lower – uncoordinated SRLGs	Higher – SRLGs are in sync
	Low – unplanned maintenance is not coordinated	High – even unplanned maintenance activity is coordinated
<b>Management</b>	Separate IP and DWDM management systems	Separate or integrated management, NLAC
<b>Space and Power consumption</b>	Sub-optimal	Optimal

# Summary

- Traffic growth requires more focus on IP routers and DWDM technology
- Other services must still be supported but the network is not optimized around them
- IPoDWDM provides the required innovation to save CAPEX, OPEX and reduce power for the network
- Today's features are only the beginning. We are committed to evolve the solution to a new level that is unachievable w/o integration
- Main challenges are non-technical. If you see the value, you can make it happen

# Q and A





# WDMPHY: Cost-Effective 10GE DWDM

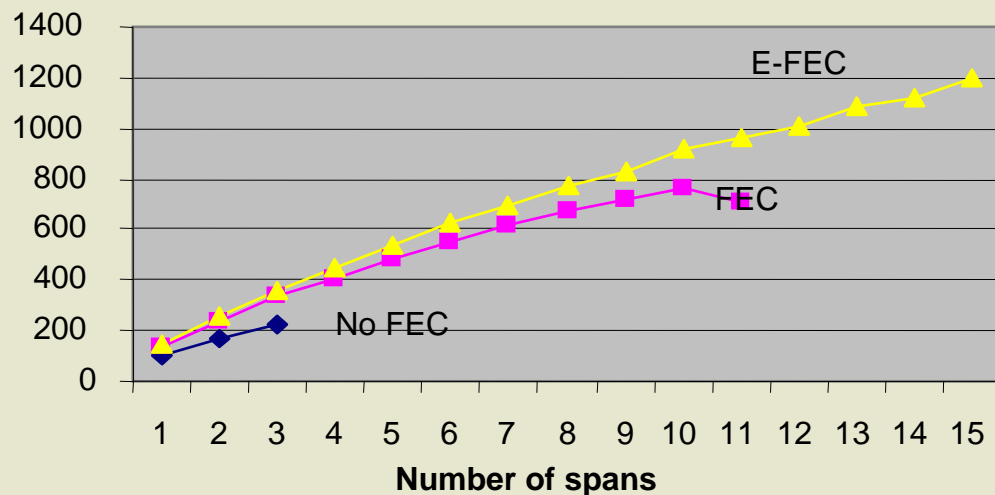
- **10GE LANPHY payload over G.709 payload (over-clocked)**
- **OAM&P based G.709 Standard (SDH-like)**
- **FEC enabled transmission G.709 Standard modes, and Enhanced-FEC >1500 km**

## ITU standard references:

- **G.709**
- Overclocking: G.sup43, sub-clause 7.1
- Enhanced FEC: G.975.1 Appendix I.7



