Cisco Expo 2008

DWDM technology for NGN SP infrastructure

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Enable Your Network
Empower Your Business

Evolution of DWDM systems

- Concept first published in 1970 with first system available in 1978 in the lab
- Evolution is happening in many areas:
  - supported topologies
  - number of transported channels
  - support for new client channel types
  - speed of transported channels
  - reach of the system (amplification, FEC)
  - functionality and flexibility
  - management and integration with other equipment

Cisco ONS 15454 MSTP

Platform introduction and overview

Cisco ONS 15454 MSTP
Fully reconfigurable, intelligent DWDM platform

- **Carrier Class DWDM Transport**
  - **Combines TDM, Ethernet, SAN and video services (fully integrated with Cisco ONS 15454 MSPP)**
  - **Originally introduced in 2003 as advanced metropolitan DWDM platform (broad services range, 800 km reach)**
  - **Through several releases evolves into platform covering all requirements for enterprise BC/DR solutions, metropolitan DWDM networks and LH applications (2300 km in release 8.5)**

- **Flexible optical networking platform**
  - **Cost effective Reconfigurable Optical Add/Drop Multiplexers (ROADM) with support for optical mesh**
  - **Full band Tunable 10G Lasers, modular client interfaces**
  - **Tight integration with IP core routers (IPoDWDM strategy)**

- **Future proof extensible platform**
  - **Up to 112 wavelengths available for the platform today**
  - **Qualified for 40G Transport**
  - **Further developed to extend the reach and functionality**

Cisco ONS 15454 MSTP

Examples of installations in Central and Eastern Europe

•Hansapank Estonia

•KPSI – Regional Government Poland

matáv

•Hungarian PTT National backbone

CESNET

•Czech Republic (NREN)

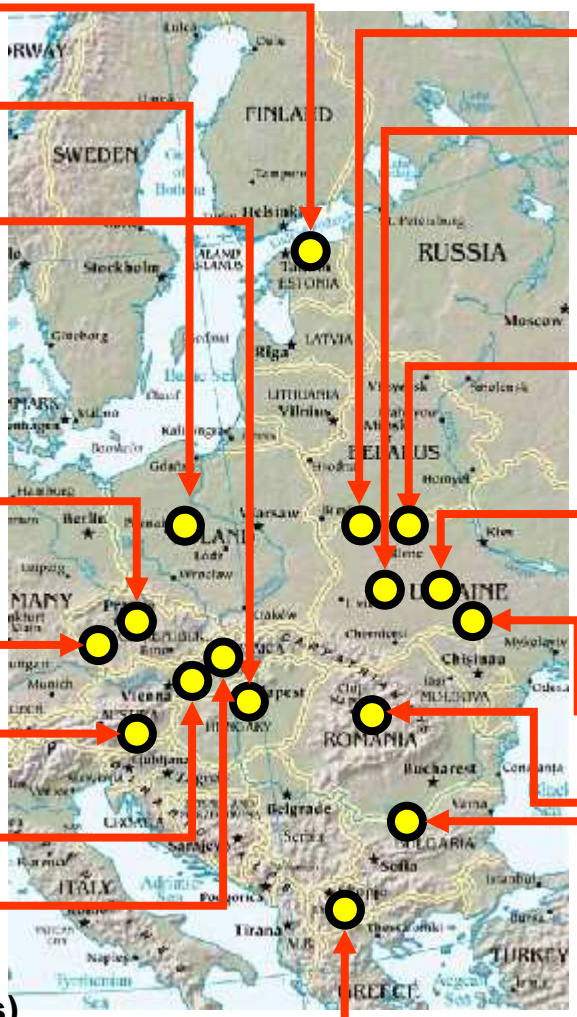
•Sloane Park Czech Republic

•Elekto Maribor Slovenia

•Slovanet Slovakia

•Energotel Slovakia

OSE (Greek Railways) National Backbone



UMC – Mobile SP National Backbone

Ucomline

UComLine - Ukrainian Challenger National Backbone

KievStar - Mobile SP National Backbone

DATAGROUP

Datacom - Ukrainian Challenger National Backbone

• UkrTelecom - Ukrainian PTT National Backbone

• ComBridge - Romania

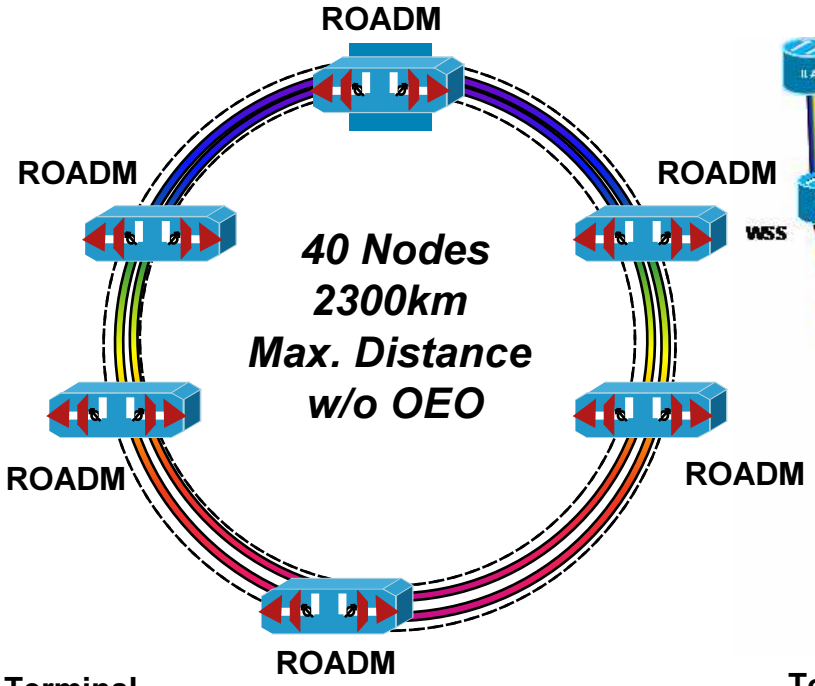
БТК

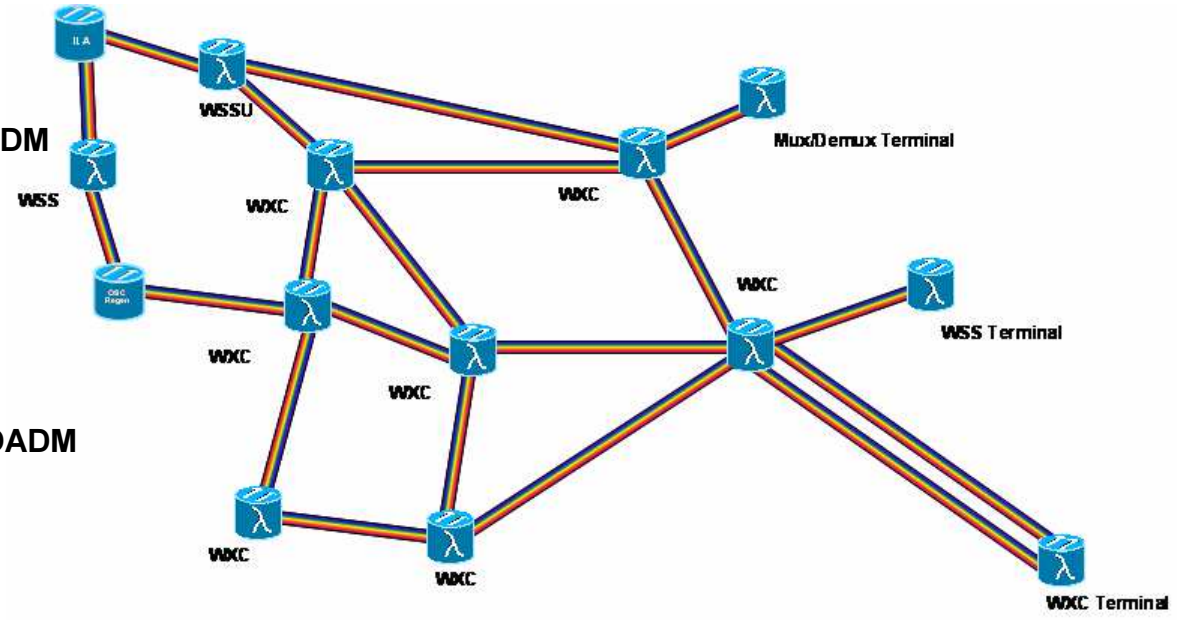
Bulgarian Telecom (BTC) National Backbone

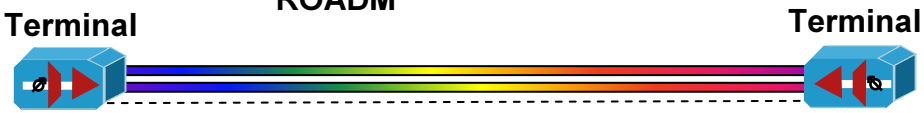
Cisco ONS 15454 MSTP

System performance, topologies and supported interfaces

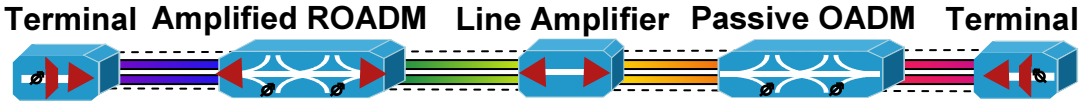
Cisco ONS 15454 MSTP release 9.0:
Network Topologies (examples w/o RAMAN)







Single Span: 37dB max w/OSC
44 dB max w/o OSC

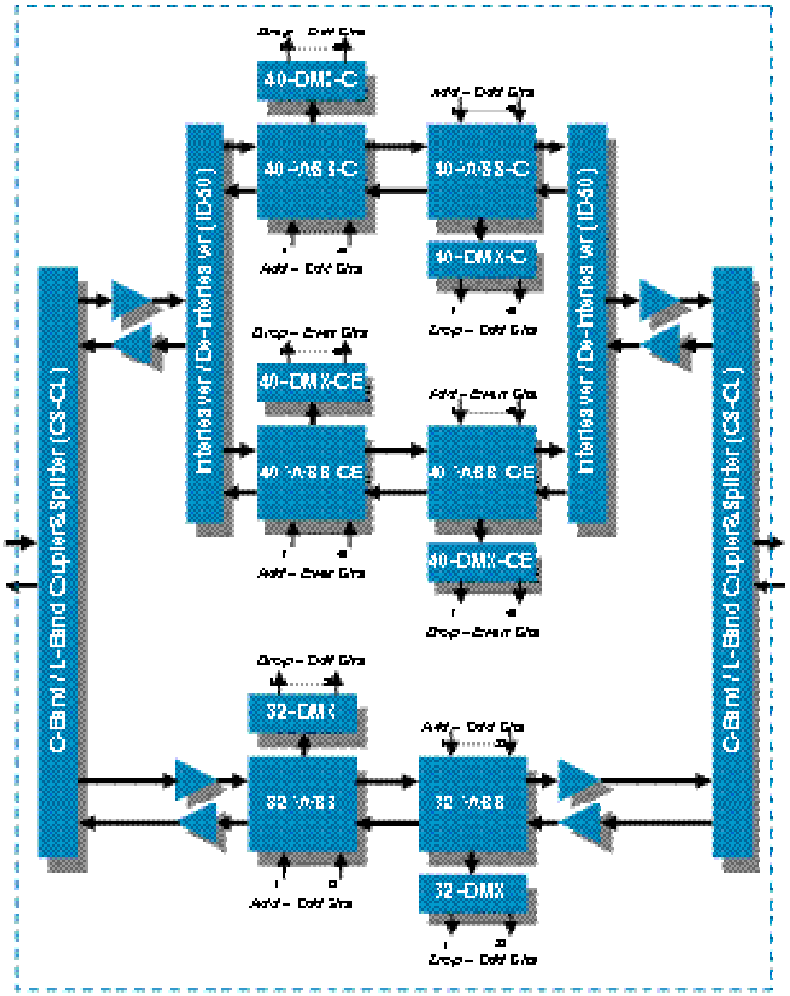


Point-to-Point 2300 km w/o OEO

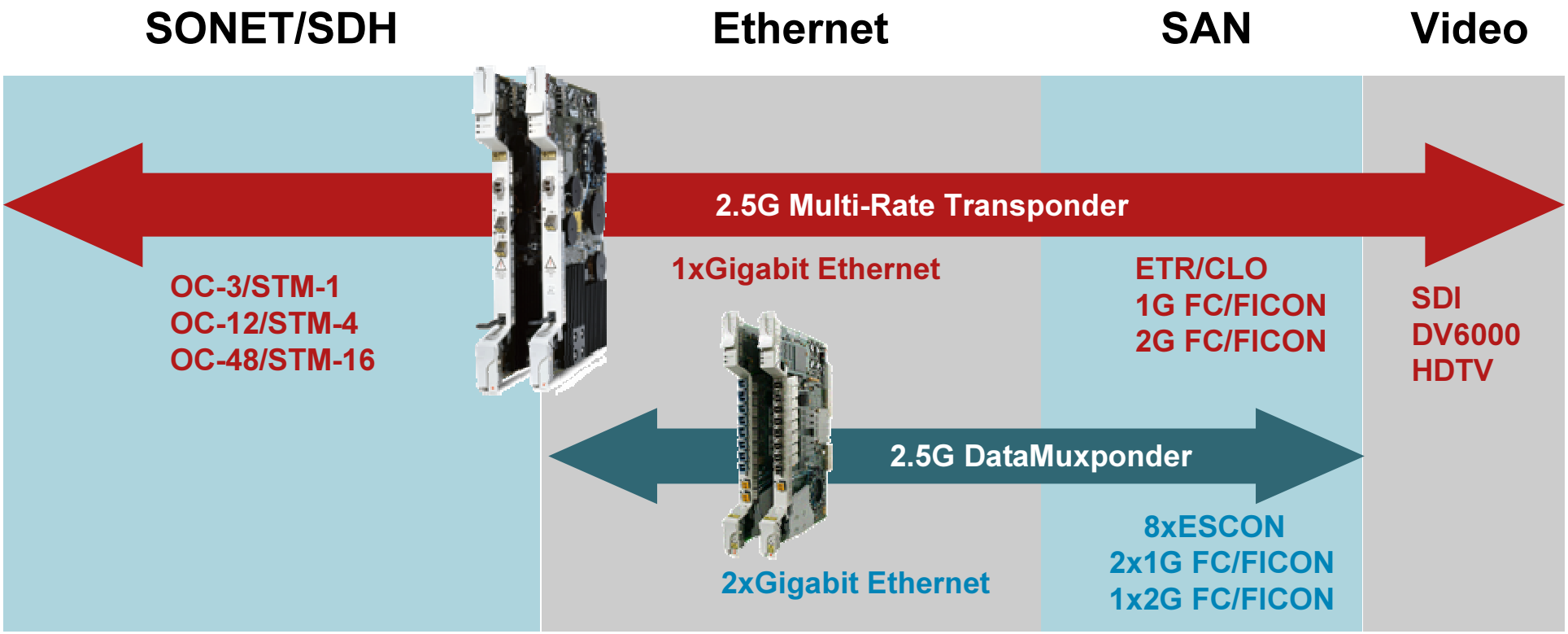
- ***Ring***
- ***Single span point to point***
- ***Multi span point to point*** **(bus)**
- ***Optical mesh*** **- manually patched (OIC) or using WXC (OXC)**

Scaling number of channels
50 GHz channel spacing in C-band, L-band

- **C-band**
  - Up to 80 chs available in C-band
  - Same amplifier set as for 40 channels
  - Improved unregenerated reach leveraging on OPT-AMP-C
  - In-Service upgradeable configuration for low day-1 cost
  - Interleaver/deinterleaver
- **L-band**
  - Additional 32 chs available in L-band
  - Different set of amplifiers
  - C/L splitter combiner

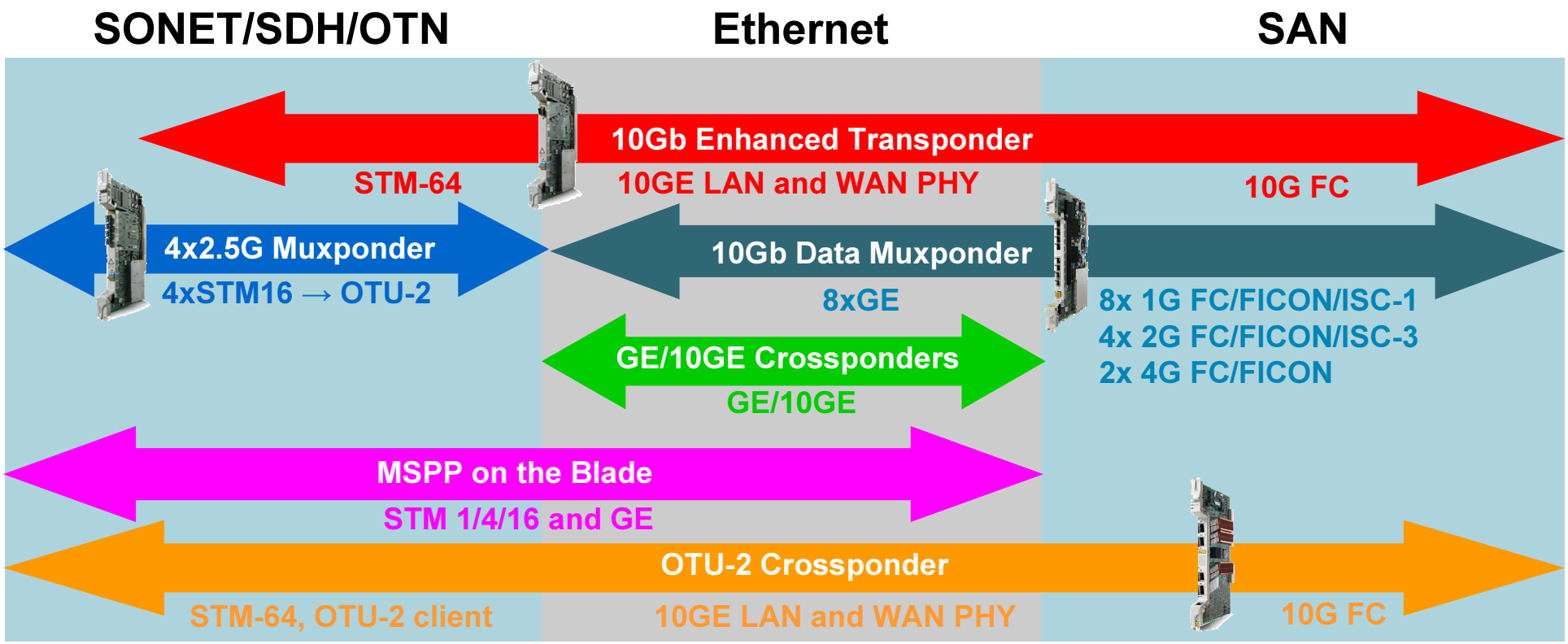


Cisco ONS 15454 MSTP
2.5Gbps Service Cards



- Simple planning, sparing, and ordering with multi-rate, multiprotocol and pluggable optics
- Optical, G.709 and payload monitoring
- FEC support at 2.5Gbps transponder
- G.709 support, trunk lasers 400GHz tunable in 100GHz grid
- Client 1+1, Y-cable and splitter protection

