Optical Impairment-Aware WSON Control Plane for Cisco ONS 15454 MSTP

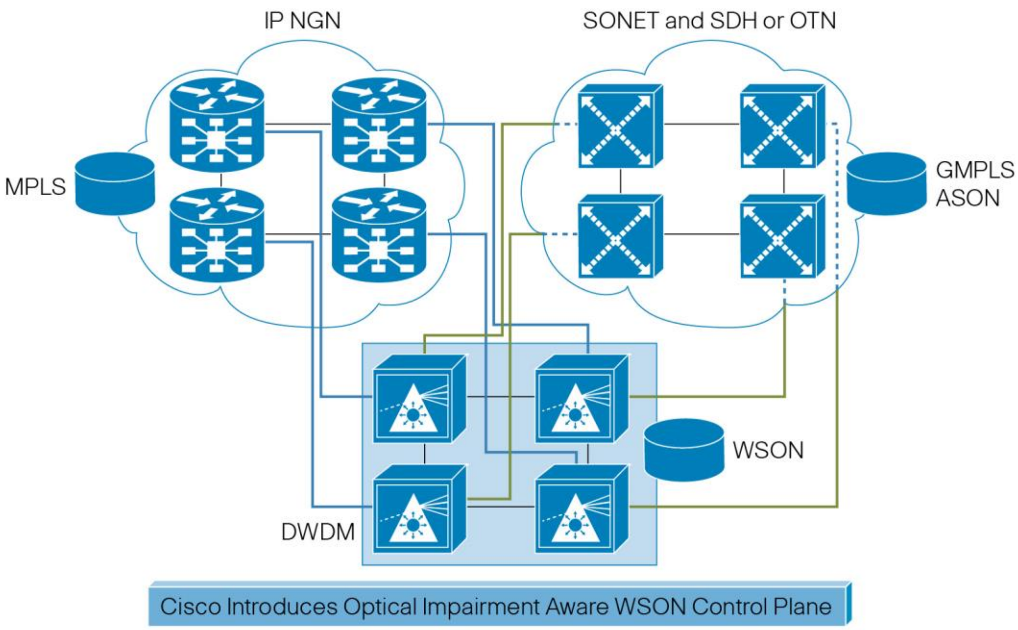
Transport network solutions have undergone a tremendous technology evolution. In addition to increases in network bandwidth and reach, management and service provisioning have become easier. Generalized Multiprotocol Label Switching (GMPLS) has helped to introduce dynamic service provisioning into the transport network. In time-division multiplexing (TDM) networks and IP Next-Generation Networks (IP-NGNs), dynamic service provisioning is made possible by Automatic Switched Optical Network (ASON) and GMPLS technology for SONET/SDH, along with Optical Transport Network (OTN) cross-connects and IP/MPLS for routers.

For any high-bandwidth network, dense wavelength-division multiplexing (DWDM) forms the underlying transport layer. ASON, GMPLS, and MPLS assume all-regenerated networks or preprovisioned wavelengths, because they consider all links as point-to-point, without optical awareness. DWDM has evolved from a point-to-point transport technology used to overcome the fiber exhaust problem to a more flexible wavelength-switching platform, with the evolution of multidegree reconfigurable optical add-drop multiplexers (ROADMs) with omnidirectional and colorless switching capabilities. The multidegree and reconfiguration capabilities translate into a full-mesh network, with a large number of possible optical paths. It is not feasible to validate all these paths during the planning stage, and real-time validation is needed while provisioning new services or assigning new paths to existing services.

Product Overview

The architecture of the Cisco® Wavelength Switched Optical Network (WSON) Control Plane for the Cisco ONS 15454 MSTP enhances GMPLS capabilities with awareness of wavelength properties and optical impairments, offering dynamic service provisioning and restoration on a flexible DWDM network. This approach provides a converged dynamic network architecture, as shown in Figure 1.

Figure 1. Converged Dynamic Network Architecture



Together with the advances in DWDM hardware, such as multidegree ROADMs with colorless and omnidirectional switching, the Cisco WSON Control Plane gives operators the following benefits.