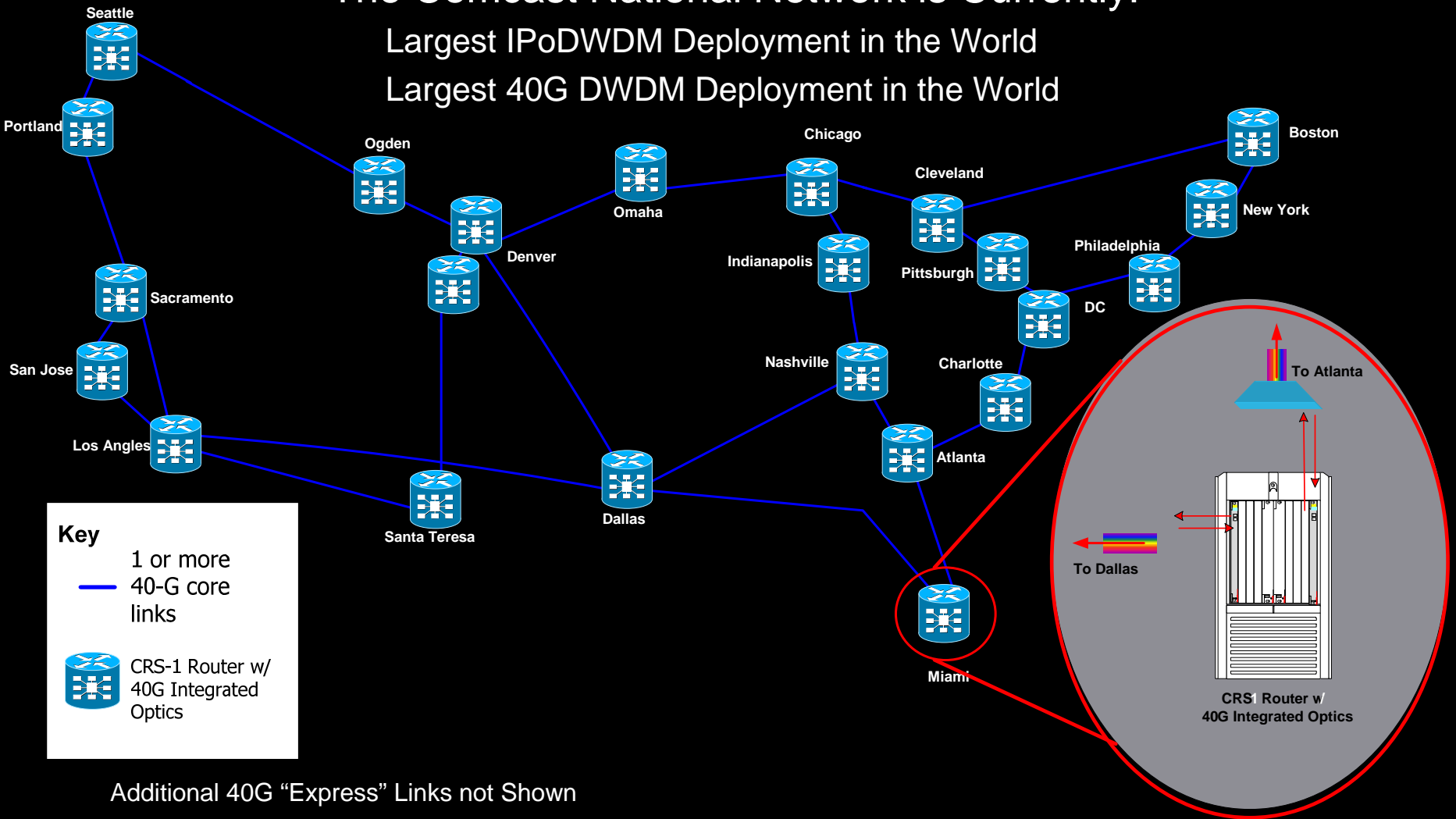
km of Reach (in a typical WDM system)