Cisco ONS 15454 MSTP
10*Gbps Service Cards*



- All 10G applications covered by 1 transponder,
- Aggregation cards reduce the cost of service delivery
- Full C-band or L-band tunability - 80 channels @ 50GHz spacing (*except crossponders)*
- FEC and EFEC support (G.975, G.975.1), G.709 support
- Optical, G.709 and payload monitoring, Client 1+1, Y-cable protection and 'splitter' (XP)

Cisco ONS 15454 MSTP

Wide range of telco and enterprise client interfaces

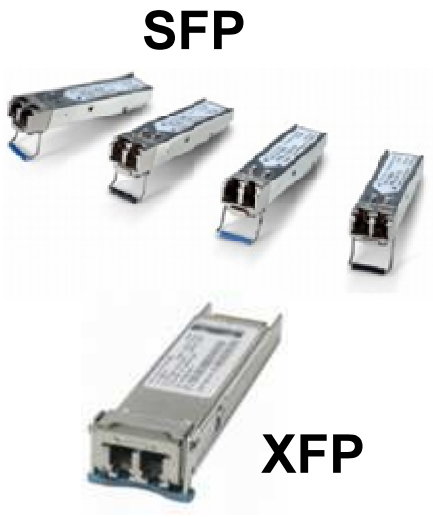
TDM/OTN	***Data***	***Storage***	***Video***	***2R***
•STM-1 •STM-4 •STM-16 •STM-64 •OTU-2 •STM-256 •E1, E3 (MSPP integration)	•FE •GE •10GE LAN PHY •10GE WAN PHY	•1G FC/FICON •2G FC/FICON •4G FC/FICON •10G FC •ESCON •ISC 1 •ISC 3 •Sysplex CLO •Sysplex ETR	•DV-6000 •HDTV •SDI •D1 video •DVB ASI	•Any rate from 100 Mbps to 2.5 Gbps

- *BENEFIT: High flexibility in system deployment, most of applications covered*
- *BENEFIT: Broad range of potential service offerings*
- *BENEFIT: 40Gbps support allows for further bandwidth scaling*

Pluggable client interfaces

Integrating flexible core with cost effective edge

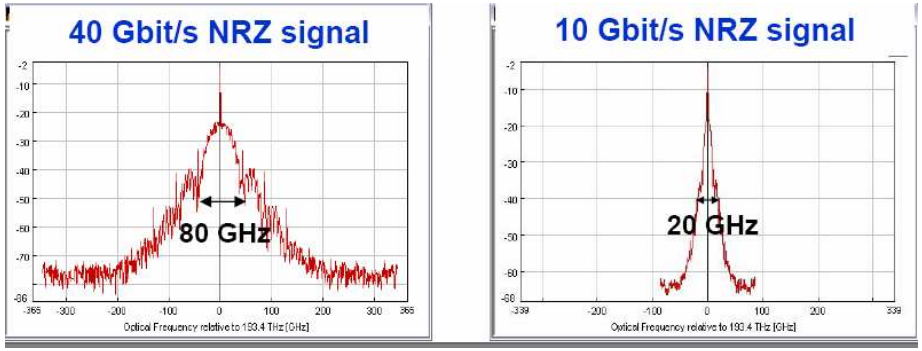
Type/category	Example
Grey optics 850 nm SFP	1000BaseSX, MMF FC clients
Grey optics 1310 nm SFP	1000BaseLX, SDH SR/IR clients, FC SMF clients
Grey optics 1550 nm SFP	1000BaseZX, SDH LR clients
Grey optics 1310 nm XFP	10GBaseLR, 10G FC, STM-64
Grey optics 1550 nm XFP	10GBaseER/EW/ZR, STM-64 LR
CWDM client optics	GE, 1/2G FC, STM-16
DWDM client optics	GE/10GE, 1/2/10G FC, STM-16/64, OTU-2
Metalic client SFP	10/100/1000BaseT for GE Xponder

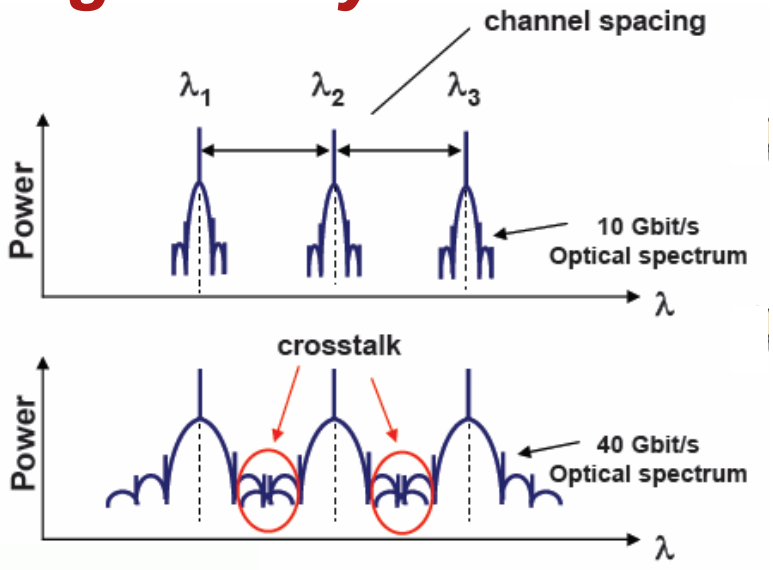


- *BENEFIT: Lower opex through common sparing with other Cisco products*
- *BENEFIT: Per port reach and rate selection*
- *BENEFIT: Tight integration of CWDM and DWDM from network perimeter*
- *BENEFIT: High transponder reusability for different services*

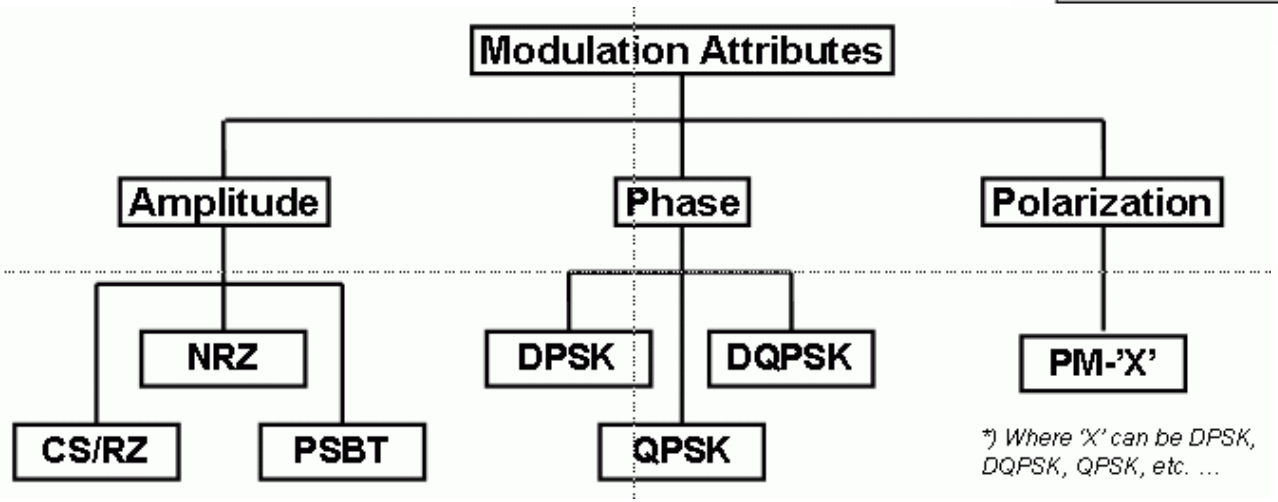
40Gbps transport
What is the market demand?

Compatibility with existing 10G systems.





New modulation formats are needed!



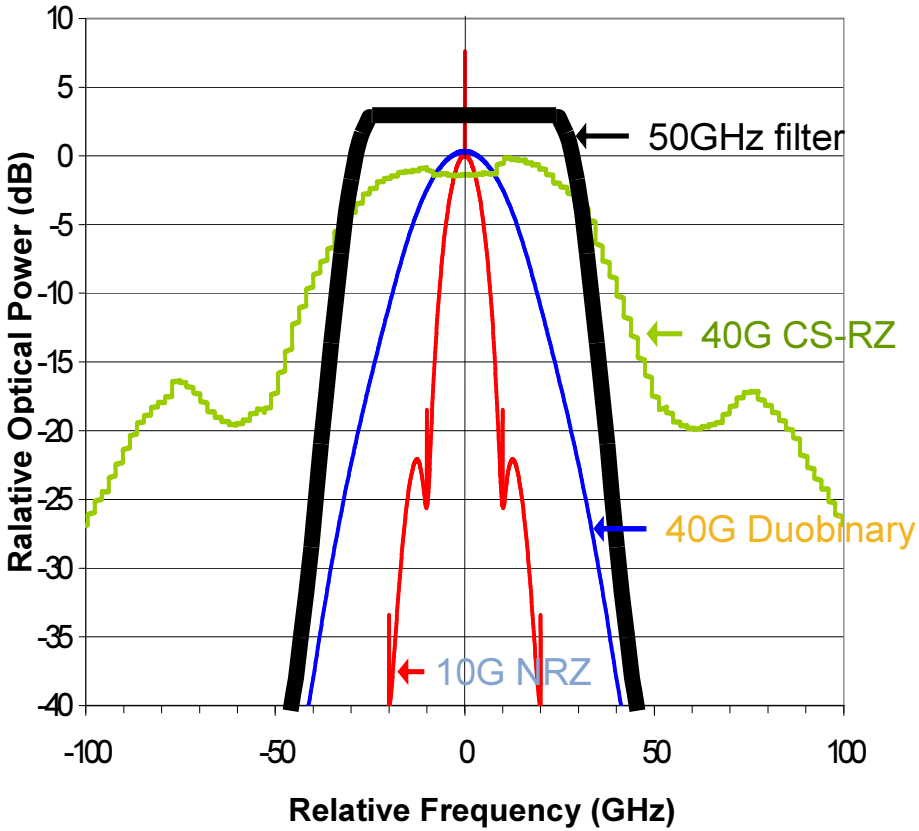
40Gbps transport
Technology options

Parameter	10G NRZ		ODB CRS Gen1	DPSK CRS Gen2	MC DWDM ODB	MC DWDM DQPSK		PM-QPSK
Required OSNR B2B (dB)	5		13	7.5	11	7.5		4
Reach (km)	>2000		<500	>1000	<1000	>1000		>2000
50 GHz Compatible	Y		Y	Y	N	Y		Y
Chromatic Dispersion Robustness with 1 / 2 dB of OSNR margin (+/-ps/nm)	500/800		100/150	700 (with TDC)	2000/3000	500/800		20,000
PMD Robustness with 1 / 2 dB of OSNR margin (ps)	10 / 14		2 / 2.8	2.5 / 3.5 / 8*	10 / 14	10 / 14		20
Complexity	LOW		LOW	MEDIUM	LOW	MEDIUM		HIGH

*G+ DPSK can get to 8 ps PMD adding PMDC and with 2.5 dB of OSNR margin (PMDC has limited dynamic reach)

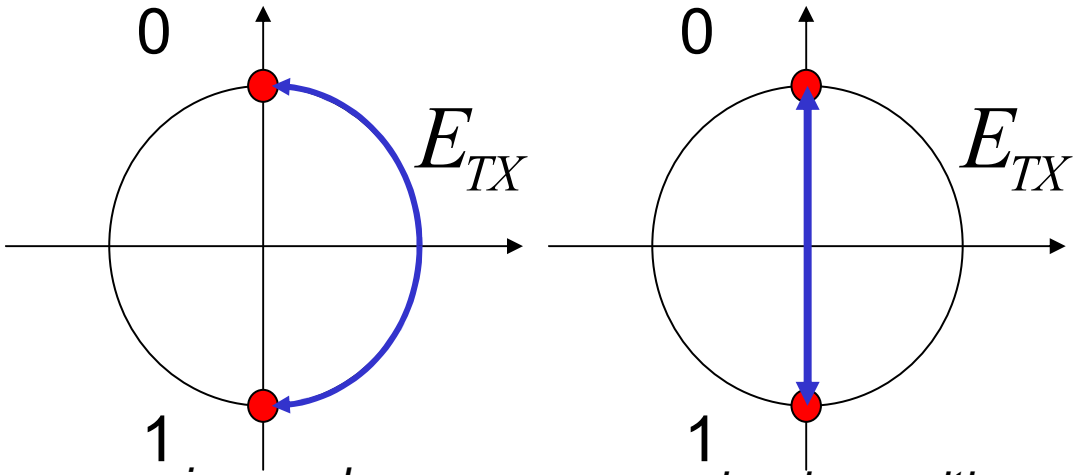
40Gbps transport
Optical Duobinary (ODB)

- Duobinary is a three level signaling scheme (-1,0,+1) that uses correlation between adjacent bits, introducing intersymbol interference in a controlled way
- The 2x narrower spectrum benefits optical filter and dispersion compensation robustness – allowing easier 40Gbps transmission over 10Gbps system



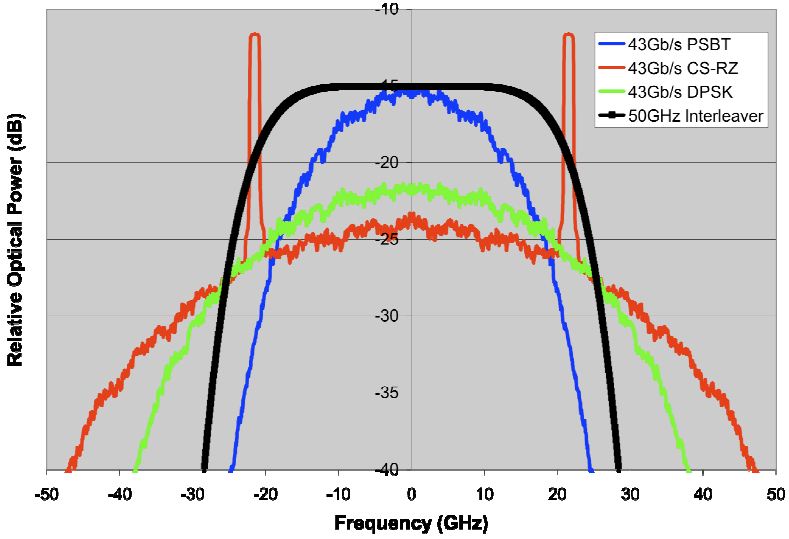
40Gbps transport
Differential Phase Shift Keying Encoding (DPSK)

- Transmitted bit encoded as binary differential phase shift 0 or π, each bit interferes with preceding bit
- DPSK transmission can be performed either at constant power or going through the origin of the complex phasor plane:



requires a phase modulator

can be done with a conventional MZ modulator

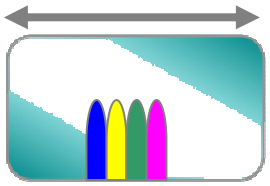


- Must be modified to fit into 50GHz channel spacing - DPSK+

40Gbps transport
What is Multi-Carrier-DWDM technology?

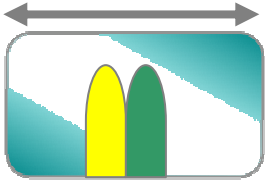
- **Multi-Carrier DWDM technology squeezes multiple 10Gbps signals in a single ITU-T compliant channel.**
- **Advantages of this technique are:**
  - 10G equivalent PMD robustness
  - 10G based technology (reduce electronic complexity)
  - Appropriate trade-off between cost and performances
- Challenge is the filter pass-band and the ability to squeeze Nx10G signals or Nx20G signals in the deployed system.

