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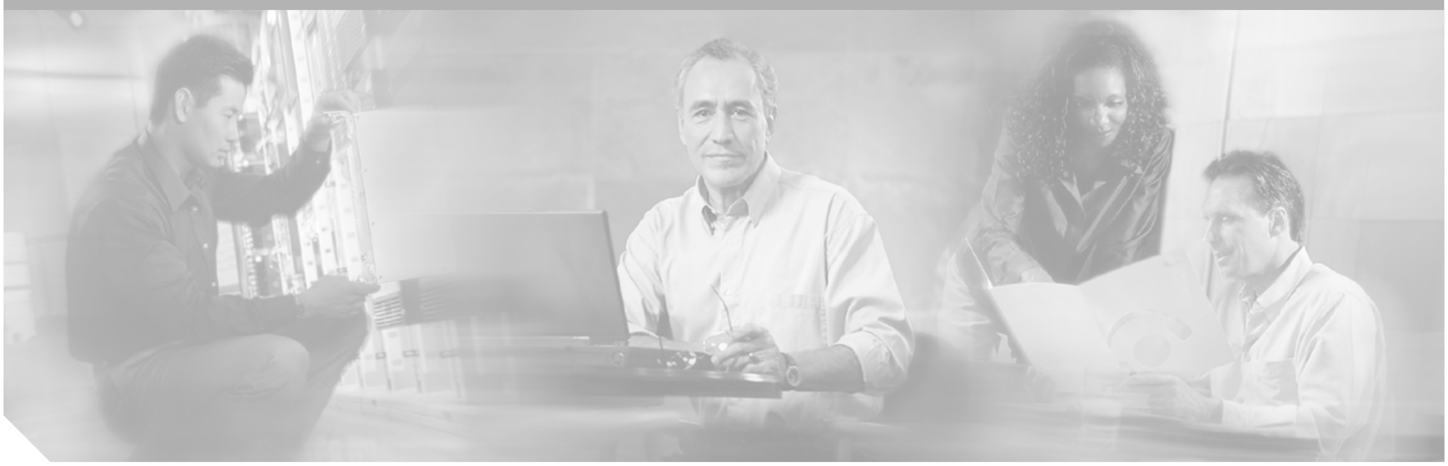

Cisco ONS 15454 DWDM Engineering and Planning Guide

Software and Product Release 7.x
Last updated: September 3, 2007

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CONTENTS

FIGURES

TABLES

About this Guide

This section explains the objectives, intended audience, and organization of this publication and describes the conventions that convey instructions and other information.

Note The terms "Unidirectional Path Switched Ring" and "UPSR" may appear in Cisco literature. These terms do not refer to using Cisco ONS 15xxx products in a unidirectional path switched ring configuration. Rather, these terms, as well as "Path Protected Mesh Network" and "PPMN," refer generally to Cisco's path protection feature, which may be used in any topological network configuration. Cisco does not recommend using its path protection feature in any particular topological network configuration.

Revision History

Date	Notes
03/19/2007	Revision History Table added for the first time
03/23/2007	Corrected product part numbers for the UBIC-V and UBIC-H DS3 cables.
08/20/2007	Updated About this Guide chapter.

This section provides the following information:

- Document Objectives
- Audience
- Related Documentation
- Document Conventions
- Where to Find Safety and Warning Information
- Obtaining Documentation
- Documentation Feedback
- Cisco Product Security Overview
- Obtaining Technical Assistance
- Obtaining Additional Publications and Information

Document Objectives

The Engineering and Planning Guide provides information about the features, engineering guidelines, applications, configurations, and technical specifications for a Cisco ONS 15454 DWDM node and network. Use this guide in conjunction with the appropriate publications listed in the Related Documentation section.

Audience

To use this publication, you should be familiar with Cisco or equivalent optical transmission and telecommunications equipment. The Engineering and Planning Guide is intended for network planners and engineers.

Related Documentation

Use this Cisco ONS 15454 DWDM Engineering and Planning Guide, R7.x in conjunction with the following referenced publications:

- *Cisco ONS 15454 DWDM Procedure Guide, Release 7.2*
- *Cisco ONS 15454 DWDM Reference Manual, Release 7.2*
- *Cisco ONS 15454 DWDM Troubleshooting Guide, Release 7.0.1*
- *Cisco ONS 15454 DWDM MetroPlanner Operations Guide, Release 7.0.1*
- *Release Notes for the Cisco ONS 15454 Release 7.2*
- *Release Notes for the Cisco ONS 15454 SDH Release 7.2*

Document Conventions

This publication uses the following conventions:

Convention	Application
boldface	Commands and keywords in body text.
italic	Command input that is supplied by the user.
[ ]	Keywords or arguments that appear within square brackets are optional.
{ x I x I x }	A choice of keywords (represented by x) appears in braces separated by vertical bars. The user must select one.
Ctrl	The control key. For example, where Ctrl + D is written, hold down the Control key while pressing the D key.
`screen font`	Examples of information displayed on the screen.

Convention	Application
`boldface screen font`	Examples of information that the user must enter.
< >	Command parameters that must be replaced by module-specific codes.

Note Means *reader take note*. Notes contain helpful suggestions or references to material not covered in the document.

Caution Means *reader be careful*. In this situation, the user might do something that could result in equipment damage or loss of data.

Warning **IMPORTANT SAFETY INSTRUCTIONS**

This warning symbol means danger. You are in a situation that could cause bodily injury. Before you work on any equipment, be aware of the hazards involved with electrical circuitry and be familiar with standard practices for preventing accidents. Use the statement number provided at the end of each warning to locate its translation in the translated safety warnings that accompanied this device. Statement 1071

SAVE THESE INSTRUCTIONS

Where to Find Safety and Warning Information

For safety and warning information, refer to the *Cisco Optical Transport Products Safety and Compliance Information* document that accompanied the product. This publication describes the international agency compliance and safety information for the Cisco ONS 15xxx systems. It also includes translations of the safety warnings that appear in the ONS 15xxx system documentation.

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Cisco documentation and additional literature are available on Cisco.com. Cisco also provides several ways to obtain technical assistance and other technical resources. These sections explain how to obtain technical information from Cisco Systems.

Cisco.com

You can access the most current Cisco documentation at this URL:

http://www.cisco.com/techsupport

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Cisco Optical Networking Product Documentation CD-ROM

Optical networking-related documentation, including Cisco ONS 15xxx product documentation, is available in a CD-ROM package that ships with your product. The Optical Networking Product Documentation CD-ROM is updated periodically and may be more current than printed documentation.

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Nonregistered Cisco.com users can order technical documentation from 8:00 a.m. to 5:00 p.m. (0800 to 1700) PDT by calling 1 866 463-3487 in the United States and Canada, or elsewhere by calling 011 408 519-5055. You can also order documentation by e-mail at tech-doc-store-mkpl@external.cisco.com or by fax at 1 408 519-5001 in the United States and Canada, or elsewhere at 011 408 519-5001.

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From this site, you will find information about how to:

- Report security vulnerabilities in Cisco products.
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- Register to receive security information from Cisco.

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http://www.cisco.com/go/psirt

To see security advisories, security notices, and security responses as they are updated in real time, you can subscribe to the Product Security Incident Response Team Really Simple Syndication (PSIRT RSS) feed. Information about how to subscribe to the PSIRT RSS feed is found at this URL:

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  An emergency is either a condition in which a system is under active attack or a condition for which a severe and urgent security vulnerability should be reported. All other conditions are considered nonemergencies.

- For Nonemergencies—psirt@cisco.com

In an emergency, you can also reach PSIRT by telephone:

- 1 877 228-7302
- 1 408 525-6532

Tip We encourage you to use Pretty Good Privacy (PGP) or a compatible product (for example, GnuPG) to encrypt any sensitive information that you send to Cisco. PSIRT can work with information that has been encrypted with PGP versions 2.*x* through 9.*x*.

Never use a revoked or an expired encryption key. The correct public key to use in your correspondence with PSIRT is the one linked in the Contact Summary section of the Security Vulnerability Policy page at this URL:

http://www.cisco.com/en/US/products/products_security_vulnerability_policy.html

The link on this page has the current PGP key ID in use.

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Submitting a Service Request

Using the online TAC Service Request Tool is the fastest way to open S3 and S4 service requests. (S3 and S4 service requests are those in which your network is minimally impaired or for which you require product information.) After you describe your situation, the TAC Service Request Tool provides recommended solutions. If your issue is not resolved using the recommended resources, your service request is assigned to a Cisco engineer. The TAC Service Request Tool is located at this URL:

http://www.cisco.com/techsupport/servicerequest

For S1 or S2 service requests, or if you do not have Internet access, contact the Cisco TAC by telephone. (S1 or S2 service requests are those in which your production network is down or severely degraded.) Cisco engineers are assigned immediately to S1 and S2 service requests to help keep your business operations running smoothly.

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Asia-Pacific: +61 2 8446 7411 (Australia: 1 800 805 227)
EMEA: +32 2 704 55 55
USA: 1 800 553-2447

For a complete list of Cisco TAC contacts, go to this URL:

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Definitions of Service Request Severity

To ensure that all service requests are reported in a standard format, Cisco has established severity definitions.

Severity 1 (S1)—An existing network is down, or there is a critical impact to your business operations. You and Cisco will commit all necessary resources around the clock to resolve the situation.

Severity 2 (S2)—Operation of an existing network is severely degraded, or significant aspects of your business operations are negatively affected by inadequate performance of Cisco products. You and Cisco will commit full-time resources during normal business hours to resolve the situation.

Severity 3 (S3)—Operational performance of the network is impaired, while most business operations remain functional. You and Cisco will commit resources during normal business hours to restore service to satisfactory levels.

Severity 4 (S4)—You require information or assistance with Cisco product capabilities, installation, or configuration. There is little or no effect on your business operations.