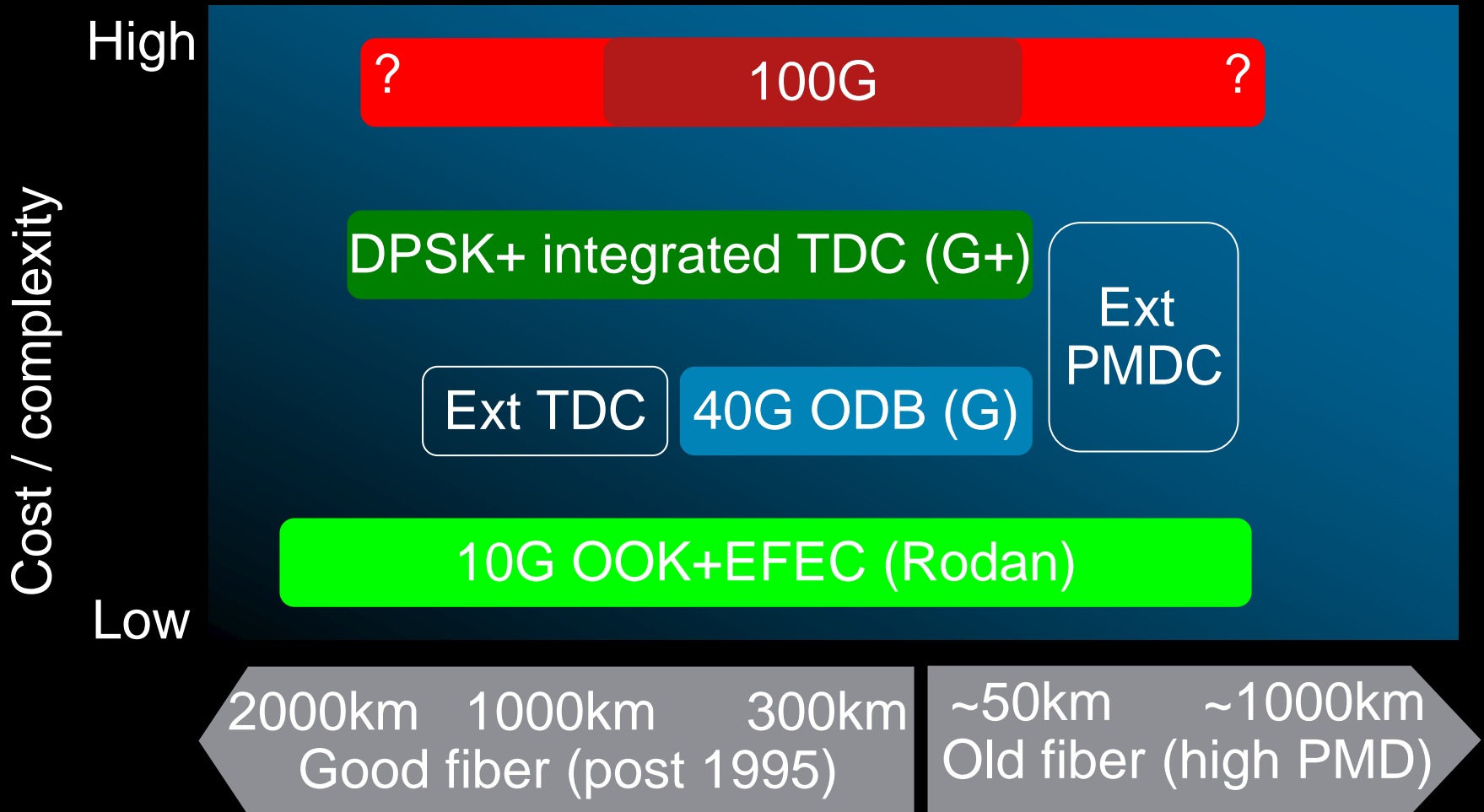
# Network Architecture

## First 40G IPoDWDM Network in the World

- The Comcast National Network is Currently:
  - Largest IPoDWDM Deployment in the World
  - Largest 40G DWDM Deployment in the World



# IPoDWDM Interface Evolution

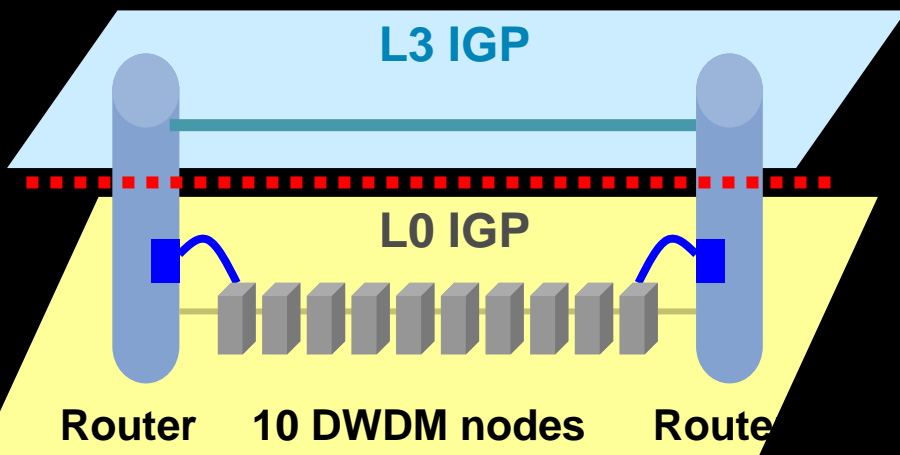


# Where is 100Gig



- Cisco is working closely with IEEE and ITU
- Cisco is also working in Parallel on a final product, not waiting for entire standard
- IEEE focused on 40Gig E and 100Gig E SR  
Cisco will also implement WDMPHY
- Target FCS 1HCY10

