REDUCING CAPEX AND OPEX THROUGH CONVERGED OPTICAL INFRASTRUCTURES

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Abstract

Today's Cable Operator optical infrastructure designs are becoming more important as customers are increasingly demanding high-bandwidth services such as residential and commercial data and VoD. The network must be able scale to increasing service requirements and customers, be flexible to deliver new services, and be cost effective to lower CapEx and OpEx. At the same time the solution must offer investment protection. To accomplish this, optical equipment vendors are offering a wide array of solutions to allow Cable Operators flexible service offerings while reducing CapEx and OpEx through network convergence.

New infrastructure platforms offer a breadth of options for delivering an optical infrastructure based on two primary architectures. Transponders-based solutions integrate DWDM intelligence including auto topology discovery, wavelength provisioning, and auto power management. These platforms can converge the network at multiple layers including DWDM, SONET/SDH, Ethernet, and IP. Passive-based solutions integrate optics into the switch/router via gigabit interface connectors (GBICs) while using passive optical solutions to support native gigabit Ethernet solutions. Both solutions enable the Cable Operator to offer new revenue generating services while optimizing network efficiency, lowering CapEx, and lowering OpEx.

PAPER

This session will focus on the capabilities of Optical infrastructure options, when and where to use them, and highlight real world analysis derived from implementation by several Cable Operators deploying deliver voice, video, and data services to residential and commercial customers.

To help ensure future profitability, leading cable operators are exploring how best to deliver new revenue-generating services while lowering capital and operational expenses (CapEx and OpEx). Many operators looking to converged networks to improve efficiencies, especially when delivering new services and applications

Figure 1 shows an example of an unconverged network that comprises five individual fiber networks. The network requires a total of 1960 fiber miles in order to deliver digital broadcast video, voice over IP (VoIP), high-speed data (HSD), SONET for analog video, and video on demand (VoD). This approach incurs the high CapEx of installing new fiber, especially in metropolitan areas where cable operators are reaching fiber capacity limits.

