The Role of Packets in Converged Networks
Recap from this morning

- Rob talked about Tier1 SP in the US migrating from SONET/SDH to packet based transport-like infrastructure
- Ramesh talked about flex-LSP and the benefits it brings to the transport world from the MPLS world
- You heard Simon talk about WSON and its capabilities
- I’m going to take you through additional options of convergence and how we can leverage WSON in an IP environment
IP/LDH+ Optical Integration

- Traditional approach
  - Packet Node and Transponder managed separately
  - Ships in the night on data plane
  - Allow Control Plane Interaction

- IP+Optical
  - Multilayer interaction
  - Integrated management and monitoring
  - G.709 frame terminates on Packet Node
Multi-Layer Interface Integration

- Lower CapEx
  Elimination of client optics+fiber

- Lower OpEx
  Space, power, management

- Enhanced Resiliency
  Fewer active components

- Multi-Layer Interaction
  Proactive Protection

- Less Packet Latency
Cisco nV Optical Satellite

- Transponder becomes an extension of the router
- Power levels, OTN overhead, and alarms available in real-time on the router
- DWDM interface controlled and monitored by router CLI, or OTN MIB

Control Plane Interaction
IP+Optical Data Plane Integration

ASR 9000
- 400G / slot
- 2 x 100G/200G CFP2 IPoDWDM
- 20x10G
- HD/SD/Staircase FEC
- Coherent, Tunable Optics

CRS-X
- 400G / slot
- 1 x 100G/200G CFP2 IPoDWDM
- 3 x 100G CPAK Grey
- HD/SD/Staircase FEC
- Coherent Tunable Optics

NCS 6000
- 800G / slot
- 4x100G IPoDWDM/8x100GGrey (TBD)
- 6 x 100G CPAK Grey
- HD/SD/Staircase FEC
- Coherent Tunable Optics

NCS 2000 as nV Satellite (ASR 9000, CRS, NCS 6000)

Integrated Optics, Reduced TCO by over 40%
Converged Packet/OTN Platform

- **Great Flexibility** with just ONE transport platform!
  - Lower Opex, simpler network
  - Convergence

- OTN switching over grey or a wavelength
  - Allows for greater Bandwidth usage
  - Less Router ports with bypass

- Accommodate Circuit Traffic
  - Packet over OTN over DWDM
ODU Statistical Multiplexing

OTN Only provides no Statistical Multiplexing

Statistical Multiplexing with L2/MPLS

Tunably Utilized GigE/10 GigE

Tunably Utilized 100 GigE
NCS 4000 Series

Benefits:

- Packet-OTN- DWDM
- Optimal footprint
- Service velocity
- High lambda utilization
- Increased resiliency
- Circuit Emulation over Packet
  With Flex LSP
Proactive Protection
Proactive Protection
Achievable with or without DWDM interface in Packet Node

Traditional

**React**ive Protection
- **working route**
- **fail over**
- **protect route**

**FEC Limit**
- Time

**Pre-FEC Bit Errors**

**Router Bit Errors**

**ROADM**

**IP+Optica**

Proactive **Protection**
- **working route**
- **protect route**

**FEC Limit**
- Time

**Pre-FEC Bit Errors**

**Router Bit Errors**

**ROADM**
Control Plane Interaction
Dynamic Control Plane Depends on a Touchless Optical Layer

**Omni-Directional** — ROADM ports are not direction specific (re-route does not require fiber move)

**Tunable Laser** — Transmit laser can be provisioned to any frequency in the C-band (96 channels)

**Colorless** — ROADM ports are not frequency specific (re-tuned laser does not require fiber move)

**Tunable Receiver** — Coherent receiver can select one wavelength among a composite signal (no demux needed)

**Flex Spectrum** — Ability to provision the amount of spectrum allocated to wavelength(s) allowing for 400G and 1T channels.