# Segmented Control Plane



## L0 topology visibility (OSPF database)

```
RP/0/RP0/CPU0:MiniRex#sh ospf vrf optical database
```

OSPF Router with ID (10.10.10.10) (Process ID 1)

### Summary ASB Link States (Area 0)

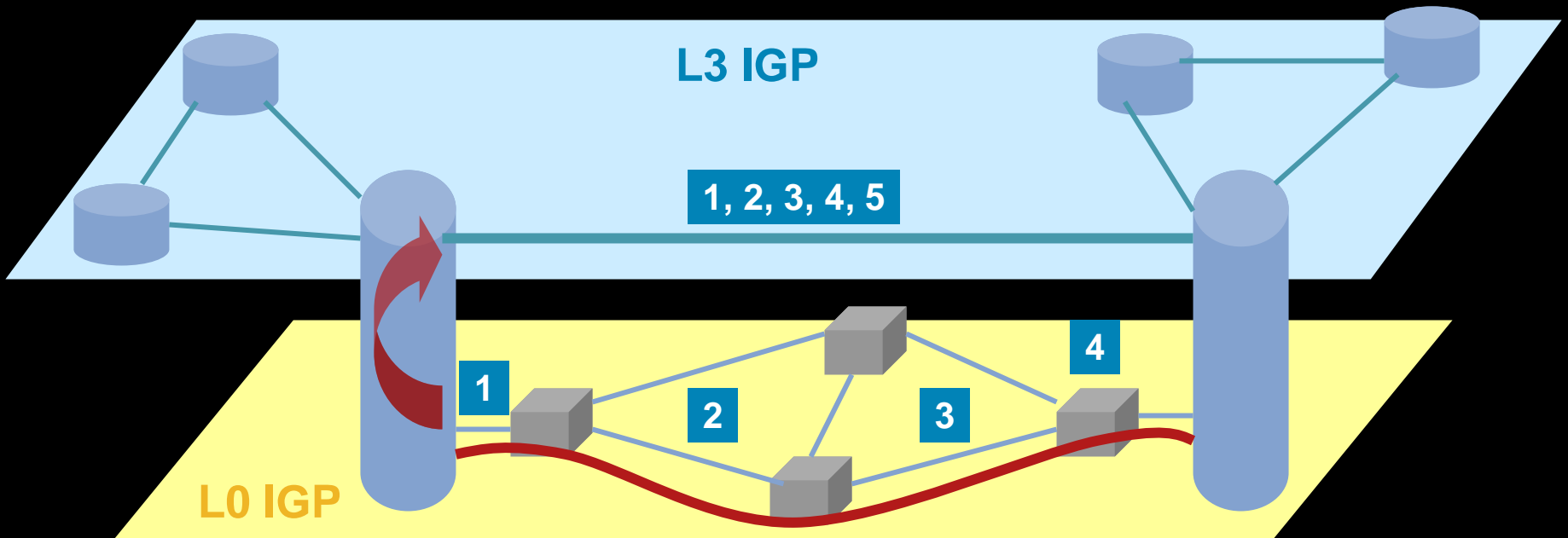
Link ID	ADV Router	Age	Seq#	Checksum
10.85.85.200	10.85.85.229	182	0x80000006	0x00027e
10.85.85.200	10.85.85.238	177	0x8000000b	0x002840
10.85.85.201	10.85.85.229	182	0x80000006	0x0049c7
10.85.85.201	10.85.85.238	177	0x8000000b	0x00cb0a
10.85.85.230	10.85.85.229	182	0x80000006	0x004f6d
10.85.85.230	10.85.85.238	177	0x8000000b	0x007f70
10.85.85.235	10.85.85.229	182	0x80000006	0x00b60b
10.85.85.235	10.85.85.238	177	0x8000000b	0x00b32d
10.85.85.236	10.85.85.229	182	0x80000006	0x00c163
10.85.85.236	10.85.85.238	177	0x8000000b	0x0095e5
10.85.85.237	10.85.85.229	182	0x80000006	0x00cbbc
10.85.85.237	10.85.85.238	177	0x8000000b	0x00779e
10.85.85.239	10.85.85.229	182	0x80000006	0x00658f
10.85.85.239	10.85.85.238	177	0x8000000b	0x00b4f0
10.85.85.244	10.85.85.229	182	0x80000006	0x00ae9b
10.85.85.244	10.85.85.238	177	0x8000000b	0x00083e

