IPoDWDM: 100G and Beyond

Moustafa Kattan, Consulting Systems Engineer, Emerging

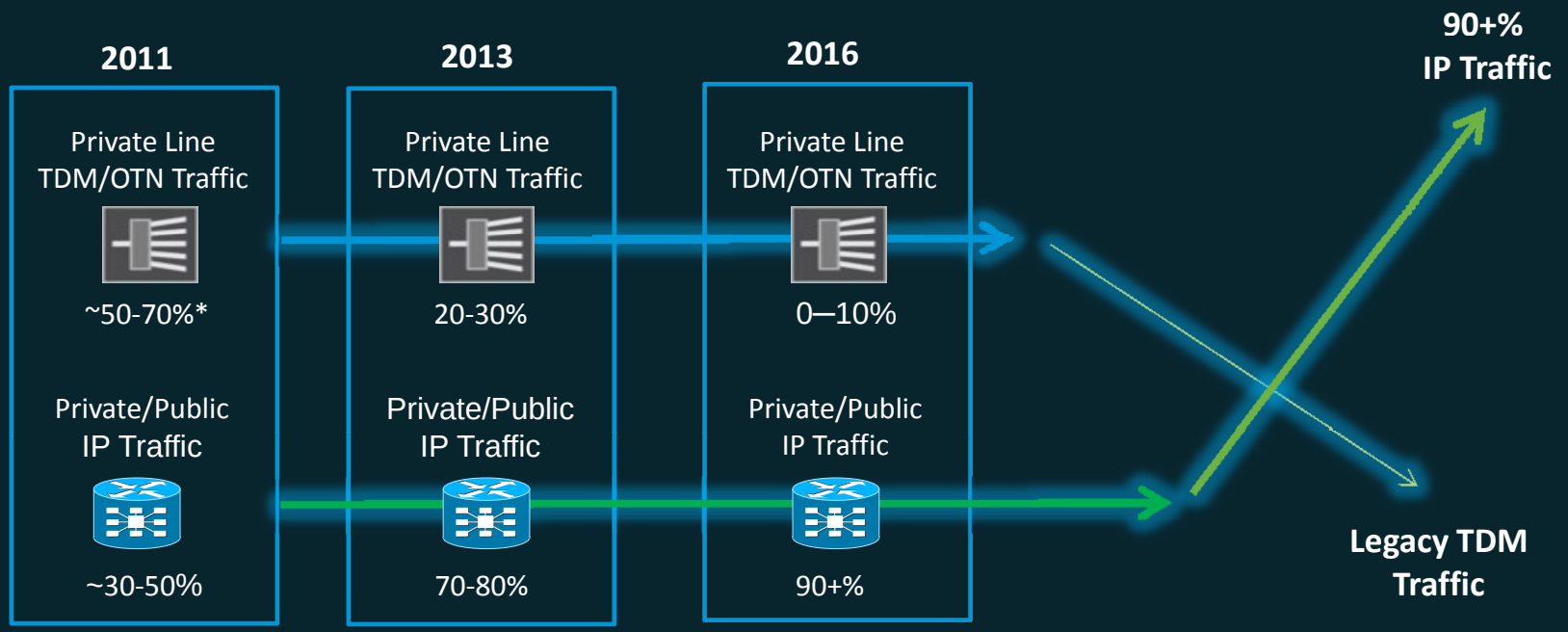
Dec 6, 2011

Agenda

- **IP NGN Transport Trends**
- **100G**
- **Beyond 100G**
- **Control Plane**

IP NGN Transport Trends

Circuit to Packet Migration



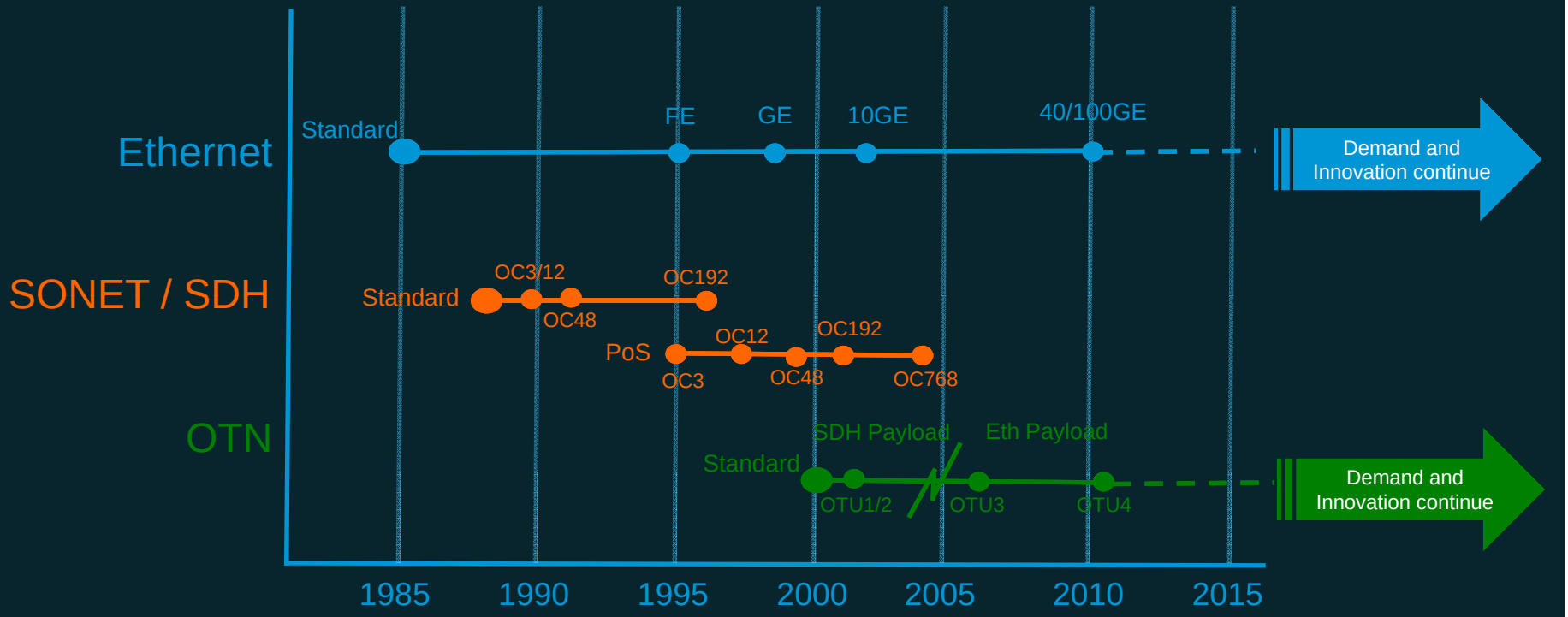
- Massive change in SP traffic make-up in next 5 years*
- SP revenue shifting from circuits to packet services**