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  http://www.cisco.com/ipj

- Networking products offered by Cisco Systems, as well as customer support services, can be obtained at this URL:

  http://www.cisco.com/en/US/products/index.html

- Networking Professionals Connection is an interactive website for networking professionals to share questions, suggestions, and information about networking products and technologies with Cisco experts and other networking professionals. Join a discussion at this URL:

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Overview

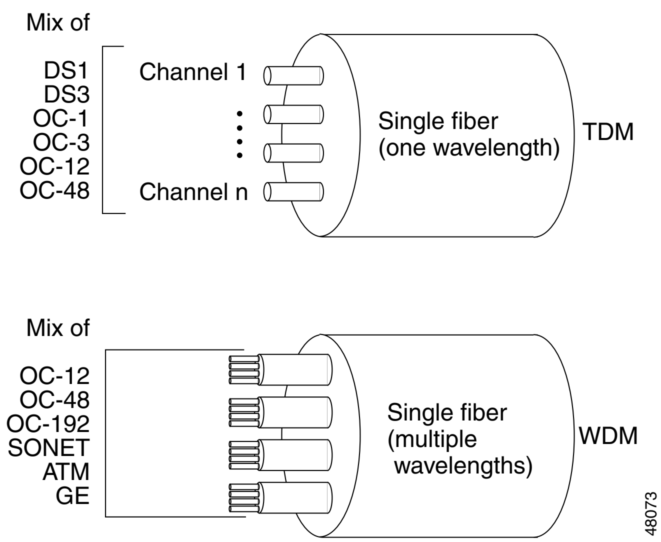
This chapter provides an overview of dense wavelength division multiplexing (DWDM) systems.

The following topics are covered in this chapter:

1.1 Time Division Multiplexing Versus Wave Division Multiplexing

SONET time division multiplexing (TDM) multiplexes synchronous and asynchronous signals to a single higher bit rate for single-wavelength transmission over fiber. Before being multiplexed, source signals might be converted from electrical to optical, or from optical to electrical and back to optical. Wave division multiplexing (WDM) maps multiple optical signals to individual wavelengths and multiplexes the wavelengths over a single fiber. Another difference between TDM and WDM is that WDM can carry multiple protocols without a common signal format, whereas SONET cannot. Some of the key differences between TDM and WDM interfaces are illustrated in Figure 1-1.

Figure 1-1 TDM and WDM Interfaces



Bandwidth, the chief driver in the long-haul market, is also a big driver in metropolitan area, access, and large enterprise networks. In these types of networks, additional applications drive the demand for bandwidth, including storage area networks (SANs), which make possible the serverless office, consolidation of data centers, and real-time transaction processing backup.

1.2 Wavelength Division Multiplexing Versus Dense Wavelength Division Multiplexing

In a WDM system, each of the wavelengths is launched into the fiber, and the signals are demultiplexed at the receiving end. Like TDM, the resulting capacity is an aggregate of the input signals, but WDM carries each input signal independently of the others. This means that each channel has its own dedicated bandwidth and all signals arrive at the same time, rather than being broken up and carried in time slots.

The difference between WDM and dense wavelength division multiplexing (DWDM) is one of degree only. DWDM spaces the wavelengths more closely than WDM, and therefore DWDM has a greater overall capacity. The full capacity is not precisely known, and probably has not been reached.

DWDM can amplify all the wavelengths at once without first converting them to electrical signals and can carry signals of different speeds and types simultaneously and transparently over fiber, meaning DWDM provides protocol and bit rate independence.

From both technical and economic perspectives, potentially unlimited transmission capacity is the most obvious advantage of DWDM technology. Not only can the current investment in fiber plant be preserved, but it can also be optimized by a factor of at least 32. As demands change, more capacity can be added, either by simple equipment upgrades or by increasing the number of lambdas on the fiber, without expensive upgrades. Capacity can be obtained for the cost of the equipment, and the existing fiber plant investment is retained.

In addition to bandwidth, DWDM has several key advantages:

- Transparency—Because DWDM is a physical layer architecture, it can transparently support both TDM and data formats such as asynchronous transfer mode (ATM), Gigabit Ethernet, Enterprise System Connection (ESCON), and Fibre Channel with open interfaces over a common physical layer.
- Scalability—DWDM can leverage the abundance of dark fiber in many metropolitan area and enterprise networks to quickly meet demand for capacity on point-to-point links and on spans of existing SONET/SDH rings.
- Dynamic provisioning—Fast, simple, and dynamic provisioning of network connections give providers the ability to provide high-bandwidth services in days rather than months.

For more information, refer to *Introduction to DWDM Technology* (http://www.cisco.com/univercd/cc/td/doc/product/mels/cm1500/dwdm/index.htm).

1.3 Value of DWDM in the Metropolitan Area Network

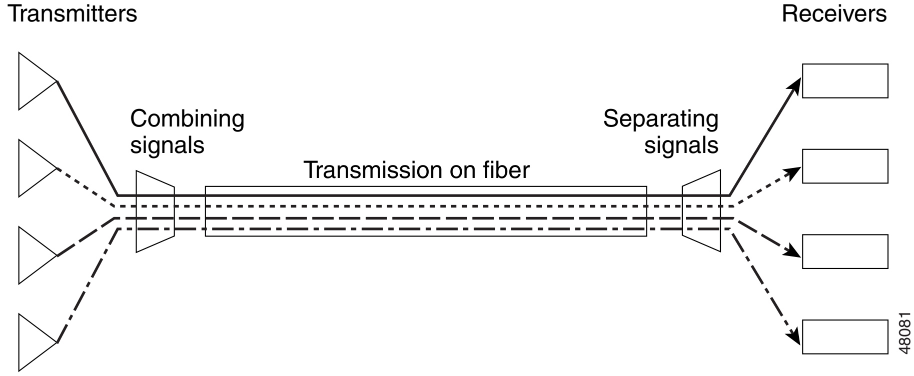
DWDM has been very successful in the network backbone. It was first deployed on long-haul routes in a time of fiber scarcity. Then the equipment savings made it the solution of choice for new long-haul routes, even when ample fiber was available. While DWDM can relieve fiber exhaustion in the metropolitan are network (MAN), its value in this market extends beyond the fiber advantage. DWDM provides fast and flexible provisioning of protocol transparent and bit-rate transparent, data-centric, protected services, along with new and higher-speed services at less cost.

The need to provision services of varying types in a rapid and efficient manner is a distinguishing characteristic of the metropolitan area networks. With SONET, which is the foundation of the vast majority of existing MANs, service provisioning is a lengthy and complex process. Network planning and analysis, add/drop multiplexer (ADM) provisioning, digital cross-connect system (DCS) reconfiguration, path and circuit verification, and service creation can take several weeks. With DWDM equipment installed, provisioning a new service can be as simple as turning on another lightwave in an existing fiber pair.

1.4 DWDM System Functions

At its core, DWDM involves a small number of physical-layer functions. These are depicted in Figure 1-2, which shows a DWDM schematic for four channels. Each optical channel occupies its own wavelength.

Figure 1-2 DWDM Functional Schematic



A DWDM system performs the following primary functions:

- Generating the signal—The source, a solid-state laser, must provide stable light within a specific, narrow bandwidth that carries digital data modulated as an analog signal.
- Combining the signals—Modern DWDM systems employ multiplexers to combine the signals. There is some inherent loss associated with multiplexing and demultiplexing. This loss is dependent on the number of channels but can be mitigated with optical amplifiers, which boost all the wavelengths at once without electrical conversion.
- Transmitting the signals—The effects of crosstalk and optical signal degradation or loss must be considered in fiber-optic transmission. Controlling variables such as channel spacing, wavelength tolerance, and laser power levels can minimize these effects. The signal might need to be optically amplified over a transmission link.
- Separating the received signals—At the receiving end, the multiplexed signals must be separated out.
- Receiving the signals—The demultiplexed signal is received by a photodetector.

In addition to these functions, a DWDM system must also be equipped with client-side interfaces to receive the input signal. The client-side interface function can be performed by transponders. Interfaces on the DWDM side connect the optical fiber to DWDM systems.

1.5 DWDM Components and Operation

DWDM is a core technology in an optical transport network. The essential components of DWDM can be classified by their place in the network:

- On the transmit side, lasers with precise, stable wavelengths
- On the link, optical fiber that exhibits low loss and transmission performance in the relevant wavelength spectra, in addition to flat-gain optical amplifiers to boost the signal on longer spans
- On the receive side, photodetectors and optical demultiplexers using thin film filters or diffracting elements
- Optical add/drop multiplexers and optical cross-connect components

These components and others, along with their underlying technologies, are discussed in the following sections.

1.5.1 Optical Fibers

The main job of optical fibers is to guide lightwaves with a minimum of attenuation (loss of signal). Optical fibers are composed of fine threads of glass in layers, called the core and cladding, that can transmit light at about two-thirds the speed of light in a vacuum. Transmission of light in optical fiber is commonly explained using the principle of total internal reflection. With this phenomenon, 100 percent of the light that strikes a surface is reflected. By contrast, a mirror reflects about 90 percent of the light that strikes it.

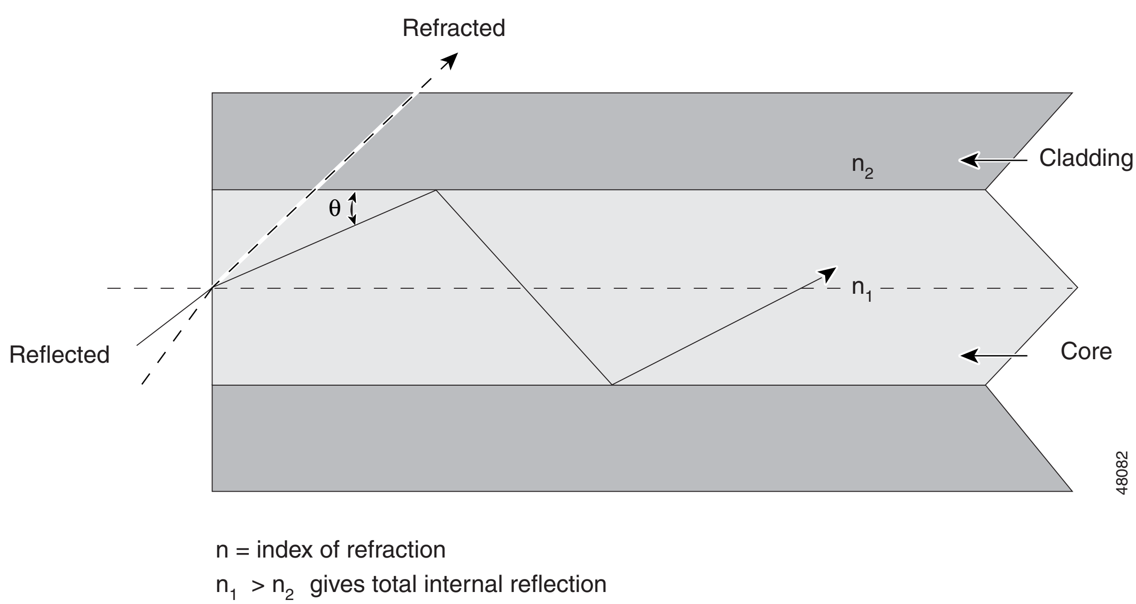
Light is either reflected (it bounces back) or refracted (its angle is altered while passing through a different medium) depending on the angle of incidence, which is the angle at which light strikes the interface between more optically dense material and optically thinner material.