## Control plane debugging (Ping)

```
RP/0/RP0/CPU0:MiniRex#ping vrf optical 10.85.85.200
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 10.85.85.200,
timeout is 2 seconds:
!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max
= 1/1/4 ms
```

# Control Plane Futures

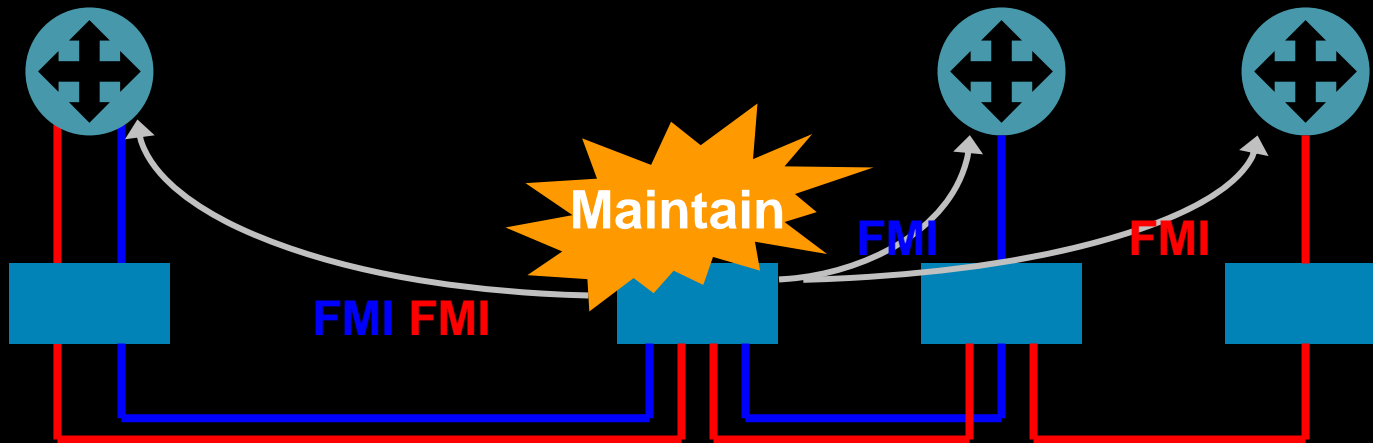
## Sharing L0 SRLGs w L3



1. Provision L0 SRLGs into DWDM nodes & discover them via L0 IGP
2. Discover SRLGs per link in L0 network
3. Aggregate SRLG info & advertise SRLGs in the L3 IGP
4. Periodically check if SRLGs have changed
5. Use this info for applications such as FRR, alarms, and L3 planning