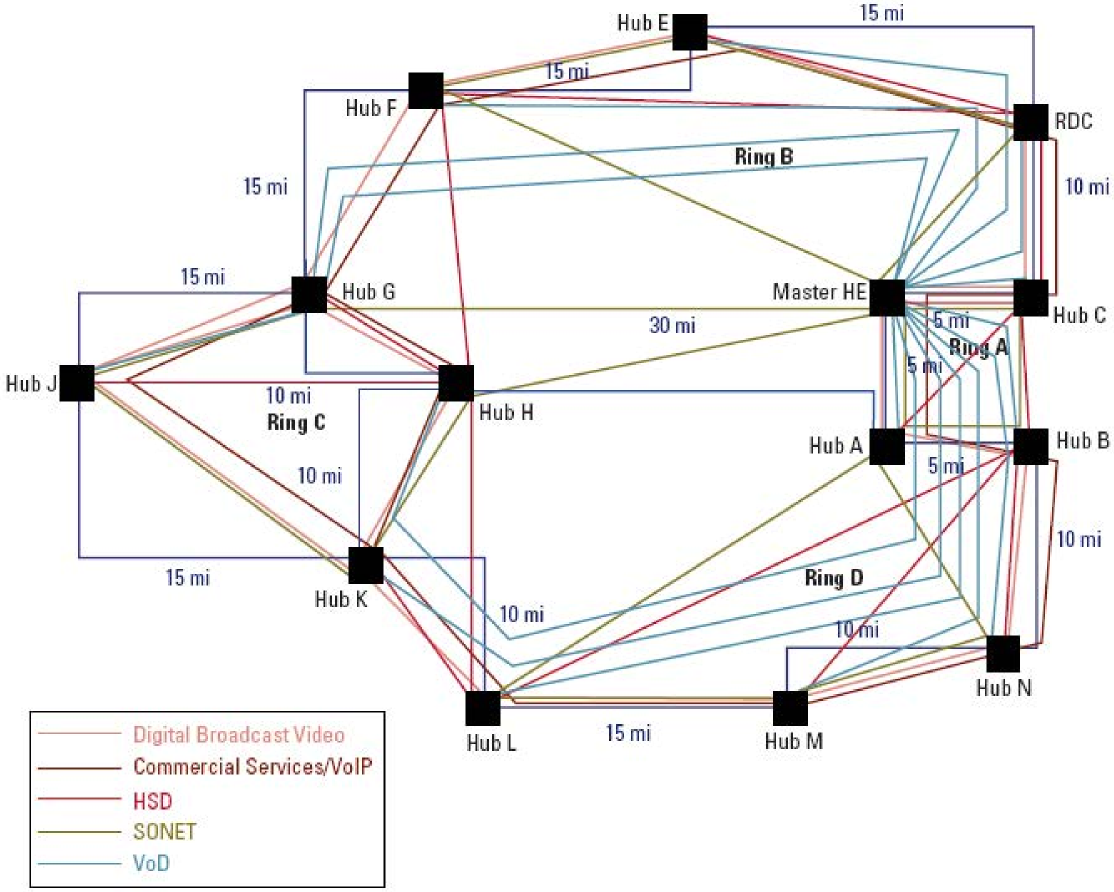

Figure 1 An Unconverged Network Running Multiple Services

Convergence Benefits

Convergence at different layers can bring significant savings. For example, the Cisco® ONS 15454 with the ML-Series card allows convergence at layer 2, and further convergence at the optical layer, layer 1,brings greater savings. With an optically converged architecture, the network described above would save US$5.7 million in fiber installation costs alone—all of the services could be carried over a single fiber pair, requiring only 380 fiber miles. This is based on an estimate that the cost to lay each fiber mile is $3615, factoring in fiber, amplification and regeneration equipment, and trenching costs. The $5.7 million figure is derived by multiplying the extra fiber of 1580 miles required (1960 minus 380) by the per-mile fiber cost of $3615 (Figure 2).

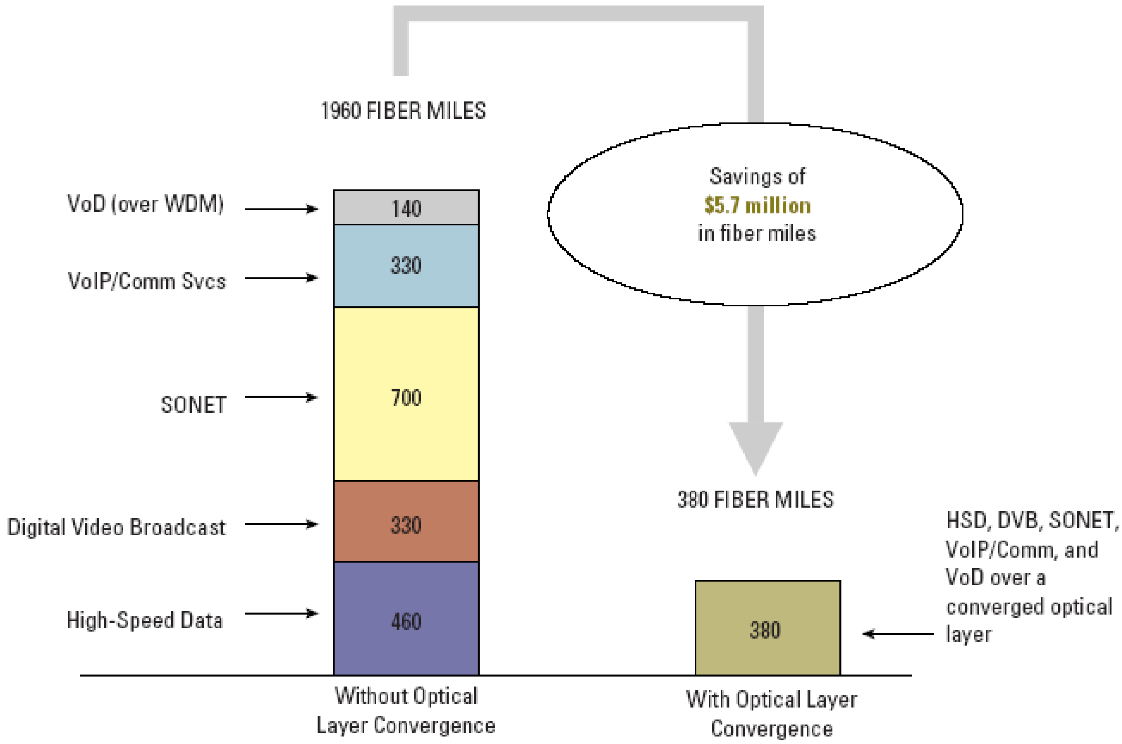

Figure 2 Optical Convergence Saves Fiber

In addition, management becomes increasingly complex with multiple networks, where each network has separate management systems and processes that must be maintained.