**Contention-less** — Same frequency can be added/dropped from multiple ports on same device.

**WSON**
Wavelength Switched Optical Network

Complete Control in Software, No Physical Intervention Required
Cisco WSON
Foundation for Multi-Layer Information Exchange

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)

Topology
- Lambda assignment
- Route choices (C-SPF)

Interface Characteristics
- Bit rate
- FEC
- Modulation format

Regeneration Capability
Wavelength Switched Optical Network

Example

NCS2000 Network

Beijing

Tokyo

Bangkok

Phuket
Wavelength Switched Optical Network

Example

NCS2000 Network

Beijing

Tokyo

Bangkok

Phuket
Example WSON Restoration

Fiber Cut! Path Beijing to Bangkok affected

Wavelength Switched Optical Network

Beijing

Tokyo

Bangkok

Phuket

NCS2000 Network
Wavelength Switched Optical Network

Example

No other path for blue wavelength - other wavelengths tried

Beijing

Tokyo

Bangkok

Phuket

NCS2000 Network
Wavelength Switched Optical Network

Example

Embedded WSON intelligence locates and verifies a new path, with new lambda
Wavelength Switched Optical Network

Example

Same Router interfaces and Transponders used!

Beijing

Tokyo

Bangkok

Phuket

NCS2000 Network
### Who is standardizing and drafting WSON?

<table>
<thead>
<tr>
<th>Title</th>
<th>Draft</th>
<th>Vendor Contributing</th>
<th>Service Provider</th>
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</thead>
<tbody>
<tr>
<td>Framework for GMPLS and PCE Control of Wavelength Switched Optical Networks (WSON)</td>
<td>RFC6163</td>
<td>Huawei</td>
<td>NTT</td>
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<td>Routing and Wavelength Assignment Information Encoding for Wavelength Switched Optical Networks</td>
<td>draft-ietf-ccamp-rwa-wson-encode-23.txt</td>
<td>Huawei, Cisco</td>
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<td>General Network Element Constraint Encoding for GMPLS Controlled Networks</td>
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<td>Signaling Extensions for Wavelength Switched Optical Networks</td>
<td>draft-ietf-ccamp-wson-signaling-06.txt</td>
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<td>NICT</td>
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<td>GMPLS OSPF Enhancement for Signal and Network Element Compatibility for Wavelength Switched Optical Networks</td>
<td>draft-ietf-ccamp-wson-signal-compatibility-ospf-12.txt</td>
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<td>A Framework for the Control of Wavelength Switched Optical Networks (WSON) with Impairments</td>
<td>RFC6566</td>
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<td>Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extension for Additional Signal Types in G.709 OTN</td>
<td>draft-ietf-ccamp-additional-signal-type-g709v3-00.txt</td>
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<td>Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Path Diversity using Exclude Route</td>
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<td>Information Model for Wavelength Switched Optical Networks (WSONs) with Impairments Validation</td>
<td>draft-ietf-ccamp-wson-info-00</td>
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<td>PCEP Requirements for WSON Routing and Wavelength Assignment</td>
<td>draft-ietf-pce-wson-routing-wavelength-10.txt</td>
<td>Huawei</td>
<td>NTT KDDI Telefonica</td>
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## Current Status of WSON Deployment

<table>
<thead>
<tr>
<th>Deployed</th>
<th>Evaluating</th>
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</thead>
<tbody>
<tr>
<td>Deutsche Telekom – Germany (Cisco)</td>
<td>Verizon – USA</td>
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<tr>
<td>Trans Telekom – Russia (Cisco)</td>
<td>Cogent – USA</td>
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<td>Indosat - Indonesia</td>
<td>Comcast – USA</td>
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<td>Samsung SDS – Korea</td>
<td>Cox – USA</td>
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<td>Reliance – India</td>
<td>XO – USA</td>
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<td>Maxis - Malaysia</td>
<td>Level 3 – Global</td>
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<td>DTAC - Thailand</td>
<td>Telmex – Mexico</td>
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<td>True - Thailand</td>
<td>Telefonica – Spain</td>
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<td>FET – Taiwan</td>
<td>ComHem – Sweden</td>
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<tr>
<td>FPT – Vietnam (Cisco)</td>
<td>Tele2 – Sweden</td>
</tr>
<tr>
<td>Vietnam Telekom – Vietnam</td>
<td>Telecom South Africa – SA</td>
</tr>
<tr>
<td></td>
<td>MOI KSA – Saudi Arabia</td>
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</table>
nLight Provisioning

