Designing Convergent New Age Networks for Greenfield IXCs

Session 3006
The Core Network Challenge

- Abundant ‘raw’ bandwidth with DWDM
  
  DWDM ‘dumb’ fiber-multiplier
  
  Capable of supporting exponential demand

- Difficult to harness for services due to:
  
  Cumbersome core network architecture
  
  Ineffective core networking equipment

Optical Core

Bandwidth Scarcity, Despite Bandwidth Abundance
Massive Growth in Core Wavelengths

In-service, Non-blocking Nodal Scalability to Manage Thousands of Wavelengths REQUIRED

Core Network Architecture Today

- IP data over ATM traffic-engineered network; over SONET TDM transport; over point-to-point DWDM
- Slow-to-scale, functional overlap, outdated functions
Cisco ONS 15900 Series Wavelength Router

- Background: Cisco has pioneered a new optical system category
- Purpose: To provide intelligent wavelength connectivity at DWDM junctions
  - Intelligent: Automated provisioning and mesh restoration at SONET speeds
  - Wavelength: OC-48 and higher speeds
- Opportunity Test: Deployment of DWDM

Wavelength Router Solution

- Streamline layers, remove functional overlap
- Deliver optical transport and traffic-engineering at wavelength level complementing IP, MPLS
- New functions: Rapid end-to-end provisioning, fast path restoration, bandwidth efficiencies
Wavelength Router provides non-blocking any-to-any connectivity

Wavelength Router Value Proposition

- Fiber Junction Management
  Operations Support = 80% Lifetime Equipment Costs

- Service Velocity
  Competitive Differentiator with rapid provisioning of wavelengths

- Service Reliability
  100% Availability SLAs

- Reduction in Networking Costs
  Capital—bandwidth inefficiencies of ring architectures
  Expense—cost of operating a centralized or manual network
Rapid End-to-End Provisioning

IP Routers Requiring Connectivity

Virtual Wavelength Path Selected

Source and Destination Wavelength Routers

STS-1 and Wavelength Provisioning

- Four OC-48s LA to Chicago
- Example: Six interconnection points
  @ STS-1 granularity = 1152 cross-connects
  @ Wavelength granularity = 24 cross-connects
- Faster provisioning with less cost, and rework
**New World Operations**

- Three-fold reduction in number of managed objects

**Infrastructure Class Reliability**

- No single failures cause traffic outage
  - 50 ms restoration
  - System failures
  - Human defensiveness

- Switching in two separate bays to maintain physical isolation and redundancy.
- Network cabling includes fiber management up to a full meter
- Can replace cards without touching the fiber on the card, or any other cards
- Fully optical interconnect of I/O, and control plane
- No data paths buried in backplanes
- Graceful, in-service upgrades
- Support all fiber connector types without having to order specific card types.
- Fully redundant and physically diverse power feeds to each bay
- No midplane designs, or removal of one card causing removal of other units
- 12” depth
- Supports integrated and isolated electrical environments
Calculated System Availability

<table>
<thead>
<tr>
<th>Annual Downtime (Minutes)</th>
<th>Seven 9's</th>
<th>Five 9's</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 circuit</td>
<td>0.052596</td>
<td>5.2596</td>
</tr>
<tr>
<td>100 circuits</td>
<td>5.2596</td>
<td>525.96</td>
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Cisco 15900 “Seven 9’s” Dramatically Reduces Downtime

Wavelength Router Business Case
Network Simulation and Analysis

BLSR Example—US Service Provider Network

Created realistic national optical ring connectivity

Network Simulation and Analysis

WaRP Example—US Service Provider Network

Used same national optical connectivity as ring model
Comparison Data

- Total BLSR Network Wavelength\(\cdot\)km
  Working = 1,276,800  Protect = 1,276,800
  \textit{Total} = 2,553,600

- Total WaRP Network Wavelength\(\cdot\)km
  Working = 615,800  Protect = 832,800
  \textit{Total} = 1,448,600

Mesh Bandwidth Analysis

- 43% savings in wavelength \(\cdot\) km
- Key factors: Connectivity, restoration time and demand paths
Economic Definition of a Span

Basic 16 wavelength 660km Span Calculations:

4 WDM multiplexers ($75k) $300k
12 amplifiers ($45k) $540k
32 10 Gb/s transponder ($115k) $3680k

Total $4520k

Applied distance formula to derive costs

Core Transport Comparison

<table>
<thead>
<tr>
<th></th>
<th>WaRP Network</th>
<th>BLSR Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restoration Time</td>
<td>&lt;50 ms</td>
<td>&lt;50 ms per Ring</td>
</tr>
<tr>
<td>BW Efficiency</td>
<td>43.3% Less</td>
<td>43.3% More</td>
</tr>
<tr>
<td>Provisioning Time</td>
<td>Minutes</td>
<td>Weeks/Months?</td>
</tr>
<tr>
<td>Rapid Scalability</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Differentiated CoS</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Source/Destination Provisioning</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>WDM Costs</td>
<td>$624 Million</td>
<td>$1094 Million</td>
</tr>
</tbody>
</table>
Prove-in Summary

