LET’S
BUILD
TOMORROW
TODAY
Multi-Layer Network Architectures
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BRKOPT-2118
Agenda

• Intro Multi-Layer Architecture
• Multi-Layer Network Components
  • IP/MPLS
  • OTN
  • Photonic Layer
  • Control Plane
• Converged Multi-Layer Network Architecture
• Summary
Introduction
Market Trends – 2018 Projections

**Growth Trends (Cisco VNI)**
- 4 Billion Internet Users
  - 52% of world Population
- Faster Broadband Speeds
  - 2.6 fold increase in user rates
- More Connected Devices
  - 21 Billion devices
- Video continues to dominate
  - 79% of all internet traffic
- Mobile connectivity
  - 50% of all connections are mobile

**Emerging Trends**
- Focus on **Service Optimization**
  - Rather than layers / elements
- Step-Up **Network Convergence**
  - New Multi-Layer Opportunities
- **Dynamic** Service Activation
  - Anywhere, anytime
- Static to **Dynamic** Transport
  - Flexible data rates and spectrum
- **Dynamic** = Complexity?
  - SW - Simplify, Simplify, Simplify
Architectural Goal

**Present Mode of Operation**

- Customer Request
- Service Fulfilled

**Desired State**

- Services Orchestration Controller
- Layer-Agnostic Resource Pool

- Focus on service - network layering must be **transparent**;
- The network must behave as a **single entity** – a pool of resources;
- Build an **agile, service focused** architecture.
The Multi-layer Network Architecture

- Breaks network silos;
- Potentially multi-vendor;
- Leverage latest industry technology developments:
  - Distributed multi-layer control plane;
  - Multi-layer network planning tools;
  - SDN controller with global network view;
  - Service orchestration platform;
  - Converged network platforms;
  - Dynamic transport layer;
- Each network layer can participate in the multi-layer architecture while still provides traditional services.
Cisco Evolved Programmable Network Architecture
Addressing Today’s and Tomorrow’s Challenges

- ACCELERATE
- OPTIMIZE
- MONETIZE

Always “ON”
Intelligent Convergence
Application Interaction

On-Demand Services Anywhere
Policy

Dynamic Scale
Open and Programmable
Seamless Experience

Application

Unified Access
VM
ESP

Service Orchestrator/App
VM Storage Control

APIs

ACCELERATE
Video
M2M
Cloud
Mobility

OPTIMIZE

MONETIZE

Cisco Evolved Programmable Network Architecture

Cisco live!

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Parallel Innovations Required for the Next-Gen Multi-Layer Network

End-to-End Automation / Orchestration
Cisco WAE + SDN

Silicon
No Trade-Off: Both Performance + Intelligence
High Bandwidth for Video vs. High Transaction Rate for SDN

Systems
Common Technology Foundation for CapEx & OpEx Savings
Converged IP + Optical Unified Access

Software
Applications and Services Move into the Cloud
Virtualization for Scale SDN for Control and Efficiency

Cisco Investments
Custom NPUs & Fabrics
Coherent Optical DSPs
Silicon Photonics (SiP)

NCS, ASR 9000
Integrated DWDM
nV Optical with nLight Restoration

NFV, Controllers, Virtualized Services, Open APIs
Open Multi-Layer Infrastructure Foundation

- **Transport Layer**
  - Open DWDM architecture based on ITU G.698.2 extend to 40Gig and 100Gig
  - Multi Vendor DWDM OEO interoperability
    - Supporting PMO or IPoDWDM with or without Regen

- **Cisco nLight Multi-Layer Control Plane**
  - Based on IETF GMPLS-UNI as defined in RFCs
  - Architecture supports IP+Optical and also OTN
  - Respects Operational Boundaries yet supports intelligent Sharing of information
  - Laying the path for vendor agnostic SDN
  - **Upto 60% interface savings can be achieved!!**
Enabling SDN

- Multi-Layer Applications
  - Multi-layer design
  - Multi-layer optimization
  - Services provisioning and assurance
  - Network slicing
- Layer flexibility – no strict hierarchy
- Multi-layer global view and APIs
- Dynamic ML Control Plane
- Dynamic Packet Layer
- Dynamic Optical Control Plane
- Dynamic DWDM Foundation
A Phased Approach to Multi-Layer Network with SDN

Building Trust

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

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 WAN Automation Engine (WAE)
Technology Trends:
Packet, OTN and Photonic Layers
IP/MPLS
IP/MPLS Considerations