Phase 1
100GHz-spaced
4xODB



40G
(4x10G)

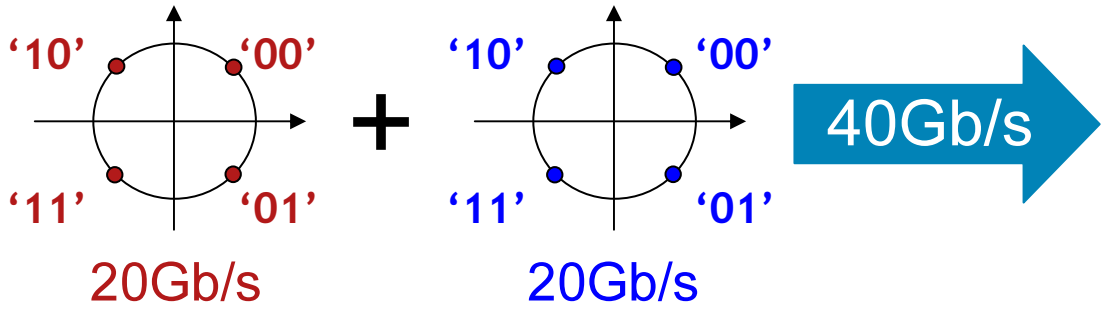
Phase 2
50GHz-spaced
2xDQPSK



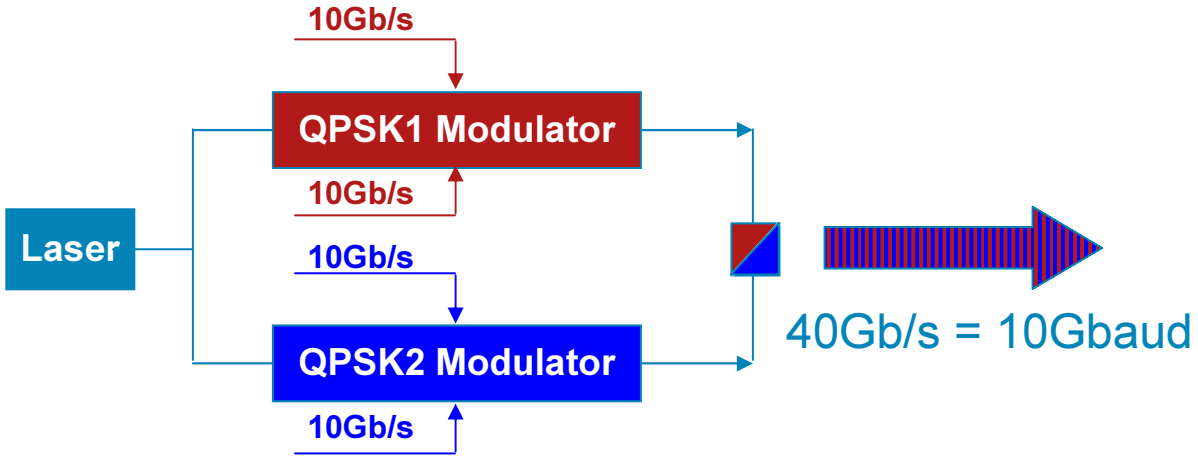
40G
(2x20G)

40Gbps transport - PolMux Solution
Dual Polarization QPSK with Coherent Detection

- **Transmitter:** Two QPSK signals are muxed in polarization



Same optical bandwitdh as a 10G NRZ

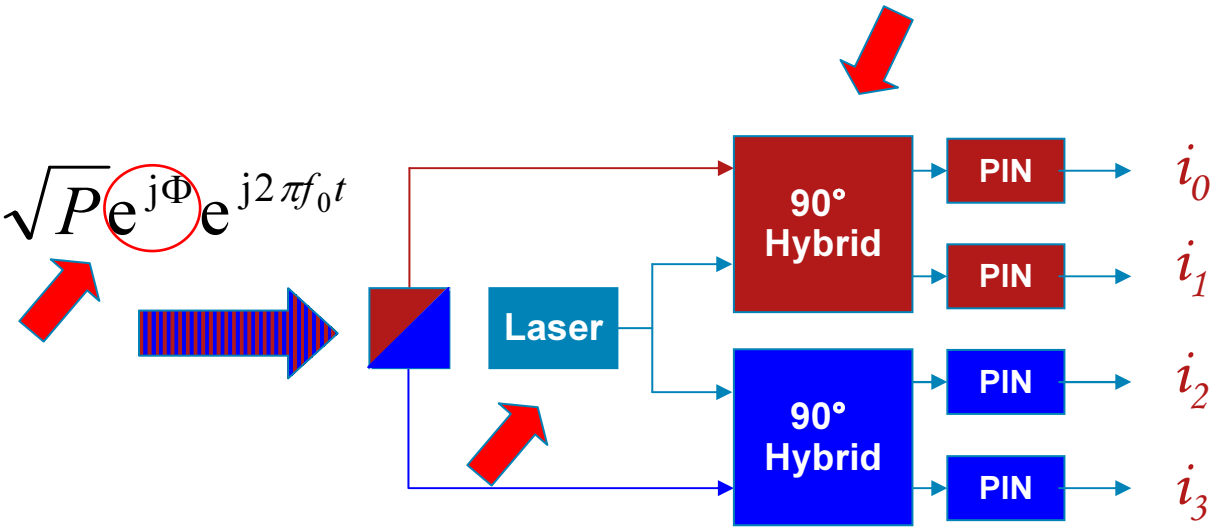


10Gbaud signal propagate into the fiber as a 10Gb/s signal

40Gbps transport - PolMux Solution

Dual Polarization QPSK with Coherent Detection

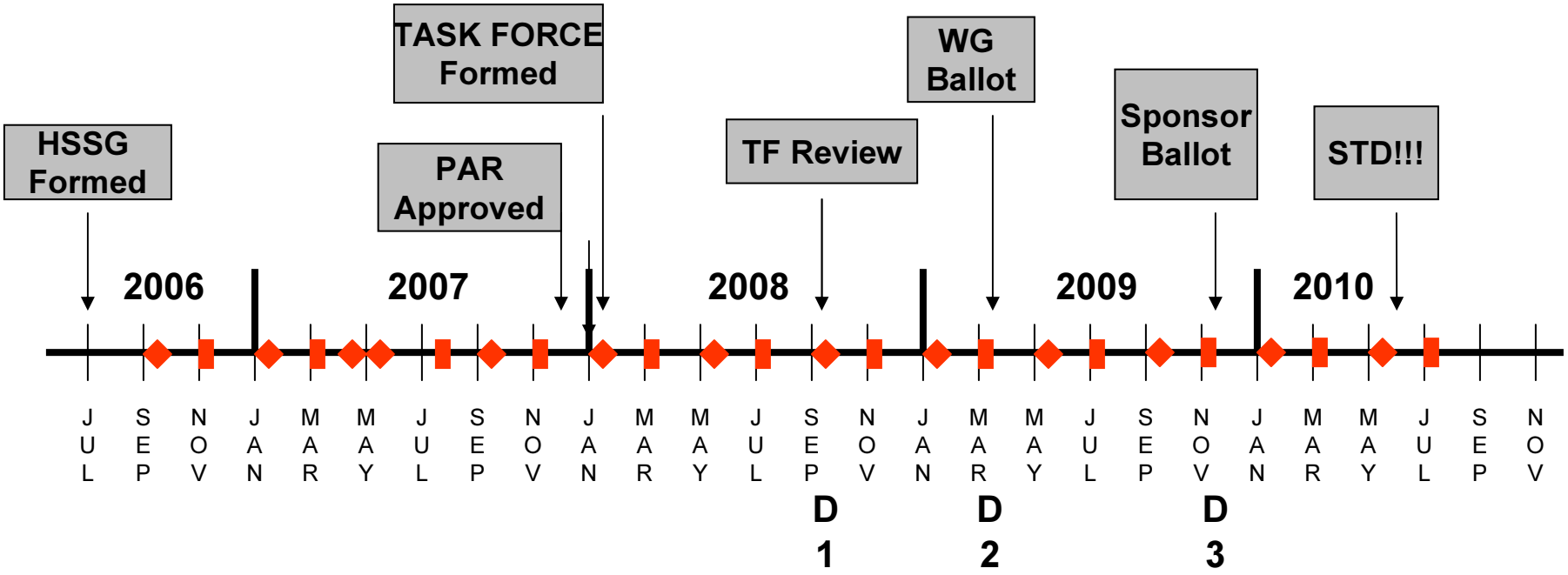
$$E(t) = \sqrt{P}\, e^{j\Phi} e^{j2\pi f_0 t}$$



- **<u>Receiver:</u>** Coherent detection
  - $e^{j\Phi}$: information to be detected
  - Local Oscillator provide a polarization reference
  - 90° Hybrid:

1. *Converts phase modulation in amplitude modulation*
2. *provides in-phase and quadrature information Φ (i_0, i_1)*

100 Gbps Ethernet
Timeline



- Cisco is working closely with IEEE and ITU
- First demo with Comcast in June 2008
  h*ttp://newsroom.cisco.com/dlls/2008/prod_062608c.html*
- IEEE focused on 40Gig E and 100Gig E LR
- Target FCS 1HCY10

100Gig E in the IEEE
802.3ba Objectives

- **Support full-duplex operation only**
- **Preserve the 802.3 / Ethernet frame format utilizing the 802.3 MAC**
- **Preserve minimum and maximum FrameSizeof current 802.3 standard**
- **Support a BER better than or equal to 10-12at the MAC/PLS service interface**
- **Provide appropriate support for OTN**
- **Support a MAC data rate of 40 Gb/s**
- **Provide Physical Layer specifications which support: 40 Gb/s**
  - –at least 100m on OM3 MMF
  - –at least 10m over a copper cable assembly
  - –at least 1m over a backplane
- **Support a MAC data rate of 100 Gb/s**
- **Provide Physical Layer specifications which support:**
  - –at least 40km on SMF
  - –at least 10km on SMF (likely to become 2-4km)
  - –at least 100m on OM3 MMF
  - –at least 10m over a copper cable assembly

100GE and the ITU

- ITU agreed to optimize new OTU4 rate for 100GE transport
- Industry appears to have learnt it's lesson from 10GE (i.e. LAN/WAN PHY)
  - Ideally want one mapping, one FEC and one modulation scheme !!!
  - some resistance from traditional transport vendors
- Transmission requirements are the same as 40G:
  - Must work over existing, installed DWDM common equipment;
  - Support 50GHz DWDM channel spacing;
  - Full band tunable lasers on 50GHz ITU grid
  - Optical reach of ≥ 1,500km;
  - Chromatic dispersion tolerance of >±800ps/nm;
  - Polarization Mode Dispersion tolerance of > 10ps (mean DGD);
  - Must be "plug and play" and installable by existing field technicians
- 40G was the first commercial application for advanced modulation:
  - 100G will build on similar approaches
  - DQPSK and DP-QPSK (preferred) are the front runners

Cisco ONS 15454MSTP multivendor interoperability
Alien wavelength support

Available options:

- **Colored pluggables:**
  - **DWDM XENPAK, X2, XFP**
  - **DWDM GBIC, SFP**
- **DWDM line cards (e.g. from MSPP)**
- **IPoverDWDM interfaces**
- **Generic signal (e.g. from 3rd party)**

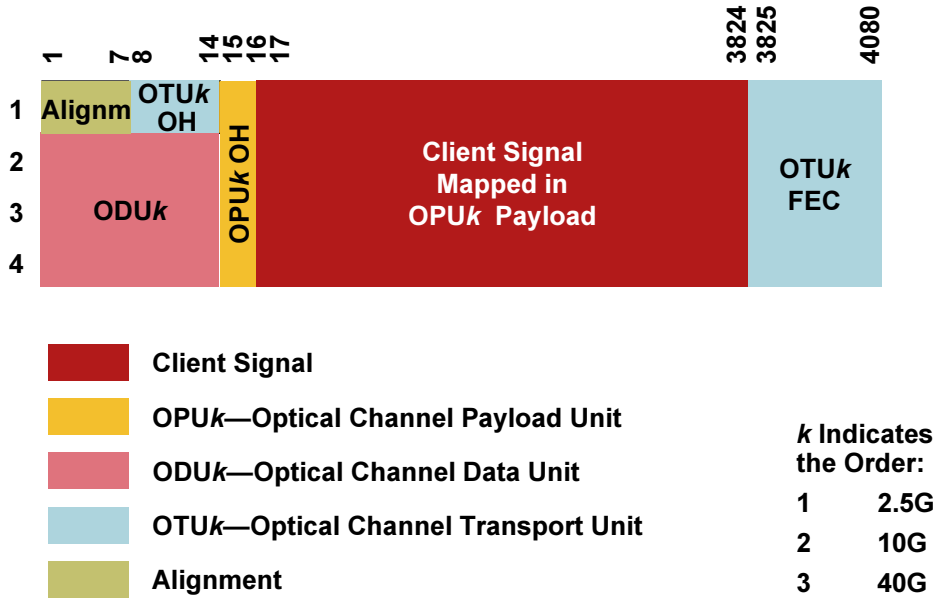
1. **Technology:**
   - **Transmitter characteristics:**
     - **Modulation format: NRZ / ODB**
     - **Transmitter type: MZ / DML / EML**
   - **Receiver characteristics:**
     - **Receiver Threshold: Opt / Avg**
     - **no-FEC / FEC / E-FEC**
     - **2R / 3R**
2. **Bit Rate**
3. **Sensitivity Back-to-Back**
4. **TX Optical Output Power Range: Pmin ÷ Pmax [dBm]**
5. **TX Wavelength Stability: [±pm]**
6. **Chromatic Dispersion Robustness**
7. **Scale Factors: F-PPL, F-POL, F-OSNRPL, F-OSNROL**
8. **Gaussian X-Talk-penalties**
9. **Single-interfering X-Talk penalties**

- *BENEFIT: High degree of interoperability with 3rd party equipment*
- *BENEFIT: Lower cost per channel where transponder is not needed*

Advanced monitoring functionalities
Monitoring of multiple levels of communication

- Optical parameters
  - signal levels
  - laser bias
- OTN
  - G.709
  - FEC/EFEC statistics
- Payload specific
  - RMON like information for ethernet
  - 8B/10B, running disparity for FC
  - SDH specific
  - others (ESCON, ...)

Encapsulation for optical channels
OTN G.709 support on Transponder/Muxponder



- SW selectable OTN and GCC ON/OFF support available on 10Gb transponders and muxponders and 2.5G MR transponder
- G.709 used for 10GE and 10G FC in overclocking mode

BENEFIT: OTN is ITU standard for mapping and managing WDM network which allows for interoperability of equipment at wavelength layer

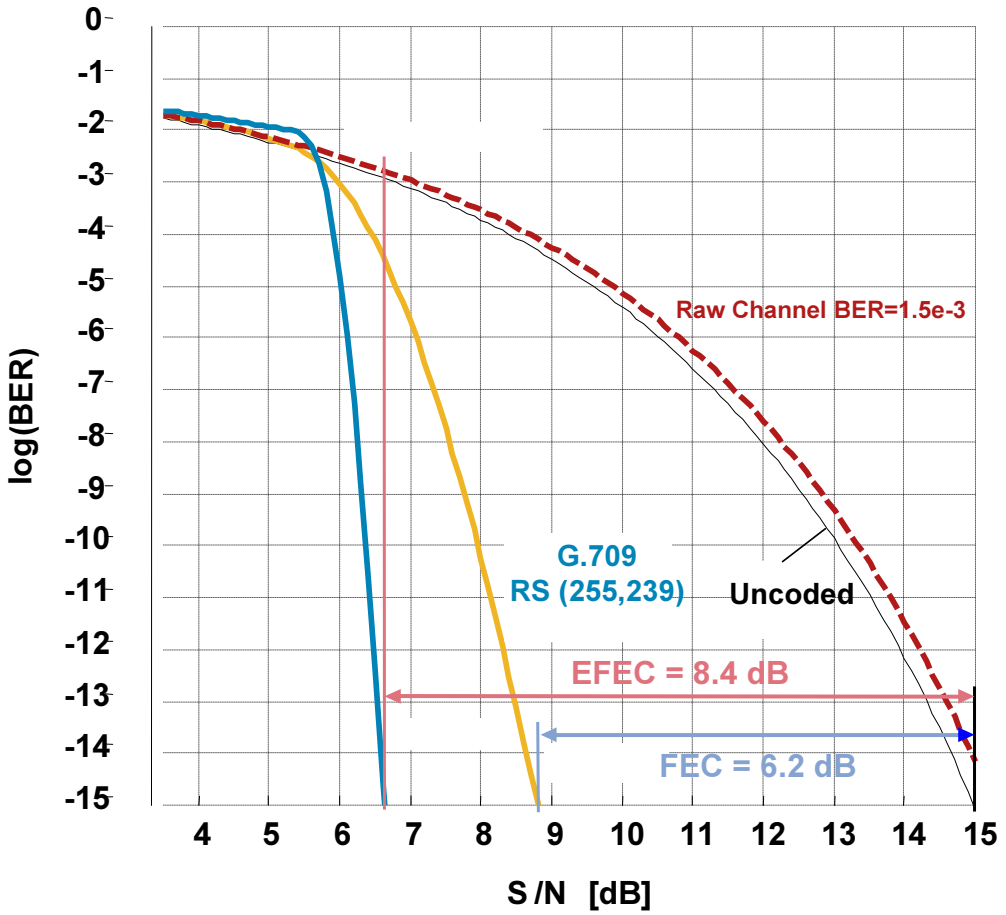
BENEFIT: Provides payload and signal performance monitoring

BENEFIT: Digital wrapper allows FEC to be applied in non-proprietary fashion

Enhancing system reach
Software selectable FEC configuration

- All 15454 10G transponders/ muxponders offer SW Selectable No FEC/FEC/EFEC
- 2.5G transponders offer SW Selectable No FEC/FEC

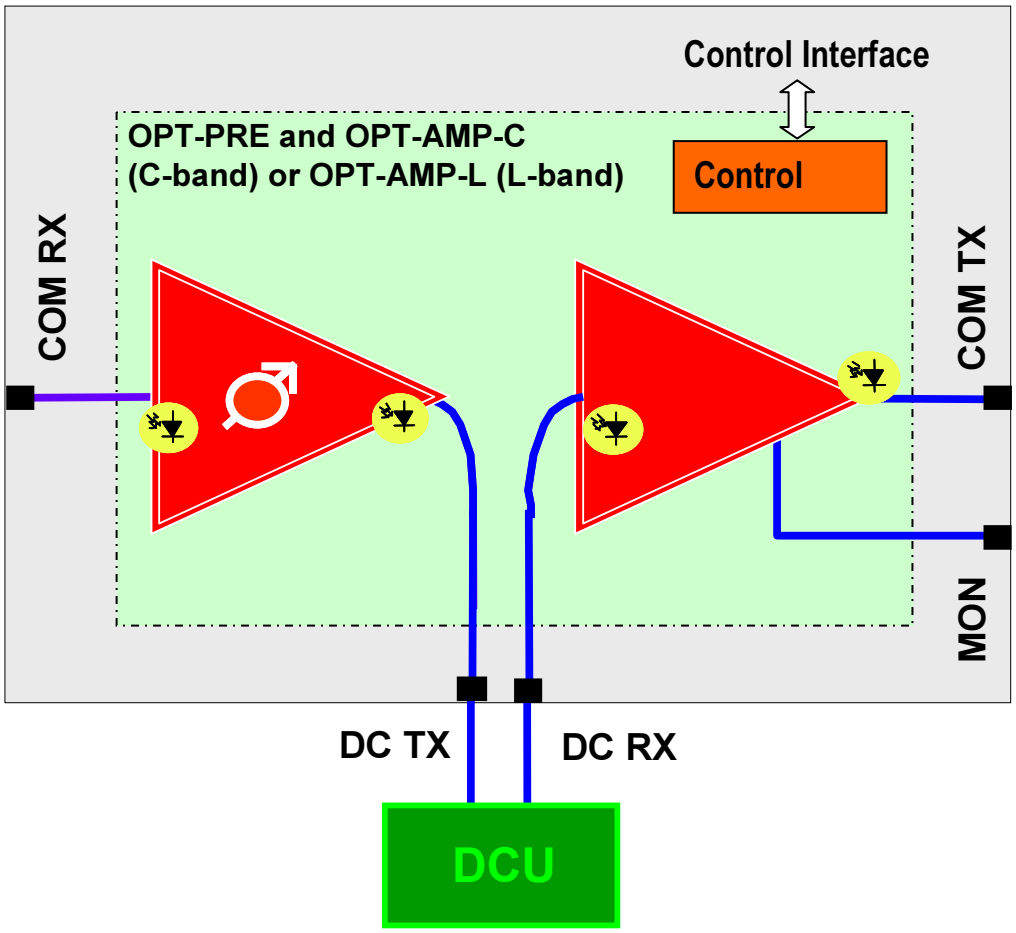
- FEC extends reach and design flexibility
- G.709 standard improves OSNR tolerance by 6.2 dB (at 10^{-15} BER)
- Higher gains (8.4dB) possible by enhanced FEC (with same G.709 overhead)