- WDM Prove-in 12,16 Demand Case
  - Network Cost with WR—$624 Million
  - Network Cost with Rings—$1094 Million

WDM Equipment Savings—$470 Million

15900 Wavelength Router versus 32 OC-192 Systems

15900 Wavelength Router
- 256 OC48 Port Matrix
- 128 OC48 User Ports, 32 OC192 Network Ports
- 7 Bay System which includes:
  - 1 Admin Bay, 2 Matrix Bays, and 4 Line Bays

OC-192 ADM Systems
- 32 OC-192 ADM Systems
- 128 OC-48 Tributary Ports
- 32 Bays housing the 32 OC-192 systems with 4 OC-48 tributaries in each system
**Connectivity Model—Operations $**

**Network**
- Intermediate Nodes (Interconnect): 5
- Pass Through Nodes per "Link": 5
- Cut Over Service: 0.2
- Maintenance Circuits: 5%

**SONET ADM Rings/Linear**
- Cable New Service (End Node): 4 hr
- Cable Intermediate Node: 5 hr
- Provision Service (End Node): 0.2 hr
- Provision Service (Through Node): 0.2 hr
- Provision Traffic (Intermediate Node): 0.4 hr
- Test Circuit (Single Ring/Link): 4 hr
- Additional End/End Test (Int. Node): 2 hr
- Connect Service (Intermediate Node): 1 hr

**Wavelength Router**
- Cable New Service (End Node): 4 hr
- Provision Wavelength Router Ckt: 0.2 hr
- Test Wavelength Router Ckt: 1 hr

**Operations Cost per Year**
- $10,000,000
- $20,000,000
- $30,000,000
- $40,000,000
- $50,000,000
- $60,000,000

Over $50M per year in operational cost savings

**Wavelength Router Application Summary**

- Individually; as an automated patch panel
- Network level; automated provisioning of end to end wavelength level services
- Network level; automatic restoration of wavelength class of service traffic
- Dynamic restoration process with 50 ms switching
- Extreme reliability for network operations
Wavelength Router Architecture

- Fully redundant signal path end-to-end
- Preserves switch capacity for facility protection schemes
- 256 x 256 non-blocking architecture
- Scales in service to 4096 ports
Infrastructure Class Reliability

- No single failures cause traffic outage
  - Extreme redundancy: *All* active components
  - Extreme diversity: Switching, cabling, power, ...
  - Extreme isolation: No electrical data-path backplane
- Calculated system availability (cross-section):
  - <0.01 minutes per year (99.9999981%) 
- Calculated availability of any single facility:
  - <0.1 minutes per year (99.999981%)

Wavelength Router Lineup

Admin Bay
Matrix Bay
Matrix Bay
Line Bay
Line Configuration

- 128 line cards per bay
  - 128 revenue ports, plus
  - 256 matrix connectivity ports
- Protection and restoration options
  - 1+1 linear protection
    - APS based, 50 msec
  - WaRP restoration
    - Fast Reserved (virtual 1+1 path restoration)
    - Fast dynamic (mesh restoration—50 ms)
  - Trail protection
    - 0:1 Unprotected
- 7” x 23” x 12”

Wavelength Router Line Shelf

- Fully hot-swappable cards \textit{without} fiber swap
- Redundant Shelf Processors (1+1)
- Line cards
  - OC-48 (SR)
  - OC-48 (LR)
  - OC-192 (SR)
  - OC-192 (LR)
Line Subsystem-Based 1+1 Protection Switching

- Preserves up to 50% of system capacity
- Up to 50% reduction in inter-bay cabling

OC-48 Line Card
Switch Matrix Configuration

- Capacity: 256 OC-48s
- Scales in-service
  - Size
    - 1024 x 1024
    - 4096 x 4096
  - Technology
    - Upgradeable to fully optical core
- 7’ x 23” x 12”
- Matrix 1+1 redundant

Wavelength Router Matrix Shelf

- Fully hot-swappable 16x16 switch modules without fiber swap
- Redundant shelf processors (1+1)
- Retain shelf, bay, cabling, for in-service switch matrix upgrades
Matrix Card

System Cable Management

- Color coded clad cables
  - Red = Signal Copy A
  - Blue = Signal Copy B
  - Yellow = timing and control
Ultra-Short-Reach-Optics

- Cost-effective 1310nm Single-Mode @ 2.5 Gbps
  - Optimum: 1:1 cabling-to-switching granularity match
- Used to interconnect line and switch subsystems
- Potential for external use
- 500 meter reach yields 1 km system diameter

