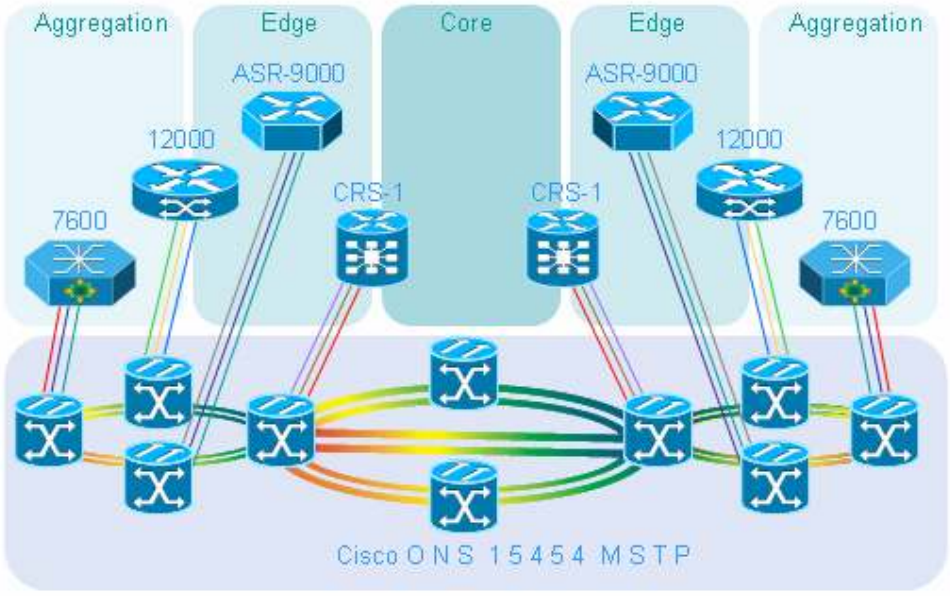
# IP over DWDM: Empower Your Next-Generation Optical Network


Service providers are increasingly migrating their networks to an IP-based architecture while the overall volume of IP traffic is dramatically growing worldwide. Both traditional and new applications are adopting IP such as television, video, and voice as well as music and video podcasting and peer-to-peer (P2P) file sharing.

Service providers are preparing their next-generation optical networks for the integration of IP and DWDM by cutting intermediate layers and simplifying the overall network architecture. To support this evolution, Cisco implemented an IP-over-DWDM solution on the Cisco® ONS 15454 Multiservice Transport Platform (MSTP) and on the Cisco CRS-1 Family, 7600 Series, and 12000 Series Routers (Figure 1).

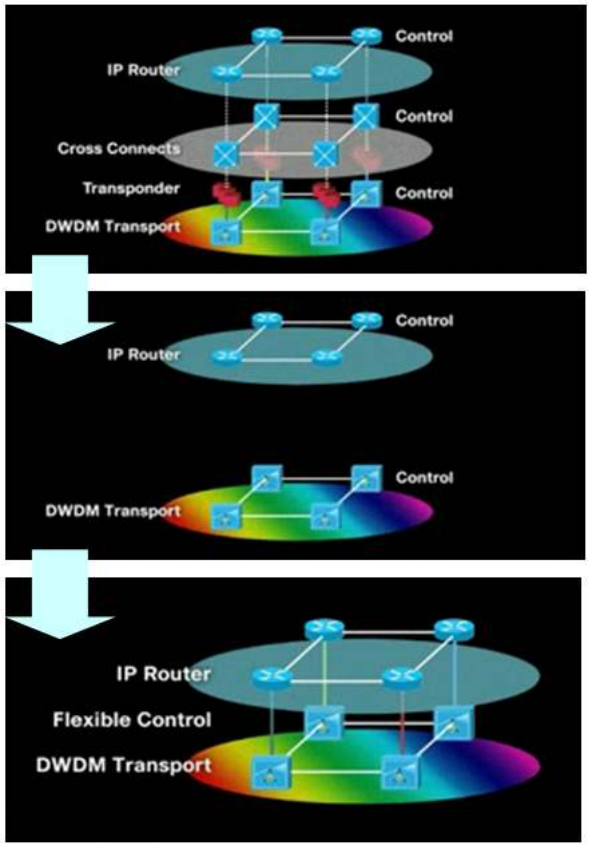
**Figure 1.** IPoDWDM Solution with Cisco ONS 15454, CRS-1, 7600 Series, and 12000 Series Routers




The traditional optical network model was based on several layers, including SONET/SDH in addition to IP and DWDM. Implementing IP over DWDM means cutting these intermediate layers and thus reducing operating expenses (OpEx) and capital expenditures (CapEx); this simplifies the network layout and offers the same features such as grooming, protection, and restoration. This approach allows for the reduction of transport elements by

eliminating the optical transponders, for example, and in some cases completely eliminating regeneration sites (see Figure 2).