  5 yrs → ~80% revenue derived from packet services

  Packet traffic increasing at 34% CAGR***

*ACG Research 2011, ** Cisco Research 2010, ***Cisco VNI 2011

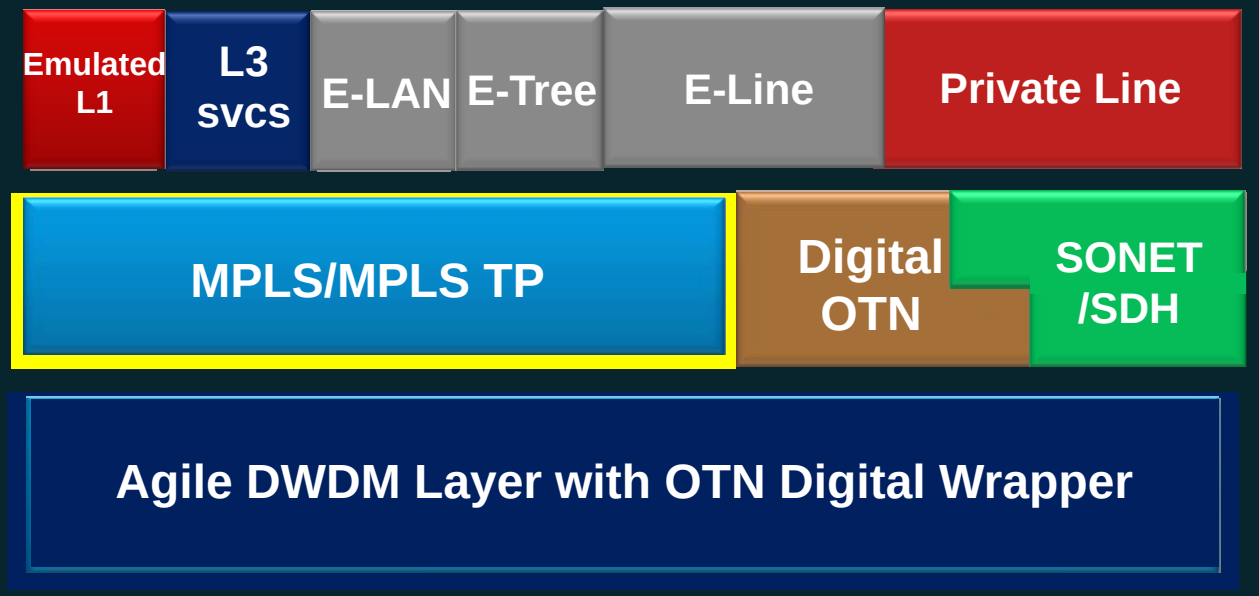
POS / Ethernet / OTN Migration



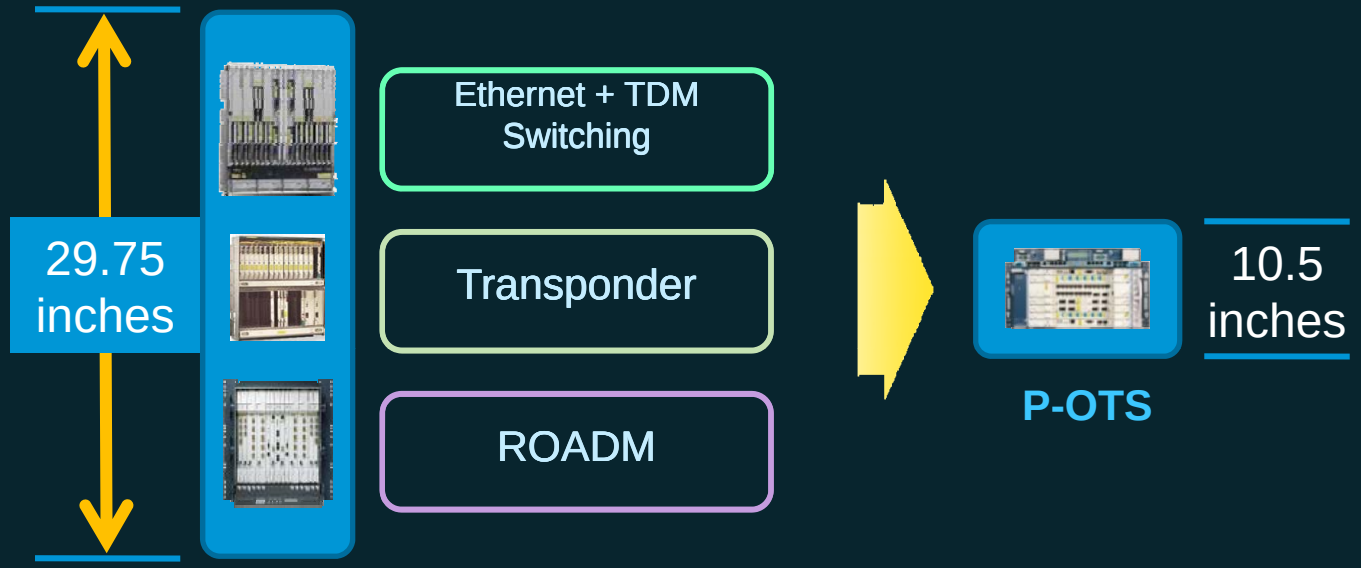
- POS and SDH R&D / Innovation caps 1995 / 2004
- Ethernet has undergone continual innovation since standardization
- OTN transitions in 2004/5 from SDH hierarchy to Ethernet payloads

SPs are making transition from SDH / POS to Ethernet

Transport Evolution Layers



Packet Optical Transport Systems



P-OTS properties

- Integrates DWDM, packets and TDM into the same system
- Predictable, deterministic
- Resiliency – 50-msec or better
- Granular service differentiation
- Higher BW (Tbps), lower cost/bit

Cisco Optical Investment

1990-1999

1st Avail Optical EDFA MP
1st In field Amplified System (T20)
1st WDM System (Sprint)
1st Tech Trial 32ch system
1st Demo of 128ch (Scom '98)
1st Deployed 128ch (Global Crossing)

1999 - 2002

Industry 1st MSPP
1st OC-192 MSPP

2000 - 2009

Industry 1st MSTP
#1 WW ROADM Share
Alien Wavelength
Mesh DWDM
1st L2 XPonder
1st to market IPoDWDM
1st 40G IPoDWDM
1st 100G IPoDWDM trial
1st Single Module ROADM
1st Omnidirectional ROADM

2010

10G MLSE
40G CP-QPSK
Coherent DSP
ColorLess ROADM

2011

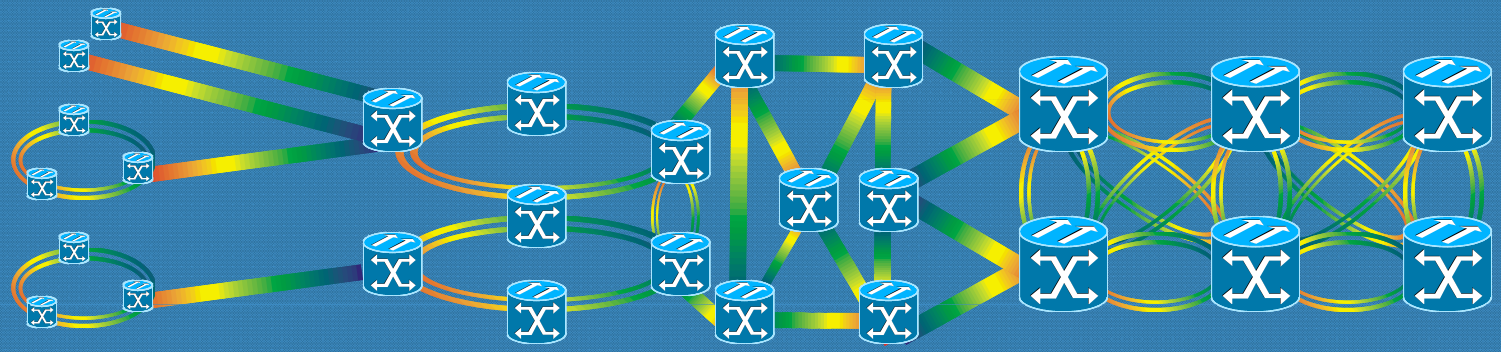
1st industry MPLS-TP
1st industry WSON

Coming Soon

100G CP-DQPSK
Bandwidth manager
…
400G / 1TB WDM

Cisco Multi-Reach Packet Optical Transport

WSON/GMPLS Control Plane



Product	 15454-M2	 15454-M6	 15454-M6	 15454-M12
Distance	**Metro Access 80km**	**MetroCore 1500 km**	**Regional/Long Haul Core 1500 to 3000 km**	
Applications	EDFA ILA 80G MPLS-TP Aggregation Stand-Alone Service Shelf	RAMAN ILA Metro ROADM DWDM 240G MPLS-TP	Mesh ROADM 40G Core DWDM 240G MPLS-TP	Mesh ROADM 40/100G+ Core DWDM 3.2Tb OTN/MPLS-TP/IP
Technologies	C/DWDM Tunable and Pluggable Low Power Simply to Deploy	C/DWDM Tunable and Pluggable Low Power 2/4 Degree ROADM	50/100GHz Mesh ROADM 40G Coherent Optics 2/4/8 Degree ROADM Touchless Photonics	50/100GHz Mesh ROADM 40G/100G Cohernet Optics 23-Degree ROADM LSP, ODU XC

Universal Software, Circuit Packs, Optics

End to End Service & Wavelength Connections

Cisco Packet Optical Transport Direction

Photonics

Flexibility & OpEx

- ROADM
  - 40 to 80 to 96 Channels
  - Colorless, Gridless
  - Directionless
  - > 8-Degrees
- Reach & Amplification
  - Up to 2500km
- GMPLS Control Plane

40/100G

Capacity & Density

- Cisco Coherent Technology
  - 40G CP-DQPSK
  - 100G CP-DQPSK
- >100Gb per RU
  - 6.4Tb /Rack
- 1.6Tb to 9.6Tb/s
- No Guard Band up to 1000km on 10Gb Overlay