Rather than running each service application in a separate network silo, a flexible, adaptable converged infrastructure gracefully combines networks with different quality-of-service (QoS) requirements, bandwidth needs, protection, topology, and protocol requirements (Figure 3). A properly designed converged optical network is transparent for all higher-layer protocols that transit the network, and provides simple manageability of the optical layer.

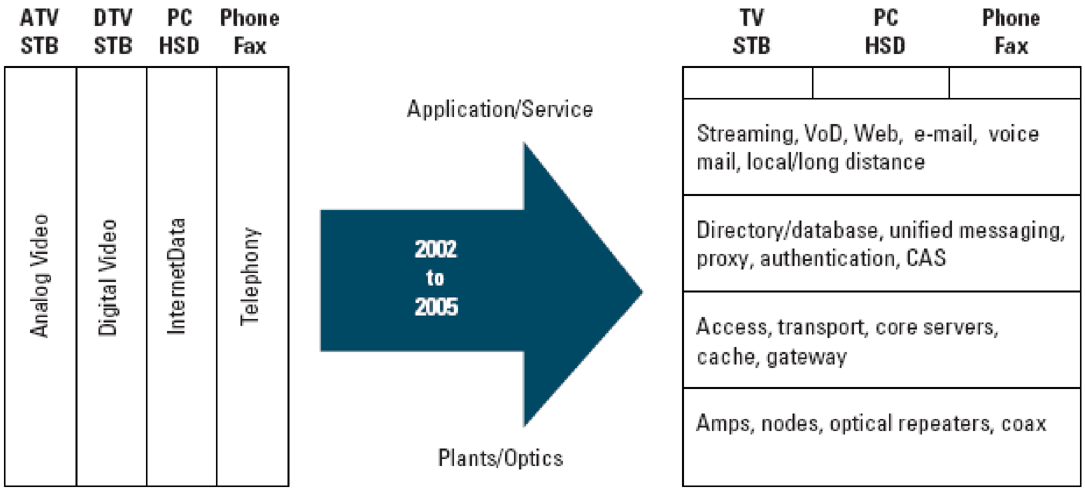

Figure 3 A Fundamental Challenge is Migration to a Converged Network

Cisco Optical Architecture Options

Cisco Systems® offers two primary architectures for implementing converged optical networks. The first architecture is an active, intelligent, auto-adjusting DWDM solution based on the Cisco ONS 15454 Multiservice Transport Platform (MSTP). The second architecture takes advantage of the fact that many client devices (multiservice provisioning platforms [MSPPs], switches, and routers, for example) can source ITU-grid optics directly. This architecture couples these native dense wavelength-division multiplexing (DWDM) sources with the DWDM components of the Cisco ONS 15216 product line (filters, amps, and dispersion compensation units (DCUs), for example). The emergence of ITU-grid pluggable optics for switches, routers, and optical transport platforms has made this architecture an attractive and lower-priced alternative to the MSTP-based design for less complex networks.