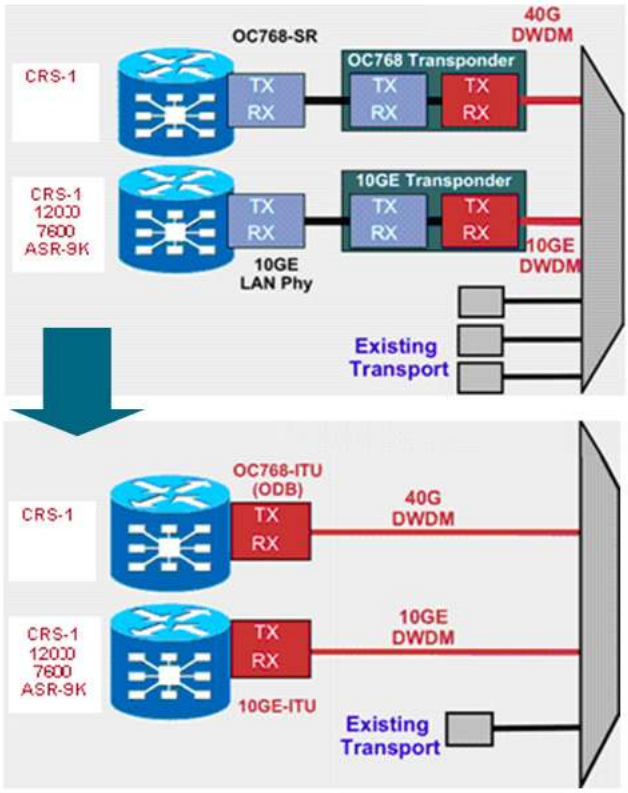
**Figure 2.** IPoDWDM Reduces the Number of Layers and Simplifies the Network Architecture




The Cisco IPoDWDM solution offers the following key features:

- Flexible and fully reconfigurable DWDM network with zero-touch Cisco ONS 15454 MSTP omnidirectional and colorless ROADM
- Proactive protection on Cisco CRS-1 and ONS 15454 MSTP
- Common management interfaces
- Router IPoDWDM interfaces that eliminate the need for optical transponder equipment (see Figure 3):
  - Cisco CRS-1 Carrier Routing System: 1x 40-Gbps and 4x 10-Gbps IPoDWDM interfaces
  - Cisco 7600 Series Routers: 2x 10-Gbps and 4x 10G IPoDWDM interfaces
  - Cisco 12000 Series Routers: 1x 10-Gbps IPoDWDM interface
  - Cisco ASR-9000 Series Routers: 8x 10-Gbps and 2x 10-Gbps IPoDWDM interfaces

**Figure 3.** DWDM Interfaces Inside the Routers Reduce CapEx and OpEx and Enhance Resiliency




## IPoDWDM on Cisco ONS 15454 MSTP

The Cisco ONS 15454 Multiservice Transport Platform (MSTP) is the most deployed metropolitan-area (metro) and regional DWDM solution in the world.

The Cisco ONS 15454 MSTP delivers a rich set of features including fully reconfigurable optical add/drop multiplexers (ROADMs) for superior network flexibility and reduced complexity, supporting 50-GHz channel spacing (80 wavelengths), 2- through 8-degree mesh and multi-ring topology, and omnidirectional and colorless switching. The platform is available with three different shelf densities (Figure 4).