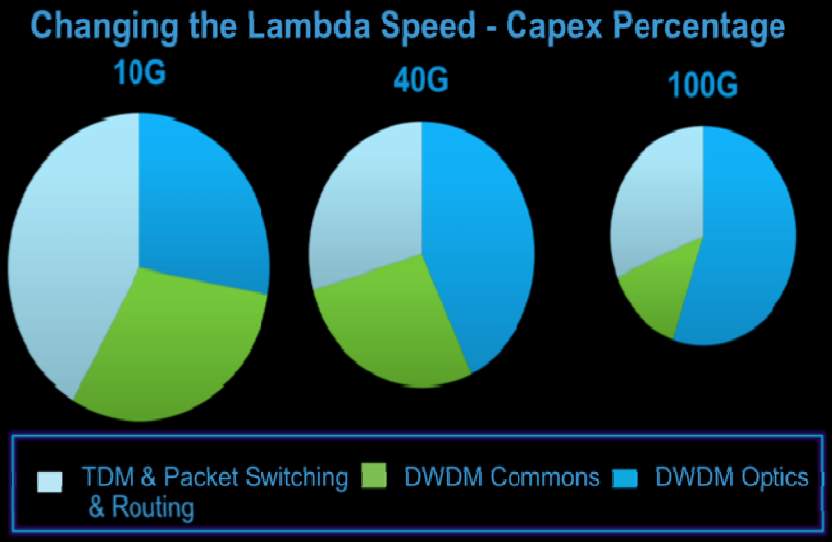
Packet Transport

Grooming & Muxing

- Pre-Aggregation (<10G)
  - MPLS-TP and MPLS
  - Allow SONET to sunset
  - Same OAM&P as TDM
- Aggregation/Core (>10G)
  - IP/MPLS - IPoDWDM
  - OTN – PL and 100G λ packing

100G Solution

High Speed Optics



THE OLD POST

ILLUSTRATED WEEKLY NEWSPAPER

Est. 1869 | Thursday May 20, 2010 | Price 6d

Cisco Acquires CoreOptics

Acquisition Reinforces Cisco's Commitment to Deliver High-Speed Networking and Enable Service Providers to Meet Growing Network Demands

SAN JOSE, Calif. – Cisco today announced its intent to acquire privately held CoreOptics Inc., a designer of digital signal processing (DSP) solutions for high-speed optical networking applications. Based in San Jose, with the majority of its employee base in Nuremberg and Gerlingen, Germany, CoreOptics will enable Cisco to equip service provider customers with highly advanced 100 Gigabits per second (Gbps) transmission technology to scale their networks to meet the demands of rapidly growing Internet Protocol traffic driven by video, mobility and cloud services. According to Cisco's Visual Networking Index research, global IP traffic will increase fivefold from 2008 to 2013 with a 40 percent compound annual growth rate.

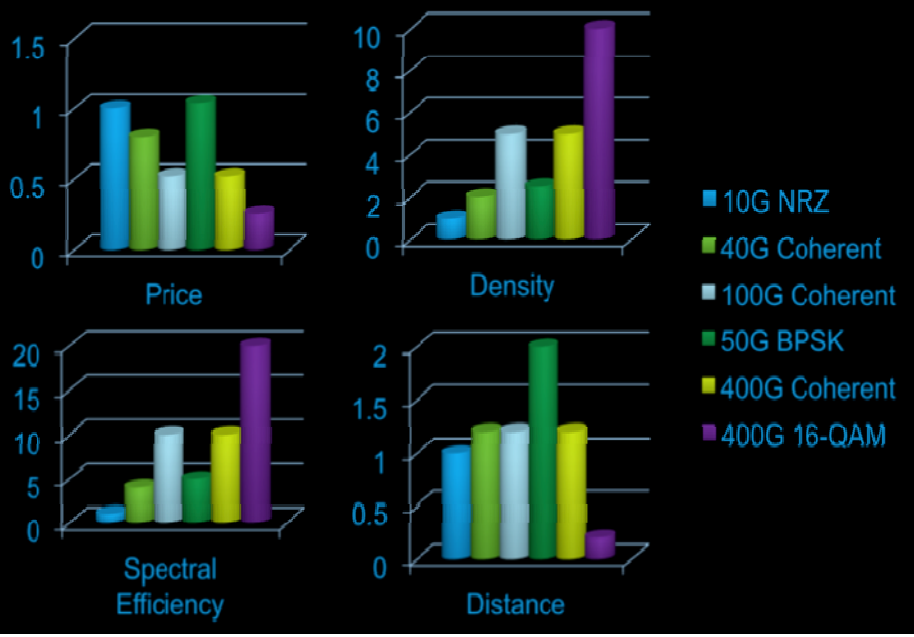
"With this acquisition, Cisco reinforces its commitment to continue to invest in its core networking business and to deliver IP next-generation networks at 100 Gbps and beyond," said Surya Panditi, vice president and general manager, Cisco's Service Provider Access and Transport Technology Group. "We are focused on continuing to deliver an industry-leading portfolio of routing, switching and optical transport systems that enable our service provider customers to better address the ever-present business challenge of managing tight capital and operating budgets while accommodating the tremendous growth in network traffic."

The next phase of innovation in optical networking will be driven by sophisticated modulation formats and advanced DSP technologies. These new capabilities enable the efficient transmission of large amounts of data over existing fiber optic installations. By enabling high speeds across an existing infrastructure, Cisco and CoreOptics will address the challenge facing service providers of accommodating the growth in network traffic while managing tight capital expenditure budgets.

The acquisition of CoreOptics expands Cisco's optical presence in Europe, builds on its existing European operations in Monza, Italy, and will contribute to continued innovation in optical networking. CoreOptics will bring to Cisco a team with strong expertise in digital ASIC design, advanced modulation formats, as well as optical systems, applications and network architecture. Upon completion of the acquisition, CoreOptics

Receiver ASIC Checklist

10G MLSE	✔
40G Coherent	✔
100G Coherent	✔
SW Selectable BPSK, Coherent, 16-QAM	In Dev