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

Enhancing system reach

Amplifiers, Dual-stage EDFA amplifiers, RAMAN

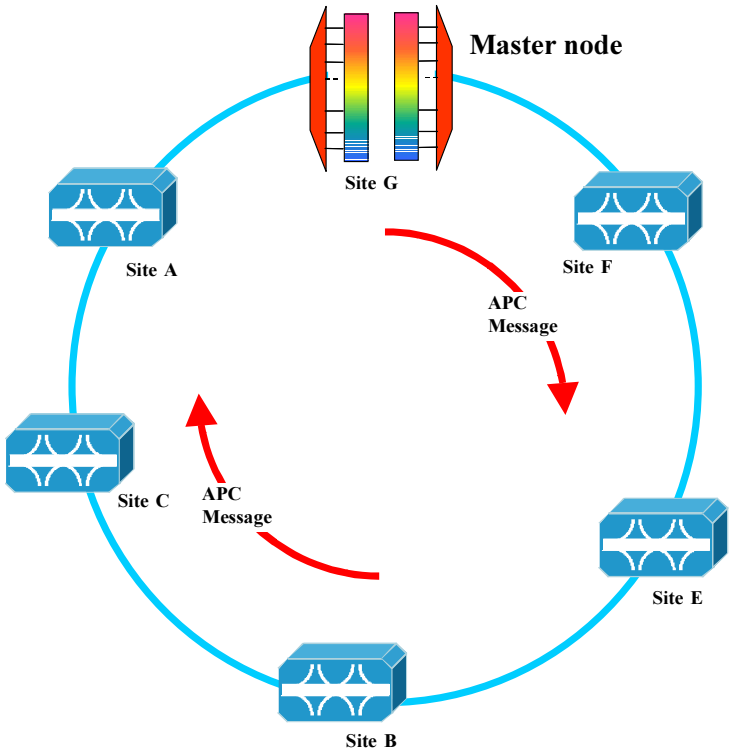


- **Dual stage EFDA provides mid stage access for DCU placement**
- **RAMAN enhances system reach and delivers improvement of OSNR**

BENEFIT: Dispersion compensation does not impact overall span budget

Automatic Power Control

The tool for keeping the network operational and stable



- **Keep either power or gain constant on each amplifier**
- **Avoid BER or non linear effect**
- **APC automatically starts when network detects needs for a gain correction**
- **No human intervention required**
- **Correct amplifier power/gain**
  - **whenever the # of channels changes**
  - **to compensate ageing effects**
  - **To compensate changing in operating conditions (e.g. temperature increase)**

BENEFIT: Automatic reaction of network to fast and slow changes in the network

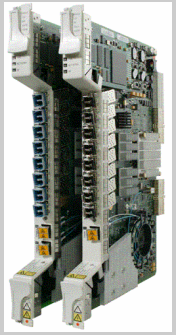
Cisco ONS 15454 MSTP

Muxponding, crossponding and MSPP integration

Flexible muxponding
Effective use of bandwidth by Cisco ONS 15454 MSTP

10G Data Muxponder
- 8 ports
- GE
- 1/2/4G FC
- 1/2/4G FICON
- ISC-1, ISC-3
- signal mix supported

2.5G Data Muxponder
- 8 ports
- GE
- 1/2G FC
- 1/2G FICON
- ESCON
- signal mix supported

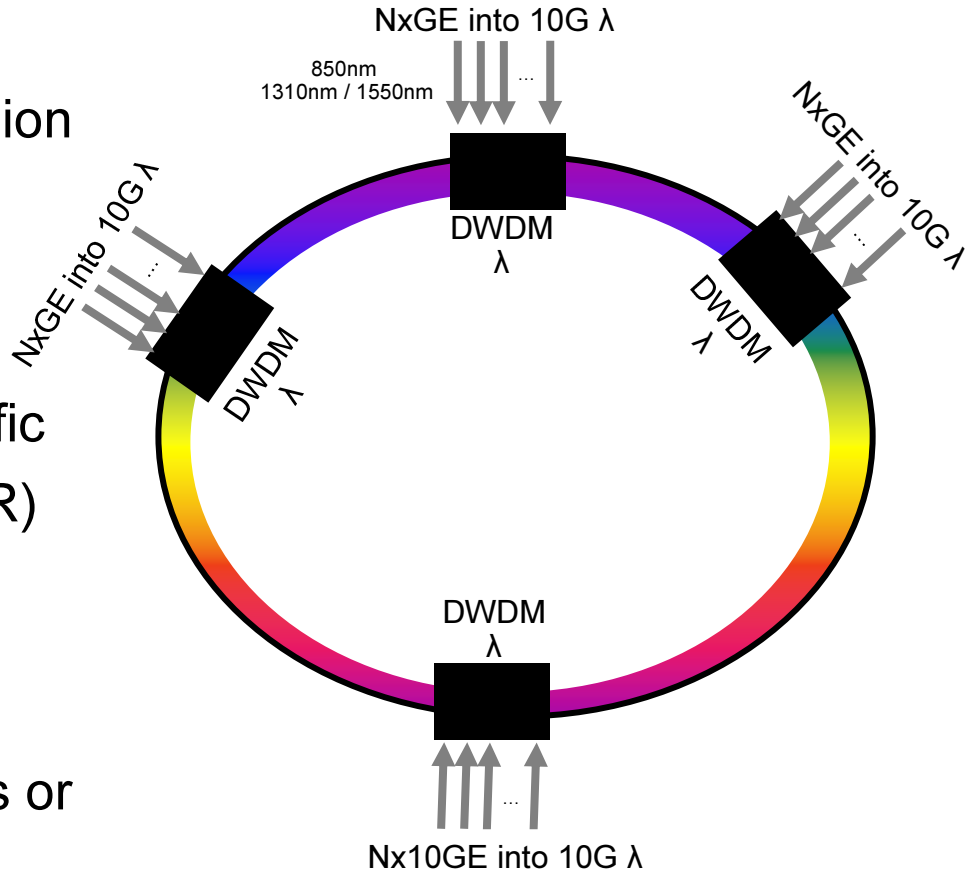


4xSTM-16 ->OTU2 Muxponder
- 4 ports
- STM-16 clients
- ODU1 into OTU2

- *BENEFIT: Better lambda capacity utilization*
- *BENEFIT: Higher service density and flexibility*

What is Ethernet Enabled WDM

- Enabled by Xponder cards
- L2 intelligence on WDM – extension of IPoDWDM
- Ethernet services are statistically multiplexed to maximize ring utilization
- Add and drop sub λ Ethernet traffic
- Sub 50ms restoration times (RRR)
- ELINE and ELAN services
- Multicast with drop and continue approach
- Scalable to connect multiple sites or provide multiple services
- Conformance to MEF service and QOS definitions.



Ethernet enabled DWDM
Solution components - GE/10GE XP/XPE

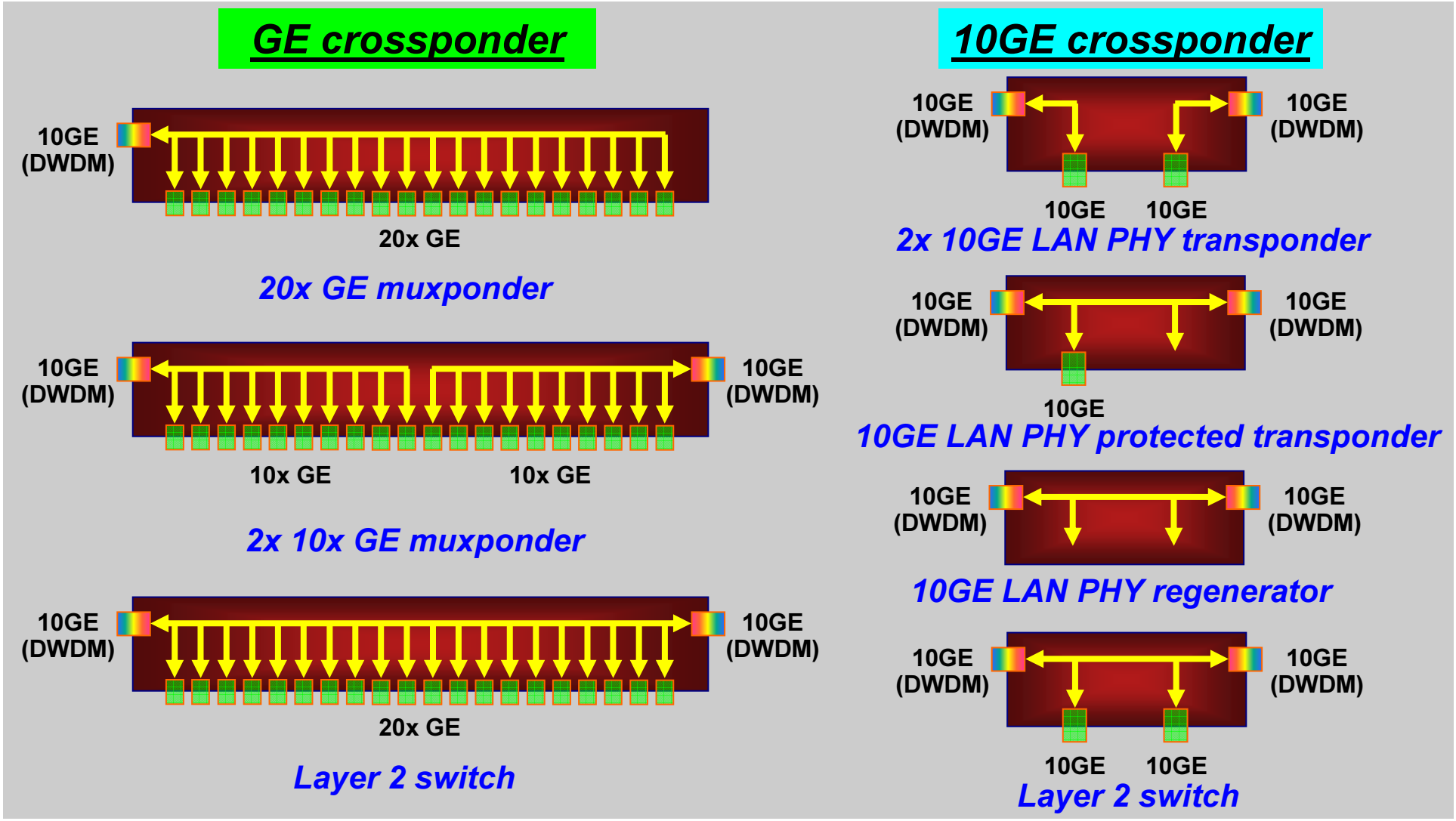
GE crossponder
- 20x GE ports (UNI)
- 2x 10GE ports (NNI)

10GE crossponder
- 2x 10GE ports (UNI)
- 2x 10GE ports (NNI)

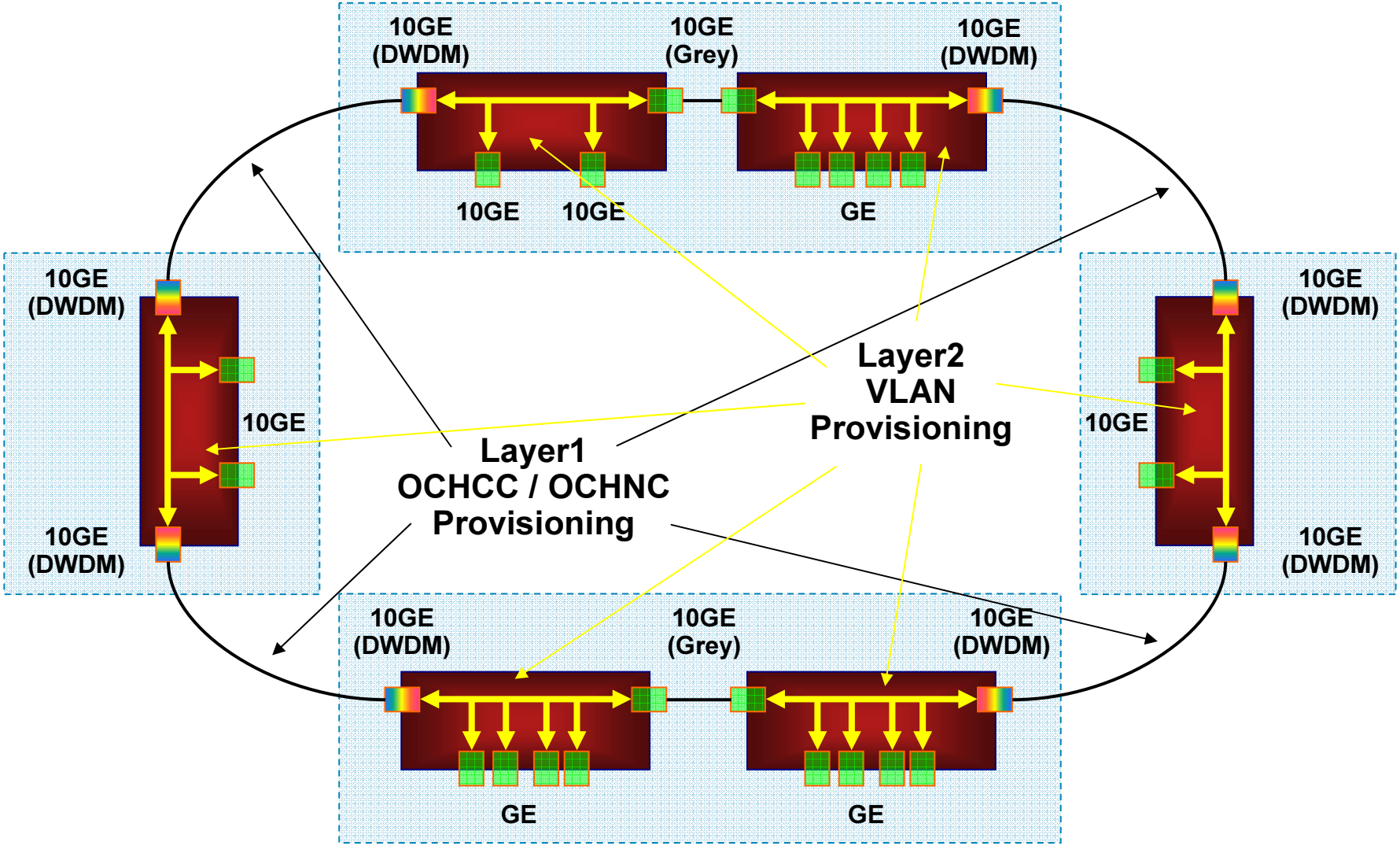
Features
- Smart optical ring protection based on G.709 overhead (sub 50 ms)
- Configurable as muxponder, transponder, 10GE regenerator and in L2 switch mode
- SFP for GE ports
- XFP for 10GE ports (DWDM or 'grey')
- Can interoperate with IPoDWDM card in routers
- Enhanced version available in release 9 at lower price

CARRIER ETHERNET
MEF
Certified Compliant

Ethernet crossponding - modes of operation
How Cisco ONS 15454 MSTP Xponder operates



Ethernet crossponding
Example of Layer 2 switch mode



GE/10GE XPonder Layer2 Switch Mode

- **MAC Address**
  - Support a MAC address table with up to 16k entries (XP) or 32k entries (XPE)
- **VLAN Management**
  - Virtual Bridged LANs support according to the IEEE 802.1Q
  - VLAN tagging support according to IEEE 802.1Q standard
  - Up to 4096 VLAN-ids on all ports
- **Port Security**
  - Per-port traffic block for a user provisionable pre-defined set of MAC addresses (MAC filtering up to 8 MAC address per port)
- **Provider bridges support as defined in IEEE 802.1ad standard**
  - S-TAG (or Outer tag, or QinQ) support
  - User provisioned L2 Control Protocols behavior (Drop or Tunnel)

Protection basic concept

- Protection mechanism is achieved using mix of Layer 1 and Layer 2 functionality
- Fault detection and failure propagation is done via the G.709 bytes. Failure propagation is done at HW level
- Traffic is flood for each protected VLAN around all 10GE WDM ring.
- One node is identified as master-designated node/port. This node/port is responsible for open-close L2 VLANs loop in case of failure
- Up to 256 protected VLAN can be configured
- 50ms recovery time
- In point-to-point application it can be used as “splitter portection mechanism” (i,e. 1+1 protection) overcoming the 256 protected VLAN limitation

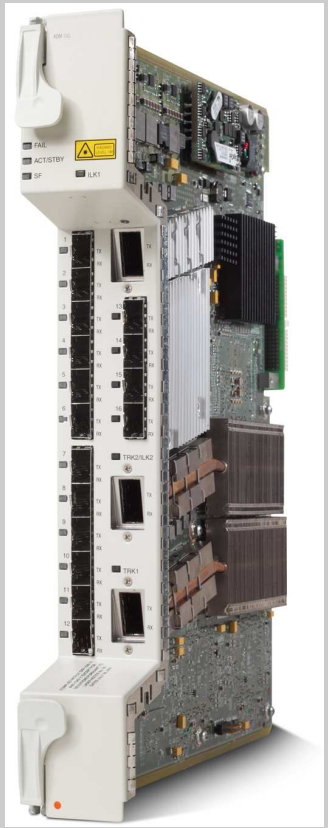
Cisco ONS 15454 MSTP flexible optical networking
MSPP on the blade

HW features

- 16 SFP Based Client (Grey and CWDM optics available)
- Support of OC-3/OC-12/OC-48 and GE client signals
- 1 Trunks XFP Based supporting E-FEC/FEC and G.709
- 2 SR XFP supporting redundancy connection with protection board and Pass-through Traffic
- GFP-F Mapping

SW features

- OTN PM on Trunk
- A to Z Circuit provisioning (STS layer)
- SDH PM (B1, B2 on Trunk and aggregate) and Alarm Management (Line, Section and Path)
- Ethernet RMON statistics
- SNCP Protection