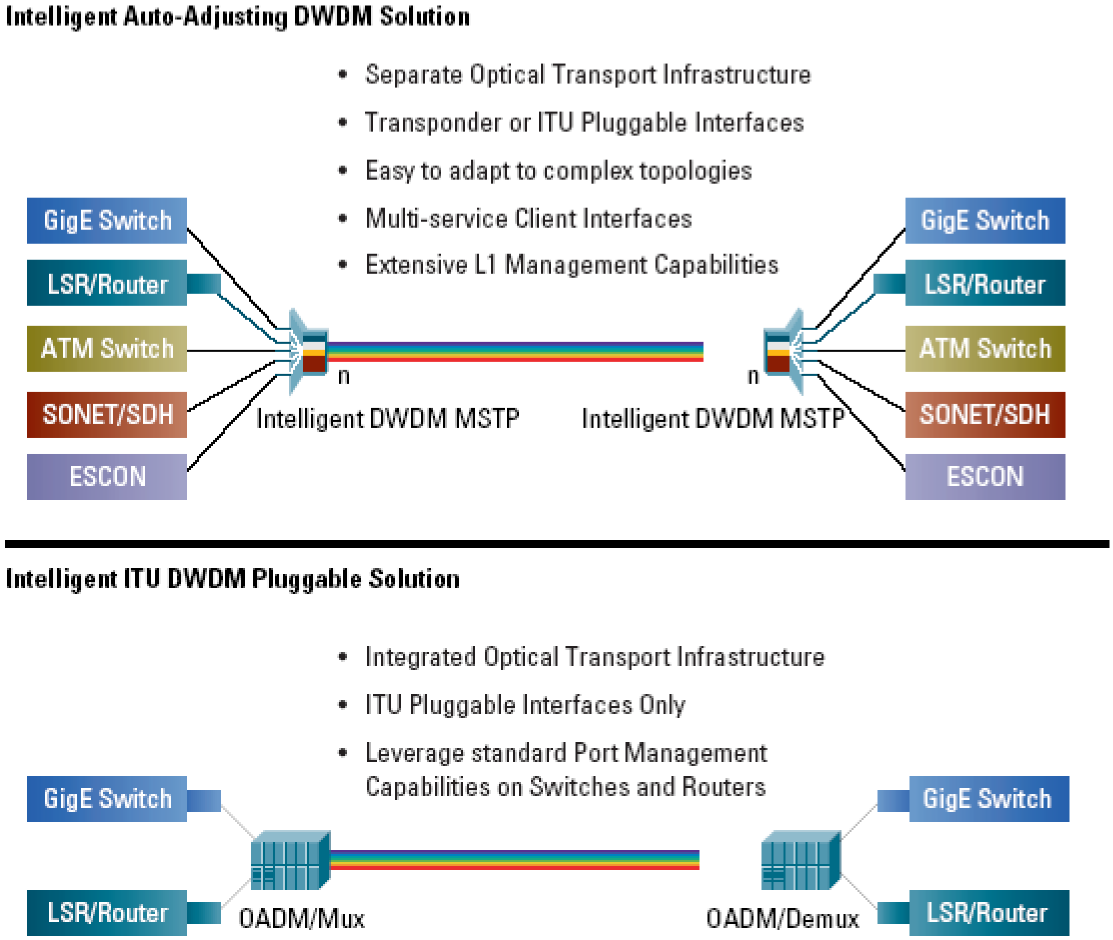

Figure 4 Optical Architecture Options

Intelligent Auto-Adjusting DWDM Solution

The Cisco ONS 15454 MSTP delivers an intelligent, auto-adjusting DWDM solution. It brings capital and operational efficiency by converging many disparate networks at multiple layers, including the optical layer. The Cisco ONS 15454 MSTP features all of the familiar capabilities of the Cisco ONS 15454 MSPP, delivering time-division multiplexing (TDM), Ethernet, and SONET services, but adds support for numerous standards-based, auto-adjusting wavelength services within the same platform. The converged network can deliver several optical wavelength services, as well as sub-rate multiplexing. Video transport is typically accomplished with unidirectional Gigabit Ethernet (GE) or 10-GE wavelengths. Data networks can be connected with GE, 10-GE, SONET/SDH, or other signals. Voice network transport can be handled with the standard DS-1 or DS-3 signals or with SONET/SDH connectivity. Storage networking can be delivered with 1-G and 2-G Fibre Channel interfaces, Fibre Connection (FICON), Enterprise Systems Connection (ESCON), or GE. Each wavelength can be customized as to bit rate, protocol, protection scheme, and direction (uni- or bidirectional).