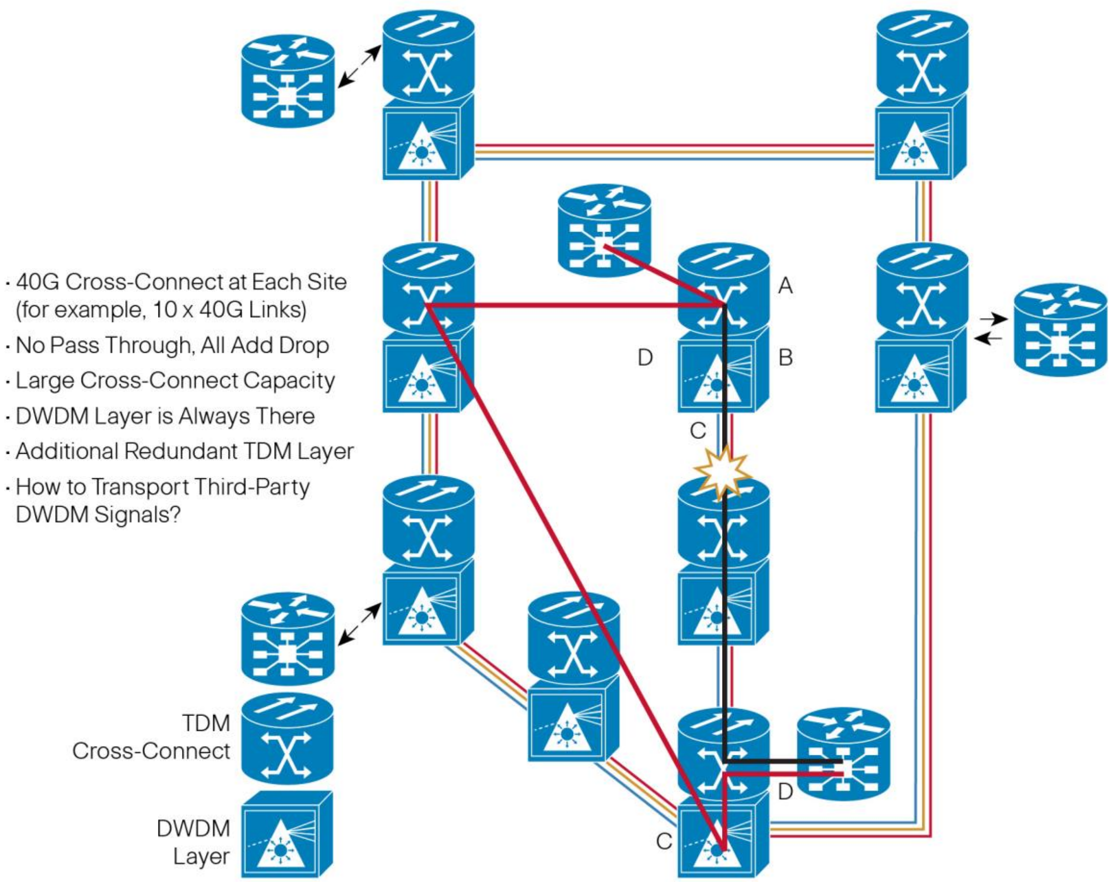
- Network availability: Availability is improved, because the network is tolerant of multiple failures and can reroute wavelengths without complex replanning exercises and service calls. Tiered service-level agreements (SLAs) can be offered with multiple protection and restoration schemes. The Cisco WSON provides 1+R restoration, providing resiliency when multiple failures occur, and 1+1+R restoration that provides resiliency with 50ms protection, if multiple failures occur.
- Network optimization: Network topology is modified over a period of time, as service requirements change. The optical-aware Cisco WSON Control Plane helps to reoptimize and reduce or eliminate network fragmentation.
- Wavelength on demand: Time to market is significantly improved with rapid service setup. With streamlined network planning, a simplified GUI and a script-oriented TL1 User-Network Interface (UNI) allow users to dynamically demand wavelength services across DWDM networks.
- Value-added services: The Cisco WSON Control Plane provides optical rerouting capabilities, allowing service providers to offer services with new SLA levels, in addition to their present modes of operations.
- Multilayer convergence: Cisco WSON restorations can be triggered by alarms in the DWDM network and by client devices using GMPLS-UNI. This approach allows intelligent multilayer protection and restoration capabilities.
- Cost savings: With the intelligent Cisco WSON Control Plane, operators can benefit from the efficiency of ROADMs and reduce the number of wavelengths and transponders needed in the network. At the lowest layer in the network, this directly translates into savings in DWDM equipment. In addition, for higher-layer equipment including cross-connects and routers, fewer ports are required resulting in tremendous overall CapEx savings for operators. For example, Cisco WSON with GMPLS-UNI allows an IP/MPLS router to use 1+R restoration at the optical layer, along with fast reroute (FRR) with proactive protection at the router. The

GMPLS UNI also enables routers to request diverse paths based on the Label Switched Path identifier (LSP-ID). As a result, the resiliency requirements of the network are improved while the network cost is also reduced, because there is no need to preprovision multiple paths for each router port in the DWDM network.