Packet Layer requests WSON circuit via GMPLS UNI

- User-Network Interface (UNI) to implement an overlay model (RFC 4208) between two networks – with limited communication between them
- Enables a router to signal paths dynamically through a DWDM network
- Paths may be signaled with diversity requirements
- Building block for multi-layer protection
- Adds agility to network
nLight Control Plane

Packet Layer
- Programmable and Virtualized
- Massive Scale and Density – NCS 6000, ASR 9000, CRS, NCS4000

nLight Control Plane
- GMPLS-UNI extensions – submitted to IETF
- Constraint based routing - latency, SRLG, diversity
- Multi-layer Restoration

Optical Layer
- OTN, DWDM, and Packet Integration – NCS 4000
- Touchless, Programmable ROADM – NCS 2000
Packet Node A – “I need a wavelength to Packet Node B.” (basic provisioning – shortest path)
Packet Node A – “I need a wavelength to Packet Node B, disjoint from circuit blue.”
Packet Node A – “I need a wavelength to Packet Node B, that avoids SRLG’s #1 and #2.”
Control Plane Evolution

SDN
The Network is the Database
Automation + Programmability

nLight Control Plane
Information Sharing between Layers

GMPLS-UNI
Multi-Layer Provisioning and Control

WSON
Embedded Optical Intelligence

The Network is the Database
Automation + Programmability

nLight Control Plane
Information Sharing between Layers

GMPLS-UNI
Multi-Layer Provisioning and Control

WSON
Embedded Optical Intelligence
Control Plane: Multi-Layer or Optical Restoration

Why should I care?

Maintain the same capacity and resiliency while using fewer IP and DWDM interfaces.

This results in lower CapEx.

How is it done?

By allowing higher interface utilization due to the fast and intelligent re-use of stranded network assets during failures.
Restoration for optical failures

- **Premium: 30G**
- **BE: 90G**

**BB1** 3x 100G **BB2**

- 120G on 300G
- Avg IP util: 120/300 = 47%

**BB1** 2x 100G **BB2**

- 120G on 100G. BE loss for short time but..
- 120G on 200G
- Avg IP util: 120/200 = 60%

In a real SP network: 10-34% less interfaces
(less router ports, less transponders, less wavelengths, less power, more scale)
Real World Analysis

• Multi-Layer Capacity Planning for IP-Optical Networks
  • IEEE Comm Mag January 2014 paper authored by Cisco, Deutsche Telekom, and Telefonica

• Multi-layer Restoration - The Impact on the Optical Layer
  • OFC 2014 paper authored by Deutsche Telekom
Note: this not only saves CAPEX for IP router ports, but also transponders, wavelengths, power, chassis, …
Multi-Layer/Optical Restoration - Summary

The combination of nLight ROADM and nLight Control Plane allows the duration of IP link failures to be seconds or minutes, instead of hours or days.

If critical traffic is prioritized, and temporary congestion for best-effort traffic is acceptable, the utilization of IP interfaces can be increased, and therefore their quantity reduced, while maintaining SLA’s.

A 30% to 60% reduction in core interfaces (IP and DWDM) is achievable.
Packet/Optical Integration Summary

**RESILIENCY**
- Pro-Active Protection - FRR
- Optical or Multi Layer Restoration
- Shared Risk Visibility
- 3-Level Protection

**CAPITAL EXPENSE**
- Elimination of Interconnect Optics
- Increase Utilization of Links
- Cross Layer Optimization
- Investment Protection

**OPERATIONAL SIMPLICITY**
- Simplified Turn-up
- Coordinated Maintenance
- Reduced Planning/Forecasting

**PROVISIONING**
- End-End Automation
- SRLG Awareness

**LOWER TCO**
**FASTER TIME TO REVENUE**
A Phased Approach to SDN - Building Trust in the Network

nLight Multi-Layer Control Plane
Multi-Layer Information Sharing and Provisioning
Leverage GMPLS-UNI

Building Trust

Dynamic Online Multi-Layer Control
Dynamic Online Multi-Layer Capabilities
Hybrid Control - best of distributed and centralized

Network Optimization
Powerful offline analysis of real-time data
Cisco Quantum WAN
Orchestration – Cisco MATE
TOMORROW starts here.