Total internal reflection happens when the following conditions are met:

- Beams pass from a more dense to a less dense material. The difference between the optical density of a given material and a vacuum is the material's refractive index.
- The incident angle is less than the critical angle. The critical angle is the maximum angle of incidence at which light stops being refracted and is instead totally reflected.

The principle of total internal reflection within a fiber core is illustrated in Figure 1-3. The core has a higher refractive index than the cladding, allowing the beam that strikes the surface at less than the critical angle to be reflected. The second beam does not meet the critical angle requirement and is refracted.

Figure 1-3 Principle of Total Internal Reflection

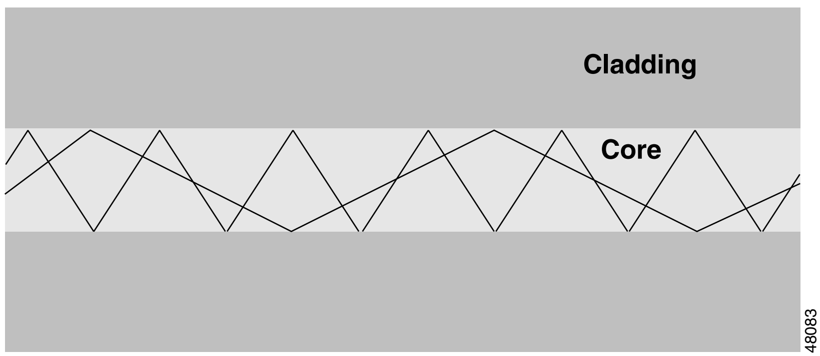


The core and the cladding are mixed with specific elements, called dopants, to adjust their refractive indices. The difference between the refractive indices of the two materials causes most of the transmitted light to bounce off the cladding and stay within the core. The critical angle requirement is met by controlling the angle at which the light is injected into the fiber. Two or more layers of protective coating around the cladding ensure that the glass can be handled without damage.

1.5.1.1 Multimode Fiber

Two general categories of optical fiber are in use today, multimode and single-mode. Multimode fiber has a larger core than single-mode fiber. It gets its name from the fact that numerous modes, or light rays, can be carried simultaneously through the waveguide. Figure 1-4 shows an example of light transmitted in the first type of multimode fiber, called step-index. Step-index refers to the fact that there is a uniform index of refraction throughout the core; thus there is a step in the refractive index where the core and cladding interface. Notice that the two modes must travel different distances to arrive at their destinations. The disparity between the arrival times of the light rays is called modal dispersion. Modal dispersion results in poor signal quality at the receiving end and ultimately limits the transmission distance, which is why multimode fiber is not used in wide-area applications.

Figure 1-4 Reflected Light in Step-Index Multimode Fiber

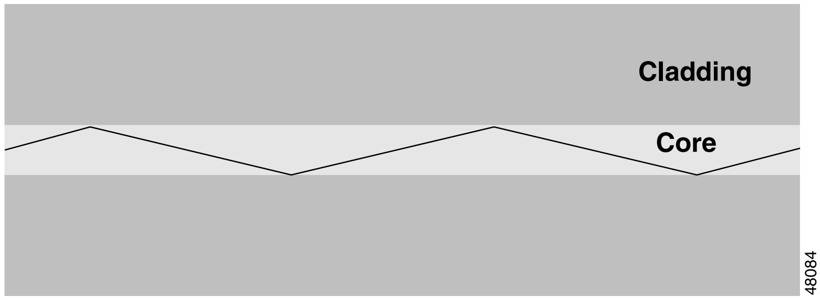


To compensate for the dispersion drawback of step-index multimode fiber, graded-index fiber was invented. Graded-index refers to the fact that the refractive index of the core is graded; it gradually decreases from the center of the core outward. The higher refraction at the center of the core slows the speed of some light rays, allowing all the rays to reach their destination at about the same time and reducing modal dispersion.

1.5.1.2 Single-Mode Fiber

The second general type of fiber, single-mode, has a much smaller core that allows only one mode of light at a time through the core (see Figure 1-5). As a result, the fidelity of the signal is better retained over longer distances, and modal dispersion is greatly reduced. These factors contribute to a higher bandwidth capacity than multimode fiber can accommodate. For its large information-carrying capacity and low intrinsic loss, single-mode fibers are preferred for longer distance and higher bandwidth applications, including DWDM.

Figure 1-5 ***Reflected Light in Single-Mode Fiber***



1.5.1.3 Single-Mode Fiber Designs

The three principle types of single-mode fiber and their ITU-T specifications are:

- Nondispersion-shifted fiber (NDSF), ITU-T G.652
- Dispersion-shifted fiber (DSF), ITU-T G.653
- Nonzero dispersion-shifted fiber (NZ-DSF), ITU-T G.655

There are four windows within the infrared spectrum that have been exploited for fiber transmission. The first window, near 850 nm, was used almost exclusively for short-range, multimode applications. Nondispersion-shifted fibers, commonly called standard single-mode (SM) fibers, were designed for use in the second window, near 1310 nm. To optimize the fiber's performance in this window, the fiber was designed so that chromatic dispersion would be close to zero near the 1310-nm wavelength.

As optical fiber use became more common and the needs for greater bandwidth and distance increased, a third window, near 1550 nm, was exploited for single-mode transmission. Manufacturers developed dispersion-shifted fiber for the third window, or C-band. The fourth window is L-band, near 1600 nm; it was added to increase the band for C-band applications.

The third type of fiber, nonzero dispersion-shifted fiber, is designed specifically to meet the needs of DWDM applications. The aim of this design is to make the dispersion low in the 1550-nm region, but not zero. This strategy effectively introduces a controlled amount of dispersion, which counters nonlinear effects such as four-wave mixing that can hinder the performance of DWDM systems.

Table 1-1 provides dispersion ratings for three commonly used fiber types. Two general types of dispersion that affect DWDM systems, chromatic dispersion and polarization mode dispersion (PMD), are provided for each fiber type.

Table 1-1 ***Fiber Dispersion Characteristics***

Fiber Type	Manufacturer	Chromatic Dispersion [ps/(nm x km)]	PMD (ps/km$^{1/2}$)
SMF-28	Corning	17.0	<0.2 (0.1 typical)
E-LEAF	Corning	2.0 – 6.0 (1530 – 1565)	<0.1 (0.04 typical)
TrueWave RS	Lucent	2.6 – 6.0 (1530 – 1565)	<0.1

1.5.2 Transmission Challenges

Transmission of light in optical fiber presents several challenges that can be grouped into three categories:

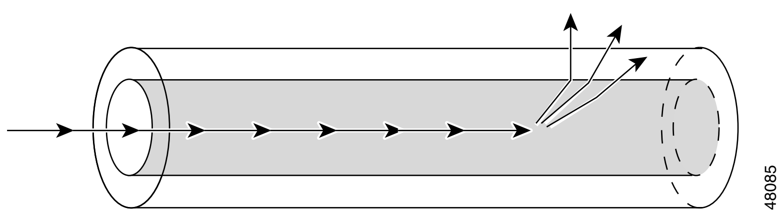
- Attenuation—Decay of signal strength, or loss of light power, as the signal propagates through the fiber.
- Chromatic dispersion—Spreading of light pulses as they travel down the fiber.
- Nonlinearity—Cumulative effects from the interaction of light with the material through which it travels, resulting in changes in the lightwave and interactions between lightwaves.

Each of these effects has several causes, not all of which affect DWDM. The discussion in the following sections addressesthe transmission challenges relevant to DWDM.

1.5.2.1 Attenuation

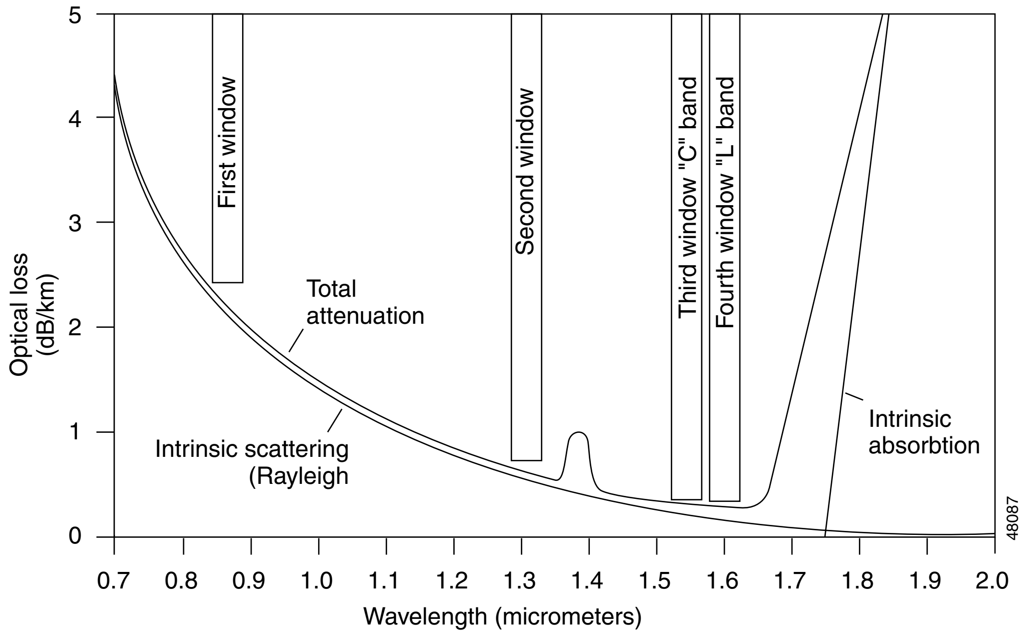
Attenuation in optical fiber is caused by intrinsic factors, primarily scattering and absorption, and by extrinsic factors, including stress from the manufacturing process, the environment, and physical bending. The most common form of scattering, Rayleigh scattering, is caused by small variations in the density of glass as it cools. These variations are smaller than the wavelengths used and therefore act as scattering objects (see Figure 1-6). Scattering affects short wavelengths more than long wavelengths and limits the use of wavelengths below 800 nm.