- **IP/MPLS** is a ubiquitous forwarding plane for **L2 and L3 Services**:  
  - VPWS, VPLS, EVPN, L3VPN, RFC3107 Hierarchical LSPs;

- **Reliability, Scalability and Simplicity** greatly improved:
  - TI-LFA FRR;
  - BGP PIC Core/Edge;
  - *Segment Routing*;

- **MPLS** became more “**Transport like**”:
  - MPLS-TP;
  - FlexLSP (bi-directional TE Tunnels)

- **L2 Service Redundancy** greatly improved
  - Hot-Standby PW Redundancy, Multi-Chassis LAG/LACP, L2 TCN – PW MAC Withdrawal Interworking
MPLS-TP (Transport Profile)

<table>
<thead>
<tr>
<th>Service Capability</th>
<th>IP/MPLS</th>
<th>MPLS-TP</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Line, E-LAN, E-Tree, E-Access, L3 VPN</td>
<td>Extensive edge processing</td>
<td>E-Line, E-Access</td>
</tr>
<tr>
<td>Edge Functionality required</td>
<td>Extensive edge processing</td>
<td>Extensive edge processing</td>
</tr>
<tr>
<td>Data Plane</td>
<td>MPLS</td>
<td>MPLS</td>
</tr>
<tr>
<td>Control Plane</td>
<td>IP/MPLS</td>
<td>No control plane - NMS</td>
</tr>
<tr>
<td>LSP config / Mgmt</td>
<td>Signalled (LDP/BGP or MPLS-TE)</td>
<td>Static, node by node</td>
</tr>
<tr>
<td>Protection</td>
<td>Primarily Control Plane driven</td>
<td>OAM driven</td>
</tr>
<tr>
<td>OAM</td>
<td>Basic, but MPLS-TP OAM applicable</td>
<td>Extensive</td>
</tr>
<tr>
<td>LSP</td>
<td>Unidirectional</td>
<td>Co-routed Bi-directional LSPs</td>
</tr>
</tbody>
</table>

Network Management System (FCAPsS)
Flex-LSP: Co-routed Associated Bidirectional LSP

- R1 acting as master and request red tunnel towards R2;
- Upon completion R2 request blue tunnel in the exact reverse path;
- OAM - Extensive using GAL/GACH – Probe and event;
- Completely compatible to with native MPLS services;
<table>
<thead>
<tr>
<th>Capability</th>
<th>MPLS-TP</th>
<th>Flex-LSP</th>
<th>LDP/BGP</th>
<th>MPLS-TE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocol Support</td>
<td>VPWS</td>
<td>VPWS</td>
<td>VPWS / VPLS / L3</td>
<td>VPWS / VPLS / L3</td>
</tr>
<tr>
<td>Data Plane</td>
<td>MPLS</td>
<td>MPLS</td>
<td>MPLS</td>
<td>MPLS</td>
</tr>
<tr>
<td>L2 Construct</td>
<td>Pseudo-wires</td>
<td>Pseudo-wires</td>
<td>Pseudo-wires</td>
<td>Pseudo-wires</td>
</tr>
<tr>
<td>Control Plane</td>
<td>None: NMS / G-MPLS</td>
<td>RSVP-TE</td>
<td>IP/MPLS (LDP)</td>
<td>IP/MPLS – RSVP-TE</td>
</tr>
<tr>
<td>LSP config / Mgmt</td>
<td>Static / G-MPLS</td>
<td>Signalled – RSVP-TE</td>
<td>Signalled – LDP/BGP</td>
<td>Signalled – RSVP-TE</td>
</tr>
<tr>
<td>Bidirectional LSP</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Co-routed</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes – ERO based</td>
</tr>
<tr>
<td>Midpoint associated</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Predictable Path</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes – ERO based</td>
</tr>
<tr>
<td>Diverse routed LSPs</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>LSP merge</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>PHP</td>
<td>No</td>
<td>No</td>
<td>Optional</td>
<td>Optional</td>
</tr>
<tr>
<td>Guaranteed QoS</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>LSP protection</td>
<td>OAM driven protection</td>
<td>1. OAM driven</td>
<td>CP – IP LFA</td>
<td>CP - MPLS-FRR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. MPLS-FRR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudo-wire OAM</td>
<td>Yes (ACH based)</td>
<td>Yes (ACH based)</td>
<td>Yes (ACH based)</td>
<td>Yes (ACH based)</td>
</tr>
<tr>
<td>LSP OAM</td>
<td>Extensive using GAL/GACH – Probe and event</td>
<td>Extensive using GAL/GACH – Probe and event</td>
<td>Basic probe based</td>
<td>Probe based</td>
</tr>
</tbody>
</table>
Simplification – Evolve Unified MPLS