# Control Plane Futures

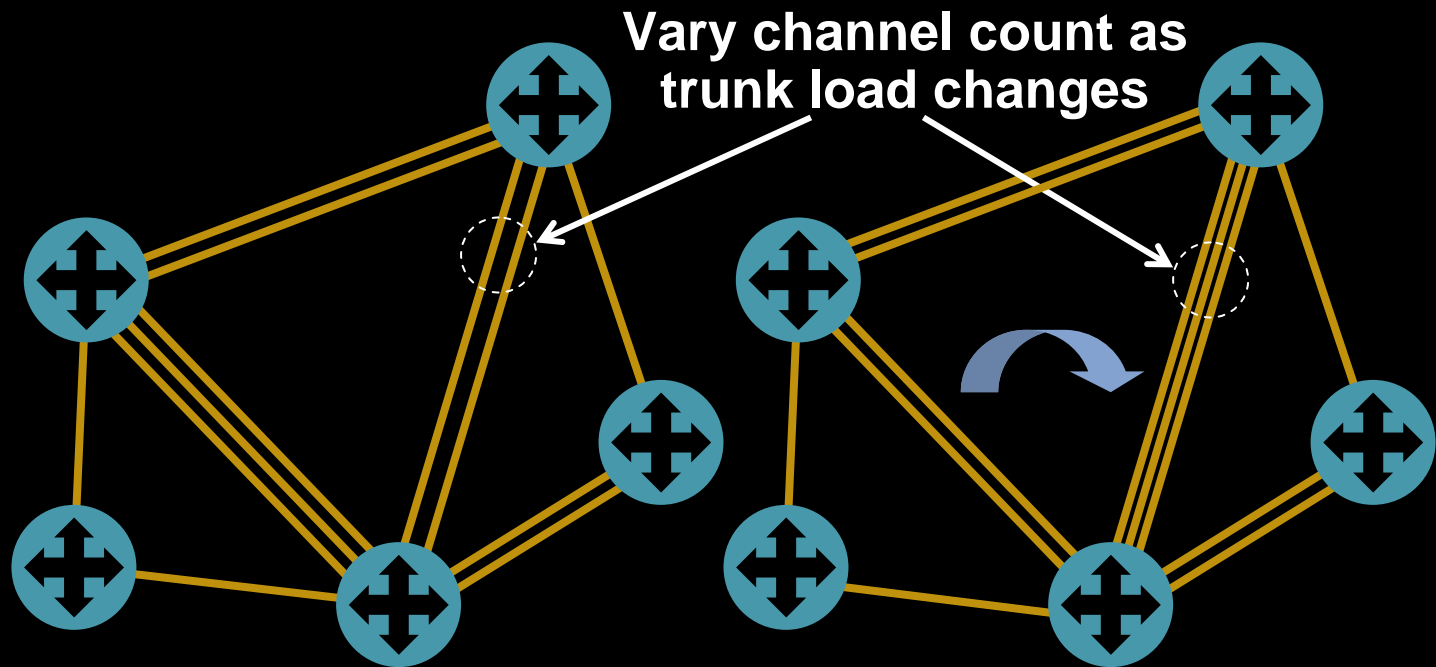
## Planned L0 Maintenance Driving Graceful L3 Shutdown



1. User informs L0 network of a span/NE that needs to be maintained
2. “Hitless” Fwd Maint Indicator (FMI) sent to end points of lightpaths traversing optical NE requiring maintenance
3. FMI signal can be propagated to router, invoking proactive protection for all traffic using these lightpaths
4. Router can alarm user or send back Nack if it cannot handle this link going down at this time
5. Eliminates need to coordinate maint activity between L0 & L3