1 km System Diameter

Administration Center

- Administration shelf
  - Control and timing
  - External timing interface
- Craft terminal
  - Terminal and keyboard
- System communications bus
  - Fully redundant hardware and system bus
Administration Shelf

- Redundant processors
  360 MHz, 512 MB
  Dedicated
  - NE Control
  - WaRP
  - Future
- Redundant hard disk
  9 Gbyte for boot disk and data storage
  CD ROM backup
- Redundant System Timing
- External Communications via LAN

Wavelength Router Lineup
Wavelength Router Growth and Scalability

Critical for Transport System

In-Service, Non-Blocking Matrix Growth

Enabling system characteristics:

- Redundant diverse non-blocking matrices
- Tri-port optical line card design (Service+M_A+M_B)

Switch traffic to one side of matrix
Upgrade Off-line matrix
Switch traffic to expanded matrix
No re-cabling of any in-service port
In-Service Growth and Expansion

- In-service growth procedures
  - Add interface cards, shelves and bays as required
  - Add matrix cards and cables up to full capacity
  - Provision new equipment via software

- In-service matrix capacity expansion
  - Switch traffic to redundant copy of matrix
  - Shuffle matrix modules
  - Add cabling
  - Repeat procedure to other copy of the matrix

Line to Matrix Bay Cables: Matrix Shelf Backplane

Matrix Shelf designed for 4096 port system
Intra-Matrix Cables

- Intra-Matrix Cables follow same principal
- Diagram is 1st Stage to Center Stage Matrix

256 Port System

- Two redundant matrix bays
- Two line bays
256 Port System
1+1 Configuration

Matrix Expansion

Switching density increases 2x, racks increase 2x
WaRP Overview

WaRP is a protocol that enables the provisioning, routing, protection, and restoration of virtual wavelength paths (VWP) through an optical network based on intelligent communication between Cisco 15900 Series Wavelength Routers.

**Delivers:**

- 50 ms restoration timeframes in a mesh network topology
- Improved fiber utilization via 30% spare capacity reduction
- Rapid end-to-end provisioning on the order of seconds
- MPLS like capabilities at Layer 1—the optical layer
Rapid End-End Provisioning

- View network as fluid bandwidth pool
- “Point and Click” provisioning of end-to-end Virtual Wavelength Paths (VWP) in seconds
- Scale up by adding VWPs, adding to VWP’s

Optical Core with Wavelength Routers

Bandwidth Efficiency

- Mesh optical core saves 30–60% of restoration bandwidth vs. ring’s 100% spare capacity
- Increases available service capacity, revenues
Rapid Mesh Restoration

- Restore virtual wavelength paths end-to-end in 50 ms
- No preplans, no dedicated restoration bandwidth
- Routes calculated in real-time, at outage time

WaRP Restoration

Includes four methods of protection:
- Fast Reserved (Virtual 1+1 Path Restoration)
- Fast Dynamic (mesh restoration—50 ms)
- Trail Protection
- 0:1 Unprotected
Fast Reserved (Virtual 1+1 Wavelength Path Restoration)

- Wavelength path protection across many network elements
- Data is transmitted on both paths
- Switching is done at the end points

Fast Dynamic Restoration

- Restore wavelength paths end-to-end in 50 ms
- No preplans, dedicated restoration bandwidth
- Routes calculated in real-time, at outage time
 WaRP Trail Protection

- Before Beginning Mesh Restoration, Attempts Trail Switch
- Checks for available bandwidth on link
- Equivalent to span switch

0:1 Unprotected

- Allows fast provisioning of unprotected VWPs
- In the event of an outage affected 0:1 VWPs remain down until failure is repaired
- After repair, WaRP verifies path with Path Integrity Check (K1/K2)
WaRP Summary

- WaRP is the product differentiator for Cisco’s optical control plane
- WaRP enables the dynamic provisioning, routing, protection, and restoration of virtual wavelength paths (VWP) through an optical network
- WaRP will grow and adapt to meet market demands and emerging standards

Network Management and Planning
Wavelength Router Manager (WRM)

- Comprehensive GUI-based Element Management System (EMS) and craft terminal
- Provisioning of Wavelength Routers and virtual wavelength paths
- Hierarchical configuration management
- Performance monitoring
- Fault management

Cisco Optical Network Planner

- Sophisticated GUI-based network modeling and simulation tool
- Create an initial topology
- Modify an existing topology
- Optimize topologies
- Understand network behavior
  - Restoral strategies
  - Growth strategies
  - Optimization strategies
Wavelength Routing Is the Future of Core Optical Networking

- Advent of distributed, not centralized intelligence
- Winning business strategies in the carrier market are dependent on service velocity
- Profitability is driven by the operational costs
- Wavelength-routed architectures:
  Scale in capacity to meet the unprecedented rate of growth
  Create networks that are rapidly provisionable and restorable
  Provide fundamental data network architectures that are simple, low cost and easy to manage
  Meet the infrastructure-class reliability requirements

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