Today

Unified MPLS
Data plane: MPLS
Domain CP: IGPv4 + LDP
Inter-domain CP: BGPv4 with labels
VPN: MP-BGP and tLDP signaling
VPN data plane: Label in MPLS

Evolve Unified MPLS

Future

Unified MPLS with SR
Data plane: MPLS
Domain CP: IGPv4/v6 + SR
Inter-domain CP: Controller based
VPN: Static, MP-BGP and tLDP signaling
VPN data plane: Label in MPLS

- Close existing gaps in Unified MPLS (multicast, timing etc)
- Protocol simplification – SR and SDN concepts
- Configuration simplification – autonomic networks ./ zero touch provisioning
- Service configuration and linkage – SDN driven service activation / SDN driven n/w adjustment
Segment Routing in MPLS

- **Source Routing:**
  - the source chooses a path and encodes it as a stack of labels;
  - Each label acts as a “segment” along the source-routed journey;
  - the rest of the network executes the labels one by one; without any further per-flow state;

- **Segment/label:**
  - an identifier for any type of instruction;
  - forwarding or service.
Simplicity

• Simple **ISIS/OSPF extensions** to program MPLS dataplane:
  • MPLS hardware is leveraged. SW upgrade only;
  • Complex MPLS Classic Control Plane is removed (LDP, RSVP-TE);
• **Seamless interworking** with the MPLS Classic CP;
• **Automated 50msec FRR** in any topology and end-to-end;
• **Centralized BW Optimization** to maximize ROI on infrastructure asset:
  • 100 to 1000 times tunnel reduction;
• **Obvious business requirements** finally delivered at scale:
  • Latency vs cost, disjointness, resource avoidance;
• **Drastic reduction of control-plane and hardware state.**
Simplicity

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  - Latency vs cost, disjointness, resource avoidance;
- Drastic reduction of control-plane and hardware state.

  - Clear reduction of CAPEX and OPEX;
  - Better SLA;
  - Finally offer services that differentiate infrastructure:
    - Latency, disjointness, avoidance.
Application interaction with the network

• SR allows applications to get what they need from the network:
  • End-to-end: DC, WAN, Metro, Peering
  • Scale: millions of flows
  • Simple: fewer protocols than you operate today!
  • Cost-efficient: fewer states than you operate today!

• Service richness and velocity
• Unleash application-network innovation
IGP Prefix Segment

- Shortest-path to the IGP prefix
- Global
- 16000 + Index
- Signaled by ISIS/OSPF
IGP Adjacency Segment

- Forward on the IGP adjacency
- Local
- 1XY
  - X is the “from”
  - Y is the “to”
- Signaled by ISIS/OSPF

DC (or AGG)  
WAN  
PEER
Segment Routing Interaction with Controllers

- Example:
  - Controller collects topology information via BGP-LS:
    - IGP segments
    - Topology
An end-to-end path as a list of segments

- WAE computes that the green path can be encoded as:
  - 16001
  - 16002
  - 124
  - 147

- WAE programs a single per-flow state to create an application-engineered end-to-end policy

Low Latency to 7 for application …

DC (or AGG) to PEER:

Low Lat, Low BW

Default ISIS cost metric: 10
Applications express requirements – bandwidth, latency, SLAs

SDN controllers are capable of collecting data from the network – topology, link states, link utilization, …

Applications are mapped to a path defined by a list of segments

The network only maintains segments. No application state.

Application Engineered Routing
An end-to-end path as a list of segments
IP/MPLS Importance in the Multi-Layer Architecture

• Provides the converged data plane for any type of services:
  • MEF compliant L2 VPN: E-LINE, E-LAN, E-TREE, E-Access;
  • L3 VPNs;
  • Multicast;
  • Circuit emulation for legacy TDM services;

• Transport like data plane using FlexLSP in lieu of MPLS-TP;

• Traffic engineering and protection;
  • LFA / MPLS-TE FRR

• Segment routing:
  • Simplifies MPLS layer, enabler for SDN and Application Engineered Routing.