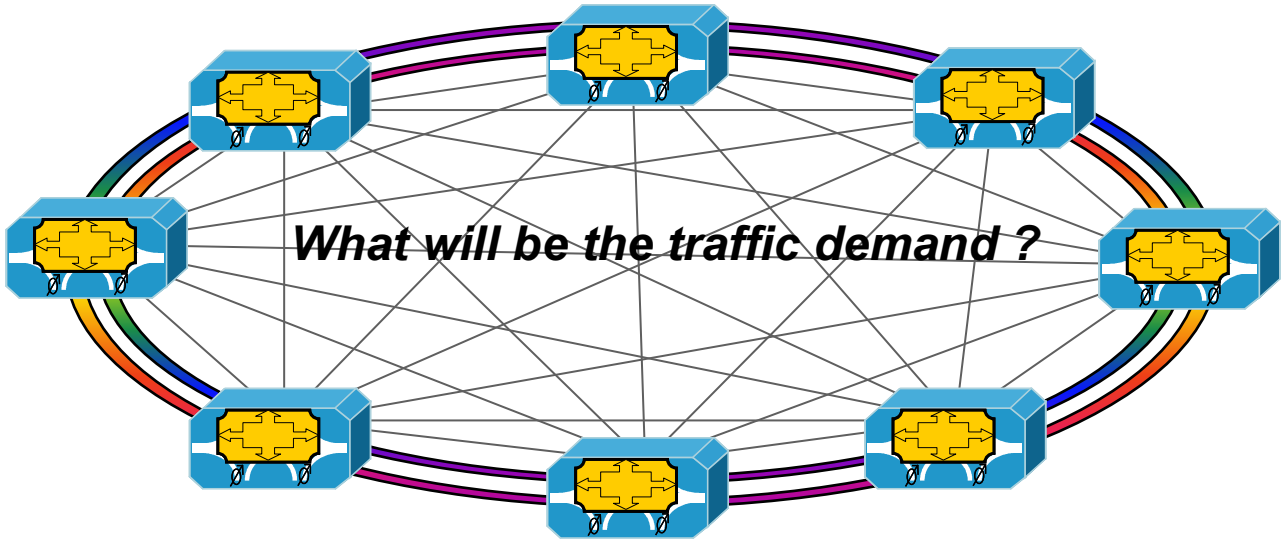


- *BENEFIT: Better lambda capacity utilization*
- *BENEFIT: Higher service density and flexibility*
- *BENEFIT: Compact MSPP integration*

Cisco ONS 15454 MSTP

Reconfigurable OADM and optical mesh implementation

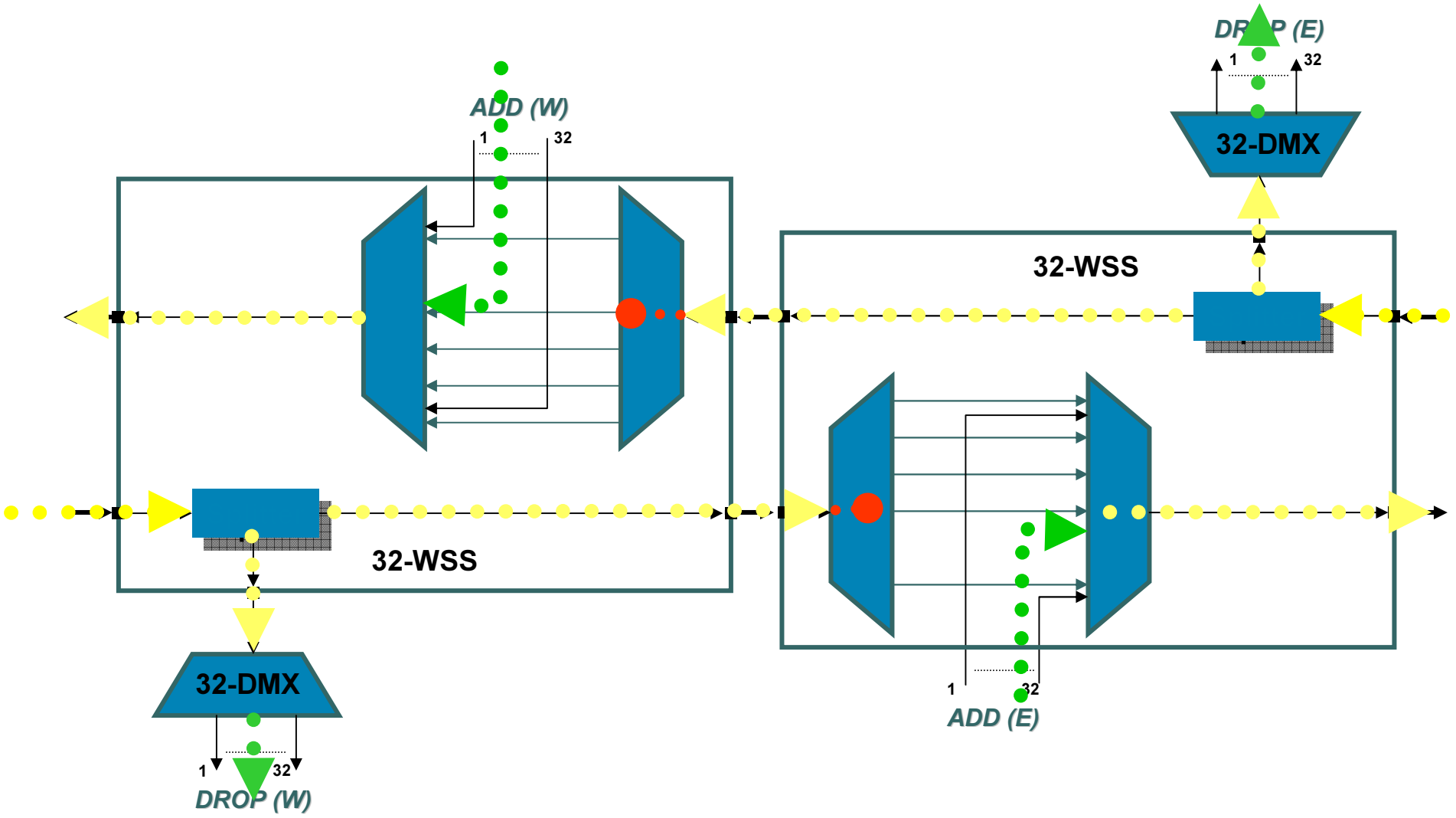
Reconfigurable OADMs
Key for building future proof flexible optical networks



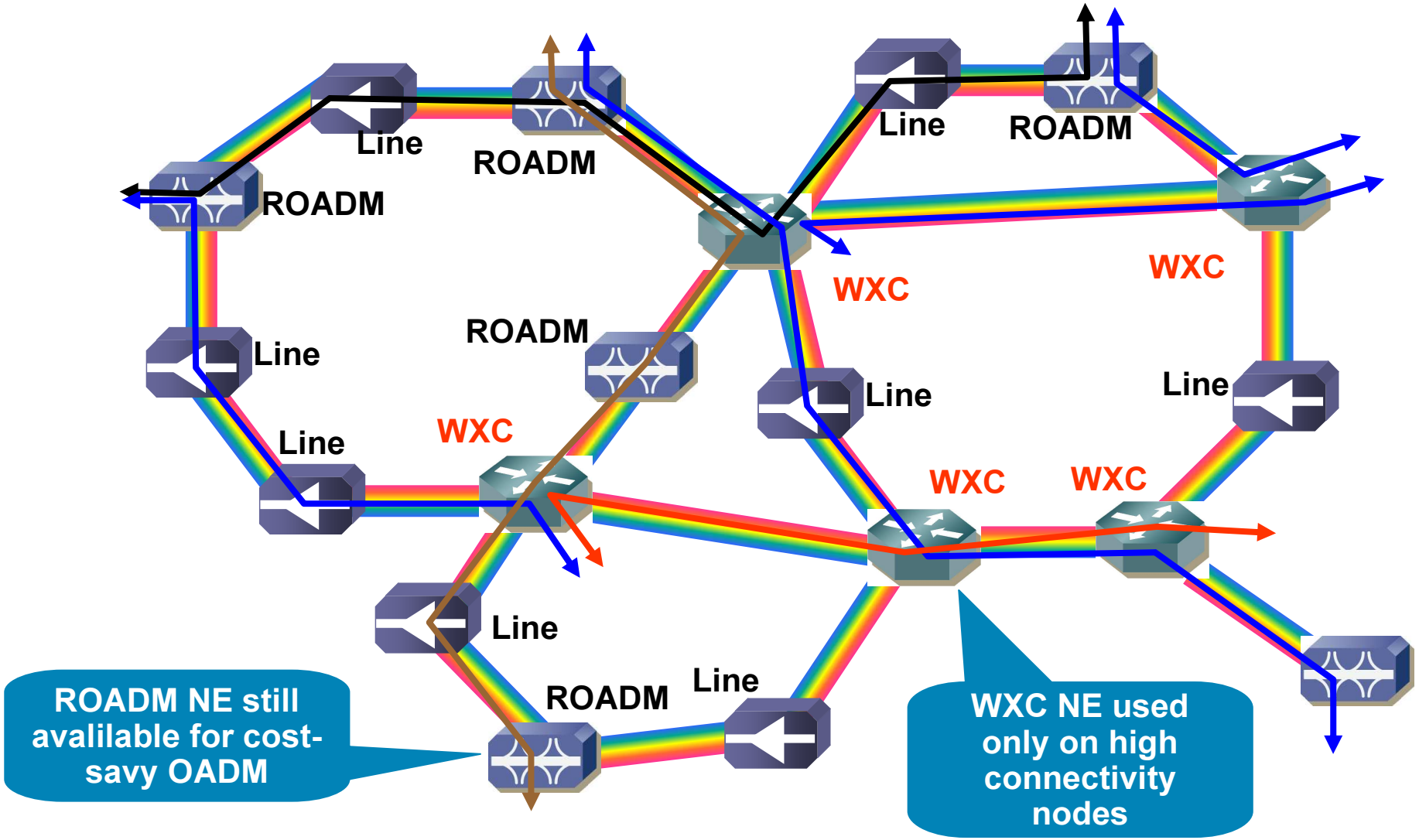
- **Two main components – iPLC based wavelength selective switch (WSS) and demux (DMX), 2 pairs for degree 2 node**
- **Fully controlled by software, fast switching time (< 5ms)**
- **C band (32 odd, 40 odd, 40 even) and L band (32) versions**

- *BENEFIT: Any-to-Any protocol agnostics (SDH, IP, Ethernet and Storage) wavelength connectivity with software provisioning of wavelength paths*
- *BENEFIT: Foundation for dynamic, intelligent optical networks of different topology (linear, ring and mesh)*

Cisco ONS 15454 MSTP ROADM implementation
Reconfigurable OADMs – principle of operation

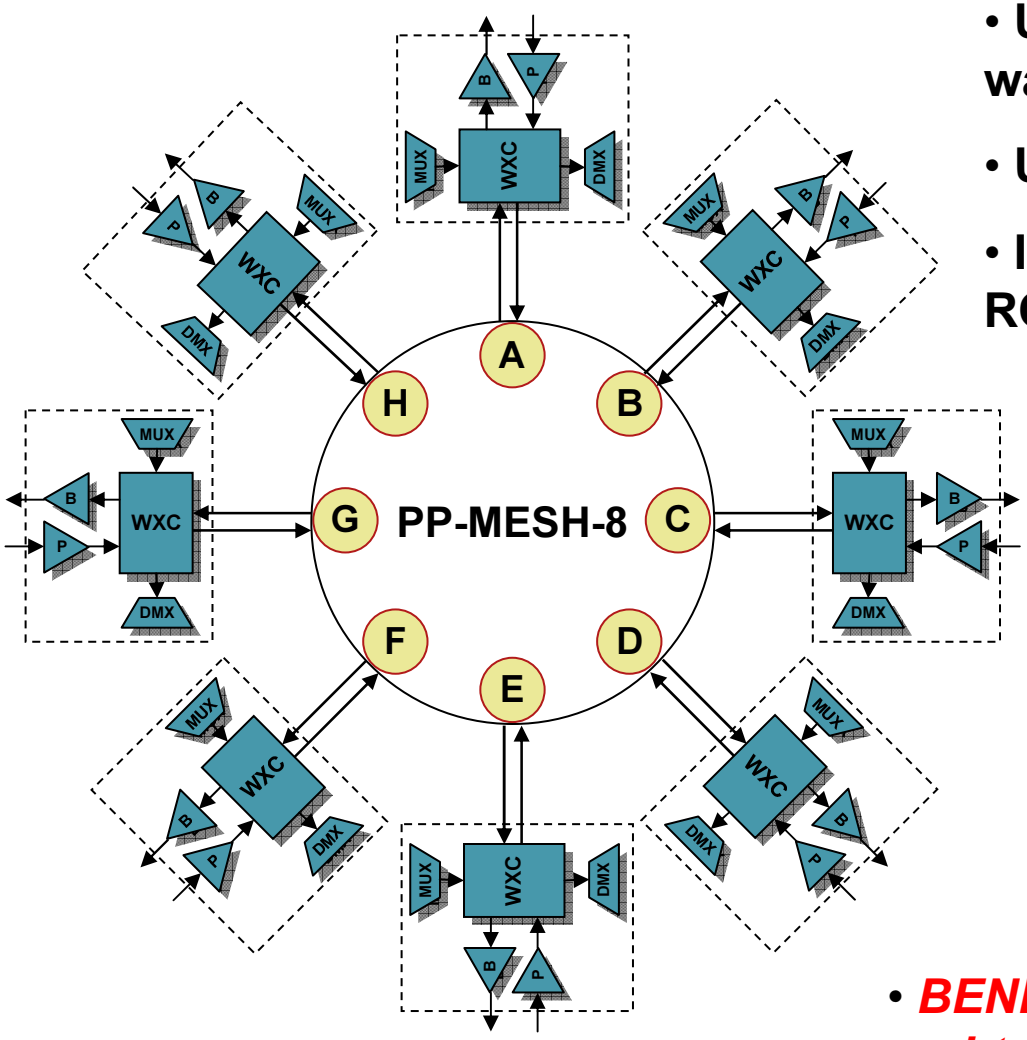


Cisco ONS 15454 MSTP Optical mesh

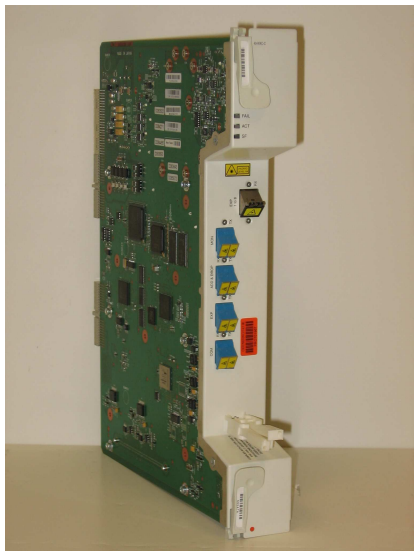


Multi degree ROADM node

Key element for building optical junctions



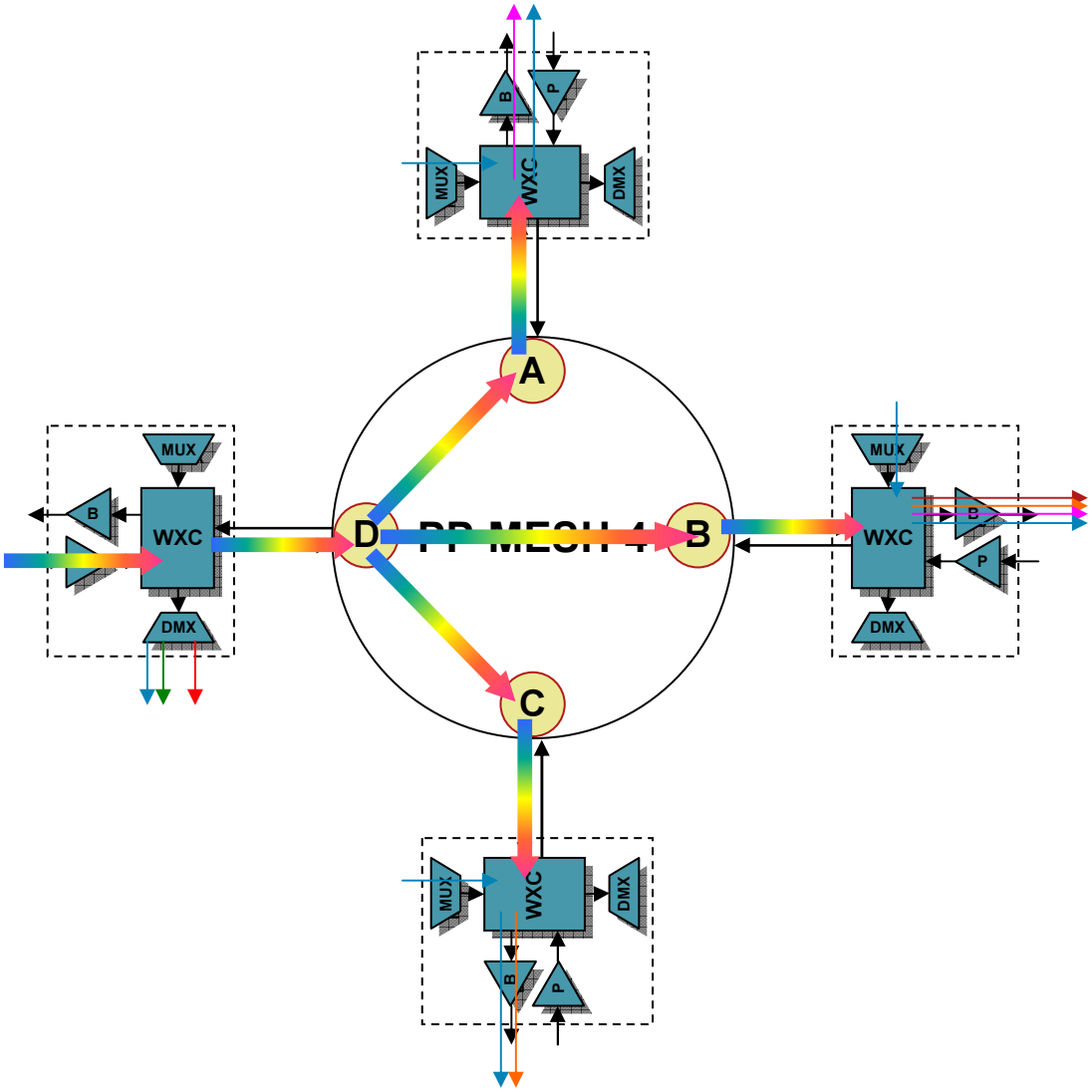
- **Uses new 40 channel MEMS based wavelength cross connect**
- **Up to degree 8**
- **Interoperates with current 32 channel ROADM and new 40 channel ROADM**



- ***BENEFIT: Full optical mesh network with end-to-end wavelength provisioning***