Control Plane Capabilities

In networks with an ASON and GMPLS control plane, establishing a connection only considers bandwidth and whether the link is up or down. Optical layer impairments are not considered, and the optical channel is assumed to work by design. In this case, only preplanned channels are guaranteed to work, as shown in Figure 2. GMPLS alone is not sufficient to decide whether a proposed path is feasible in the photonic domain.

Figure 2. 40 Gbps Service with ASON and GMPLS Path Computation



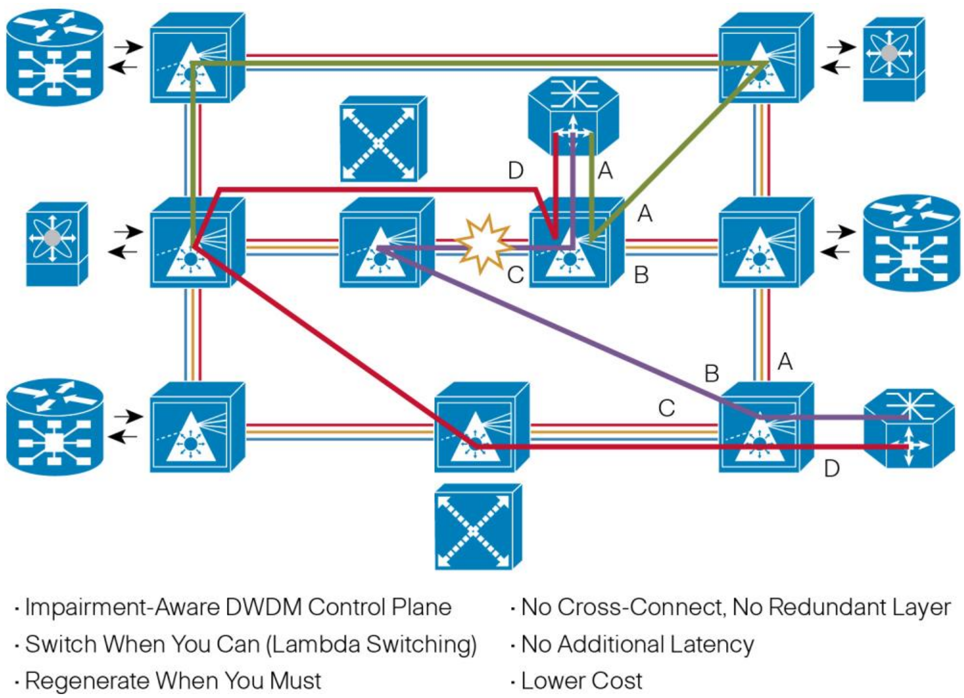
The Cisco WSON was introduced to achieve dynamic service provisioning and restoration capabilities in DWDM networks. This solution provides extensions to GMPLS that supply path computation with optical feasibility analysis, while providing protocol interoperability with the GMPLS suite. Optical feasibility analysis and verification require GMPLS to be aware of physical optical impairments. Cisco's DWDM-aware GMPLS is aware of optical network topology, optical component functional models, node models, node configuration, and fiber characteristics, which are all fundamental in optical channel path verification. The following crucial impairments are considered while performing feasibility analysis:

- Linear impairments: Optical signal-to-noise ratio (OSNR), optical power budget, chromatic dispersion (CD), and polarization mode dispersion (PMD)

- Nonlinear Impairments: Four-wave mixing (FWM), self phase modulation (SPM), and cross-phase modulation (XPM)
- Interface properties: Bit rate, Forward Error Correction (FEC) scheme, modulation, sensitivity, etc.

With these comprehensive capabilities, creation of an optical path is extremely simple and reliable. The operator needs to select the endpoints of the service, and the control plane determines an optically feasible path across the DWDM network. This path is calculated using all the benefits of Cisco hardware and optical flexibility. With the availability of omnidirectional and colorless wavelength switching, it becomes very easy for an operator to handle network failures and to optimize wavelength paths as the network evolves, as illustrated in Figure 3. The hardware allows a service to be introduced using a new wavelength and provides a new path either automatically (in the case of 1+R or 1+1+R restoration) or at the click of a button (in the case of manual restoration) using the rerouting capabilities of the DWDM control plane.