• Common signaling protocol with the OTN and DWDM layer - GMPLS
Optical Transport Network
OTN
Optical Transport Network (OTN)

- Standards:
  - G.709 → Hierarchy and frame structures;
  - G.872 → Architecture;
  - G.798 → Management functions, etc;

- Defines G.709 as a **framing** technology and hierarchy that is very similar to SONET/SDH;
  - G.709 started as a wrapper around WDM client signals to improve reach and manageability;
  - Evolved to a complex **multiplexing hierarchy** that enables a service layer

- Forward error correction (FEC) to improve error performance and enable longer optical spans.

### G.709 Hierarchy

<table>
<thead>
<tr>
<th>Frame</th>
<th>Payload (OPU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODU0</td>
<td>1,238,954 kbit/s</td>
</tr>
<tr>
<td>OTU1</td>
<td>2,488,320 kbit/s</td>
</tr>
<tr>
<td>OTU2</td>
<td>9,995,276 kbit/s</td>
</tr>
<tr>
<td>OTU3</td>
<td>40,150,519 kbit/s</td>
</tr>
<tr>
<td>OTU4</td>
<td>104,355,975 kbit/s</td>
</tr>
</tbody>
</table>
Optical Transport Network (OTN) Model

Optical Channel (OCh)

Optical Multiplex Section (OMSn)*

Optical Transmission Section (OTS)*

MUX/DEMUX

Optical Channels

Optical Amplifiers

MUX/DEMUX

Optical Transmission Section (OTS)*

OTS

OTS

OTS

OMS

OCh

OTN Options

- **Optical OTN:**
  - DWDM Transport
  - All Optical Network
  - Lambda or Sub-lambda services
  - Cross-connect or switching at the Lambda/Wavelength Level

- **Electrical OTN:**
  - SONET/SDH Evolution
  - Switching of ODU-k containers
  - Circuit services
  - Can use Optical OTN as transport

*Under Definition.
G.709 Frame

Client Signal
- OPUk - Optical Channel Payload Unit
- ODUk - Optical Channel Data Unit
- OTUk - Optical Channel Transport Unit
- Alignment

OTUk FEC
ODUk
OPUk OH
Alignm
OTUK OH
OTN Overhead

- OTN Overhead information allows for network monitoring and management, between Network Elements (NEs) and end-to-end.
Forward Error Correction (FEC) Compensates for Optical Impairments

- FEC extends reach and design flexibility, at “silicon cost”
- G.709 standard improves OSNR tolerance by 6.2 dB (at 10–15 BER)
- Offers intrinsic performance monitoring (error statistics)
- Higher gains (8.4 dB) possible by enhanced FEC (with same G.709 overhead)

FEC/EFEC Extends Reach and Offers $10^{-15}$ BER
Basic G.709 Multiplexing Hierarchy

*ODUFlex – Any size ODU Container (nx ODU0s).
ITU-T G.709 Mapping

**Client Payload**

- GFP-T
- GFP-F
- G.Sup43
- SONET/SDH
- ATM

**OH**

- ESCON/FC
- Ether

**OTUk**

- OPUk
- ODUk
- OTUk

**0** = 1.25G (ODU Only)

**1** = 2.5G

**2** = 10G

**3** = 40G

**4** = 100G

K Indicates the Order:
OTN Framing Enables New Applications

Transponder in Router

**Reactive Protection**
- Working route
- Failover
- Protect route
- LOF
- FEC Limit
- Time

**Proactive Protection**
- Working route
- Protect route
- Switch
- Protection Trigger
- Time

Traditional

FEC

Pre-FEC Bit Errors

Router Bit Errors

ROADM

IP-over-DWDM

ROADM

FEC

Pre-FEC Bit Errors

Router Bit Errors

Cisco Live!
Importance of OTN in context of the Multi-Layer Architecture.