**Figure 4.** Cisco ONS 15454 MSTP

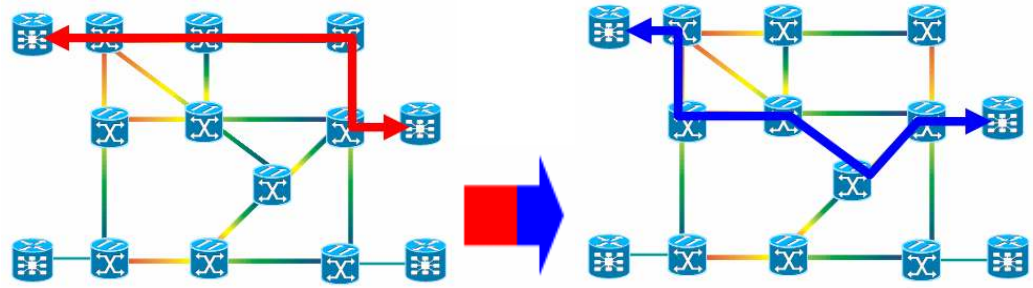
Single-module ROADM solutions dramatically improve system density and flexibility. With the integration of ROADM and optical amplification into a single slot, the Cisco ONS 15454 MSTP can be configured to support multi-degree ROADM in a very compact and power-efficient single-shelf configuration (see Figure 5)

**Figure 5.** Single-Module ROADM Unit and Cisco ONS 15454 MSTP 2-Degree ROADM Node with M6 Chassis

### Zero Touch – Colorless and Omnidirectional

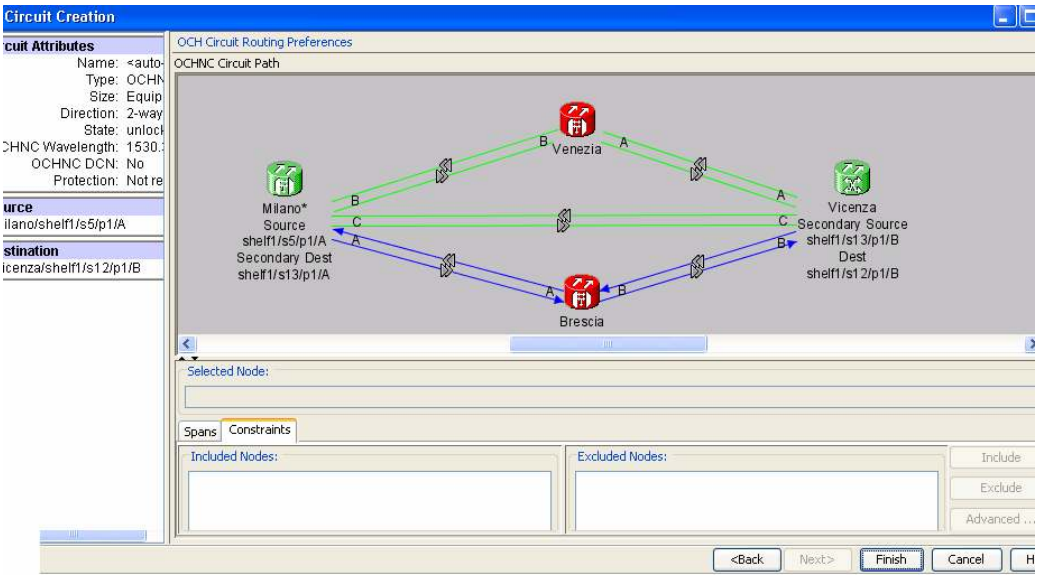
The Cisco ONS 15454 MSTP supports omnidirectional add/drop multiplexing of wavelengths and color-independent ports. This allows the flexibility to remotely reconfigure wavelengths to any color or any degree in mesh networks and to deliver true “zero-touch” wavelength provisioning (Figure 6).

**Figure 6.** Zero Touch: Changing the Color and Direction of a Channel Dynamically with Software Only



Using Cisco Transport Controller, a network-based, point-and-click management interface, you can remotely reroute and recolor the circuit (see Figure 7).