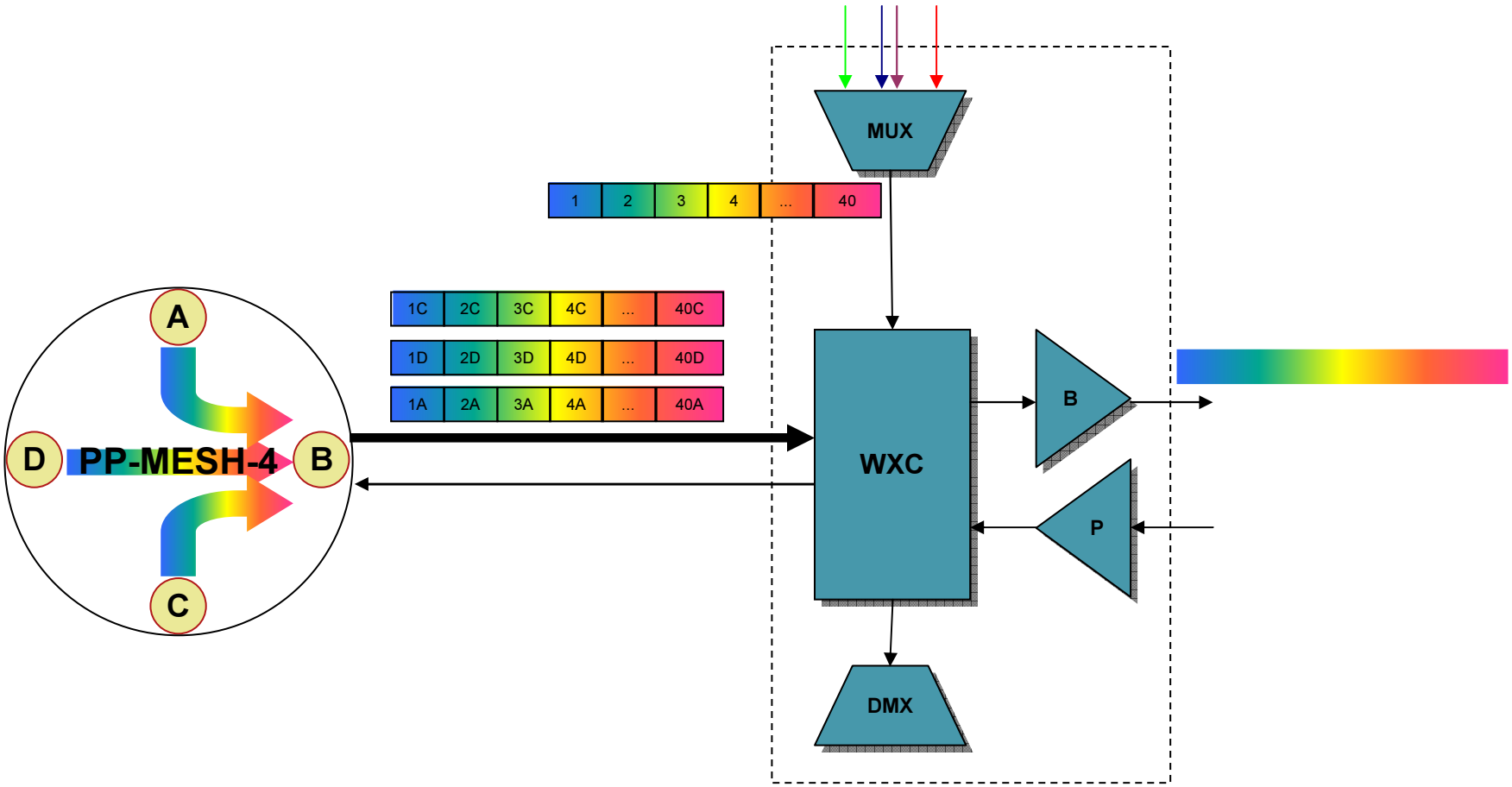
Multi degree ROADM node

Block diagram



Multi degree ROADM node

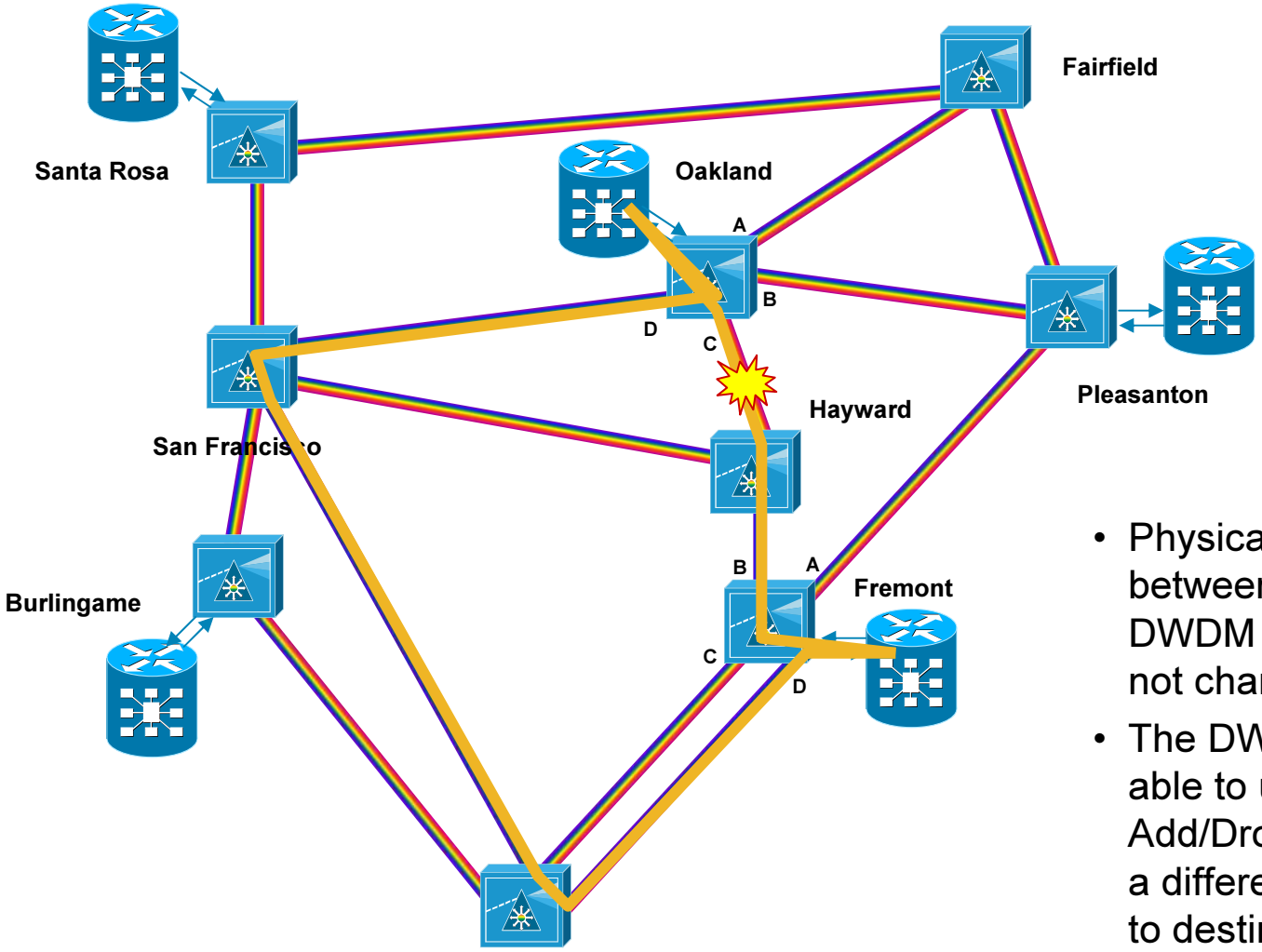
Single degree detail



ROADM evolution - next steps

- Directionless ROADM
  - ability to direct/redirect wavelength to desired direction
- Colorless ROADM
  - ability to choose the port where wavelength is dropped in the node (make sense when used with tunable lasers)
- Intelligent control plane - 'DWDM aware' GMPLS
  - ability to dynamicaly find the path in the network with validation of optical path parameters like OSNR, optical power, CD compensation, PMD, NLE etc.

Directionless Add/Drop Applications

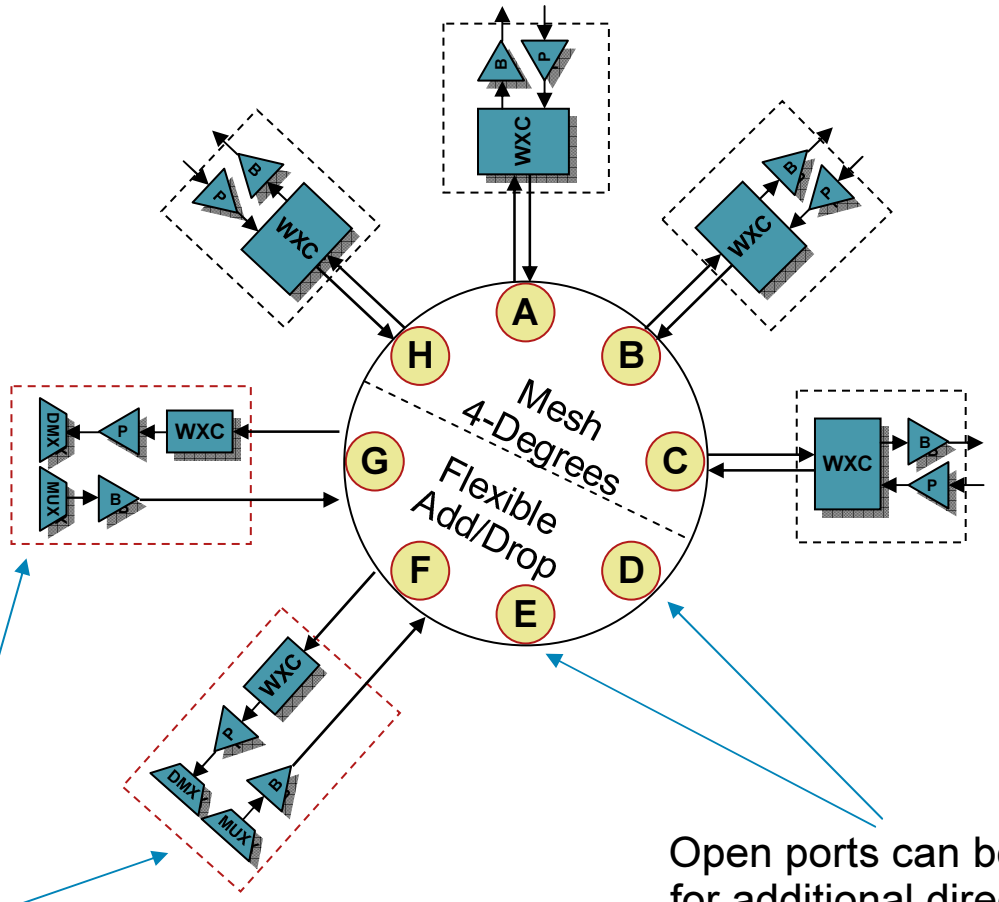


- Physical connections between Client and DWDM equipment do not change
- The DWDM Node is able to use a different Add/Drop direction and a different Optical Path to destination

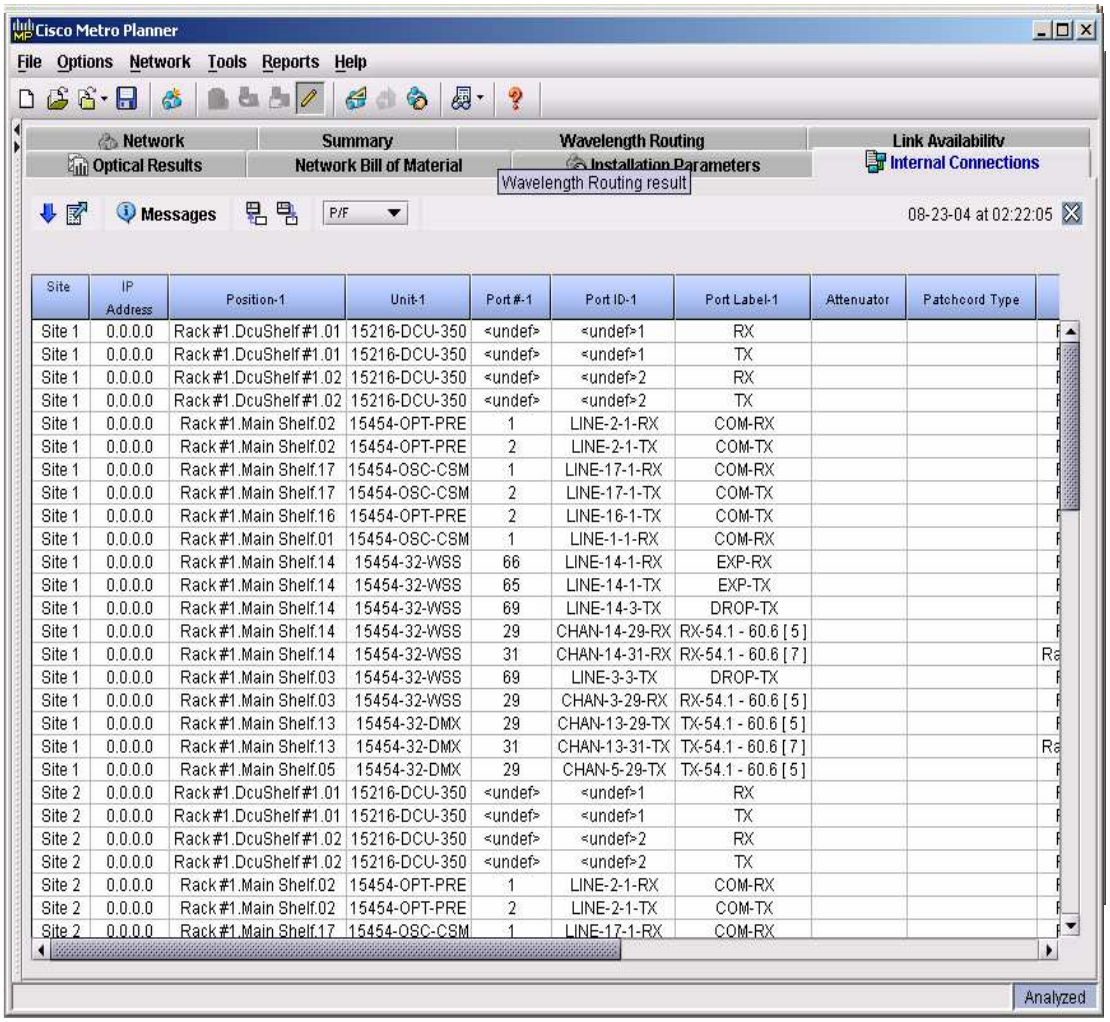
Directionless ROADM

Available in Cisco ONS 15454 MSTP release 8.5

- Current architecture can support Directionless Add/Drop
- PP-MESH ports can be configured as Local Add/Drop ports or to support a specific direction
- Broacast&Select architecture allows to support more than simple P2P connections in the optical domain



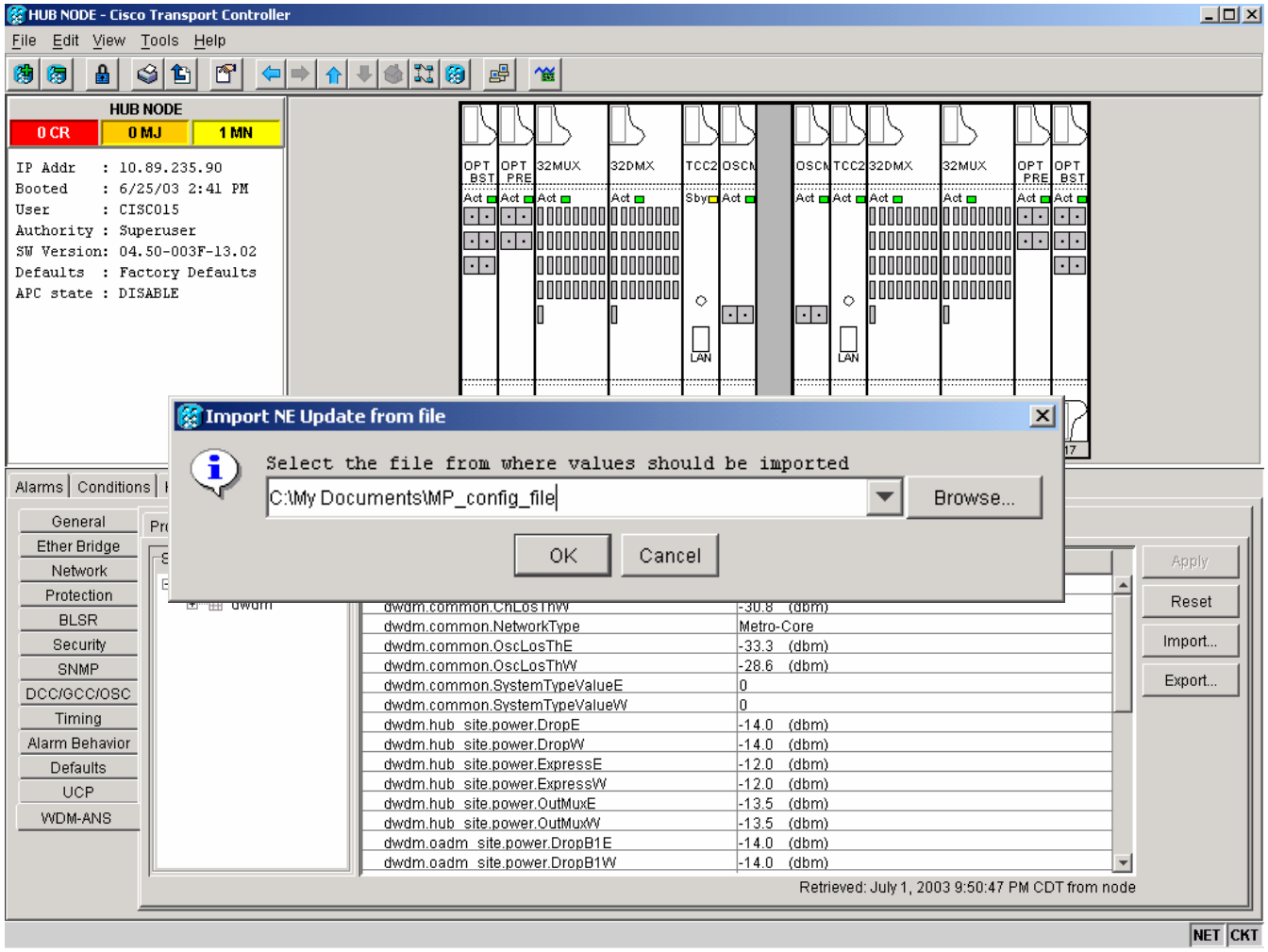
Cisco ONS 15454 MSTP:
Comprehensive design tool - Cisco Transport Planner