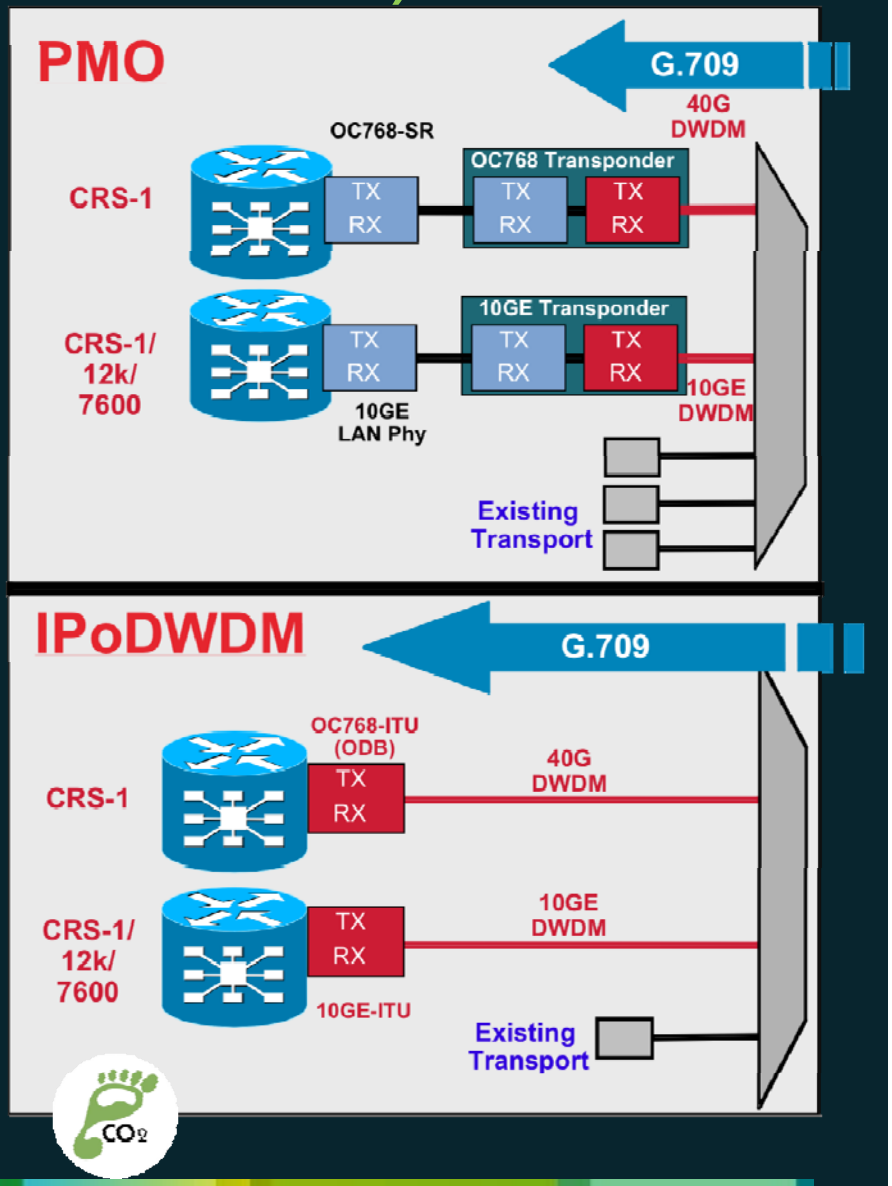


Less layers = lower cost

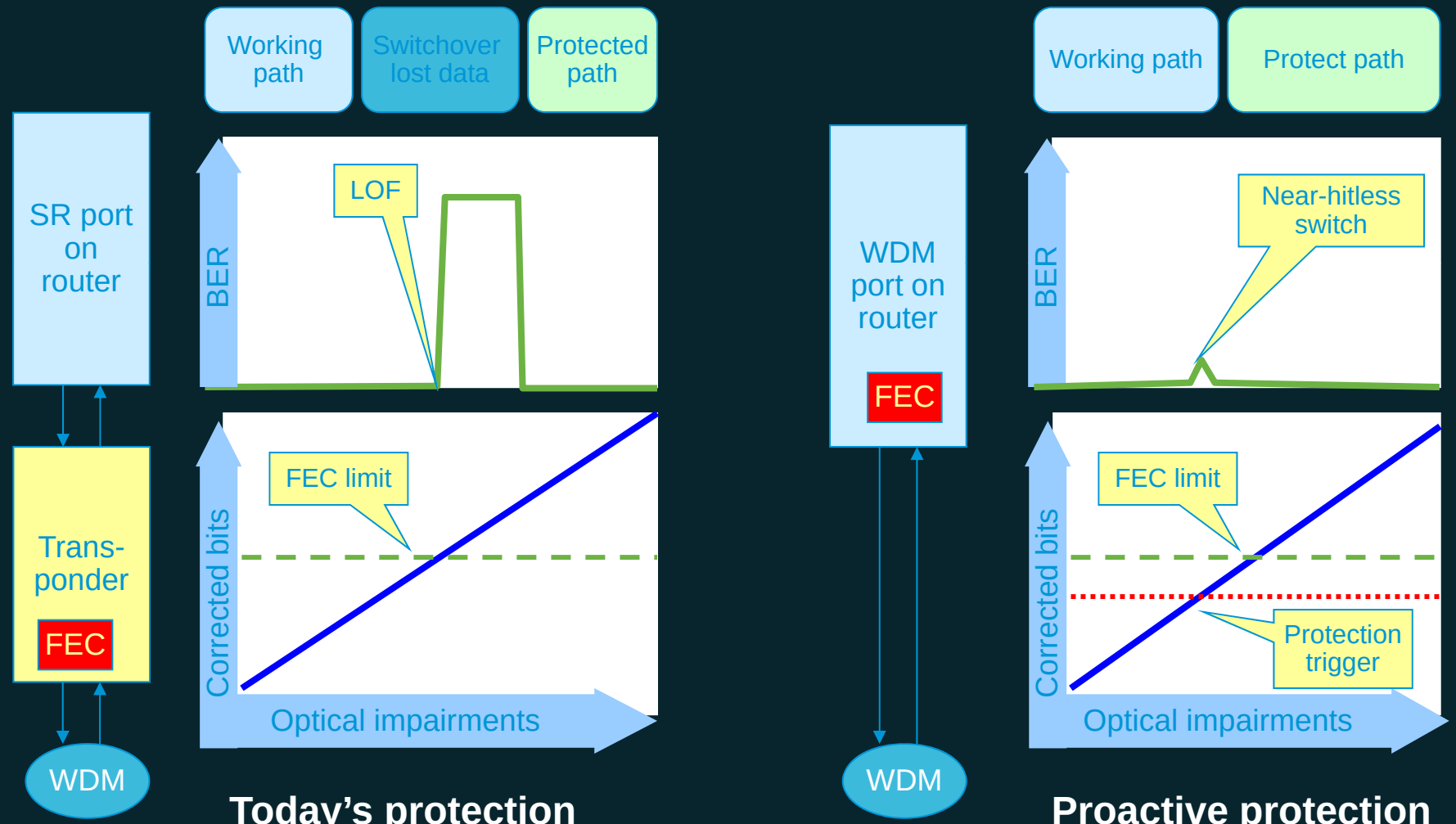
- A big % of the cost in NG network will be in optical interfaces
- Not only DWDM but also grey optics
- Therefore removing handoff between is important
- As long as we don't lose the ability to reconfigure
- Which is why "Any-X ROADMs" are so important

Why IPoDWDM (basic reasons)

- 66% reduction in number of optical Interfaces
  - Reduced Cost
  - Improved reliability
- 50% reduction in the number of patch cables
  - Less operational issues at turn up
- Reduction in common equipment
  - Less racks / shelves / common cards
  - Less Real Estate
  - Less COLO fees
- Fewer fans
  - Improved reliability
- Less Power
  - Reduced Power costs
  - No new Power plant requirements
- G.709 terminates on router
  - L1 awareness
  - Enhanced troubleshooting features
  - Enhanced protection features



Proactive Protection: High Level Concept



IPoDWDM Supports 2 network management models

1. Segmented Management:
   - Retain existing operational model for certain SPs
   - Respect boundaries between data/optical groups
2. Integrated management:

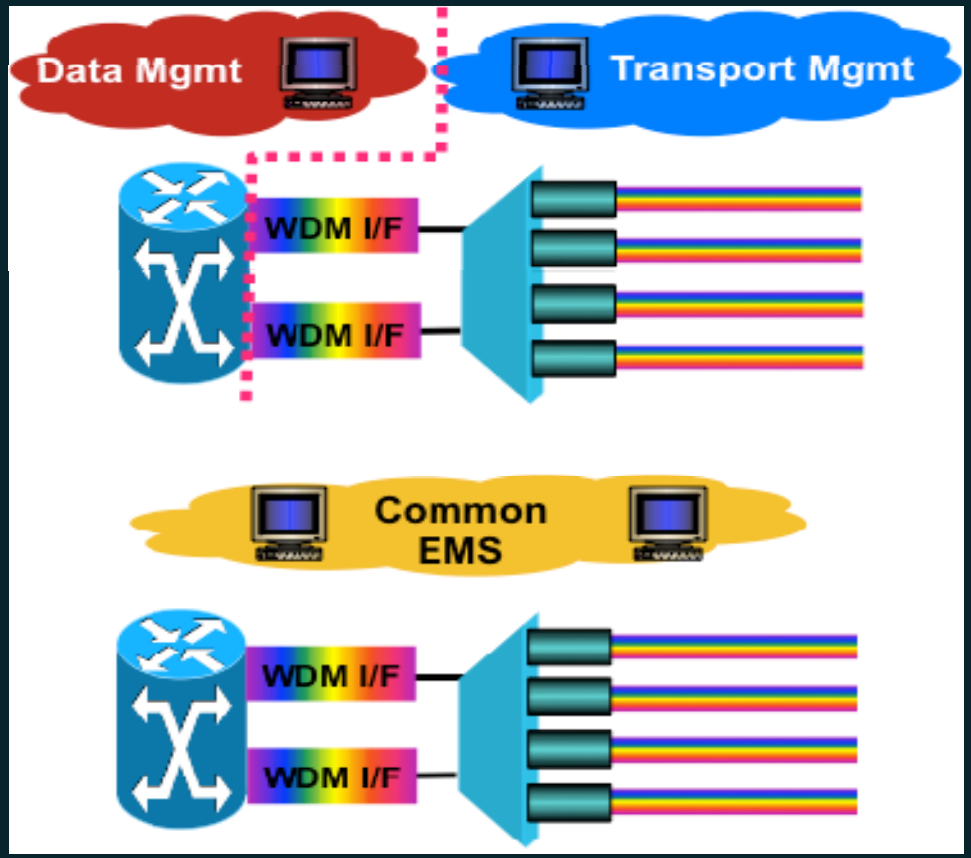
   End to end provisioning

   Better trouble shooting

   1 mgmt system, 1 DB

   Unified look & feel

   ➢ Lower OPEX



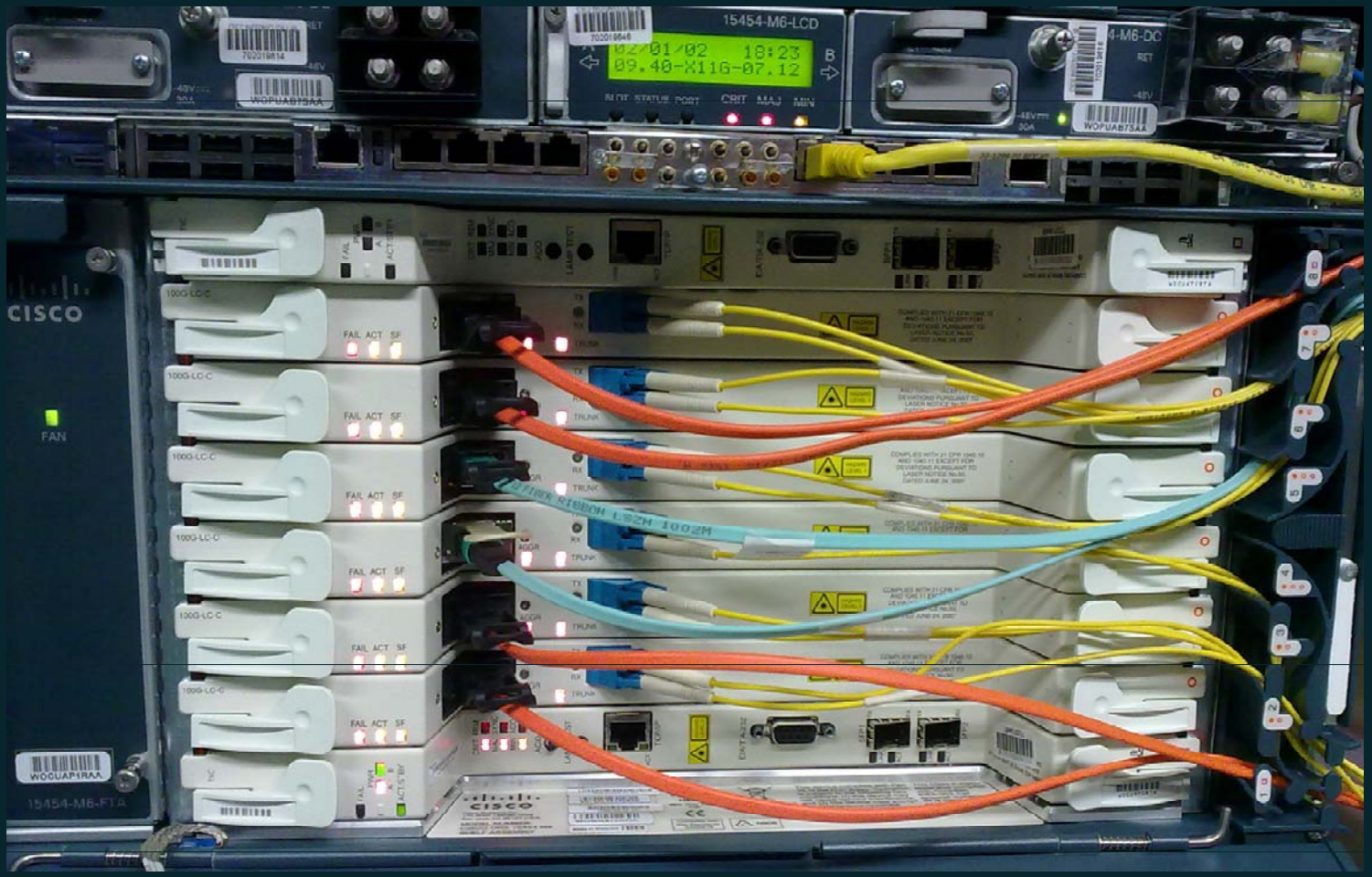
Cisco 100G Technology Choices

- Modulation: Coherent Polarized Differential Quadrature Phase-Shift Keying (CP-DQPSK)
- SW-configurable FEC algorithm to optimize Bandwidth vs. Reach:
  - 7% based on Standard G.975 ReedSolomon FEC
  - 20% based on Standard G.975.1 I.7 UFEC (1xE(-2) Pre-FEC BER)
  - 7% based on 3rd Generation HG-FEC (4.6xE(-3) Pre-FEC BER)
- Baud rate: 28 to 32 Gbaud
- 96channels Full C-band 50GHz tunable DWDM Trunk
- CD Robustness up to 70,000ps/nm, PMD Robustness up to 30ps (100ps of DGD)
- Receiver Dynamic Range (Noise Limited): +0dBm to -18dBm

OTU-4 Full C-Band Tunable Line Card

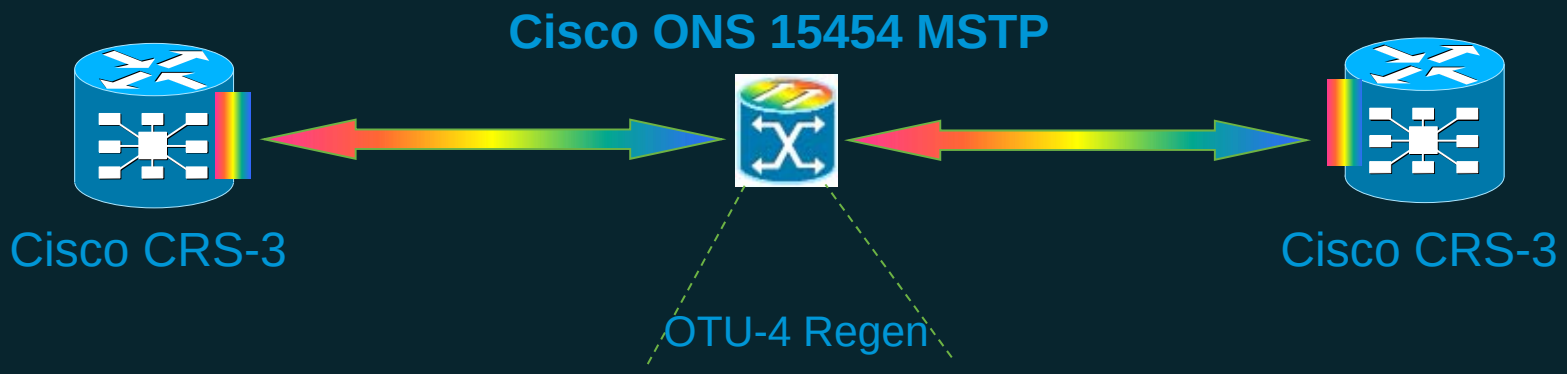
- Same unit supporting **3 working modes** (SW Configurable):
  - **100G TXP** or IPoWDM Interface (CXP as standard 100GE SR10 / OTU4 Client)
  - Trunk Line Card – coupled with a Client card to perform **Muxponder** functionality (no CXP pluggable needed)
  - Trunk Line Card – coupled with another Trunk Line card to perform **Regeneration** functionality (no CXP pluggable needed)
- High performance ITU-T Trunk interface - Full C Band Tunable OTU-4 Trunk with 50GHz stability
- PM as defined by the OTN standards
- Equipped with 1x DWDM Port and 1x CXP interface to provide a 100G Pluggable Client as well as a cost optimized connection with CRS/ASR/Nexus
  - 100G DWDM Trunk supports EFEC for optimized DWDM Performances
  - CXP allows up to 100m "low cost" connection solution towards external 100GE BASE SR10 Interface Client
- 150W Maximum Power consumption

6x 100G Transponders in 6 RU



IPoWDM 100G Interoperability – CRS-3

- Same Interface used on CRS-3 Line Card and ONS 15454 boards
- Capability to use ONS15454 Boards and chassis to Regenerate CRS-3 100G signals



- OAM integration:
  - Proactive FRR messaging supported by OTU-4 Regen (Degrade detection generates an FDI to the Router)

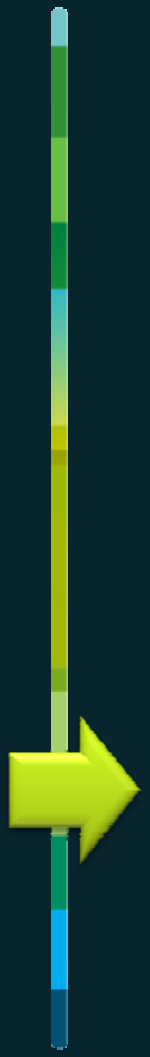
Cisco solution differentiator

- Highest density solution in the market (42x 100G DWDM TXP in a bay)
- ULH capable performances to cope with > 3000km unregenerated section
- Fully integrated IPoWDM solution with CRS-3
- Strong experience in High speed ASIC development leveraging on CO acquisition
- Best in Breed ROADM portfolio

Beyond 100G

How do we move forward to higher data rates?