**Figure 7.** Remote Rerouting and Recoloring Circuit with Cisco Transport Controller



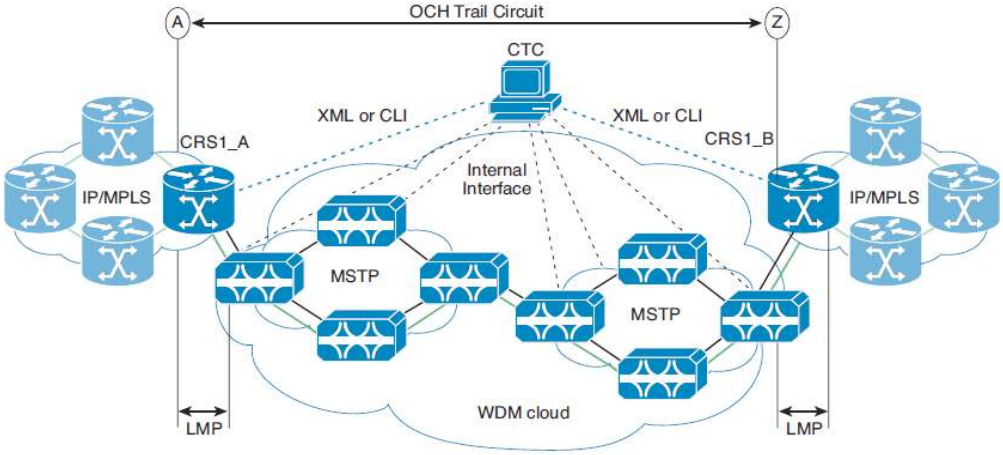
### Common Network Management and Virtual Transponder

The Cisco IPoDWDM solution allows service providers to design and manage both the DWDM interfaces of routers and the DWDM equipment from a common software suite that includes:

- Cisco Transport Controller, the Cisco ONS 15454 craft terminal with operations, administration, and maintenance (OAM) functionalities capable of managing an entire network with up to 50 network elements
- Cisco Transport Manager, the Cisco ONS 15454 element manager
- Cisco Transport Planner, the Cisco ONS 15454 design tool

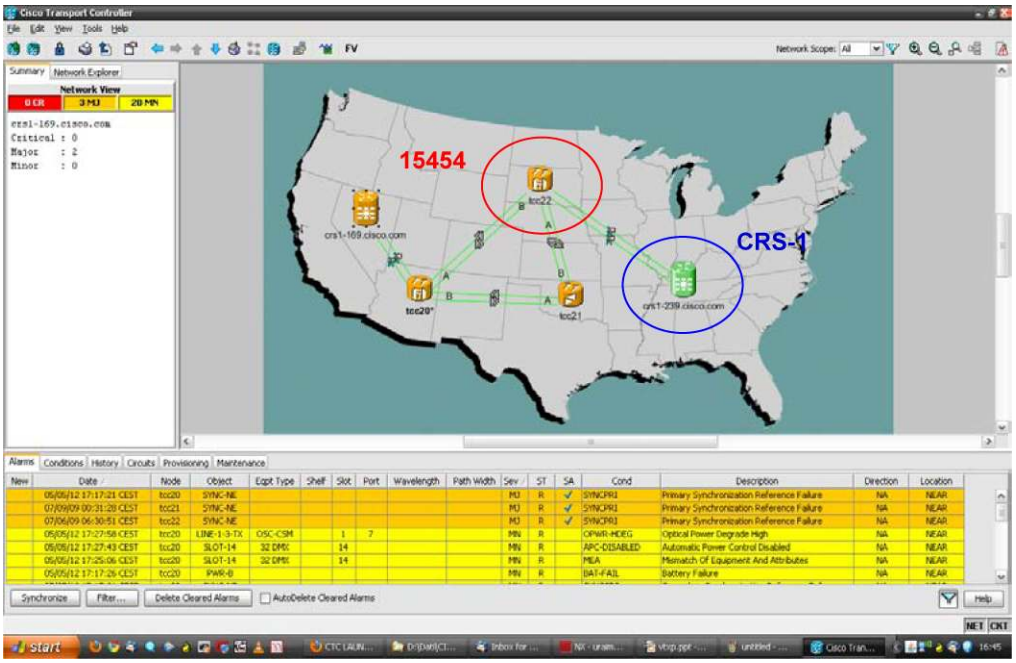
With Cisco Transport Controller, you can manage the Cisco ONS 15454 and the routers in the same network view using virtual transponder technology. Link Management Protocol (LMP), which is part of Generalized Multiprotocol Label Switching (GMPLS), allows the communication between the routers and the Cisco ONS 15454. By means of Cisco Transport Controller, you can create an end-to-end circuit between the Cisco CRS-1 routers passing through the Cisco ONS 15454 network (see Figure 8).