The Cisco ONS 15454 MSTP is the optimal choice when a separate, dedicated optical platform is required to provide a demarcation between the optical and data domains, and is ideal for optical networks of significant complexity in terms of topology, distance, protection schemes, and management requirements

Technology Innovation

The Cisco ONS 15454 MSTP uses advanced photonics technologies, combined with innovative engineering, to address the unique requirements for both metro and regional networks:

- Scalable 1 to 32 wavelengths in a single network for superior cost-versus-growth trade-off.
- Transport of 150 Mbps to 10 Gbps per wavelength, as well as sub-rate multiplexing of TDM and data services, for maximum service flexibility. The Cisco ONS 15454 MSTP supports G.709 standard encapsulation, allowing wavelength transport independent of the transport protocols embedded in the wavelength.
- Transmission distances from tens to hundreds of kilometers (up to 600 km) without regeneration through the use of advanced amplification, dispersion compensation, and Forward Error Correction (FEC) technologies. Enhanced FEC on future products will extend this range further without the need for regeneration.
- “Plug-and-play” card architecture for complete flexibility in configuring DWDM network elements—hub nodes, terminal nodes, and optical add/drop nodes—within amplified or un-amplified networks.
- Flexible 1- to 32-channel optical add/drop multiplexer (OADM) detail, supporting both band and channel OADMs, for greater ease in network planning and reduced reliance on service forecasting.
- Integration of pre- and post-amplification.
- Multilevel service monitoring—SONET/SDH, a G.709 digital wrapper, and an optical service channel for unparalleled service reliability.
- Network topology discovery, automatic power control, automatic node setup, and wavelength path provisioning to simplify DWDM network management.

Asymmetrical and Bidirectional DWDM Transmission

The Cisco ONS 15454 MSTP supports both asymmetrical and bidirectional wavelength transmission. Wavelengths can be routed independently, allowing for asymmetrical and bidirectional applications (Figure 5).

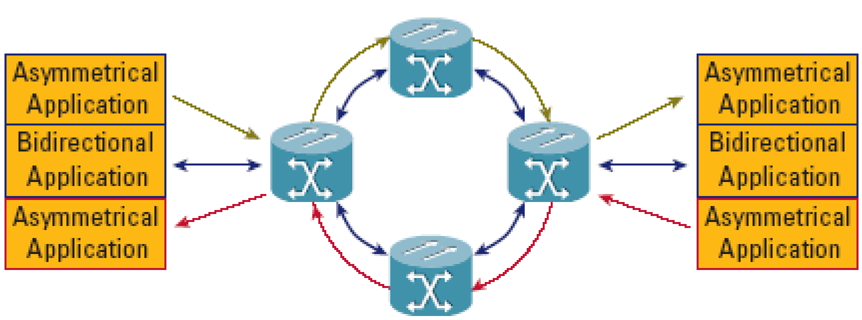

Figure 5 Asymmetrical and Bidirectional Applications Over a Converged MSTP Network

Wavelength Protection

The MSTP also offers optical path redundancy using three wavelength protection schemes. Y-cable protection protects against both wavelength path and transponder equipment failures, splitter protection reduces costs but only protects the optical path, and client protection provides protection of all fibers and equipment in both the working and protection path by allowing protection switching to be performed on the client device. Figure 6 highlights the protection schemes supported by the Cisco ONS 15454 MSTP.