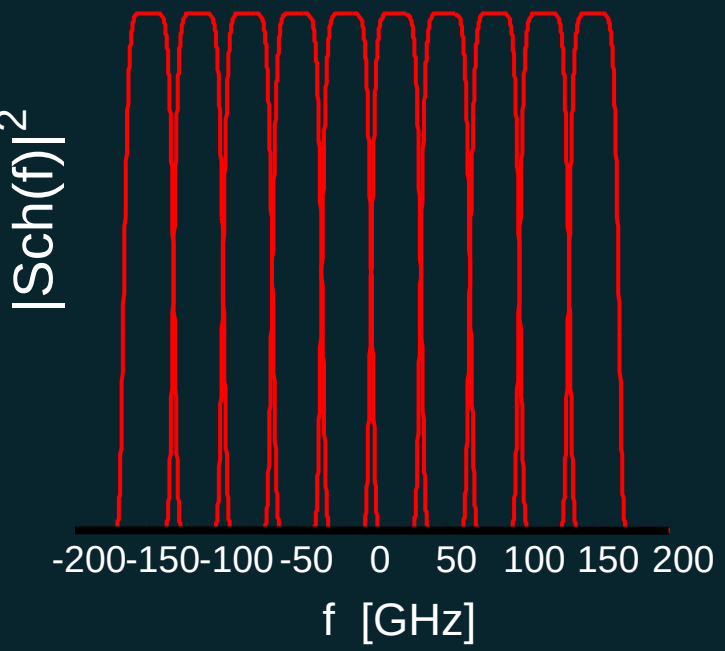
- 40Gbps Wavelengths
  22Gb/s ADC Required @ Receiver
  Optical Bandwidth of ~12GHz
- 100Gbps Wavelengths
  55Gb/s ADC Required @ Receiver
  Optical Bandwidth of ~28GHz
- 1,000Gbps Wavelengths
  550Gb/s ADC Required @ Receiver
  Optical Bandwidth of ~280GHz



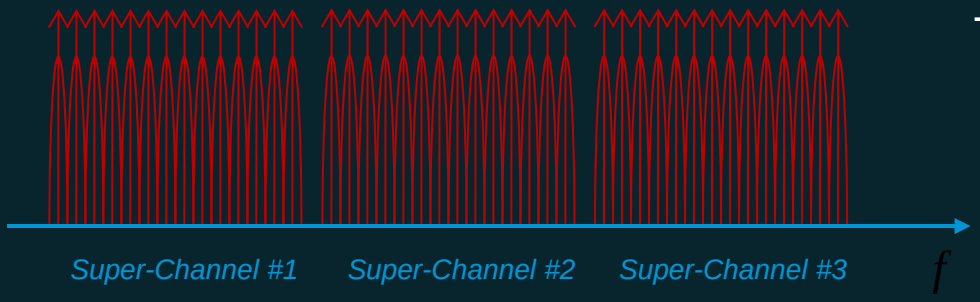
Need Extra "Complexity" to address 1,000Gbps Wavelengths

The Terabit Super-Channel

- Information distributed over a few Sub-Carriers spaced as closely as possible forming a 1,000Gbps Super-Channel
- Each Sub-Carrier transporting a lower Bit Rate, compatible with current ADCs and DSPs



10x 100Gbit/s Sub-Carriers close-to-Baud-rate spaced



What is a Flex Spectrum ROADM?

- Standard ROADM Nodes support wavelengths on the 50GHz ITU-T Grid

  Bit Rates or Modulation Formats not fitting on the ITU-T grid cannot pass through the ROADM

- A Flex Spectrum ROADM removes ANY restrictions from the Channels Spacing and Modulation Format point of view

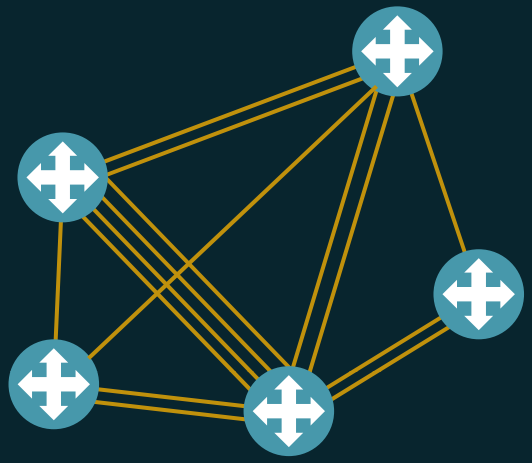
  Possibility to mix very efficiently wavelengths with different Bit Rates on the same system

  Allows scalability to higher per-channel Bit Rates

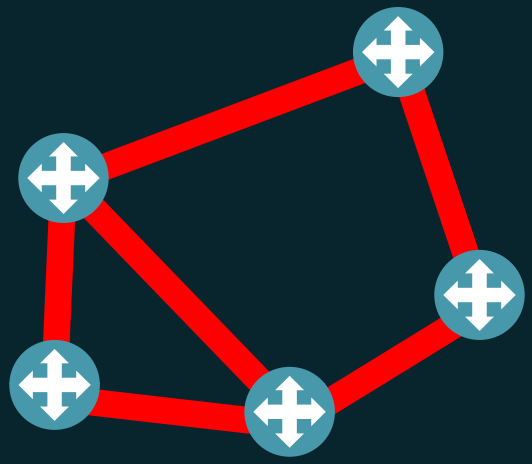
  Allows maximum flexibility in controlling non-linear effects due to wavelengths interactions (XPM, FWM)

  Allows support of Alien Multiplex Sections through the DWDM System

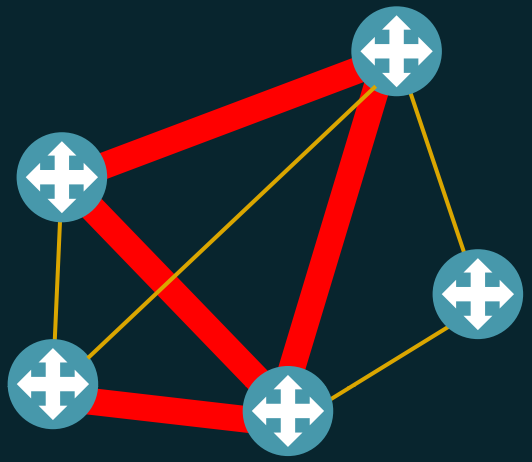
How to deal with flexible bandwidth needs?



Many low speed WLs

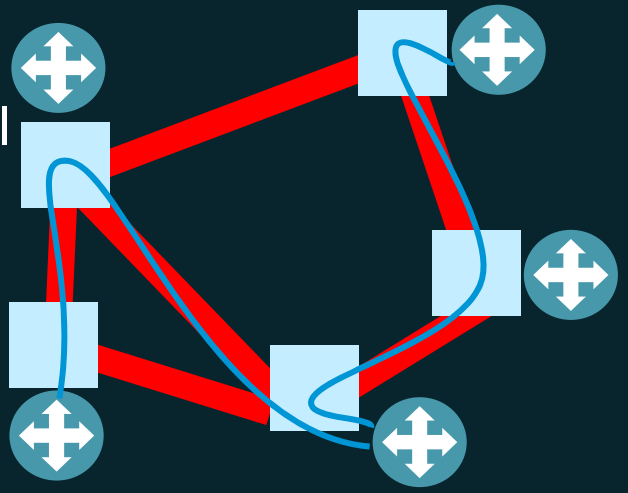


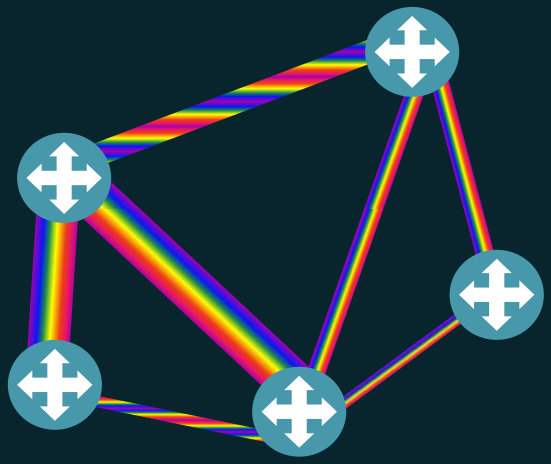
High speed WLs only



Mix high/low speed WLs

Electrical TDM layer





Elastic DWDM

Next Generation Optical Amplifiers

- Erbium Doped Fiber Amplifiers (EDFA) are generally used in DWDM Transport Networks to extend Unregenerated Distance between End Points in the Network
- Typical Optical Bandwidth of EDFA units allows to transport 80wavelengths (50GHz spacing) in the C-band spectrum
- Raman amplification has been used to support very long spans
- Can EDFA and Raman be jointly used to improve the number of wavelengths in the C-band and to provide better OSNR?