**Figure 8.** End-to-End Circuits Between Cisco CRS-1 Routers in the Cisco 15454 MSTP Network



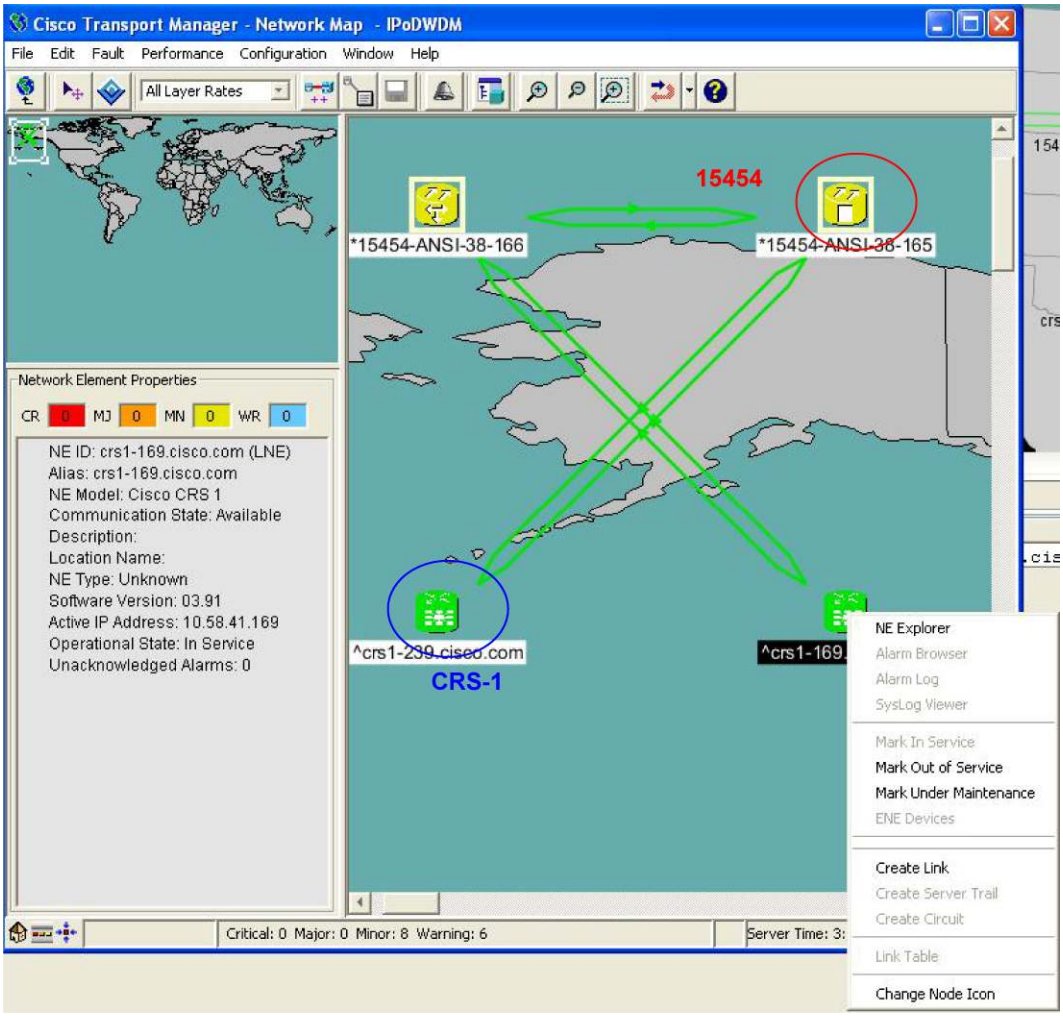

Routers and the Cisco ONS 15454 platforms are displayed in the same Cisco Transport Controller network view (see Figure 9). The same interface will allow, in addition to circuit creation, performance monitoring and alarm monitoring of both the IP and DWDM systems in a consistent way.