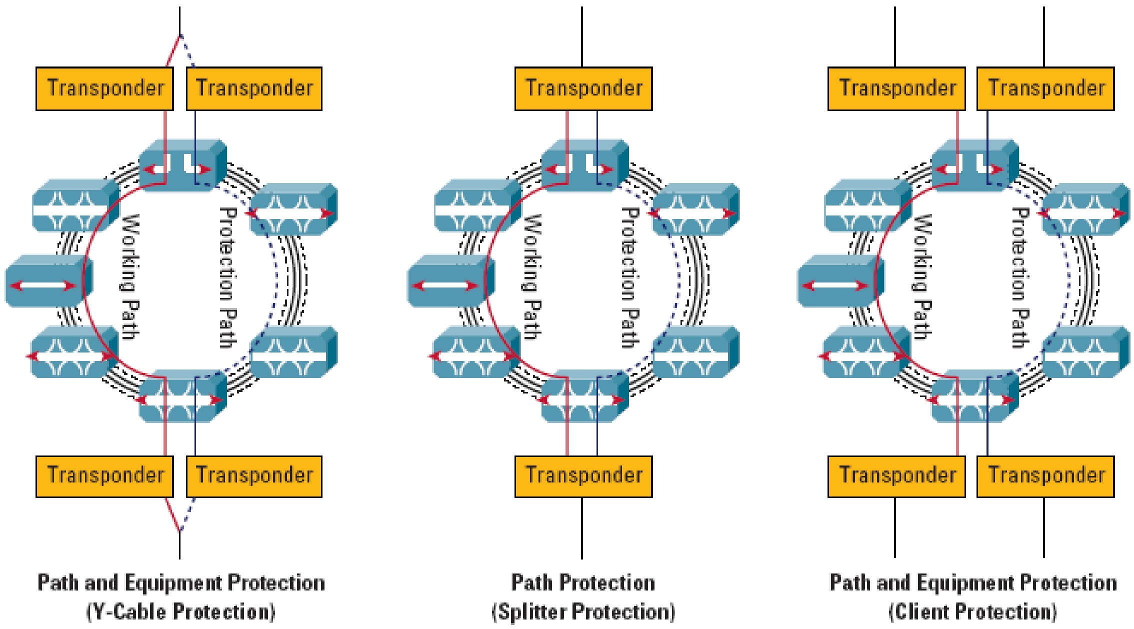

Figure 6 Protection Schemes on the Cisco ONS 15454 MSTP

New Advances for Managing Wavelengths in the Metro

Traditional DWDM solutions have rigid network architectures and require considerable manual interaction to manage, particularly when new sites are added or network capacity is upgraded. Traditional solutions are optimized for low-cost, per-bit, fixed topologies that cannot efficiently address the operational constraints of metro and regional networks. Metro networks face unique challenges, such as the inherent difficulty in predicting demand. Furthermore, complexities are involved in managing metro DWDM network architectures. These include dynamically adding and dropping wavelengths, controlling in real time the power across wavelengths on the fiber, and setting up and provisioning the DWDM network. The Cisco ONS 15454 MSTP deals with these complications through several innovations, including network topology discovery, wavelength path provisioning, automatic power control, and automatic network setup.

Network topology discovery, based on the industry-standard Open Shortest Path First (OSPF) protocol, enables the auto discovery of nodes in a layered network without the provisioning of neighboring nodes, and provides network topology information for amplifier power control and wavelength path provisioning.

Wavelength path provisioning enables the same "A-to-Z" provisioning that is widely used on the Cisco ONS 15454 MSTP for SONET/SDH circuits to be used for wavelength provisioning. The application tunes transponders to the correct wavelengths and prevents the provisioning of unavailable wavelengths.

Automatic power control dynamically monitors and controls optical power across all wavelengths. This enables constant per-channel power as channels are added and dropped and constant per-channel power under span loss degradation due to changing conditions, fiber aging, or laser aging. It also provides automatic provisioning of amplifier parameters (gain, for example) during network installation.

Finally, automatic network setup equalizes the optical power of all channels prior to amplification by controlling the ingress power level of each channel as it is added to the network, further simplifying network management.

Equalization is necessary because individual channels will hit the ingress point of the network at differing power levels, and may take different paths through the network and thus experience different amounts of attenuation—yet at any given point in the network, particularly prior to amplification, it is crucial that the individual wavelengths in the fiber be at a uniform power level.

<u>Lambda Management</u>

In order to perform lambda management, cable operators can make use of Cisco Transport Controller, a powerful craft interface tool resident on the Cisco ONS 15454 platform, and Cisco Transport Manager, a workstation-based element management system (EMS) capable of managing thousands of elements. Cisco Transport Controller and Cisco Transport Manager monitor the power of wavelengths as reported by the network elements. Typically, individual wavelength powers are monitored at ingress to or egress from the network, and composite signal power is measured as the composite signal enters and leaves active components. Monitoring of the composite signal is an efficient and cost-effective way to maintain the network—failure of an individual wavelength, once it is aggregated within a composite signal, is extremely unlikely. Typically, impairments to the system at the composite signal level will affect multiple wavelengths and be detectible via composite signal monitoring. Individual wavelength monitoring of a composite signal at every point in the network clutters the management interface, adds cost, and does not provide additional value. It is sufficient to monitor each individual wavelength as it enters and leaves the composite signal, and to monitor the health of the composite signal at all points between a given wavelength's ingress and egress from that composite signal.