Figure 1-6 Rayleigh Scattering



The primary factors affecting attenuation in optical fibers are the length of the fiber and the wavelength of the light. Figure 1-7 shows the loss in decibels per kilometer (dB/km) by wavelength from Rayleigh scattering, intrinsic absorption, and total attenuation from all causes.

Figure 1-7 Total Attenuation Curve

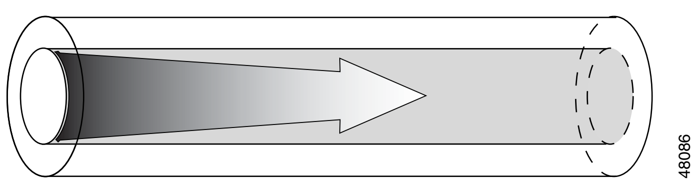


Attenuation in fiber is compensated primarily through the use of optical amplifiers.

1.5.2.2 Absorption

The intrinsic properties of the material itself, the impurities in the glass, and any atomic defects in the glass cause attenuation due to absorption. These impurities absorb the optical energy, causing the light to become dimmer (see Figure 1-8). While Rayleigh scattering is important at shorter wavelengths, intrinsic absorption is an issue at longer wavelengths and increases dramatically above 1700 nm. However, absorption due to water peaks introduced in the fiber manufacturing process is being eliminated in some new fiber types.

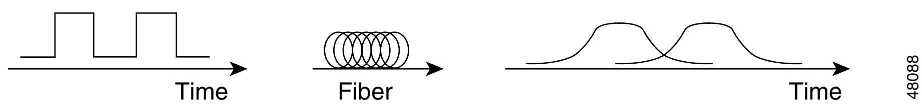
Figure 1-8 Absorption



1.5.2.3 Dispersion

Dispersion is the spreading of light pulses as they travel down optical fiber. Dispersion results in distortion of the signal (see Figure 1-9), which limits the bandwidth of the fiber.

Figure 1-9 ***Principle of Dispersion***



Two general types of dispersion affect DWDM systems: chromatic dispersion and PMD. Chromatic dispersion is linear and PMD is nonlinear.

Chromatic dispersion occurs because different wavelengths propagate at different speeds. The effect of chromatic dispersion increases as the square of the bit rate. In single-mode fiber, chromatic dispersion has two components, material dispersion and waveguide dispersion.

Material dispersion occurs when wavelengths travel at different speeds through the material. A light source, no matter how narrow, emits several wavelengths within a range. Thus, when this range of wavelengths travels through a medium, each individual wavelength arrives at a different time.

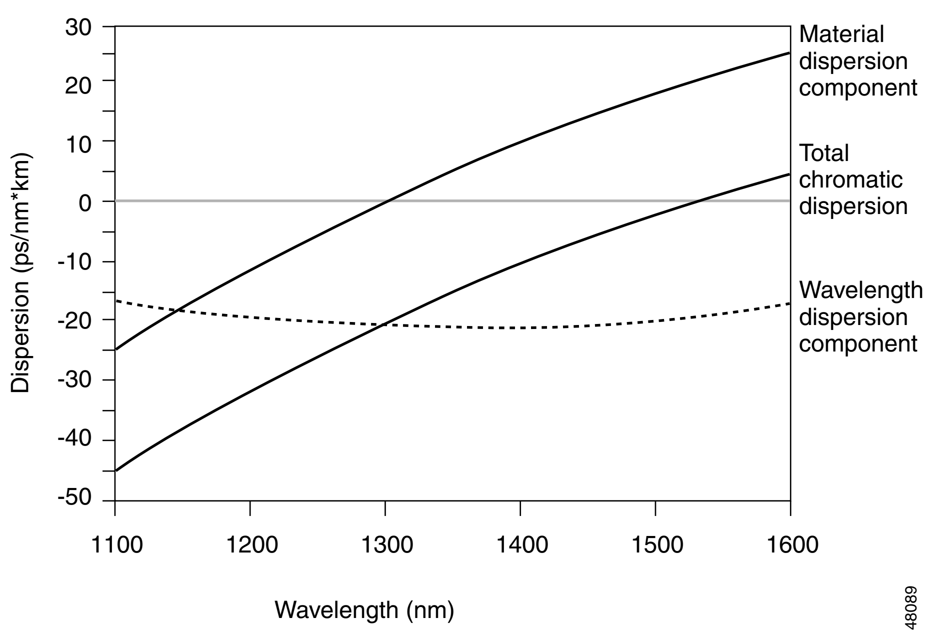
The second component of chromatic dispersion, waveguide dispersion, occurs because of the different refractive indices of the fiber's core and cladding. The effective refractive index varies with wavelength, as follows:

- At short wavelengths, the light is well confined within the core. Thus the effective refractive index is close to the refractive index of the core material.
- At medium wavelengths, the light spreads slightly into the cladding. This decreases the effective refractive index.
- At long wavelengths, much of the light spreads into the cladding. This brings the effective refractive index very close to that of the cladding.

This result of waveguide dispersion is a propagation delay in one or more of the wavelengths.

Total chromatic dispersion, along with its components, is plotted by wavelength in Figure 1-10 for dispersion-shifted fiber. For nondispersion-shifted fiber, the zero dispersion wavelength is 1310 nm.

Figure 1-10 ***Chromatic Dispersion***



Though chromatic dispersion is generally not an issue at speeds below OC-48, it does increase with higher bit rates due to the spectral width required. New types of zero-dispersion-shifted fibers greatly reduce the effects of chromatic dispersion; it can also be mitigated with dispersion compensators.

Most single-mode fibers support two perpendicular polarization modes, a vertical one and a horizontal one. Because these polarization states are not maintained, an interaction between the pulses causes a smearing of the signal. Polarization mode dispersion (PMD) is caused by the quality of the fiber shape or from external stresses. Because stress can vary over time, PMD is subject to change over time, unlike chromatic dispersion. PMD is generally not a problem at speeds below OC-192.

1.5.2.4 Other Nonlinear Effects

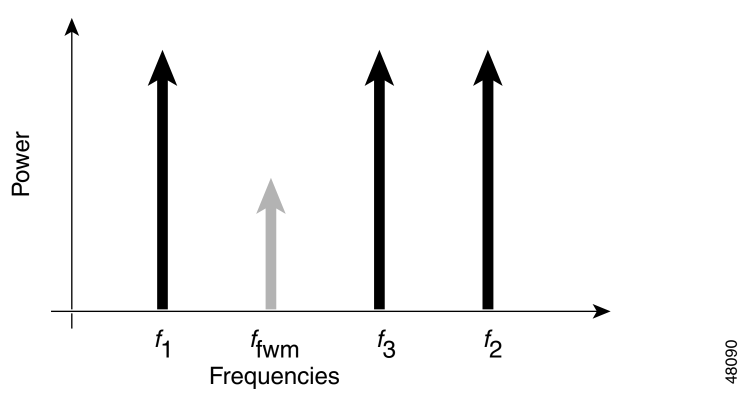
In addition to PMD, there are other nonlinear effects. Because nonlinear effects tend to manifest themselves when optical power is very high, they become important in DWDM.

Linear effects such as attenuation and dispersion can be compensated, but nonlinear effects accumulate. They are the fundamental limiting mechanisms to the amount of data that can be transmitted in optical fiber. The most important types of nonlinear effects are stimulated Brillouin scattering, stimulated Raman scattering, self-phase modulation, and four-wave mixing. In DWDM, four-wave mixing is the most critical of these types.

Raman and Brillouin scattering are inelastic processes in which part of the power is lost from an optical wave and absorbed by the transmission medium. The remaining energy is then reemitted as a wave of lower frequency. Raman and Brillouin scattering processes can become nonlinear in optical fibers due to the high optical intensity in the core and the long interaction lengths afforded by these waveguides. Stimulated Raman scattering (SRS) and stimulated Brillouin scattering (SBS) occur when the light launched into the fiber exceeds a threshold power level for each process. Self-phase modulation is a fiber nonlinearity caused by the nonlinear index of glass refraction. The index of refraction varies with optical power level, causing a frequency chirp that interacts with the fiber's dispersion to broaden the pulse.

Four-wave mixing is caused by the nonlinear nature of the refractive index of the optical fiber. Nonlinear interactions among different DWDM channels create sidebands that can cause interchannel interference. In Figure 1-11 three frequencies interact to produce a fourth frequency, resulting in crosstalk and signal-to-noise degradation.

Figure 1-11 Four-Wave Mixing



The effect of four-wave mixing is to limit the channel capacity of a DWDM system. Four-wave mixing cannot be filtered out, either optically or electrically, and increases with the length of the fiber. NZ-DSF takes advantage of the fact that a small amount of chromatic dispersion can be used to mitigate four-wave mixing.

1.5.3 Light Emitters and Detectors

Light emitters and light detectors are active devices at opposite ends of an optical transmission system. Light sources, or light emitters, are transmit-side devices that convert electrical signals to light pulses. The process of this conversion, or modulation, can be accomplished by externally modulating a continuous wave of light or by using a device that can generate modulated light directly. Light detectors perform the opposite function of light emitters. They are receive-side opto-electronic devices that convert light pulses into electrical signals.

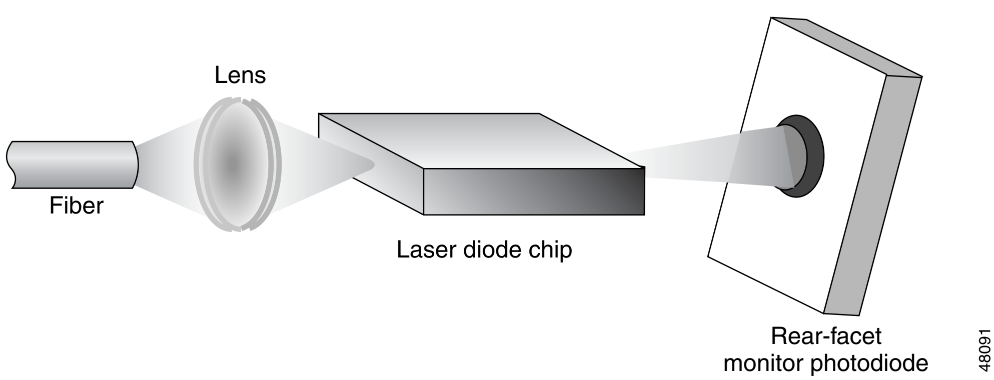
The light source used in the design of a system is an important consideration because it can be one of the most costly elements. Its characteristics are often a strong limiting factor in the final performance of the optical link. Light emitting devices used in optical transmission must be compact, monochromatic, stable, and long-lasting.