Figure 3. 40 Gbps Service with Cisco WSON Path Computation and Restoration



Traditionally, DWDM networks are managed by a centralized network management system (NMS). The impairment-aware computation can also follow a centralized model, with an NMS application helping to make the traffic path computations, but this approach has major drawbacks. The NMS needs to have a large amount of information from all the nodes. This information is aggregated over multiple links, and the network elements have to collect and pass the information from remote nodes, while adding their own information. This cumulative information collection puts a huge load on the data communication network (DCN). The DCN becomes a mission-critical bottleneck in this case, with a very stringent SLA requirement. A mismatch of information between the network and NMS can result, leading to incorrect path computations that result in service disruptions, which can also be very hard to troubleshoot.

Cisco's distributed control plane implementation avoids the need for a powerful central server, because computations are handled at network elements. As service providers introduce new network elements, add or remove facilities, or activate new circuits, the control plane automatically distributes the new information to update the network. The distributed computation model reduces DCN bottlenecks, because the exchange of GMPLS information to compute optical impairments is between adjacent network elements supporting the optical path, with final decision taking place at the egress node. This approach avoids an accumulation of information on the links and nodes and being sent to the central server. The Cisco DWDM control plane provides the following services and benefits:

- Automatic DWDM network topology discovery
- Automatic wavelength provisioning, including IP over DWDM (IPoDWDM) interoperability with GMPLS-UNI
- Automatic path computation with awareness and validation of optical impairments and interface properties
- Optical channel diversity based on LSP-ID and nodes, links, and Shared Risk Link Groups (SRLG)
- Restoration

The DWDM-aware control plane becomes crucial when deploying IPoDWDM networks, because it provides unique operational advantages and efficiency, making bandwidth-on-demand available to high-end IP networks, along with optical restoration as needed and network and resource status. GMPLS UNI enables routers to dynamically achieve LSP set-up, LSP tear down, diverse LSP request over UNI, as well as DWDM equipment to achieve wavelength change on client DWDM interfaces.

Standards

The GMPLS optical control plane has been promoted by the IETF as an extension to the MPLS data control plane (RFC 3945-GMPLS). Now the IETF Common Control and Measurement Plane (CCAMP) working group is leading the WSON standardization effort, in conjunction with the ITU-T. IETF CCAMP and the ITU-T SG-15 joint liaison are taking advantage of existing ITU-T standards work, such as G.680 and G.698.x, to advance the IETF Optical Control Plane project.

The CCAMP working group is taking a two-step approach to the Control Plane for DWDM networks. First, it is dealing with the pure routing and wavelength assignment (RWA) problem, which includes wavelength connectivity and interface signal compatibility.

Routing and Wavelength Assignment Standards

The relevant standards (or ongoing drafts) include:

- **RFC 6205 Generalized Labels for Lambda-Switch-Capable (LSC) Label Switching Routers:** This standard defines an appropriate label format when GMPLS controls WSON networks.
- **RFC 6163 Framework for GMPLS and Path Computation Element (PCE) Control of Wavelength Switched Optical Networks (WSONs):** This standard defines the context, terminology, and architectural options for a GMPLS control plane applied to WSON networks. As a framework, this is an informational document and does not define any protocol extensions.
- **draft-ietf-ccamp-rwa-info:**
    - *draft-ietf-ccamp-rwa-wson-encode*
    - *draft-ietf-ccamp-general-constraint-encode*
    - These drafts are working group documents, and they are the basis for WSON protocol extensions. Currently there are several ongoing discussions about information encoding. The ultimate solution is likely to differ from the current draft content.
- **draft-ietf-ccamp-gmpls-general-constraints-ospf-te:**
    - *draft-ietf-ccamp-wson-signal-compatibility-ospf*

- *draft-ietf-ccamp-wson-signaling*
- These drafts define the specific protocol extension. The extensions will be finalized according to the information model and encoding drafts.

After the IETF finalizes the WSON RWA, Cisco plans to implement it. Implementing a proprietary Open Shortest Path First (OSPF) RWA extension now and upgrading to a standard version may require critical software upgrades. In Release 9.6, the Cisco control plane solves the RWA problem in a distributed way, and the current solution is expected to be fully compatible with the WSON RWA standard evolution.

Optical Impairment Awareness Standards

The second step defines the WSON with optical impairment awareness. This standardization activity will be completed after the WSON RWA is established. Relevant drafts include:

- **draft-ietf-ccamp-wson-impairments (A Framework for the Control of Wavelength Switched Optical Networks [WSON] with Impairments):** Like the previous framework document, this draft defines the scenario for the optical impairment case, as well as control plane architectural options. This draft is nearly ready to become an RFC.
- **Information model and encoding drafts:** These drafts are still in an early stage, and they are individual contributions:
  - *draft-bernstein-wson-impairment-info*
  - *draft-bernstein-wson-impairment-encode*.