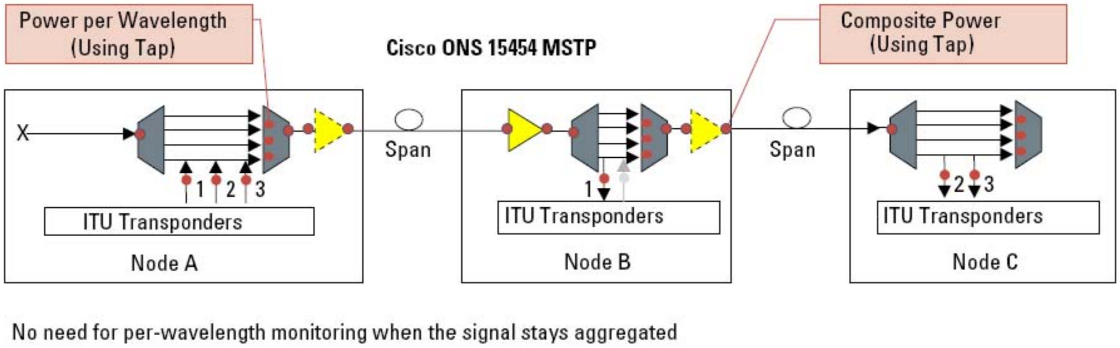

Figure 7 Monitoring DWDM Power Levels

The Cisco ONS 15454 MSTP also has the ability to set thresholds and triggers on monitored parameters at DWDM and electrical levels. This enables the system to proactively set off alarms or to take other pre-programmed actions when signals cross the pre-set thresholds.

To interface with other management systems, the Cisco ONS 15454 MSTP supports the following management protocols:

- TL1 from the network element with full fault, configuration, accounting, performance, and security (FCAPS) features
- Simple Network Management Protocol (SNMP), for fault management and Remote Monitoring (RMON) statistics, from the network element
- Common Object Request Broker Architecture (CORBA) gateway with full FCAPS from Cisco Transport Manager
- TL1 gateway with full FCAPS from Cisco Transport Manager
- SNMP gateway with trap forwarding from Cisco Transport Manager

Finally, multiple network management views are enabled through Cisco Transport Controller and Cisco Transport Manager, including lambda layer and fiber layer views, and the ability access the port level of Cisco ONS 15454 equipment to isolate problems. The lambda layer view provides a snapshot of logical connectivity and the health information between edge devices. The fiber layer view shows which lambdas are running on which fibers, filters, splitters, and amplifiers.

Cisco ONS 15216 Product Line

The Cisco ONS 15216 product line includes both unidirectional and bidirectional DWDM filters, as well as erbium-doped fiber amplifiers (EDFAs) and DCU units. The Cisco ONS 15216 product line is designed for solutions where the wavelength generation function is separate, such as when a pluggable ITU optical module is integrated within the switch or router itself.

A Cisco Catalyst® 4500 Series system, for example, configured with 1- or 10-G pluggable optical modules, enables 32 wavelengths to be delivered over the passive optical network. Voice, video (including VoD), and data services can be converged over this network with the switch or router providing a scalable and flexible aggregation point.

In Figure 8, primarily passive building blocks are used to build unidirectional distribution trees for VoD. The solution is scalable, enabling as few as two channels to be deployed on day one and scalable up to 32 DWDM channels.