- **GUI-based Network Design Entry**
- **Traffic requirements:**
  - **Any-to-Any Demand provided by ROADM**
  - **Point-to-point demands**
- **Comprehensive Analysis checks for:**
  - **wavelength routing and selection**
  - **optical budget and OSNR**
  - **CD, PMD, amplifier tilt etc.**
- **Smooth Transition from Design to Implementation**
  - **Bill of Materials**
  - **Rack Diagrams**
  - **Step-by-Step Interconnect**

BENEFIT: Fast and comprehensive network design

Cisco ONS 15454 MSTP flexible optical networking
Automatic Node Setup



BENEFIT: Fast network deployment and setup

IP over DWDM

Architecture for converged NGN network

Traditional Core Network Architecture

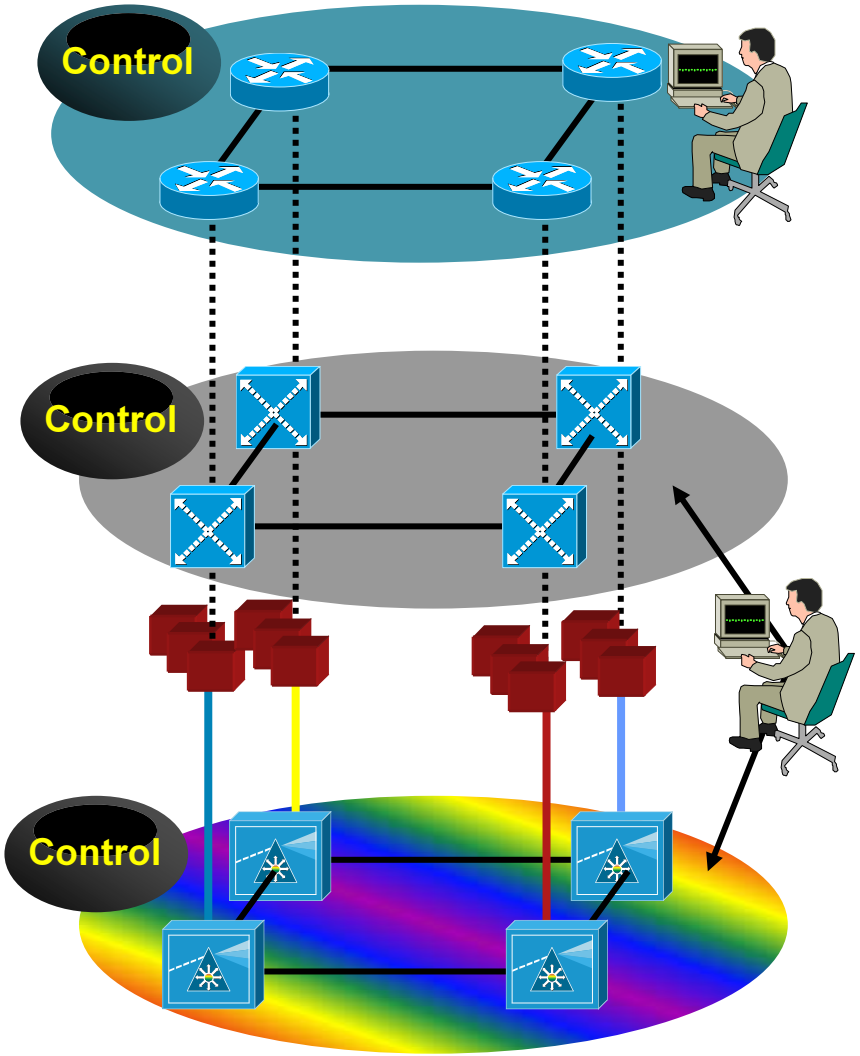
Distinct IP and DWDM Management Planes

Distinct IP and DWDM Control Planes

Expensive Electrical Cross Connects (OEO)

Multiple Transponders per Wavelength (OEO)

Truck Rolls for Reconfiguration



Routers
Aggregation of IP traffic to 10G
Fast restoration at Layer 3
Performance monitoring L2/L3

TDM Cross Connects
Groom low speed circuits
Fast restoration at Layer 1
Performance monitoring L1

Transponders
Convert short reach to color

DWDM
Multiplexing λs onto fiber

IP-over-DWDM Architecture

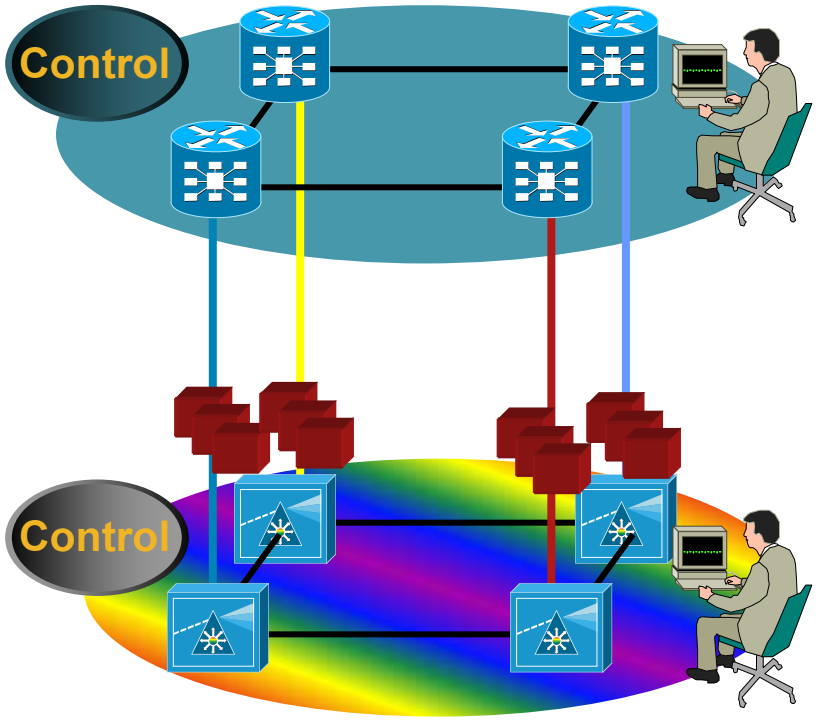
Simplifying the network to support IP efficiently

Benefits

Management and Control-plane coordination.

Less electrical processing (OEO).

Intellingent optical network. Point and click provisioning



IP Network

- **Efficient interconnection directly at 10/40G**
- **Performance Monitoring**
- **Fast L3 Protection - FRR**

DWDM Network

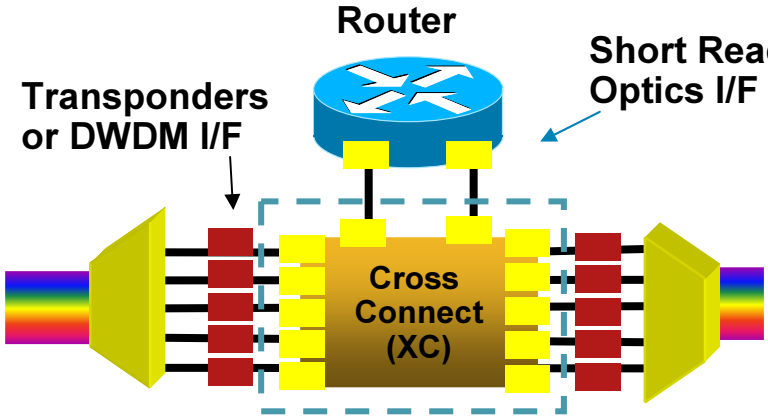
- **Transparent Multi-Service Transport**
- **WDM Automation (hiding complexity of fiber transmission)**

Why Converge at the Optical Layer ?

- Optical Transport Layer is a standard – enables interop.
  - ITU-T G.709 Digital Wrapper
- Optical Transport Layer is not so bit rate sensitive
  - Accomodate different speeds and new communication technologies without forklift upgrade
- Optical Transport Layer is transparent and flexible
  - Natively supports Synchronous and Asynchronous services
  - Point-Point, Ring and Mesh Topologies
- Optical Transport Layer provides the same OAM features as SDH
- Optical Transport Layer is scalable – can handle growth
  - Supports 40Gbps today, scale to 100Gbps+ per channel (wavelength)
  - Multiple wavelengths per fibre (e.g. 80CH @ 50GHz spacing for C-band DWDM)
- Optical Transport can provide very fast protection/restoration
  - 1+1 protection achieved with a few ms switchover times
- Optical Transport has demonstrated economical price points not just in core, but also in aggregation & access networks
  - Multi-haul capability

IP over DWDM
Impact on investments

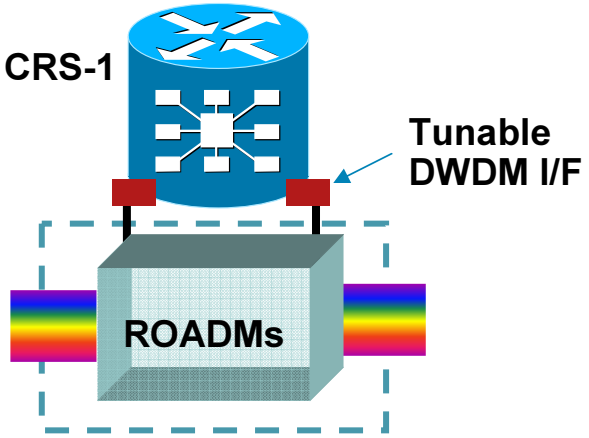
Traditional Solution



Invest in High Capacity SDH

- 10 transponders needed
- 4-14 Short Reach optics
- Every Lambda OEO
- Addt'l transponder & SR for each λ
- Expensive switch w/active electronics

Cisco's IPoDWDM Solution



Invest in IPoDWDM

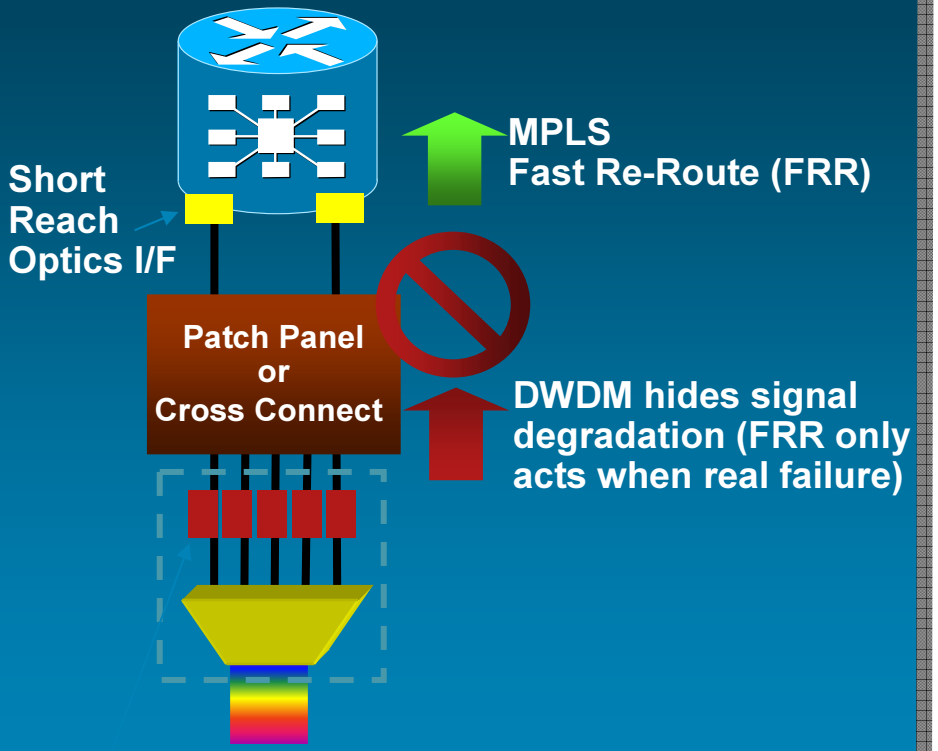
- 0 transponders needed
- 2 Tunable DWDM interfaces in router
- All pass-through traffic stays optical
- ROADM full provisioned, no truck rolls
- Expensive switch eliminated

Continue to Invest in XCs & Transponders

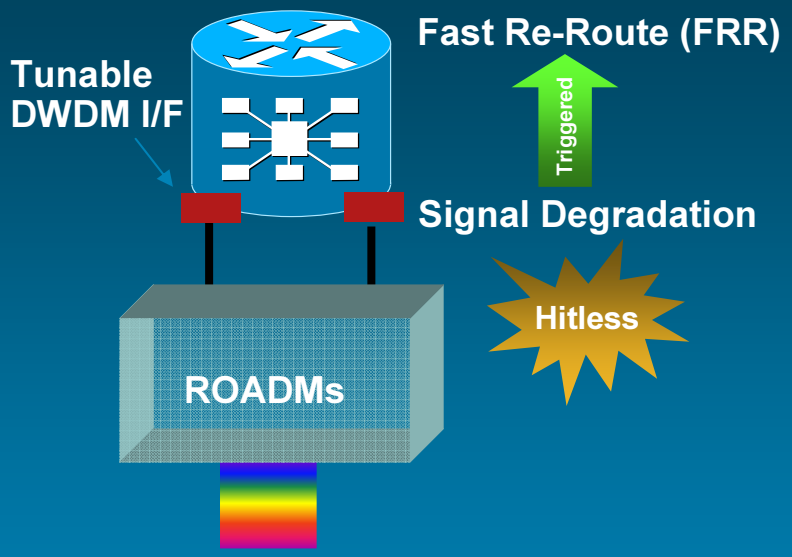
Eliminate Unnecessary OEO XC & Transponders

IP over DWDM
Impact on reliability

Competitors Solution
Optical-Electrical-Optical (OEO)



Cisco's IPoDWDM Solution



Element integration allows router visibility into transmission layer performance, enabling superior protection compared to transponder based networks

Pre-FEC Results for IP FRR

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

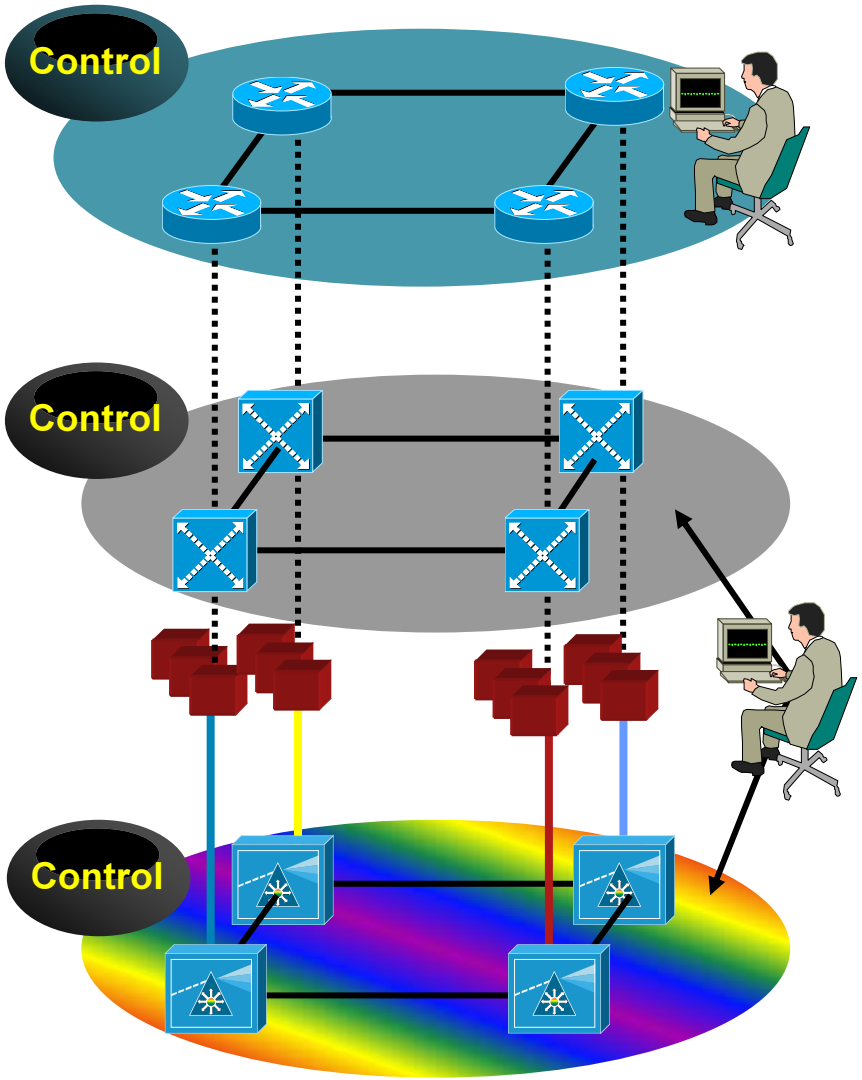
pre-FEC FRR	Fault	Packet Loss (ms)		
		Highest	Lowest	Average
Y	Optical-switch	11.50	11.18	11.37
Y	Noise-injection	0.02	0.00	0.00
Y	Fibre-pull	11.05	0.00	3.23
Y	PMD-injection	0.08	0.00	0.02
N	Optical-switch	11.47	11.54	11.37
N	Noise-injection	7404.00	1193.00	4305.00
N	Fibre-pull	28.81	18.52	21.86
N	PMD-injection	129.62	122.51	125.90