**Figure 9.** Management with Cisco Transport Controller



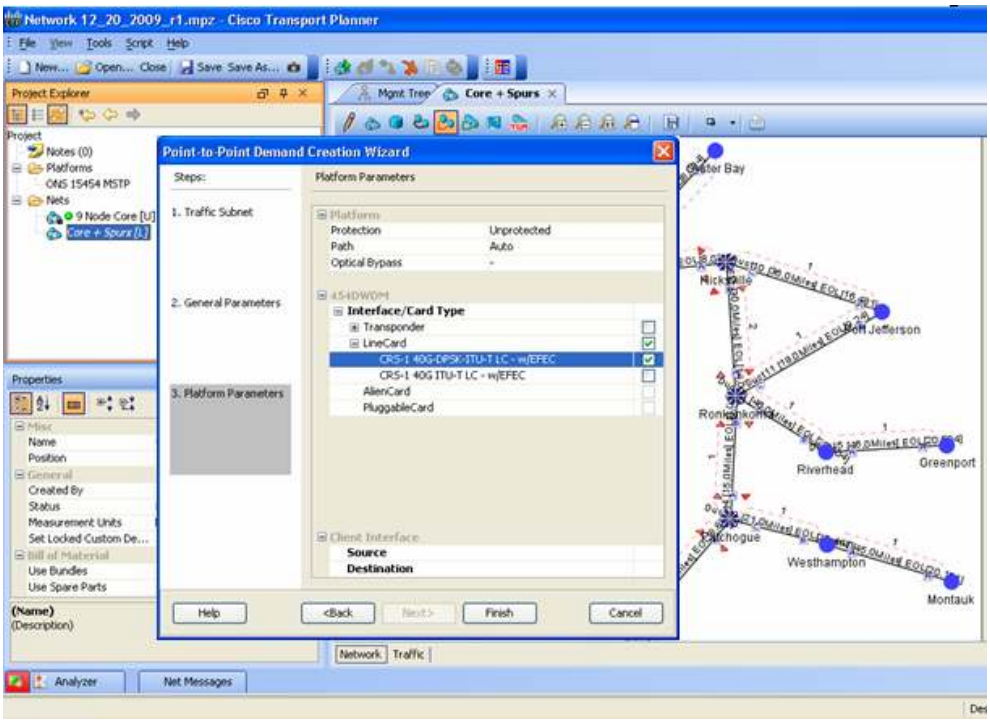

Similar functionalities are offered by the Cisco Transport Manager, which is also capable of managing both the Cisco CRS-1 and Cisco ONS 15454 (see Figure 10).

**Figure 10.** IPoDWDM Management with Cisco Transport Manager




And finally the Cisco Photonic Planner, the Cisco ONS 15454 design tool, can be used to design a network where the CRS-1 and other IPoDWDM interfaces can be provisioned during the design phase (see Figure 11).

**Figure 11.** IPoDWDM Design with Cisco Transport Planning Tool

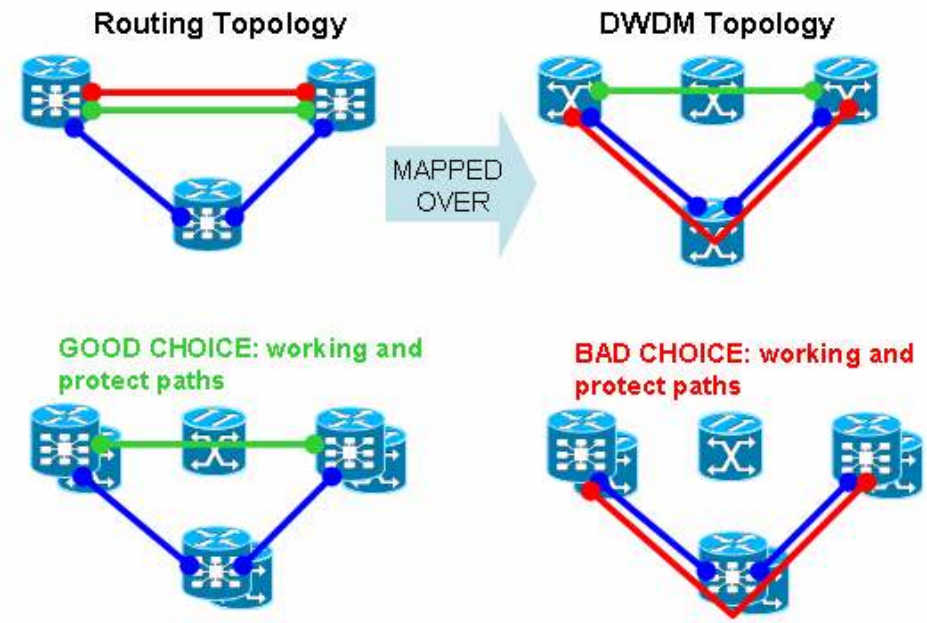



### Shared Risk Link Group

The Shared Risk Link Group (SRLG) feature on the Cisco ONS 15454 allows the sharing of DWDM risk information between the optical layer and the IP layer. Typically the IP part of a network is not aware of existing DWDM physical connectivity when performing routing decisions. The advent of multi-degree ROADM technology and IPoDWDM makes SRLG a valuable feature for planning routes that help ensure survivability against all DWDM signal faults and for increasing utilization.