EDRA: Erbium Doper Raman Amplifier

- Integrating Raman and EDFA in a single card has already proven to be an effective solution to allow optimal balance between Distributed (Raman) and Concentrated (EDFA) amplification
- The goal is to provide a completely integrated Optical Amplifier solution which can include everything needed to face a single direction of the fiber:

  Counter-Propagating Raman – Features variable power allowing to control the overall amount of Raman amplification for the specific Site Degree

  Low-Noise Pre-Amplifier – True Variable Gain EDFA optimized to operated with the Counter-Propagating Raman

  Optional Booster Amplifier – True Variable Gain EDFA which can be excluded via SW if not needed for a given span

- 2 different versions of the unit will be made available for optimal Gain set point – Up to 96chs (50GHz spacing) supported

Next Generation Optical Layer

Tunable Laser – Transmit laser can be provis… frequency in the C…

Restoration – Ability to reroute a dangling resource to another …tection switch.

Key Values

- Complete Control in Software
- No Manual Movement of Fibers
- Increased Service Velocity
- Control Plane Can Automate Provisioning, Restoration, Network Migration, Maintenance

Foundation for IP+Optical!!

Flex Spectrum – Ability to provision the amount of spectrum allocated to each Wavelength allowing for 400G and 1T bandwidths.

Colorless – ROADM add ports provisioned in software and rejects any other wavelengths.

Tunable Receiver – C… Detection accepts provis… wavelength and rejects a…

…ntention-less – In the same …d/Drop device you can add …d drop the same frequency to …ltiple ports.

Omni-Directional – Wavelength can be routed from any Add/Drop port to any direction in software.

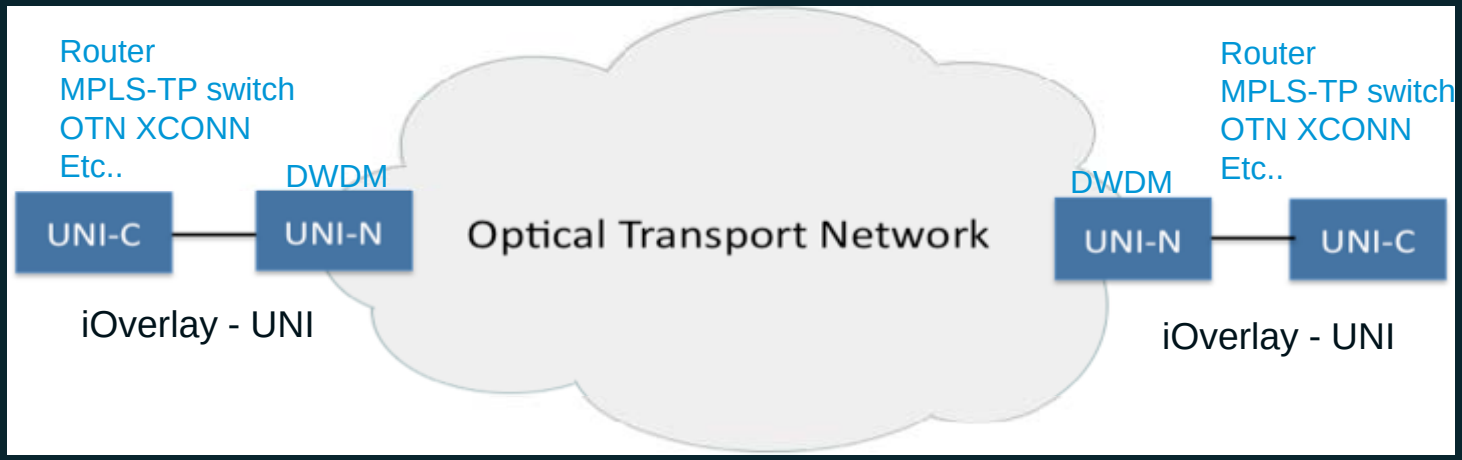
Multi-Layer Control Plane

How do we meet objective – **FIA**
Racing ahead of the competition

- **F**eatures
  - Integration by itself is not enough
  - Control Plane by itself is not a differentiator
  - Features are the “GLUE” we need to continue driving
- **I**ntegrate
  - HW integration where feasible
    - Solves first order CAP EX by eliminating Client optics
- **A**utomate
  - Build in Multi-Layer Control Plane
    - This is an enabler

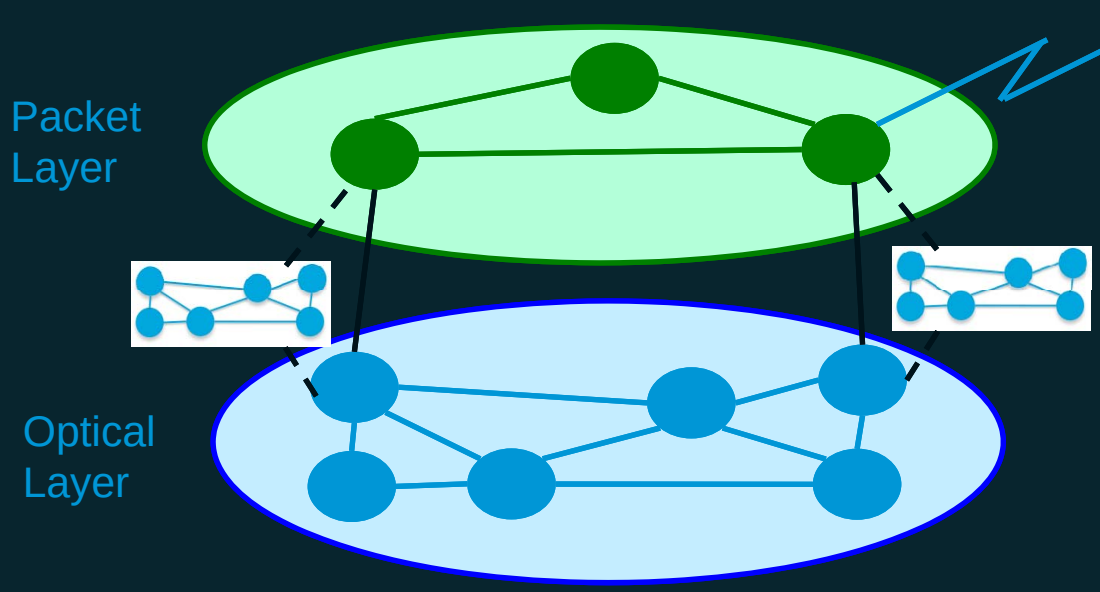
Control Plane - iOverlay

- iOverlay can provide the network knowledge of peering while providing greater scale
- Provide Multi Layer Support while Respecting Organizational Boundaries
- Leverage Expertise across layers
- Share and leverage information across layers



iOverlay: Solving the Multi-layer Control Plane Problem

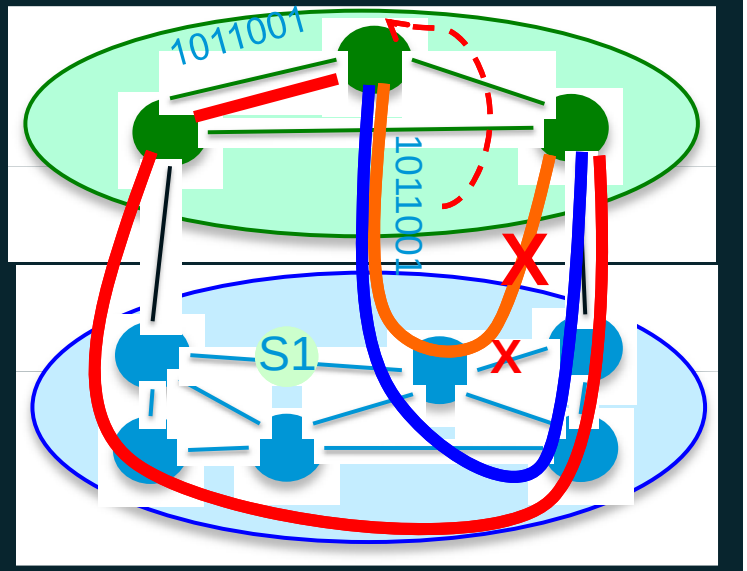
- Phase 1: Deliver WSON capability in Optical Layer
- Phase 2: Enable interfaces between packet layer and optical layer using G-MPLS UNI
- Phase 3: Extend interfaces to add new capabilities
- Phase 4: In-line fully automated decision making



Network is the Database

The Interaction

- Restoration – L3 Protect -> L0 Restores
  - Today:
  - Protection is provided via L0 Team
    - 1+1, Fiber protection, etc…
    - Does not efficiently utilize available BW
    - Increases Cost per Bit
  - Protection is provided via L3 team
    - Decrease Interface Utilization based on WC BW
    - Does not efficiently Utilize BW
    - Increase Cost per Bit



iOverlay:

L3 detects Circuit degradation and initiates Proactive Protection

L0 Restores capacity back to network and signals existing router port to change if needed

No SRLG data is propagated and recorded

Multi-layer Control Plane Benefits

SP Wants….	Multi-layer Control Plane Benefit
Increase Service Velocity	Eliminate network layers No coordinating correct interface Utilize Control Plane for Circuit Turn Up No waiting on feasibility No waiting on Resource allocation Leverage L0 SRLG
Enhance Resiliency / Availability	Proactive Protection for L3 Protect Optical Restoration after Protect Adaptive B/W Leverage L0 SRLG
Reduce planning / forecasting cycles	On Demand Circuit verification Eliminate Network Layers Leverage L0 SRLG Flex Spectrum / Adaptive Data Rates Up-to-date Circuit Data
Enhance Operations	Maintain current Circuit data Reuse of network resources Fewer layers to troubleshoot Adaptive BW …

WSON in the Standards Bodies (Wavelength Switched Optical Networks)

IETF

Charter: Evolution of the Internet (IP) Architecture

(MPLS, MPLS-TP)

Active Participants:
- **Service Providers**
- **Vendors**
  --WSON,

ITU

Charter: Global Telecom Architecture and Standards

Member Organizations:
- **Global Service Providers**
- **PTTs, ILECs, IXCs**
- **Telecom equipment vendors**
- **Governments**
- **---ASON, impairment parameters G.680**

- **WSON Optical Impairment Unaware**

  https://datatracker.ietf.org/doc/draft-ietf-ccamp-rwa-wson-framework/

- **WSON Optical Impairment Aware Work Group Document**

  http://www.ietf.org/id/draft-ietf-ccamp-wson-impairments-06.txt

36

Why Do We Need WSON ?

- **WSON is an Impairment aware DWDM control plane (ASON is not)**
- **Client interface registration**
  - Alien wavelength (open network)
  - Transponder (closed network)
  - ITU-T interfaces
- **Wavelength on demand**
  - Bandwidth addition between existing S & D Nes (CLI)
- **Optical restoration-NOT protection**
  - Automatic Network failure reaction
  - Multiple SLA options (Bronze 0+1, Super Bronze 0+1+R, Platinum 1+1, Super Platinum 1+1+R)

WSON Foundations

WSON Building Blocks

Tunability

- Optical channels can be moved and changed to different wavelengths completely via software

Colorless

- Ability to change the wavelength aspects of these devices without moving any physical fibers

Omni-Directional

- A fixed fiber port interface directed to any of the degrees within the ROADM node

Impairment-aware

- DWDM system must be able to measure optical impairments

Cisco Zero Touch End to End Solution

WSON Should Consider all Necessary Effects

WSON input based on G.680

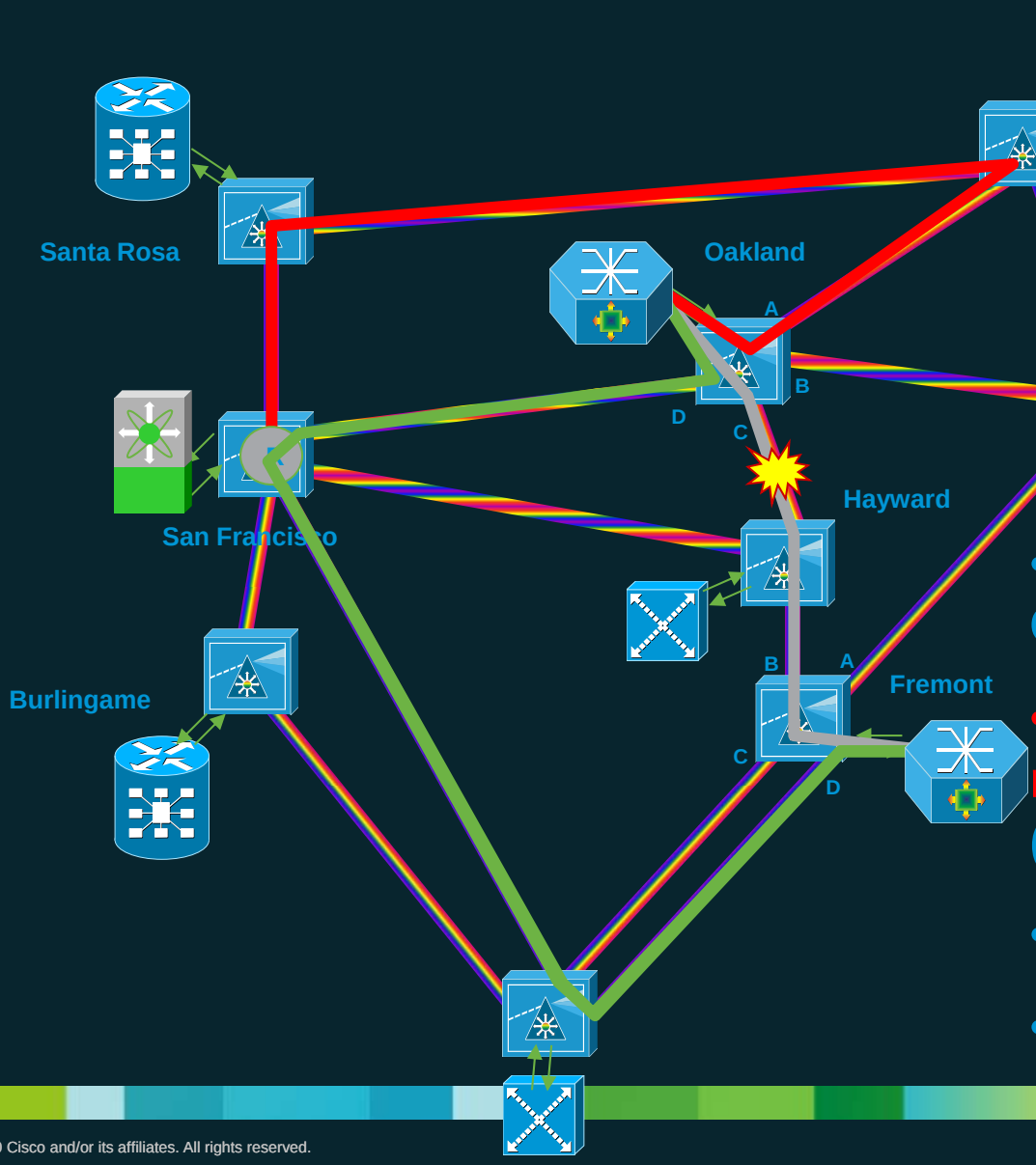
Linear impairments

- Power Loss
- Chromatic Dispersion (CD)
- Polarization Mode Dispersion (PMD)
- Optical Signal to Noise Ratio (OSNR)

Non linear Optical impairments:

- Self-Phase Modulation (SPM)
- Cross-Phase Modulation (XPM)
- Four-Wave Mixing (FWM)

WSON Restoration Example for AToDWDM



- Impairment Aware DWDM Control Plane
- Switch when you can & regenerate when you must (Lambda Switching)
- Minimize TDM XC/OEO
- Minimize Latency and cost

Consolidated IP+Optical Roadmap

	Avail	2012 Q2	2012 Q3	2012 Q4	1H2013	2H2013	Radar
CRS	CRS-10 Chassis 1x100GE PLIM	100G DWDM 4 x 40GE OTN 100GE P-FRR 100GE V-Txp		100GE GMPLS UNI-C	MSTP Satellite (Virtual Interface)	iOverlay Ph1	4x100GE
ASR9K	2x100GE Line Card	4 x 40GE OTN Line Card	100GE Proactive Protection (trigger)	100GE GMPLS UNI-C	MSTP Satellite (Virtual Interface)		100G DWDM 2x100G CXP 100GE V-TXP
XR SW	**4.2.0**	**4.2.1**	**4.2.2**	**4.3.0**	**4.3.1**		
ONS Feature	AR Xponder RAMAN 1W 96ch EDFA WSON	100G TxP, MxP, Regen 5x10G LC GMPLS UNI-C		FS ROADM EDRA Encryption LC WSON 1+1+R		1 Tb DWDM Contention-less 720G Agnostic Fabric 120G Linecards	Cross-Layer Optimization
ONS SW	**9.4**	**9.6**		**10.0**		11.0	

THANK YOU!

Please fill evaluation sheet and this nice Cisco-Linksys E4200 Dual-Band Wireless-N Router could be yours ...

42