Note Monochromatic is a relative term; in practice monochromatic light-emitting devices are only light sources within a certain range. Stability of a light source is a measure of its intensity and wavelength.

Two general types of light emitting devices are used in optical transmission, light-emitting diodes (LEDs) and laser diodes, or semiconductor lasers. LEDs are relatively slow devices, suitable for use at speeds of less than 1 Gb. LEDs exhibit a relatively wide spectrum width, and they transmit light in a relatively wide cone. These inexpensive devices are often used in multimode fiber communications. Semiconductor lasers, on the other hand, have performance characteristics better suited to single-mode fiber applications.

Figure 1-12 shows the general principles of launching laser light into fiber. The laser diode chip emits light in one direction to be focused by the lens onto the fiber; in the other direction the light is focused onto a photodiode. The photodiode, which is angled to reduce back reflections into the laser cavity, monitors the output of the lasers and provides feedback so that adjustments can be made.

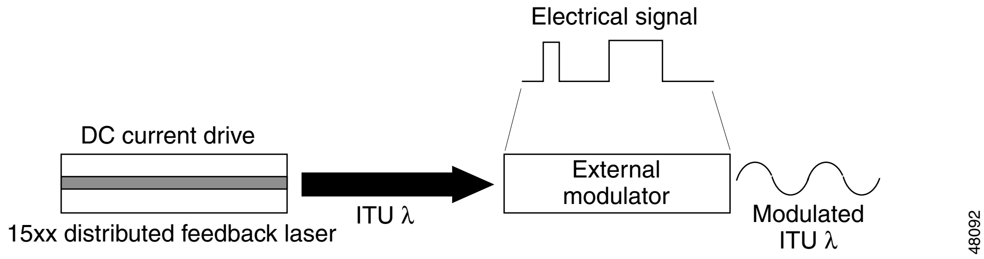
Figure 1-12 Typical Laser Design



Requirements for lasers include precise wavelength, narrow spectrum width, sufficient power, and control of chirp, which is the change in frequency of a signal over time. Semiconductor lasers satisfy the first three requirements. Chirp, however, can be affected by the means used to modulate the signal.

In directly modulated lasers, light is modulated internally to represent the digital data. With external modulation, an external device does the modulation. When semiconductor lasers are directly modulated, chirp can become a limiting factor at high bit rates (above 10 Gbps). External modulation, on the other hand, helps to limit chirp. The external modulation scheme is depicted in Figure 1-13.

Figure 1-13 External Modulation of a Laser



Two types of semiconductor lasers are widely used, monolithic Fabry-Perot lasers, and distributed feedback (DFB) lasers. The latter type is particularly well suited for DWDM applications, because it emits a nearly monochromatic light, is capable of high speeds, has a favorable signal-to-noise ratio, and has superior linearity. DFB lasers also have center frequencies in the region around 1310 nm and from 1520 to 1565 nm. The latter wavelength range is compatible with EDFAs.

On the receive end, it is necessary to recover the signals transmitted at different wavelengths on the fiber. Because photodetectors are by nature wideband devices, the optical signals are demultiplexed before reaching the detector.

Two types of photodetectors are widely deployed, the positive-intrinsic-negative (PIN) photodiode and the avalanche photodiode (APD). PIN photodiodes work on principles similar to, but in the reverse of, LEDs. That is, light is absorbed rather than emitted, and photons are converted to electrons in a 1:1 relationship. APDs are similar devices to PIN photodiodes, but provide gain through an amplification process; one photon acting on the device releases many electrons. PIN photodiodes have many advantages, including low cost and reliability, but APDs have higher receive sensitivity and accuracy.

However, APDs are more expensive than PIN photodiodes, they can have very high current requirements, and they are temperature sensitive.

1.5.4 Optical Amplifiers

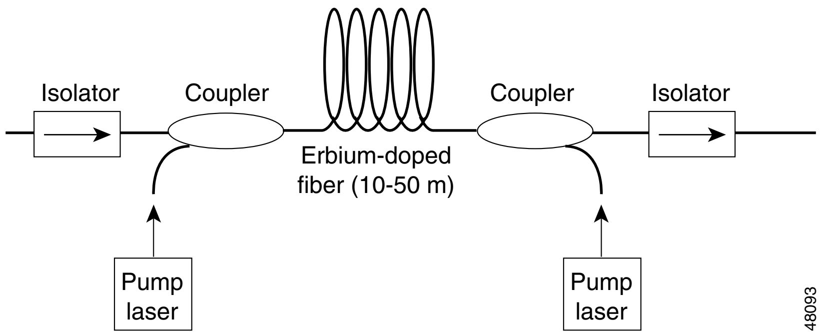
Due to attenuation, there are limits to how long a fiber segment can propagate a signal with integrity before it has to be regenerated. Before the arrival of optical amplifiers (OAs), there had to be a repeater for every signal transmitted. The OA has made it possible to amplify all the wavelengths at once and without optical-electrical-optical (OEO) conversion. Optical amplifiers also can be used to boost signal power after multiplexing or before demultiplexing, both of which can introduce loss into the system.

1.5.4.1 Erbium-Doped Fiber Amplifier

By making it possible to carry the large loads that DWDM is capable of transmitting over long distances, the erbium-doped fiber amplifier (EDFA) was a key enabling technology.

Erbium is a rare-earth element that can emit light around 1.54 micrometers, which is the low-loss wavelength for optical fibers used in DWDM. Figure 1-14 shows a simplified diagram of an EDFA. A weak signal enters the erbium-doped fiber, into which light at 980 nm or 1480 nm is injected using a pump laser. This injected light stimulates the erbium atoms to release their stored energy as additional 1550-nm light. As this process continues down the fiber, the signal grows stronger. The spontaneous emissions in the EDFA also add noise to the signal, which determines the noise figure of an EDFA.

Figure 1-14 Erbium-Doped Fiber Amplifier Design



The key performance parameters of optical amplifiers are gain, gain flatness, noise level, and output power. EDFAs are typically capable of gains of 30 dB or more and output power of +17 dB or more. The target parameters when selecting an EDFA, however, are low noise and flat gain. Gain should be flat, because all signals must be amplified uniformly. While the signal gain provided with EDFA technology is inherently wavelength-dependent, it can be corrected with gain flattening filters. Such filters are often built into modern EDFAs.

Low noise is a requirement because noise, along with signal, is amplified. Because this effect is cumulative and cannot be filtered out, the signal-to-noise ratio is an ultimate limiting factor in the number of amplifiers that can be concatenated. In general, signals can travel for up to 74 mi (120 km) between amplifiers. At longer distances of 372 mi to 620 mi (600 to 1000 km) the signal must be regenerated. That is because the optical amplifier merely amplifies the signals and does not perform the 3R functions (retime, reshape, regenerate). EDFAs are available for the C-band and the L-band.

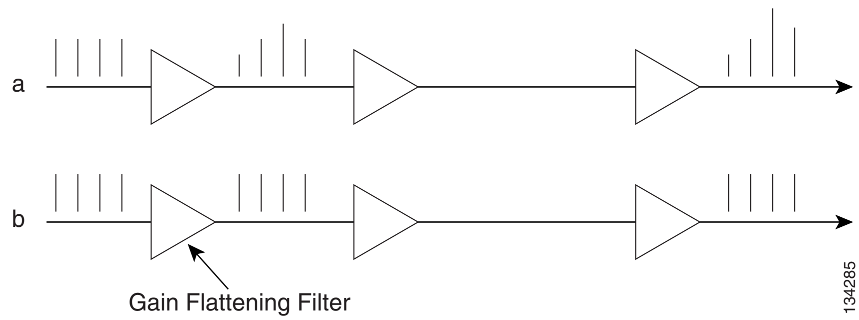
1.5.4.2 Constant Gain Mode

Constant amplification per wavelength is important for bandwidth-on-demand wavelength services. As wavelengths are added/dropped from an optical fiber, small variations in gain between channels in a span can cause large variations in the power difference between channels at the receivers. Constant gain mode is achieved using an automatic control circuit that adjusts pump power when changes in input power are detected.

1.5.4.3 Gain Flatness

Figure 1-15 illustrates the importance of an EDFA gain-flattening filter. With the first fiber (a), channels having equal power going into a cascaded network of amplifiers have vastly different powers and optical signal-to-noise ratio (SNR) at the output—without a gain flattening filter. In contrast, with the second fiber (b), the EDFAs reduce this effect by introducing a gain-flattening filter within each amplifier.

Figure 1-15 Gain Flattening Filter



1.5.4.4 Transient Suppression

Transients in the performance of EDFAs are inevitable whenever the number of signals or the relative power of signals change. The amount of time required by an amplifier to recover from a change indicates the suitability of the amplifier for add/drop applications. Some EDFAs can reconfigure rapidly to ensure constant gain and gain flatness. The lower transient suppression implied on the lower transient delay makes it suitable for dynamic channel addition and subtraction (add/drop).

1.5.4.5 Low Noise

Noise increases whenever a gain occurs in an optical system. The predominant source of noise in EDFAs is from amplified spontaneous emission (ASE). An EDFA with a low-noise figure of < 6.0 dB ensures better optical-signal-to-noise ratio (OSNR) performance for cascaded amplified networks.

1.5.4.6 Saturation-Protection Internal VOA

A saturation-protection internal variable optical attenuator (VOA) is placed before the EDFA to attenuate the channel and composite power going into the amplifier gain block. The purpose of the VOA is to protect the EDFA from being driven into saturation. The VOA can be adjusted from 1 dB to 10 dB. Since the EDFA saturation input power is –6 dBm, the internal VOA allows a higher power input to the amplifier (up to +4 dBm more). The VOA can be adjusted through software to control the gain block input to –6 dBm or less. For conditions where the gain block is in the normal operating region (that is, nonsaturated), some EDFAs can operate as a variable-gain amplifier.