For example, SRLG enables a router to implement proactive protection. Without SRLG the router might choose the same physical DWDM spans for the working and protect paths when in reality two separate paths are available (see Figure 12).

**Figure 12.** SRLG Allows the Routing Protocol to Select the Proper DWDM Path




### Regeneration-Aware, Proactive Fast Reroute

The regeneration-aware, proactive Fast Reroute (FRR) functionality on the Cisco ONS 15454 interworks with the proactive FRR feature available on routers. In general, when a span between regenerators is degrading, the downstream router will not be aware of it and therefore will not switch to an alternative path. With this Cisco ONS 15454 technology, the regenerator will instead signal the downstream router about the degradation by means of a Proactive FRR – Forward Defect Indication (PF-FDI) that will trigger the router's Layer 3 switch. The router will also inject backwards a PF-BDI flag that will trigger the same behavior on the counterpart router (Figure 13).

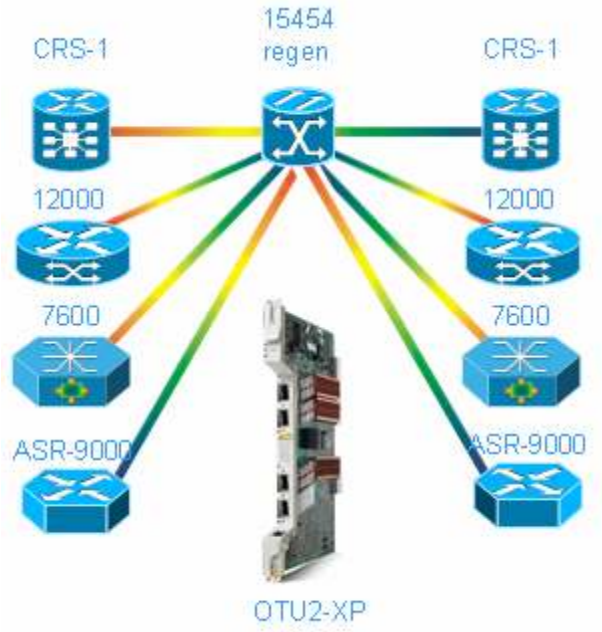
**Figure 13.** Proactive Fast Reroute Feature Avoids Traffic Slowdowns


### Optical Regeneration

The Cisco ONS 15454 can interoperate with 10-Gbps IPoDWDM router interfaces and offers the possibility to regenerate the signal.

With the Cisco ONS 15454 OTU2 XPonder cards, for example, you can regenerate Cisco 12000 Series and CRS-1 10-Gbps traffic with both enhanced and standard Forward Error Correction (FEC), and on the Cisco 7600 Series with standard FEC.

**Figure 14.** Cisco ONS 15454 Regeneration of Traffic Coming from Router IPoDWDM Interfaces




### IPoDWDM on Cisco CRS-1 Carrier Routing System

The Cisco CRS-1 Carrier Routing System supports the 1-Port OC-768c/STM-256c Tunable Wavelength-Division Multiplexing Packet-over-SONET/SDH (WDMPOS) Interface Module (Figure 15).

It can recognize signal degradation as it occurs and dynamically reroute traffic before a failure, significantly reducing or totally eliminating packet loss (proactive Fast Reroute, or FRR). This IPoDWDM proactive mechanism supports recovery in 15 milliseconds (ms) or less.

The module is completely tunable across the C band across every other wavelength on the ITU 50-GHz grid. It includes an integrated tunable dispersion compensator (TDC) while offering a robust tuning range. It supports high-gain Enhanced Forward Error Correction (EFEC), extending reach up to 2000 kilometers (km) without requiring signal regeneration.

**Figure 15.** Cisco CRS-1 1-Port OC-768C/STM-256C DPSK+ Tunable WDMPOS Interface Module

Another important element of the Cisco IP-over-DWDM solution is the Cisco CRS-1 4-Port 10GE Tunable WDMPHY Interface Module (see Figure 16). The module supports both G.709 Generic Forward Error Correction (GFEC) and high-gain EFEC, extending reach up to 2000 km without requiring signal regeneration. This module is also completely tunable across the C band with 50-GHz spacing.