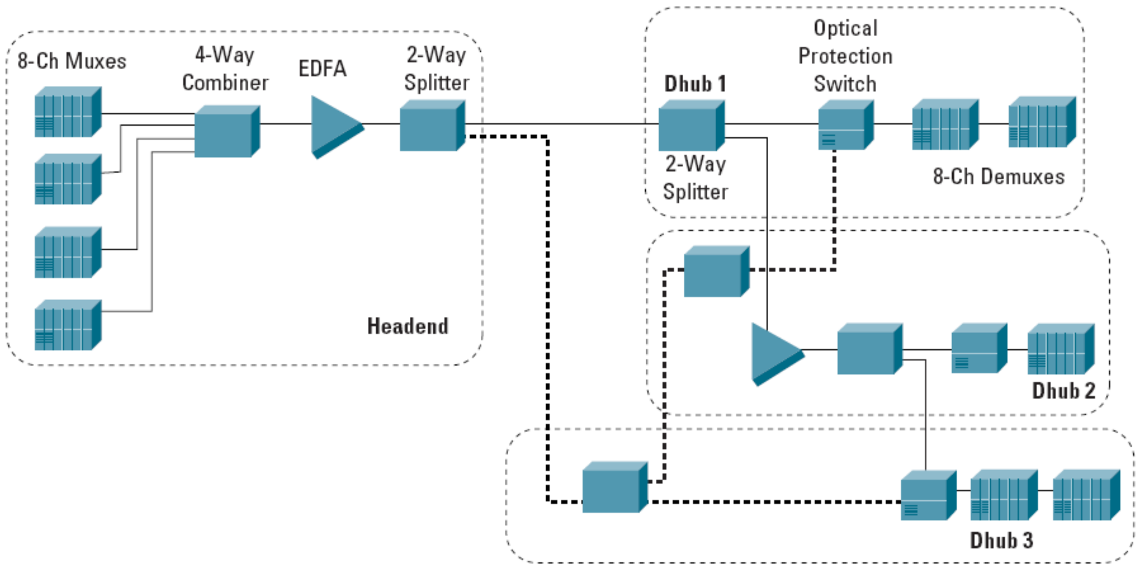

Figure 8 Example of an ITU DWDM Pluggable Optical Layer

Integrated ITU DWDM Pluggable Wavelength Management

Network administrators can manage the passive optical network through active components in the network, including the EDFAs and the 100-GHz OADMs. For example, the EDFAs implement automatic gain control and variable optical attenuators that allow software control of power at the input of the amplifier. Information from these active devices flow up to both Cisco Transport Controller and Cisco Transport Manager, allowing both management of and visibility into the network.

Optical Infrastructure Roadmap

The Cisco optical infrastructure roadmap is being implemented in three phases. The current phase, described in this document, includes the development of a robust network infrastructure. This includes an intelligent auto-adjusting DWDM network solution using the Cisco ONS 15454 MSTP or an integrated ITU DWDM pluggable solution via the Cisco ONS 15216 product family.

Phase 2, targeted for the second half of 2004, will provide increased network design flexibility and management. It will include improved aggregation for lower-cost transport with 10-Gigabit ITU pluggable optics moving to switches and routers. These pluggable optics will provide optical monitoring to improve manageability of the integrated solution.

Phase 2 will also focus on improved lambda distribution and flexibility through reconfigurable OADMs (ROADMs), allowing lambdas to be turned up remotely as traffic demands increase. As wavelengths may change at the transport layer via ROADMs, the EMS will maintain an association between the client port and the wavelength for management visibility.

Phase 3, targeted for the first half of 2005, will provide sub-rate multiplexing of multiple protocols (ESCON, IBM Fiber Connection [FICON], Fibre Channel, and GE) onto 2.5-G or 10-G lambdas, giving improved efficiencies and removing cost from the network.

Future of Optical Convergence

The combination of rich new capabilities included in Cisco platforms such as the ONS 15454 MSTP and the ONS 15216, combined with the ability to converge at multiple layers, is laying the groundwork for converged optical networks in the cable market. These will offer increased revenues from new services as well as the reduced CapEx and OpEx that naturally results from building and maintaining only a single optical network to meet all transport needs. Cisco is uniquely positioned to offer all of the components of the converged optical network.

For more information on Cisco networking solutions for the cable services network, visit www.cisco.com/placeholder or view the datasheets of the products featured in this paper:

- Cisco ONS 15454 http://www.cisco.com/en/US/products/hw/optical/ps2006/index.html
- Cisco ONS 15216 http://www.cisco.com/en/US/products/hw/optical/ps1996/index.html