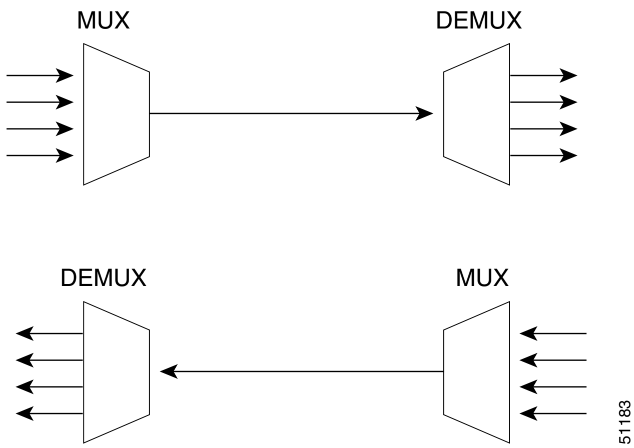
1.5.5 DWDM Multiplexers and Demultiplexers

Because DWDM systems send signals from several sources over a single fiber, they must include some means to combine the incoming signals. Combining the incoming signals is achieved with a multiplexer, which takes optical wavelengths from multiple fibers and converges them into one beam. At the receiving end, the system must be able to separate out the components of the light so that they can be discreetly detected. Demultiplexers perform this function by separating the received beam into its wavelength components and coupling them to individual fibers. Demultiplexing must be done before the light is detected, because photodetectors are inherently broadband devices that cannot selectively detect a single wavelength.

1.5.5.1 Unidirectional and Bidirectional Communication

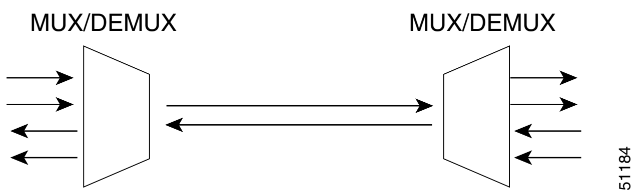
In a unidirectional system (see Figure 1-16), there is a multiplexer at the sending end and a demultiplexer at the receiving end. Two systems (back-to-back terminals) with two separate fibers are required at each end for bidirectional communication.

Figure 1-16 Multiplexing and Demultiplexing in a Unidirectional System



A bidirectional system has a multiplexer/demultiplexer at each end (see Figure 1-17) and communication occurs over a single fiber, with different wavelengths used for each direction.

Figure 1-17 Multiplexing and Demultiplexing in a Bidirectional System

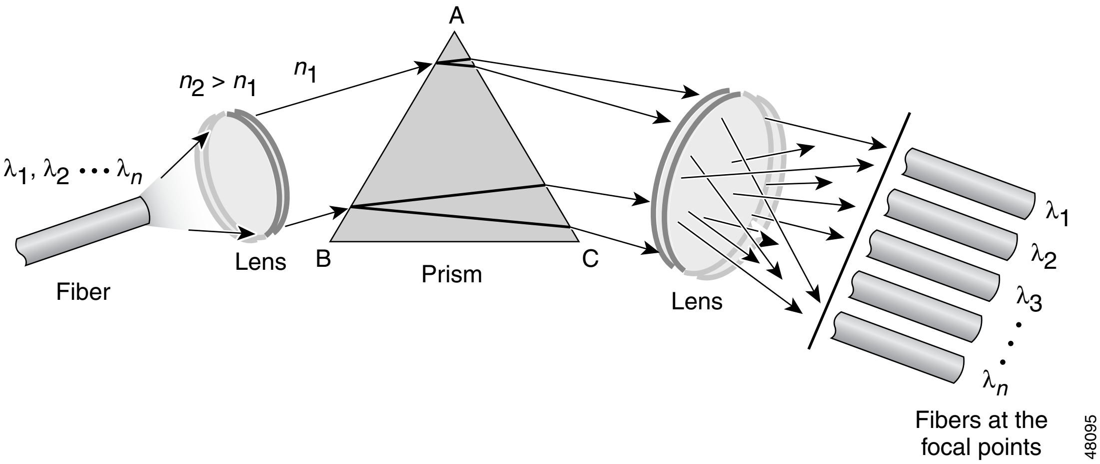


Multiplexers and demultiplexers can be either passive or active in design. Passive designs are based on prisms, diffraction gratings, or filters, while active designs combine passive devices with tunable filters. The primary challenge in these devices is to minimize crosstalk and maximize channel separation. Crosstalk is a measure of how well the channels are separated, and channel separation refers to the ability to distinguish each wavelength.

1.5.5.2 Techniques for Multiplexing and Demultiplexing

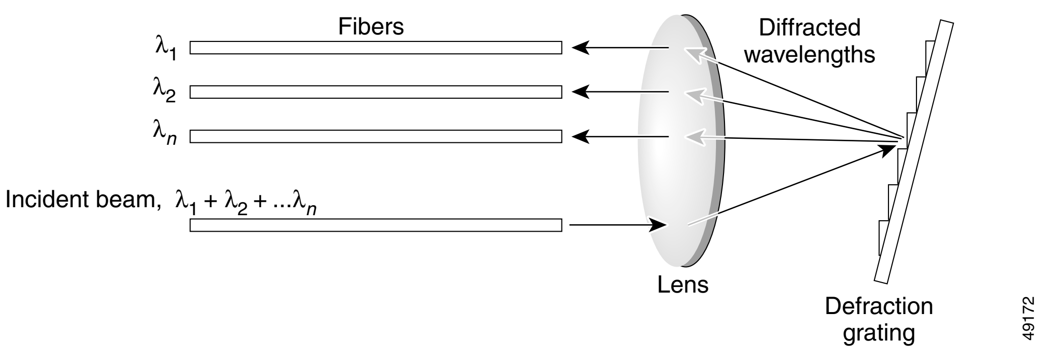
A simple form of multiplexing or demultiplexing of light can be done using a prism. Figure 1-18 demonstrates the demultiplexing case. A parallel beam of polychromatic light impinges on a prism surface; each component wavelength is refracted differently. This is the “rainbow” effect. In the output light, each wavelength is separated from the next by an angle. A lens then focuses each wavelength to the point where it needs to enter a fiber. The same components can be used in reverse to multiplex different wavelengths onto one fiber.

Figure 1-18 ***Prism Diffraction Multiplexing***



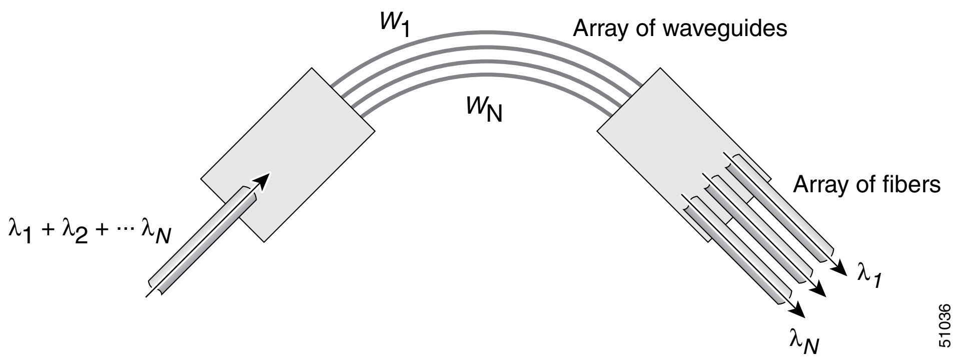
Another technology is based on the principles of diffraction and optical interference. When a polychromatic light source impinges on a diffraction grating (see Figure 1-19), each wavelength is diffracted at a different angle and therefore to a different point in space. Using a lens, these wavelengths can be focused onto individual fibers.

Figure 1-19 ***Waveguide Grating Diffraction***



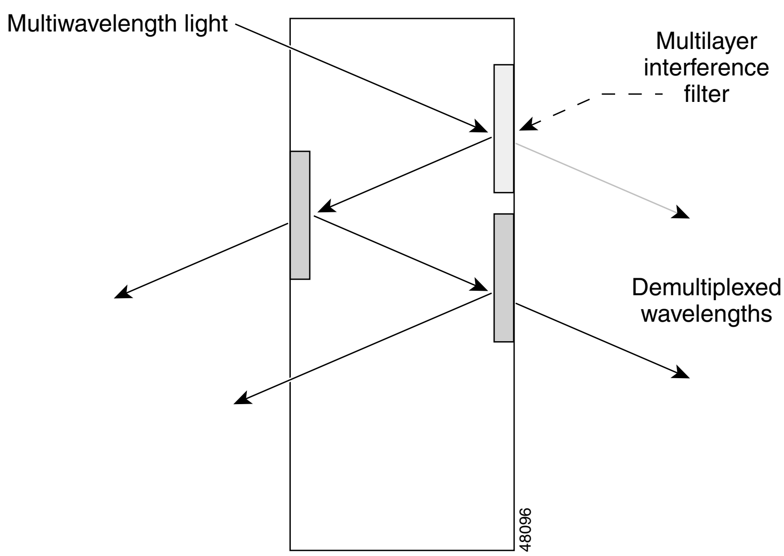
Arrayed waveguide gratings (AWGs) are also based on diffraction principles. An AWG device, sometimes called an optical waveguide router or waveguide grating router, consists of an array of curved-channel waveguides with a fixed difference in the path length between adjacent channels (see Figure 1-20). The waveguides are connected to cavities at the input and output. When the light enters the input cavity, it is diffracted and enters the waveguide array. There the optical length difference of each waveguide introduces phase delays in the output cavity, where an array of fibers is coupled. The process results in different wavelengths having maximal interference at different locations, which correspond to the output ports.

Figure 1-20 Arrayed Waveguide Grating



By positioning filters, consisting of thin films, in the optical path, wavelengths can be demultiplexed. Each filter transmits one wavelength while reflecting others. By cascading these devices, many wavelengths can be demultiplexed (see Figure 1-21).