- Bandwidth granularity:
  - Sub-lambda multiplexing;
  - Eliminates the operation pain of point-to-point muxponder;
  - Allows for upper layers to have less than lambda interface;
  - Increases lambda efficiency by grooming sub-lambda services;

- Service restoration over meshed networks (1+R or 1+1+R);

- Efficient support for legacy TDM traffic;

- Rich OAM capability;

- Near lossless convergence for IP with IP+Optical, pro-active protection;
Photonic Layer and Control Plane
Foundation EPN - Next Gen ROADM

Problem 1
Unrelenting Bandwidth Growth

Solution
More network capacity
- More Channels
  Extend the 50GHz C-Band
- Flex Spectrum
  Spectrum Optimization Future Proof

Problem 2
Dynamic traffic Tighter SLAs Inefficient Utilization

Solution
Highly meshed, programmable networks
- More Degrees
  More highly meshed networks
- Touchless Operation
  Colorless Omni-directional Programmability
Technology Enablers for ML networks – Cisco nLight

Programmability, Convergence, and Scale

**nLight Silicon:**
- 100G+ Coherent.
- Adaptive Rate.
- High Performance.

**nLight Control Plane:**
- Information Sharing.
- The Network is the Database.
- Automation to Optimization.

**nLight ROADM:**
- Complete Flexibility.
- No Manual Intervention.
- Massive Scale.
IP+Optical Integration – Touchless, Agile Optical Layer

Complete Control in Software, No Physical Intervention Required

Foundation for Multi-Layer Network Programmability

- Omni-Directional – ROADM ports are not direction specific (re-route does not require fiber move).
- Colorless – ROADM ports are not frequency specific (re-tuned laser does not require fiber move).
- Tunable Transponder – Color and modulation. Ability to derive max b/w based on distance and fiber quality.
- 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
nLight ROADM
Flex Spectrum

- Graceful growth to terabit and greater superchannels;
- Lighting the way to flexible, dynamic packet to wavelength mapping;
- Optimize bandwidth vs. distance.
FlexSpectrum DWDM Architecture

FlexSpectrum DWDM system

Today’s 50GHz Grid System

- DSP-enabled Transmitters
- FlexSpectrum ROADM
- Signal Shaping
- Denser Channel Spacing

Ch1, Ch2, Ch3, Ch4

50GHz spacing

Cisco Live!

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End to End Flexibility

Flexible, efficient and dynamic mapping of packet services to optical transport

NPU

Flex Ethernet
Flexible nx5G/25G interconnects

Transponder

Flex Mod
50G/100G/200G DWDM interfaces

Superchannels

2x50G
2x200G

DWDM

Flex Spectrum
Flexible nx12.5Ghz channels
Flex Mod

Transponders supports Nyquist shaping and software configurable modulation

- 28 Gbaud/s Nyquist shaped
- 50G PM-BPSK
- 100G PM-QPSK
- 200G PM-16QAM

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Flex Ethernet

Flex Ethernet was designed to provide the following:

- Ability to adapt the data rate of the line interface to the available performance of the DWDM layer;
- Allow for channel rate definitions outside the stringent hierarchies defined today in the ITU and IEEE without the need of LAG. Data Rate must be within capabilities of NPU;
- Allow for hitless reconfiguration of Service channels.
Optical Control Plane Evolution

nLight

Information Sharing
The Network is the Database
Automation to Optimization
Improved Network Economics

GMPLS-UNI
Multi-Layer Provisioning

WSON
Embedded Optical Intelligence
Wavelength Switched Optical Network

- **WSON** It is a **GMPLS control plane** which is “DWDM aware”:
  - LSPs are wavelengths;
  - Control plane is aware of **optical impairments**;
  - Enables:
    - Wavelength setup on the fly;
    - Wavelength re-routing (restoration – 1+R or 1+1+R);
    - Wavelength revalidation against a failure reparation;

- **Lowers CAPEX** and **OPEX** of the end-to-end solutions even further;
What if we Integrate IP Control Plane with WSON?

- Optical circuit turn up time can be reduced:
  - On Demand Bandwidth Provisioning via signaling

- Circuit request can be constrained to avoid risk sharing:
  - SRLGs information shared via signaling;

- Alarms from both layers can be correlated:
  - Easier troubleshooting;

- Automated signaling can be used for maintenance coordination;

- End-to-end network can be optimized:
  - With centralized, Multi-layer Control Plane;
GMPLS UNI

BRKOPT-3010 session provides in depth information about GMPLS.