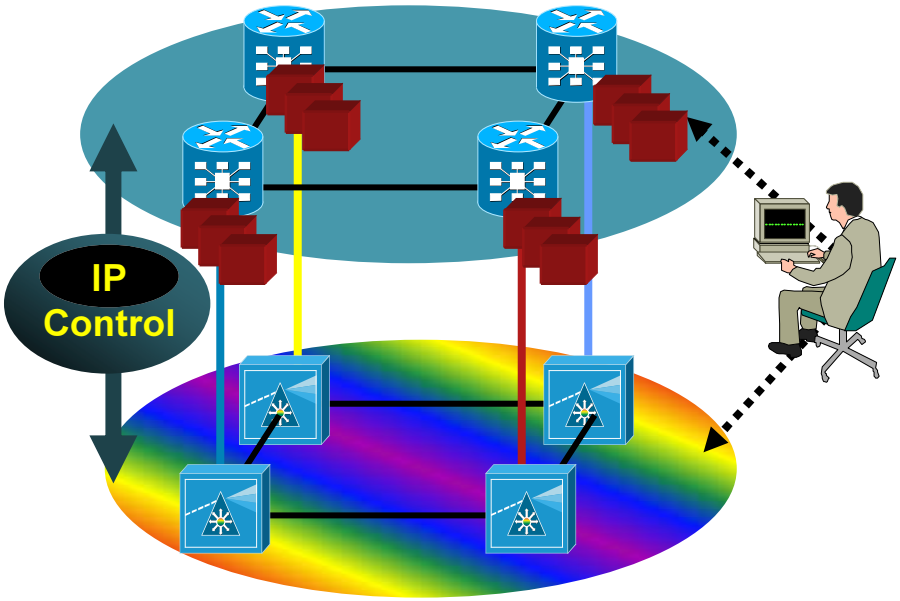
Pre-FEC Results for ISIS Fast Convergence

Protection type	Fault	Max. Packet Loss (ms)		
		C(500)	C(1000)	C(1)
Proactive	Optical-switch	170	220	163
Proactive	Slow noise-injection (0.1dB/1000ms)	3	12	0
Proactive	Fast noise-injection (0.5dB/500ms)	3	9	0
Standard	Optical-switch	180	205	159
Standard	Slow noise-injection (0.1dB/1000ms)	2990	3035	2880
Standard	Fast noise-injection (0.5dB/500ms)	596	620	540

IP over DWDM

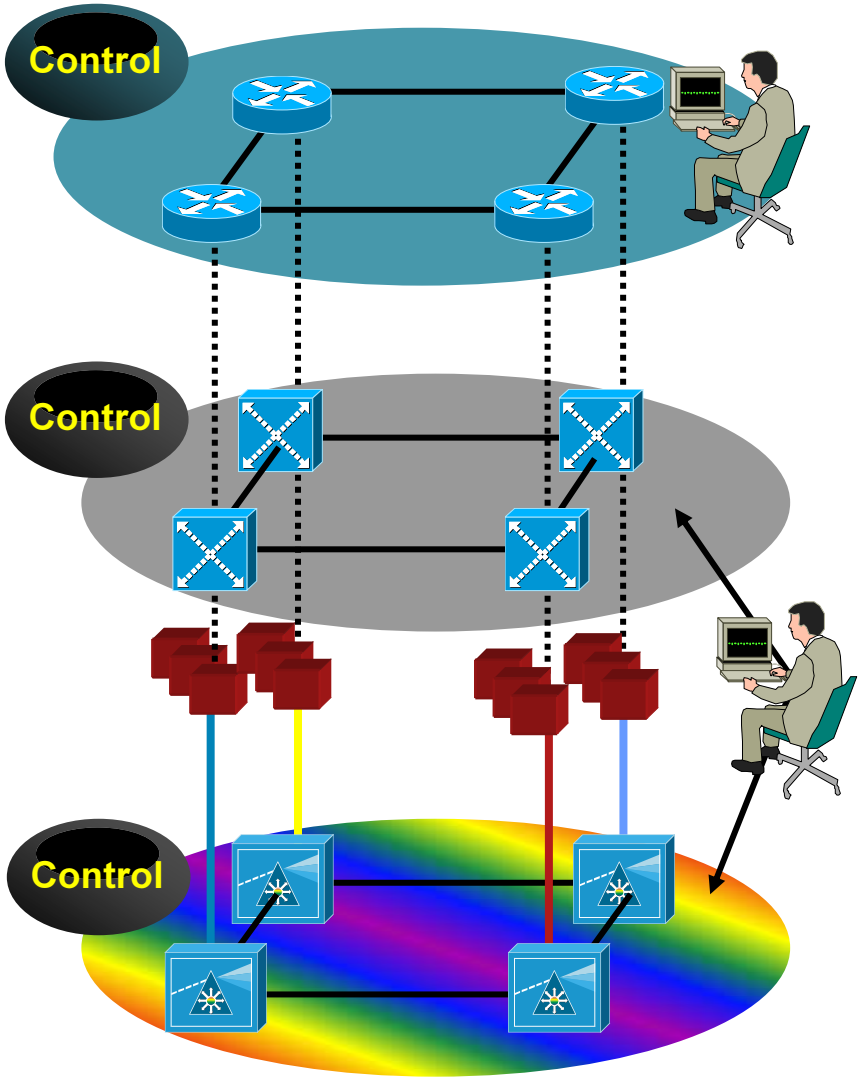
Impact on management - integrated management

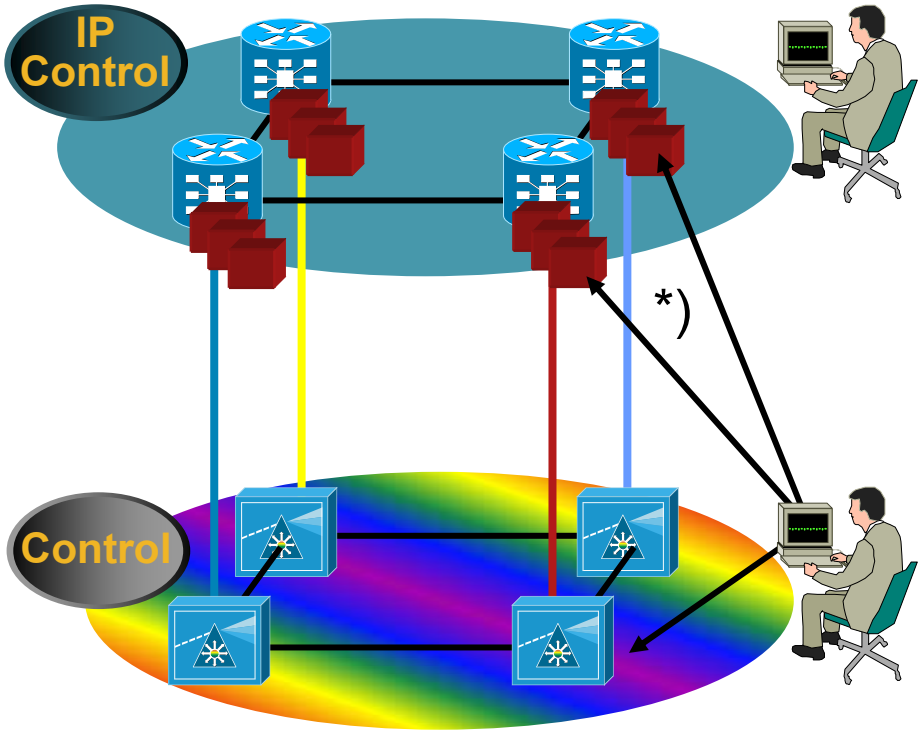




IP over DWDM

Impact on management - segmented management

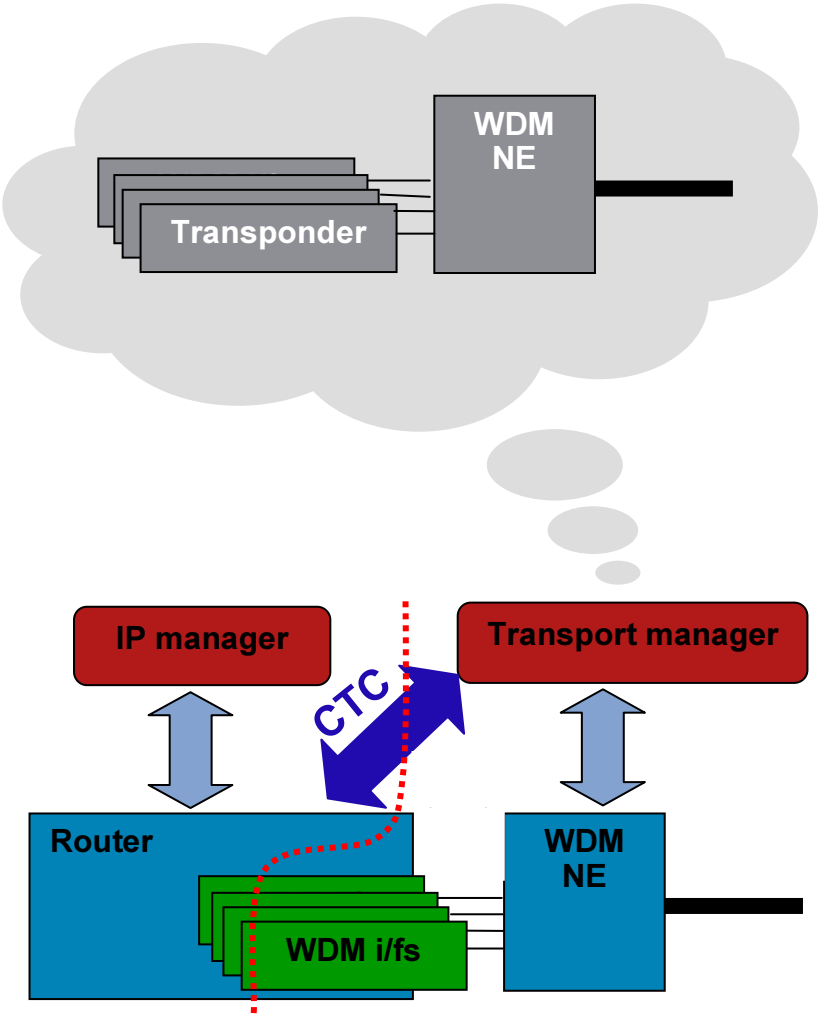




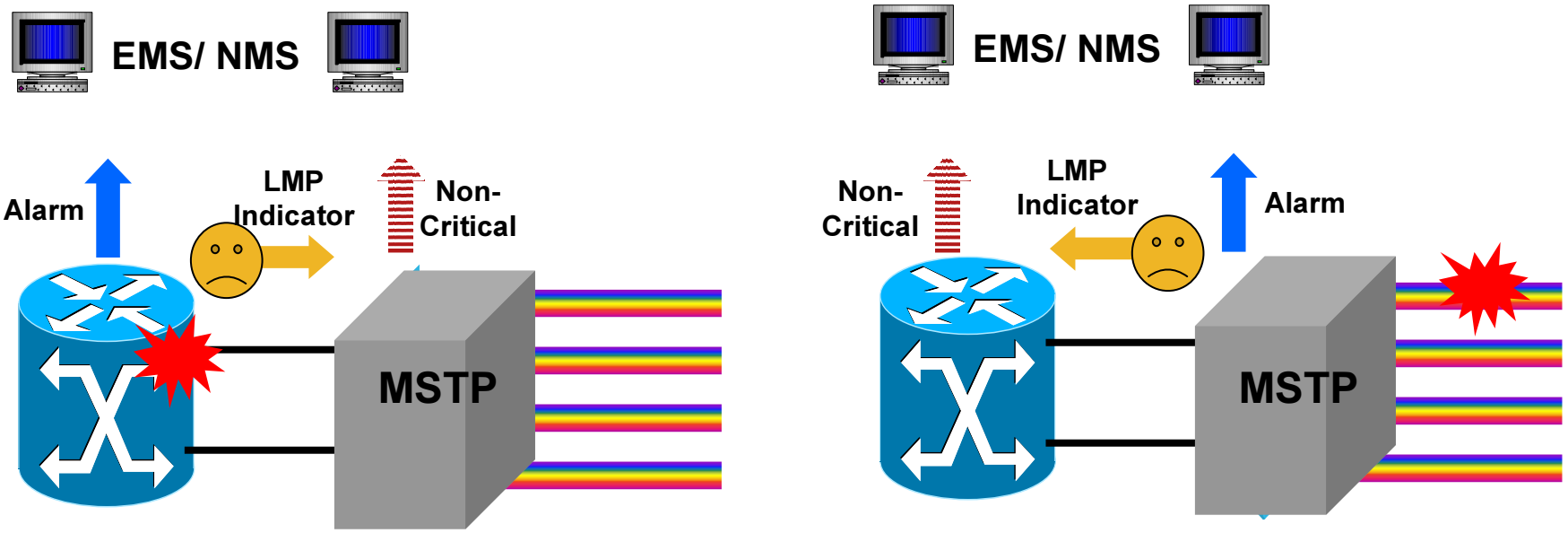
*) Options for integration with OSS:
- CLI,
- XML,
- SNMP

IP over DWDM
The Virtual Transponder (VTXP) Concept

- **Virtual transponder protocol**
  - Secure session between router and optical 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**



LMP and alarm correlation details



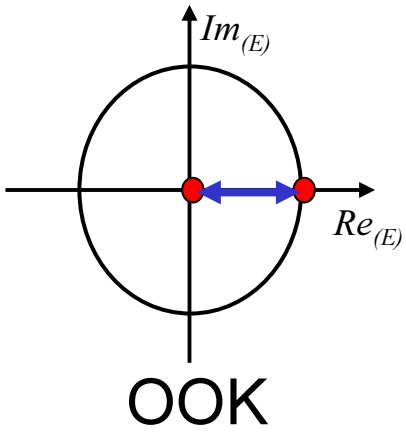
- Goal: ensure only one system must act upon a failure
- Value:

  Downstream indicator allows router alarm to be downgraded → avoid L3 craft action

  Upstream indicator allows transport alarm to be downgraded → avoid L0 craft action

Cisco CRS-1
OC-768C/STM-256C Tunable WDMPOS Interface Module (1.0)

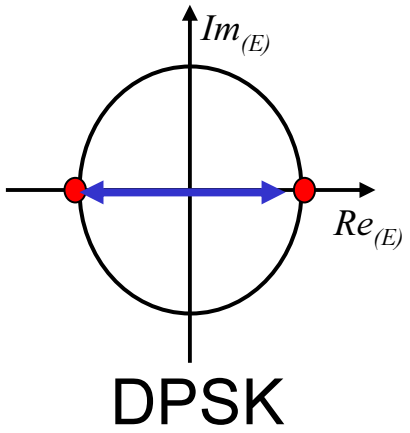
- Full C-Band tunable, 50GHz spacing, Enhanced FEC
- Duo-binary line code for spectral efficiency (43 Gb/s bandwidth-compressed signal on 50GHz grid)
- 40G retrofit onto existing 10G DWDM systems
- Line-side interoperability with ONS15454 MSTP
- OSNR 13dB, CD +/- 150 ps/nm, PMD 2.5 ps, ~500 km (typical, but more than 950 km deployed)



Cisco CRS-1

OC-768C/STM-256C Tunable WDMPOS Interface Module (1.5)

- Full C-Band tunable, 50GHz spacing, Enhanced FEC
- DPSK+ line code for spectral efficiency (43 Gb/s bandwidth-compressed signal on 50GHz grid)
- 40G retrofit onto existing 10G DWDM systems
- Line-side interoperability with ONS15454 MSTP
- OSNR 7.5dB, CD +/- 750 ps/nm, PMD 2.5 ps, > 1000 km



Cisco CRS-1
4-Port 10GE Tunable WDMPHY Interface Module

- Full C-Band tunable, 50GHz spacing
- Enhanced FEC (up to 1000km)
- SONET/SDH like OAMP
- Also supports unamplified single channel 40km/80km applications
- Future 10G WDMPOS support
- Ethernet Encapsulation
  - IEEE 802.x Flow control
  - 802.1q VLAN Support, jumbo frames
  - IEEE 802.1p Tagging
  - Source/destination MAC accounting
  - VLAN Accounting

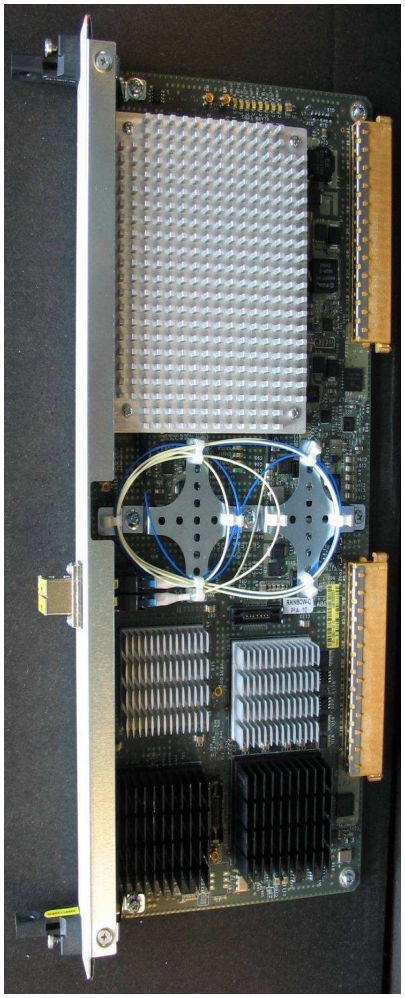
Cisco 12000
10GE DWDM SPA

- **Current 10GE SPA + UT2 + E.FEC (very similar to the CRS 4x10GE PLIM)**
- **Planned in 12.0.33S in 12K with SIP-600 & SIP-601**
- **Double Wide SPA taking the entire slot of SIP-600/SIP-601**
- **Major Features**

  Tunability → 50 Ghz ITU grid spacing with 80 lambdas

  Distance → Enhanced FEC (E.FEC) implementation

  OAM → SONET character / G.709 Performance monitoring and Alarms



IPoDWDM Product portfolio - summary

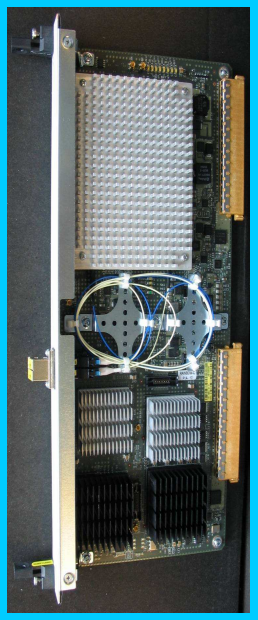
CRS-1

1x 40 Gbps - ODB
1x 40 Gbps - DPSK+

4x 10GE

Cisco 12000

1x 10GE SPA



Cisco 7600

2 and 4x 10GE
(planned for Q1CY09)

Synergic effect of all advanced DWDM features

- ✓Reconfigurable OADM
  - Supporting any traffic pattern at wavelength granularity
  - Minimizes impact of human error & Reduces truck-rolls
- ✓Tunable transponders, client pluggable modules

Customer Value: Reduce impact of human error, increase reliability, increase flexibility, covers more potential applications and services, reduce OPEX, etc.

- ✓Automatic power control
  - Protects against aging effect and fast transients
- ✓and many many more …

Q & A