Figure 1-21 Multi-Layer Interference Filters



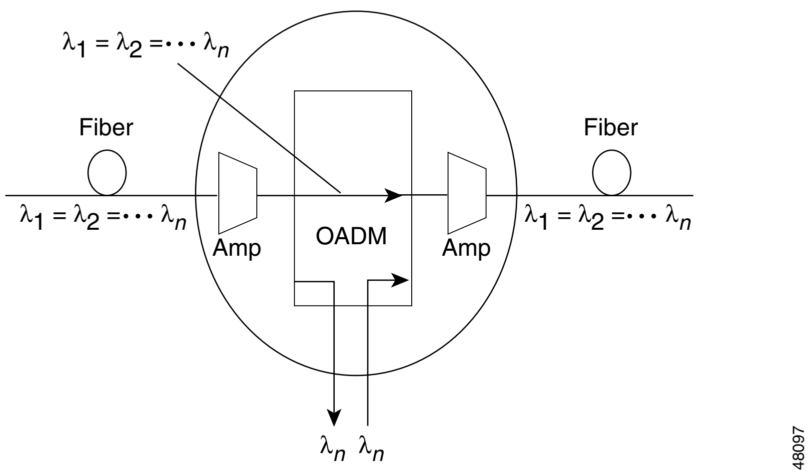
Filters offer good stability and isolation between channels at moderate cost, but with a high insertion loss. AWGs are polarization-dependent (which can be compensated), and they exhibit a flat spectral response and low insertion loss. A potential drawback to AWGs is that their temperature sensitivity makes them impractical in some environments. Their big advantage is that they can be designed to perform multiplexing and demultiplexing operations simultaneously. AWGs are also better for large channel counts, where the use of cascaded thin film filters is impractical.

1.5.6 Optical Add/Drop Multiplexers

Between multiplexing and demultiplexing points in a DWDM system, as shown in Figure 1-17 on page 1-16, there is an area in which multiple wavelengths exist. It is often necessary to remove or insert one or more wavelengths at some point along this span. An optical add/drop multiplexer (OADM) performs this removal/insertion function. Rather than combining or separating all wavelengths, the OADM can remove some while passing others on.

OADMs are similar in many respects to SONET ADMs, except that only optical wavelengths are added and dropped in an OADM, and no conversion of the signal from optical to electrical takes place. Figure 1-22 is a schematic representation of the add/drop process. This example shows both pre- and post-amplification. Some illustrated components might or might not be present in an OADM, depending on its design.

Figure 1-22 Selectively Adding and Removing Wavelengths



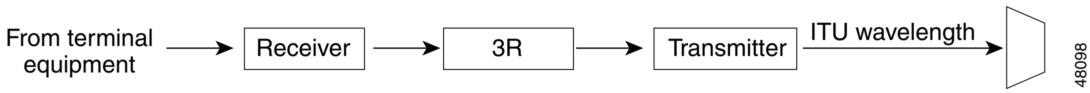
1.6 DWDM Interfaces

Most DWDM systems support standard SONET/SDH optical interfaces to which any SONET-compliant client device can attach. On the client side, there can be SONET/SDH terminals or ADMs, ATM switches, or routers. Transponders convert incoming optical signals into the precise ITU-standard wavelengths that can then be multiplexed.

Within the DWDM system, a transponder converts the client optical signal back to an electrical signal and performs the 3R functions (see Figure 1-23). This electrical signal is then used to drive the DWDM laser. Each transponder within the system converts its client signal to a slightly different wavelength. The wavelengths from all of the transponders in the system are then optically multiplexed.

In the receive direction of the DWDM system, the reverse process takes place. Individual wavelengths are filtered from the multiplexed fiber and fed to individual transponders, which convert the signal to electrical signals and drive a standard interface to the client.

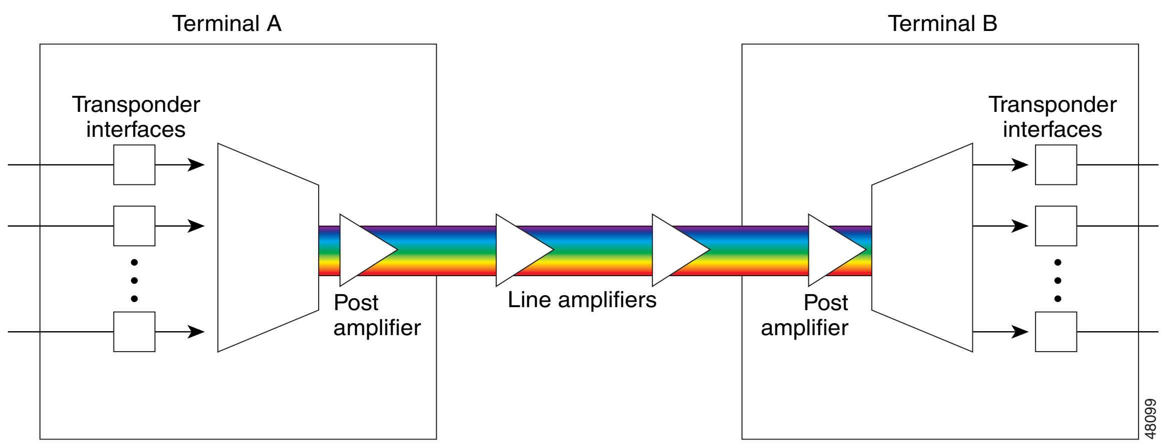
Figure 1-23 Transponder Functions



1.6.1 Operation of a Transponder Based DWDM System

Some DWDM system transponders are optical-electrical-optical (OEO) devices that transform, or map, an incoming wavelength into a DWDM wavelength. Using the Cisco ONS 15454 OC48ELR ITU optical cards reduces or eliminates (based on your channel plan) the need for transponders. Figure 1-24 shows a DWDM system with transponders.

Figure 1-24 DWDM System with Transponders



The following steps describe the system shown in Figure 1-24:

1. The transponder accepts input in the form of standard single-mode or multimode laser. The input can come from different physical media and different protocols and traffic types.
2. The wavelength of each input signal is mapped to a DWDM wavelength.
3. DWDM wavelengths from the transponder are multiplexed into a single optical signal and launched into the fiber. The system might also include the ability to accept direct optical signals to the multiplexer; these signals could come, for example, from a satellite node.
4. (Optional) A post-amplifier boosts the strength of the optical signal as it leaves the system.
5. (Optional) Optical amplifiers are used along the fiber span as needed.
6. (Optional) A pre-amplifier boosts the signal before it enters the end system.
7. The incoming signal is demultiplexed into individual DWDM lambdas (or wavelengths).
8. The individual DWDM lambdas are mapped to the required output type (for example, OC-48 single-mode fiber) and sent out through the transponder.

1.6.2 ITU Grid

For WDM system interoperability, the operating center frequency (wavelength) of channels must be the same at the transmitting end and the receiving end. The ITU-T currently recommends 81 channels in the C band starting from 1528.77 nm and incrementing in multiples of 50 GHz to 1560.61 nm. Table 1-2 lists the ITU frequencies and wavelengths.

Note Table 1-2 is the official ITU-T C-band grid. It shows 81 wavelengths with 25-GHz spacing. The Cisco DWDM cards support a subset of these wavelengths in the C-band (see Table 1-3). The cards also support L-band wavelengths (see Table 1-4).

Table 1-2 ITU Grid

Frequency (THz)	Wavelength (nm)	Frequency (THz)	Wavelength (nm)	Frequency (THz)	Wavelength (nm)	Frequency (THz)	Wavelength (nm)
196.100	1528.77	195.050	1537.00	194.000	1545.32	192.950	1553.73
196.075	1528.97	195.025	1537.20	193.975	1545.52	192.925	1553.93
196.050	1529.16	195.000	1537.40	193.950	1545.72	192.900	1554.13
196.025	1529.36	194.975	1537.59	193.925	1545.92	192.875	1554.34
196.000	1529.55	194.950	1537.79	193.900	1546.12	192.850	1554.54
195.975	1529.75	194.925	1537.99	193.875	1546.32	192.825	1554.74
195.950	1529.94	194.900	1538.19	193.850	1546.52	192.800	1554.94
195.925	1530.14	194.875	1538.38	193.825	1546.72	192.775	1555.14
195.900	1530.33	194.850	1538.58	193.800	1546.92	192.750	1555.34
195.875	1530.53	194.825	1538.78	193.775	1547.12	192.725	1555.55
195.850	1530.72	194.800	1538.98	193.750	1547.32	192.700	1555.75
195.825	1530.92	194.775	1539.17	193.725	1547.52	192.675	1555.95
195.800	1531.12	194.750	1539.37	193.700	1547.72	192.650	1556.15
195.775	1531.31	194.725	1539.57	193.675	1547.92	192.625	1556.35
195.750	1531.51	194.700	1539.77	193.650	1548.11	192.600	1556.55
195.725	1531.70	194.675	1539.96	193.625	1548.31	192.575	1556.76
195.700	1531.90	194.650	1540.16	193.600	1548.51	192.550	1556.96
195.675	1532.09	194.625	1540.36	193.575	1548.71	192.525	1557.16
195.650	1532.29	194.600	1540.56	193.550	1548.91	192.500	1557.36
195.625	1532.49	194.575	1540.76	193.525	1549.11	192.475	1557.57
195.600	1532.68	194.550	1540.95	193.500	1549.32	192.450	1557.77
195.575	1532.88	194.525	1541.15	193.475	1549.52	192.425	1557.97
195.550	1533.07	194.500	1541.35	193.450	1549.72	192.400	1558.17
195.525	1533.27	194.475	1541.55	193.425	1549.92	192.375	1558.38
195.500	1533.47	194.450	1541.75	193.400	1550.12	192.350	1558.58
195.475	1533.66	194.425	1541.94	193.375	1550.32	192.325	1558.78

Table 1-2 ITU Grid

Frequency (THz)	Wavelength (nm)	Frequency (THz)	Wavelength (nm)	Frequency (THz)	Wavelength (nm)	Frequency (THz)	Wavelength (nm)
195.450	1533.86	194.400	1542.14	193.350	1550.52	192.300	1558.98
195.425	1534.05	194.375	1542.34	193.325	1550.72	192.275	1559.19
195.400	1534.25	194.350	1542.54	193.300	1550.92	192.250	1559.39
195.375	1534.45	194.325	1542.74	193.275	1551.12	192.225	1559.59
195.350	1534.64	194.300	1542.94	193.250	1551.32	192.200	1559.79
195.325	1534.84	194.275	1543.13	193.225	1551.52	192.175	1560.00
195.300	1535.04	194.250	1543.33	193.200	1551.72	192.150	1560.20
195.275	1535.23	194.225	1543.53	193.175	1551.92	192.125	1560.40
195.250	1535.43	194.200	1543.73	193.150	1552.12	192.100	1560.61
192.225	1535.63	194.175	1543.93	193.125	1552.32	192.075	1560.81
192.200	1535.82	194.150	1544.13	193.100	1552.52	192.050	1561.01
192.175	1536.02	194.125	1544.33	193.075	1552.73	192.025	1561.22
192.150	1536.22	194.100	1544.53	193.050	1552.93	191.000	1561.42
192.125	1536.41	194.075	1544.72	193.025	1553.13	191.975	1561.62
192.100	1536.61	194.050	1544.92	193.000	1553.33	191.950	1561.83
192.075	1536.81	194.025	1545.12	192.975	1553.53	191.925	1562.03
						191.900	1562.23

While this grid defines a standard, users are free to use the wavelengths in arbitrary ways and to choose from any part of the spectrum. In addition, manufacturers can deviate from the grid by extending the upper and lower bounds or by spacing the wavelengths more closely, typically at 50 GHz, to double the number of channels. The closer the spacing, the more channel crosstalk results. In addition, the impact of some fiber nonlinearity, such as FWM, increases. Spacing at 50 GHz also limits the maximum data rate per wavelength to 10 Gbps. The implications of the flexibility are twofold:

- There is no guarantee of compatibility between two end systems from different vendors.
- There exists a design trade-off in the spacing of wavelengths between the number of channels and the maximum bit rate.