Control Plane
Data Plane
Dynamic Optical Restoration

Touchless Optical Layer + Embedded WSON Intelligence

Fiber Cut!
Embedded WSON intelligence locates and verifies a new path (using different wavelength)
Edge Nodes instruct client to re-tune its wavelength
Colorless, Omni-Directional ROADM switches the path
Service is brought back up with the same Client and Optical interfaces, zero touches
[Router A] – “I need a wavelength to Router B, disjoint from the Blue wave
[Router A] – “Fiber cut! I will re-signal with the same constraint.”
[Router A] – “Another fiber cut! I will re-signal with the same constraint.”
[NCS 2000] – “I don’t have a path that meets your constraints.”
[Router A] – “OK. I’ll relax the diversity constraint and signal again.”
nLight Control Plane enabled features

1. Ability to set up an L0 path from L3;

2. Share L3 path constraints with L0;

3. Report properties of L0 path to L3;

4. Change L0 path for L3 links, due to local failures or re-optimization opportunities;

5. Change the L3 topology, due to large failures or re-optimization opportunities.
The Foundation of the Dynamic Optical Layer

Provide L1 visibility to L3 – L3 can react to changes in L1

Shared Risk Link Groups – End to End circuit provisioning with knowledge of any Optical infrastructure risks.

ML Auto BW – Leverage CP to allow upper layers to request circuit source and destination with constraints

Coordinated Maintenance – Provide proactive notification of maintenance activity to connected NEs to proactively route around maintenance node

ML Restoration Step 1 – Leverage proactive protection to protect circuit then leverage CP to restore BW to network utilizing same interface.

ML Restoration Step 0 – Bend but do not Break! Protect traffic before failure allowing near zero packet loss

UNI-C Diversity / SRLG / Latency etc…
The Foundation of the Dynamic Optical Layer

Key Values
- Truly intelligent Service Routing with Full Transport Awareness;
- Strengthen Operational Practices;
- Advanced Protection providing ZPL;
- Restore lost BW to the network with no additional CAP nor OP Ex;

End to end Cisco provides the following value:
- Increase Service Velocity;
- Enhance Availability;
- Improve Planning and Forecasting;
- Lower TCO.
nLight Control Plane

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

Optical Layer
GMPLS-UNI extensions – submitted to IETF
Constraint based routing - latency, SRLG, diversity
Multi-layer Restoration

OTN, DWDM, and Packet Integration – NCS 4000
nLight Touchless, Programmable ROADM – NCS 2000
Features enabled by Control Plane

• The Network as the database:
  • SRLG Cost
  • Latency Path
  • Circuit ID Disjoint / Matching
  • Performance Protection

• Enhanced Multi-layer features:
  • Constraint Based Circuit Requests;
  • Multi-Layer Restoration – Optical and Port;
  • Multi Layer Optimization;
  • Coordinated Maintenance;

• Reduced CapEx and OpEx:
  • Up to 60% few interfaces;
  • Less Power;
  • Less Real estate;
MultiLayer Architecture
Defining Convergence

Packet L2/L3

OTN Switching

Grey Packet

ITU OTN

Grey OTN

ITU Packet

Protected UNI/NNI

Unprotected UNI/NNI

ODU XC

NPU Fwd

Interface ethernet

OTN-Packet Controller

odu-group

odu
Complete Multi-Layer L1+L2+L3 Architecture

Network Optimization & Modelling
- MATE Design
- MATE Live
- 3rd Party Applications

EMS/NMS & Service Provisioning
- Provisioning
- Optical
- Performance

Cisco Prime Central

Future: Netconf / YANG

Cisco live!

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Bringing the Layers together

Control Plane leverages signaling to automate what is done manually today.

PMO
- Independent IP/MPLS CP;
- Independent Optical CP – WSON;
- Wall separating layers;
- No real information sharing;

nLight Multi Layer CP
- Open the Wall;
- Leverage Layered CP
- Insert ML Signaling via UNI
- Share Relevant Layered Info

SDN
- Removes the Wall;
- Centralize CP;
- Leverage Layered CP;
- Application Driven;
- Global View – Optimization;
Use Case 1 – Global Network Planning, Design and Optimization

- ML network design (Multi Domain);
- ML network collection online:
  - Topology;
  - Circuits;
  - Resources;
- Offline Network Analysis:
  - Impact Analysis;
  - What if Scenarios;
  - ML Restoration feasibility;
  - ML Optimization;
  - Coordinated Maintenance Feasibility;
- Online Network Config or user config;
- Vendor Agnostic leveraging Industry Proven tools and algorithms.

