IPoDWDM: 100G and Beyond

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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 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

Emulated L1  L3 svcs  E-LAN  E-Tree  E-Line  Private Line

MPLS/MPLS TP  Digital OTN  SONET/SDH

Agile DWDM Layer with OTN Digital Wrapper
Packet Optical Transport Systems

29.75 inches

Ethernet + TDM Switching

Transponder

ROADM

10.5 inches

P-OTS

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

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Cisco Optical Investment

1990-1999
- Industry 1st MSPP
- Industry 1st OC-192 MSPP
- 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 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

2000 - 2009
- 10G MLSE
- 40G CP-QPSK
- Coherent DSP
- ColorLess ROADM

2010
- 1st industry MPLS-TP
- 1st industry WSON

2011
- 100G CP-DQPSK
- Bandwidth manager...
- 400G / 1TB WDM

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# Cisco Multi-Reach Packet Optical Transport

## WSON/GMPLS Control Plane

### Product
- **15454-M2**
- **15454-M6**
- **15454-M12**

### Distance
- **Metro Access**
  - 80km
- **MetroCore**
  - 1500 km
- **Regional/Long Haul Core**
  - 1500 to 3000 km

### Applications
- **15454-M2**
  - 80G MPLS-TP Aggregation
  - Stand-Alone Service Shelf
- **15454-M6**
  - 240G MPLS-TP
- **15454-M6**
  - 40G Core DWDM
- **15454-M12**
  - 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 Coherent Optics
  - 23-Degree ROADM
  - LSP, ODU XC

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**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

Changing the Lambda Speed - Capex Percentage

- 10G
- 40G
- 100G

- TDM & Packet Switching
- DWDM Commons
- DWDM Optics & Routing

Receiver ASIC Checklist

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

Cisco Acquires CoreOptics

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

SAN JOSE, Calif. — Cisco today announced its intent to acquire privately held CoreOptics Inc., a developer of digital signal processing (DSP) solutions for high-speed optical networking applications. Based in San Jose, with the majority of its employees based in Nuremberg and Erlangen, Germany, CoreOptics will enable Cisco to equip service providers with highly advanced 100 Gbps per second (100G) transmission technology to scale their networks to meet the demands of rapidly growing Internet 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 infrastructure networks at 100 Gbps and beyond,” said Surya Pandit, vice president and general manager, Cisco Service Provider Agile and Transport Technology Group. “We are focused on continuing to deliver an end-to-end product lifecycle, starting with routing and switching, and optical transport systems that enable our customers to better address the increased business challenges of managing high-capacity, evolving networks where accelerated growth in network traffic is a key driver.

The totalization of innovation in optical networking will be driven by accelerated investment in research and development of new capabilities.”

The acquisition of CoreOptics expands Cisco’s optical presence in Europe, builds on its existing European operations in Munich, Italy, and will contribute to continued innovation in optical networking. CoreOptics will bring to Cisco a team with strong expertise in optical design, automated design and verification tools, as well as critical systems, applications and network architecture.

Upon completion of the acquisition, CoreOptics will become part of Cisco’s Optical Systems Business within the Service Provider Technologies Group.
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

Today’s protection

Proactive protection
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 (1\times 10^{-2}) Pre-FEC BER
  - 7% based on 3rd Generation HG-FEC (4.6\times 10^{-3}) Pre-FEC BER
- Baud rate: 28 to 32 Gbaud
- 96 channels 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 80 wavelengths (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

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!!

- Tunable Laser – Transmit laser can be provisioned to any frequency in the C-Band.
- Restoration – Ability to reroute a dangling resource to another protection switch.
- 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 – Coherent Detection accepts provisioned wavelength and rejects all others.
- Omni-Directional – Wavelength can be routed from any Add/Drop port to any direction in software.
- Contention-less – In the same Add/Drop device you can add and drop the same frequency to multiple ports.
Multi-Layer Control Plane
How do we meet objective – FIA
Racing ahead of the competition

• **Features**
  
  Integration by itself is not enough
  Control Plane by itself is not a differentiator
  Features are the “GLUE” we need to continue driving

• **Integrate**
  
  HW integration where feasible
  Solves first order CAP EX by eliminating Client optics

• **Automate**
  
  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
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

<table>
<thead>
<tr>
<th>SP Wants….</th>
<th>Multi-layer Control Plane Benefit</th>
</tr>
</thead>
</table>
| 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)

- **WSON Optical Impairment Unaware**
  

- **WSON Optical Impairment Aware Work Group Document**
  
  http://www.ietf.org/id/draft-ietf-ccamp-wson-impairments-06.txt
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 Building Blocks

<table>
<thead>
<tr>
<th>Tunability</th>
<th>Colorless</th>
<th>Omni-Directional</th>
<th>Impairment-aware</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Optical channels can be moved and changed to different wavelengths completely via software</td>
<td>• Ability to change the wavelength aspects of these devices without moving any physical fibers</td>
<td>• A fixed fiber port interface directed to any of the degrees within the ROADM node</td>
<td>• DWDM system must be able to measure optical impairments</td>
</tr>
</tbody>
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## 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
<table>
<thead>
<tr>
<th>CRS</th>
<th>Avail</th>
<th>2012 Q2</th>
<th>2012 Q3</th>
<th>2012 Q4</th>
<th>1H2013</th>
<th>2H2013</th>
<th>Radar</th>
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</thead>
<tbody>
<tr>
<td>CRS-10 Chassis</td>
<td>CRS-10 Chassis</td>
<td>100G DWDM 4 x 40GE OTN 100GE P-FRR 100GE V-Txp</td>
<td>100GE GMPLS UNI-C</td>
<td>MSTP Satellite (Virtual Interface)</td>
<td>iOverlay Ph1</td>
<td>4x100GE</td>
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<tr>
<td>1x100GE PLIM</td>
<td>2x100GE Line Card</td>
<td>4 x 40GE OTN Line Card</td>
<td>100GE Proactive Protection (trigger)</td>
<td>100GE GMPLS UNI-C</td>
<td>MSTP Satellite (Virtual Interface)</td>
<td>100G DWDM 2x100G CXP 100GE V-TXP</td>
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<td>ASR9K</td>
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<td>4 x 40GE OTN Line Card</td>
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<tr>
<td>XR SW</td>
<td>4.2.0</td>
<td>4.2.1</td>
<td>4.2.2</td>
<td>4.3.0</td>
<td>4.3.1</td>
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<tr>
<td>ONS Feature</td>
<td>AR Xponder RAMAN 1W 96ch EDFA WSON</td>
<td>100G TxP, MxP, Regen 5x10G LC GMPLS UNI-C</td>
<td>FS ROADM EDRA Encryption LC WSON 1+1+R</td>
<td>1 Tb DWDM Contention-less 720G Agnostic Fabric 120G Linecards</td>
<td>Cross-Layer Optimization</td>
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<tr>
<td>ONS SW</td>
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<td>9.6</td>
<td>10.0</td>
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Please fill evaluation sheet and this nice Cisco-Linksys E4200 Dual-Band Wireless-N Router could be yours ...