For the impairment-aware standard, Cisco will implement *draft-martinelli-ccamp-optical-imp-signaling* (G.680 compliant), with some additional information to fully support the nonlinear impairment validation. In the first release, this is a proprietary solution, because standardization is ongoing. When IETF approves a standard, Cisco plans to provide a compliant solution through release upgrades.

The nonlinear impairment awareness is out of scope for the IETF WSON because the ITU has no model to propose for evaluating nonlinearity. Cisco control plane implementation supports linear impairment awareness through standard protocols and offers a nonlinear evaluation as a proprietary value-added solution.

GMPLS Suite RFC Support

The main RFCs implemented as part of Cisco's optical control plane are listed in Table 1. (The full implementation includes many other RFCs that are beyond the scope of this document.)

Table 1. GMPLS Suite RFC Support

Applicable Standards and Notes	Description
DC-MPLS TE-MIB	
TE-MIB for GMPLS	RFC 3812 and RFC 4802
DC-RSVP IPV4 / IPV6	
GMPLS Signaling Functional Description	RFC 3471
GMPLS Signaling CR-LDP Extensions	RFC 3472
GMPLS Signaling (RSVP-TE)	RFC 3473 (excluding sections 3.2, 4.1, 12)
RSVP control plane restart	RFC 3473 section 9, includes non-GMPLS operation
DC-OSPF IPV4 / IPV6	
OSPF v2 protocol (IPv4 routing)	RFC 2328
The OSPF Opaque LSA Option	RFC 5250 excluding section 5. Older RFC 2370 fully supported.

Applicable Standards and Notes	Description
Routing Extensions in Support of GMPLS	RFC 4202
OSPF Extensions in Support of GMPLS	RFC 4203
GMPLS-UNI	
GMPLS User Network Interface Signalling	RFC 4208

Ordering Information and System Requirements

To place an order, visit the Cisco Ordering homepage and refer to Table 2 for ordering information. The Cisco ONS 15454 Multiservice Transport Platform (MSTP) introduced the Cisco WSON Control Plane in Release 9.4 and introduced GMPLS UNI-C, 1+R, and 1+1+R restoration in release 9.6.0.3. The Cisco ONS 15454 MSTP offers two software versions, one that supports the Cisco WSON Control Plane and one that includes the traditional control plane without WSON capabilities. The part numbers supporting WSON for release 9.6.0.3 are listed in Table 2. The system requirements for products with these part numbers are listed in Table 3.

Table 2. Ordering Information

PID	Description
SF15454WC-R9.6.0K9	15454 ANSI MSTP Rel. 9.6.0 SW-WSON, Pre-loaded on TCC2P-TCC3
SF15454MC-R9.6.0K9	15454 ANSI MSTP R9.6.0SW-WSON,Preload TCC3,TNC,TNCE,TSC,TSCE
15454C-LIC-9.6.0K9	15454 ANSI ETSI MSTP-WSON Upgrade Lic 9.6.0, Right To Use
SF15454WECR9.6.0K9	15454 ETSI MSTP Rel. 9.6.0 SW-WSON , Preload on TCC2P,TCC3
SF15454MECR9.6.0K9	15454 ETSI MSTP R9.6.0SW-WSON,Preload TCC3,TNC,TNCE,TSC,TSCE
SF15454MECR9.6.0K9=	15454 ANSI ETSI MSTP-WSON Rel. 9.6.0 Pkgs,DVD,RTU License

Table 3. System Requirements

Component	Cisco ONS 15454 ANSI	Cisco ONS 15454 ETSI	Cisco ONS 15454 M6	Cisco ONS 15454 M2
Processor	TCC3, TCC2P, or TCC2	TCC3, TCC2P, or TCC2	TNC, TSC, TNC-E, or TSC-E	TNC, TSC, TNC-E, or TSC-E
Shelf assembly	15454-SA-HD or 15454-SA-HD-DDR shelf assembly with CC-FTA version fan-tray assembly	15454-SA-ETSI shelf assembly with CC-FTA fan-tray assembly	15454-M6-SA shelf assembly	15454-M2-SA shelf assembly
System software	Release 9.6.0.3 ANSI WSON package or later	Release 9.6.0.3 ETSI WSON package or later	Release 9.6.0.3 ANSI/ETSI WSON package or later	Release 9.6.0.3 ANSI/ETSI WSON package or later

For more information about the Cisco ONS 15454 MSTP, visit http://www.cisco.com/en/US/products/hw/optical/ps2006/ps5320/index.html.

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