Reduce Op / Cap EX, improve Availability
Optical Restoration – A Spectrum of Options

- **WSON Restoration Only**
- **WSON Restoration with UNI**
- **Distributed ML Restoration**
- **Centralized ML Restoration**
Use Case 2 – Service Turn Up

**nLight CP**

- Supports Multi Layer Service Turn Up
- Leverage Constraint based routing across all layers
- Single Domain Single Vendor

**SDN**

- Support Multi Layer Constraint based Service Turn Up
- Global impact assessment across all layers
- Multi Domain / Multi Vendor

Reduce Op EX, improve Availability, Increase Service Velocity
Use Case 3: ML Restoration

Reduce Op / Cap EX – increase utilization

nLight CP

- Optimized for Local / DWDM faults
- Fastest for Protection and Restoration
- Highest availability – no connectivity concerns
- Optical Restore is best effort unless designed for any to any

SDN

- Optimized Disaster Recovery / Topology Changes
- High Availability - will leverage Distributed
- Higher Restore SLA based on Global view
Use Case 4: ML Re-Optimization

Reduce Op / Cap EX, improve Availability, increase network longevity

- ML network optimizations:
  - Optimal routes after restore trigger cleared;
  - Stranded BW;
  - Congestive Spans;
  - Express routes;
  - “Hardwired” Interfaces;
- Topology or non-topology changing;
- User selectable time frames or event driven;
Re-optimization

Use Cases

- **Manual reoptimization** – triggered by L3 operator
- **Manual reoptimization test** – allowing the operator to check how the network could be reoptimized without actually changing anything
- **Periodic reoptimization** – every X hours/day or at certain times of the day/month
- **After recovery** from a physical failure that was restored via multi-layer restoration
- **Reopt requested by the optical layer** (via a path-error signaling message).

*Future Possibility*
Use Case 5: Co-ordinated Maintenance

Reduce Op EX, improve Availability, improve SLAs

- Select maintenance node;
- Verify level of service impact by maintenance event;
- Route traffic around affected node:
  - Wavelength and Packet;
- Notify time to start event;
- Restore traffic once maintenance complete.
Why a Multi-Layer Architecture?

**Multi-Layer Network Optimization**
Global network view | Optimization across layers
15% interface savings

**Multi-Layer Service Activation**
Months to Minutes | Simple, focused applications
Constraint-based routing

**Multi-Layer Restoration**
>40% Interface Savings | Zero Touches
Re-use stranded network assets

**Coordinated Maintenance**
Multi-layer service awareness | Months to Minutes
Hitless multi-layer re-route
Why a Multi-Layer Architecture?

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- 15% interface savings

Multi-Layer Service Activation
Months to Minutes | Simple, focused applications

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- Coordinated Maintenance
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Multi-Layer Restoration
>40% Interface Savings | Zero Touches
- Re-use stranded network assets

Up to 60% interface savings as capacity increases

~60% interface savings

- Baseline
- MLBO
- MLBO+MLR-O
- MLBO+MLR-O+MLR-P

IEEE Communication Magazine Jan-Feb 2014
Multilayer Optimization vs Single-layer Optimization

Reference: IEEE OFC 2015 M. Khaddam (Thursday 8 am, invited)

Fig. 1: Network Capacity Evolution

- Packet only MPLS-based Protection (no PCE)
- Multi-Layer (50% packet, and SFP optical) Hybrid Protection (PCE-based)
- Optical only Protection (Dedicated 1+1)

Applications (Multi-layer, SPRING, etc)

EMS

SDN Controller
Summary
Enabling the Evolved Programmable Multi-Layer Network

- **Dynamic Packet Layer:**
  - Proven, Scalable, and Robust IP/MPLS control plane

- **Dynamic Multi-Layer Control Plane:**
  - Information sharing - the network is the database
  - Constraint-based multi-layer provisioning

- **Dynamic Optical Foundation:**
  - Massively Scalable OTN
  - Touchless, Fully Programmable ROADM
  - Mature, feature rich, widely deployed optical control plane WSON → SSON
A Phased Approach to SDN

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

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

Building Trust

Network Optimization
Powerful offline analysis of real-time data
Cisco WAN Automation Engine (WAE)

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Months to Minutes – How do we get there?

Provisioning Process

IP
- Manual data collection, analysis and circuit request

Transport
- Offline transport analysis and manual provisioning

Layer Optimization
- WAN Automation Engine
  - MATE Design. MATE Live.

- WSON → SSON

Multi-Layer Optimization
- nLight Multi-Layer Control Plane

Dynamic Online Multi-Layer Optimization
- What’s Next?

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