# Control Plane Futures

## Optical Auto-Bandwidth

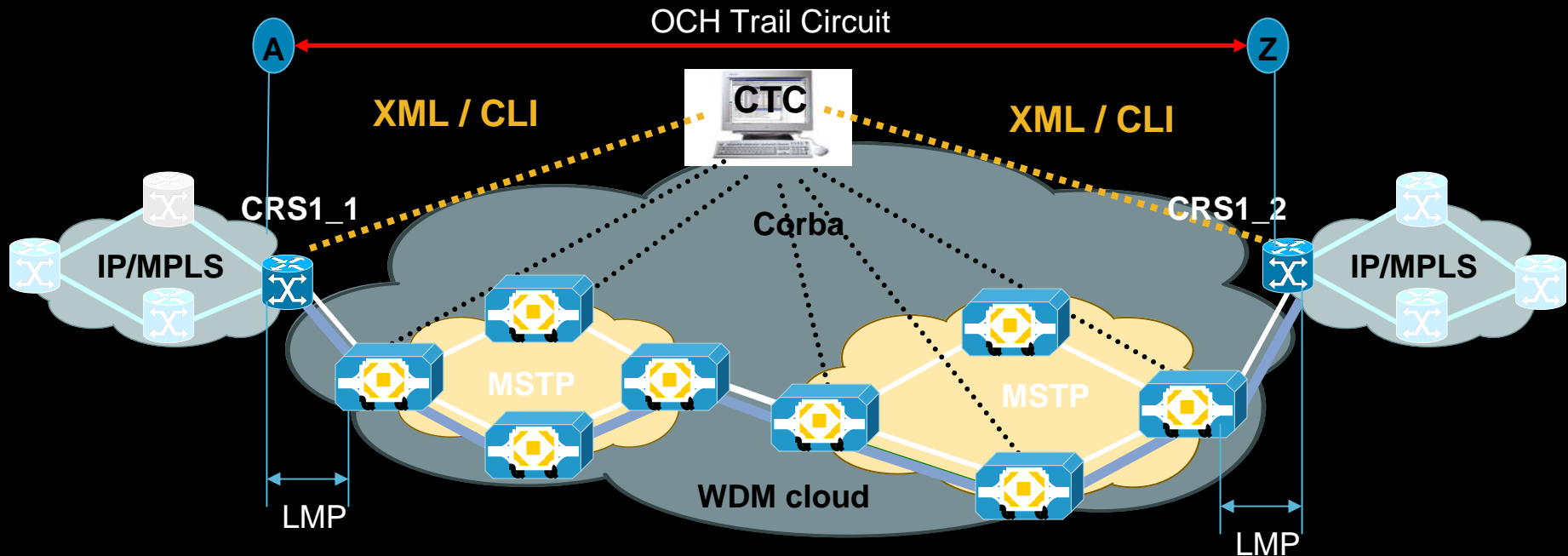


- Router measures utilization for L2 link bundles (LAG)
- If utilization is high – request the set up of another wavelength from L0 and add it to the link bundle
- Original topology retained to avoid convergence issues – channel add/remove within existing link bundles

# Segmented Management via CTC

## Managing the Transport Layer incl DWDM i/fs in MSTP R9.0

- CTC shows CRS nodes w WDM i/fs as well as MSTP nodes
- CTC can set up A-Z connections (incl DWDM controller)
- CTC displays “show DWDM controller” results and alarms



# Segmented Management via CTC

## Show Router DWDM Controller: Port status

The screenshot displays the Cisco Transport Controller (CTC) interface. The main window shows a network explorer on the left with a tree view containing nodes like 10.58.41.169, crs1-239.cisco.com, and tcc20-tcc22. A map of the United States is visible in the background. A foreground window titled "Show Router Port Status 0/1/0/1" provides detailed status for the port dwdm0/1/0/1.

**Show Router Port Status 0/1/0/1**

```

Port dwdm0/1/0/1

Controller State: up

Loopback: None

G709 Status

OTU
    LOS = 53          LOF = 0
    BDI = 0           IAE = 0
    BEI = 0           TIM = 0

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

FEC Mode: Standard FEC
                    EC(per second rate) = 0          UC
  
```

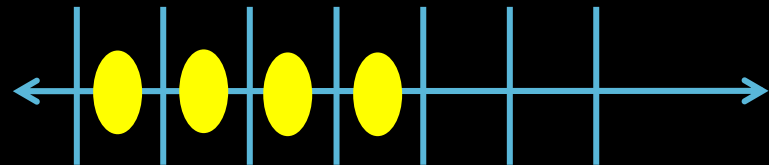
The foreground window also includes a "Download..." button and an "OK" button at the bottom.