**Figure 16.** Cisco CRS-1 4-Port 10GE Tunable WDMPHY Interface Module

### IPoDWDM on Cisco 7600 Series Routers

Designed for IP over DWDM, the Cisco 7600 Series ES Plus XT Line Cards support up to 40 Gbps of bandwidth with four ports of 10 Gigabit Ethernet interfaces, or 20 Gbps with two ports of 10 Gigabit Ethernet (see Figure 17). Additionally, the line cards have integrated G.709 GFEC to span regional distances with integration directly into OTN devices such as the Cisco ONS 15454 MSTP or core routers such as the Cisco CRS-1 Carrier Routing System. The ability to span even greater distances between Cisco 7600 Series Routers is supported with EFEC in the ES Plus XT cards (back-to-back ES Plus XT connections).

**Figure 17.** Cisco 7600 Series ES Plus XT Line Cards: 4-Port 10 GE and 2-Port 10 GE

### IPoDWDM on Cisco 12000 Series Routers

The Cisco 1-Port 10GE Tunable WDM-PHY Shared Port Adapter (SPA) (Figure 18) provides a tunable optical interface that can be used to connect directly to DWDM transport systems, eliminating the need for an optical transponder. The Tunable WDM-PHY SPA provides full 80-channel tunability with 50-GHz spacing across the C band and meets ITU specifications.

It supports G.709 framing as well as Generic Forward Error Correction (GFEC). For long-haul application support, the high-gain Enhanced Forward Error Correction (EFEC) functionality is provided, which can extend optical reach up to 2000 km without optical-electrical regeneration.

**Figure 18.** Cisco 1-Port 10GE Tunable WDM-PHY SPA

### IPoDWDM on Cisco ASR 9000 Series Routers

The Cisco ASR 9000 Series Ethernet Line Cards are the latest generation of service-provider-focused Carrier Ethernet line cards from Cisco. These line cards deliver economical, scalable, highly available, line-rate Ethernet and IP/Multiprotocol Label Switching (MPLS) edge services. The Cisco ASR 9000 Series Line Cards together with the Cisco ASR 9000 Series platforms are designed to provide the fundamental infrastructure for scalable Carrier Ethernet and IP/MPLS networks, enabling profitable business, residential, and mobile services.

The 8-port 10 Gigabit Ethernet line card and the 2-port 10 Gigabit Ethernet + 20-port 1 Gigabit Ethernet line card (Figure 19) support IPoDWDM with 10 Gigabit Small Form-Factor Pluggable (XFP) optics. Addressing the advantages of consolidating IP and DWDM networking, G.709 with Advanced FEC is provided. G.709 provides visibility into the DWDM transmission system to enable rapid detection and recovery from transmission-layer and DWDM impairments. The Advanced FEC extends transmission-layer performance over an amplified system without the cost of regenerators or transponders.

**Figure 19.** Cisco ASR 9000 Series Ethernet Line Cards: 8-Port 10GE and 2-Port 10GE + 20-Port 1GE

### Why Cisco

Cisco uniquely offers routing systems as well as DWDM transport with an integrated IPoDWDM solution. With the Cisco Transport Controller and the Cisco Transport Manager, both the Cisco CRS-1 and ONS 15454 can be managed through the same common graphical interfaces. By means of the Virtual Transponder feature, it is possible to provision end-to-end services between routers and DWDM. Alarms and performance monitoring data are displayed by consistent tools. In addition the Cisco Photonics Planner facilitates the planning of an IPoDWDM network including the design of Cisco router optics as well as the DWDM transport layer.

Cisco offers proven interoperability between the IP and the DWDM layers; routers and DWDM devices are designed and tested together to help ensure absolute compatibility.

Omnidirectional and colorless features together provide flexible transport capabilities to the upper layers. By means of various chassis sizes and the ultra-compact, single-module ROADM solution, the Cisco ONS 15454 can be positioned at all layers from access to core.

Finally Cisco offers IPoDWDM interfaces directly on the routers and compatible regeneration OTU2 crossponders on the Cisco ONS 15454 MSTP system.

### For More Information

To learn more about the Cisco IPoDWDM solution and some of the customers who are benefiting from this architecture today, visit: http://www.cisco.com/go/IPoDWDM.

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