# Careful DWDM layer design with the future in mind

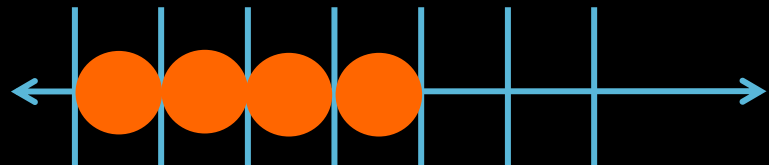
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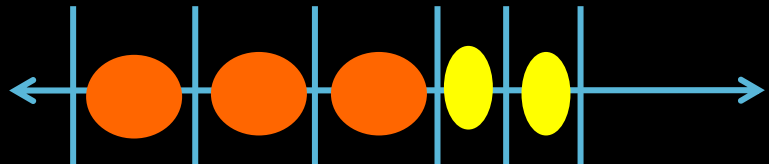
**50GHz grid (80 ch) is OK for 40G**



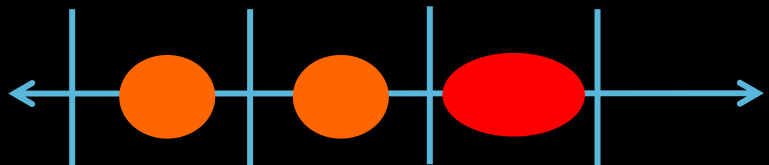
**Will it be optimized for 100G?**



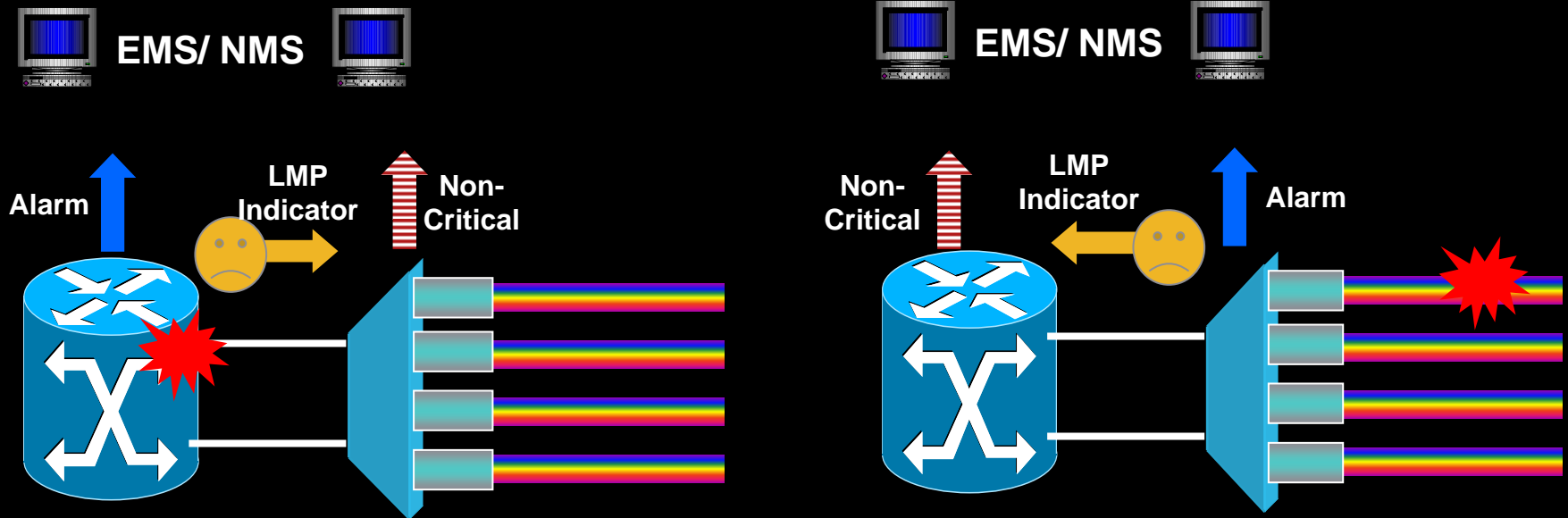
**Best solution: Flex Spectrum**



**100GHz is a safe bet near term**



# LMP and alarm correlation details



- Goal: ensure only one system must act upon a failure
- Value:
  - Downstream indicator allows router alarm to be downgraded → avoid L3 craft action
  - Upstream indicator allows transport alarm to be downgraded → avoid L0 craft action