1.7 Supported ITU-T Wavelengths in the C-Band and L-Band

Cisco DWDM cards support 32 wavelengths in the C-band and 32 in the L-band, as shown in Table 1-3 and Table 1-4. The C-band wavelengths shown in Table 1-3 are spaced at 100 GHz and are a subset of the wavelengths shown in Table 1-2.

Table 1-3 C-Band Channels

Channel #	Channel ID	Frequency (THz)	Wavelength (nm)
1	30.3	195.9	1530.33
2	31.2	195.8	1531.12

Table 1-3 C-Band Channels

Channel #	Channel ID	Frequency (THz)	Wavelength (nm)
3	31.9	195.7	1531.90
4	32.6	195.6	1532.68
5	34.2	195.4	1534.25
6	35.0	195.3	1535.04
7	35.8	195.2	1535.82
8	36.6	195.1	1536.61
9	38.1	194.9	1538.19
10	38.9	194.8	1538.98
11	39.7	194.7	1539.77
12	40.5	194.6	1540.56
13	42.1	194.4	1542.14
14	42.9	194.3	1542.94
15	43.7	194.2	1543.73
16	44.5	194.1	1544.53
17	46.1	193.9	1546.12
18	46.9	193.8	1546.92
19	47.7	193.7	1547.72
20	48.5	193.6	1548.51
21	50.1	193.4	1550.12
22	50.9	193.3	1550.92
23	51.7	193.2	1551.72
24	52.5	193.1	1552.52
25	54.1	192.9	1554.13
26	54.9	192.8	1554.94
27	55.7	192.7	1555.75
28	56.5	192.6	1556.55
29	58.1	192.4	1558.17
30	58.9	192.3	1558.98
31	59.7	192.2	1559.79
32	60.6	192.1	1560.61

Table 1-4 L-Band Channels

Channel #	Channel ID	Frequency (THz)	Wavelength (nm)
1	77.8	190	1577.86
2	78.6	189.9	1578.69

Table 1-4 L-Band Channels

Channel #	Channel ID	Frequency (THz)	Wavelength (nm)
3	79.5	189.8	1579.52
4	80.3	189.7	1580.35
5	81.1	189.6	1581.18
6	82.0	189.5	1582.02
7	82.8	189.4	1582.85
8	83.6	189.3	1583.69
9	84.5	189.2	1584.53
10	85.3	189.1	1585.36
11	86.2	189	1586.20
12	87.0	188.9	1587.04
13	87.8	188.8	1587.88
14	88.7	188.7	1588.73
15	89.5	188.6	1589.57
16	90.4	188.5	1590.41
17	91.2	188.4	1591.26
18	92.1	188.3	1592.10
19	92.9	188.2	1592.95
20	93.7	188.1	1593.79
21	94.6	188	1594.64
22	95.4	187.9	1595.49
23	96.3	187.8	1596.34
24	97.1	187.7	1597.19
25	98.0	187.6	1598.04
26	98.8	187.5	1598.89
27	99.7	187.4	1599.75
28	00.6	187.3	1600.60
29	01.4	187.2	1601.46
30	02.3	187.1	1602.31
31	03.1	187	1603.17
32	04.0	186.9	1604.03

Cards Specifications

This chapter contains specific information about cards for dense wavelength division multiplexing (DWDM) applications in the Cisco ONS 15454.

Note The terms "Unidirectional Path Switched Ring" and "UPSR" may appear in Cisco literature. These terms do not refer to using Cisco ONS 15xxx products in a unidirectional path switched ring configuration. Rather, these terms, as well as "Path Protected Mesh Network" and "PPMN," refer generally to Cisco's path protection feature, which may be used in any topological network configuration. Cisco does not recommend using its path protection feature in any particular topological network configuration.

The following topics are covered in this chapter:

2.1 Card Overview

Redundant TCC2 and TCC2P cards are required to operate the Cisco ONS 15454. If you are using an ETSI (SDH) shelf assembly, the MIC-A/P and MIC-C/T/P front mount electrical connections (FMECs) are also required. The optional AIC-I card provides external alarms and controls (environmental alarms).

Each DWDM card is marked with a symbol that corresponds to a slot (or slots) on the ONS 15454 shelf assembly. These cards can only be installed into slots displaying the same symbols.

ONS 15454 DWDM cards are grouped into the following categories:

- Optical service channel OSC) cards provide bidirectional channels that connect all the ONS 15454 DWDM nodes and transport general-purpose information without affecting the client traffic. ONS 15454 OSC cards include the Optical Service Channel Module (OSCM) and the Optical Service Channel and Combiner/Separator Module (OSC-CSM).
- Optical erbium-doped fiber amplifier (EDFA) cards are used in amplified DWDM nodes, including hub nodes, amplified OADM nodes, and line amplified nodes. Optical amplifier cards include the Optical Preamplifier (OPT-PRE) and Optical Booster (OPT-BST).
- Dispersion compensation units (DCUs) are installed in the ONS 15454 dispersion compensation shelf when optical preamplifier cards are installed in the DWDM node. Each DCU module can compensate a maximum of 65 km of single-mode fiber (SMF-28) span. DCUs can be cascaded to extend the compensation to 130 km.

- Multiplexer and demultiplexer cards multiplex and demultiplex DWDM optical channels. The cards consist of three main modules: an optical plug-in, a microprocessor, and a DC/DC converter. ONS 15454 multiplexer and demultiplexer cards include the 32-Channel Multiplexer (32MUX-O), the 32-Channel Demultiplexer (32DMX-O), the single-slot 32-Channel Demultiplexer (32DMX), and the 4-Channel Multiplexer/Demultiplexer (4MD-xx.x).
- Optical Add/Drop Multiplexer (OADM) cards are mainly divided into three groups: band OADM cards, channel OADM cards, and wavelength selective switch (WSS) cards. Band OADM cards add and drop one or four bands of adjacent channels; they include the 4-Band OADM (AD-4B-xx.x) and the 1-Band OADM (AD-1B-xx.x). Channel OADM cards add and drop one, two, or four adjacent channels; they include the 4-Channel OADM (AD-4C-xx.x), the 2-Channel OADM (AD-2C-xx.x) and the 1-Channel OADM (AD-1C-xx.x). The 32-Channel Wavelength Selective Switch (32WSS) card is used with the 32DMX to implement reconfigurable OADM (ROADM) functionality. These cards consist of three main modules: an optical plug-in, a microprocessor, and a DC/DC converter.

  Table 2-1 to Table 2-4 show the band IDs and the add/drop channel IDs for the 4MD-xx.x, AD-2C-xx.x, AD-4C-xx.x, and AD-4B-xx.x cards.

Table 2-1 4MD-xx.x Channel Sets

Band IDs	Add/Drop Channel IDs	Add/Drop Wavelengths (nm)
Band 30.3 (A)	30.3, 31.2, 31.9, 32.6	1530.33, 1531.12, 1531.90, 1532.68
Band 34.2 (B)	34.2, 35.0, 35.8, 36.6	1534.25, 1535.04, 1535.82, 1536.61
Band 38.1 (C)	38.1, 38.9, 39.7, 40.5	1538.19, 1538.98, 1539.77, 1540.56
Band 42.1 (D)	42.1, 42.9, 43.7, 44.5	1542.14, 1542.94, 1543.73, 1544.53
Band 46.1 (E)	46.1, 46.9, 47.7, 48.5	1546.12, 1546.92, 1547.72, 1548.51
Band 50.1 (F)	50.1, 50.9, 51.7, 52.5	1550.12, 1550.92, 1551.72, 1552.52
Band 54.1 (G)	54.1, 54.9, 55.7, 56.5	1554.13, 1554.94, 1555.75, 1556.55
Band 58.1 (H)	58.1, 58.9, 59.7, 60.6	1558.17, 1558.98, 1559.79, 1560.61

Table 2-2 AD-2C-xx.x Channel Pairs

Band IDs	Add/Drop Channel IDs	Add/Drop Wavelengths (nm)
Band 30.3 (A)	30.3, 31.2 and 31.9, 32.6	1530.33, 1531.12 and 1531.90, 1532.68
Band 34.2 (B)	34.2, 35.0, and 35.8, 36.6	1534.25, 1535.04 and 1535.82, 1536.61
Band 38.1 (C)	38.1, 38.9 and 39.7, 40.5	1538.19, 1538.98 and 1539.77, 1540.56

Table 2-2 AD-2C-xx.x Channel Pairs (continued)

Band IDs	Add/Drop Channel IDs	Add/Drop Wavelengths (nm)
Band 42.1 (D)	42.1, 42.9 and 43.7, 44.5	1542.14, 1542.94 and 1543.73, 1544.53
Band 46.1 (E)	46.1, 46.9 and 47.7, 48.5	1546.12, 1546.92 and 1547.72, 1548.51
Band 50.1 (F)	50.1, 50.9 and 51.7, 52.5	1550.12, 1550.92 and 1551.72, 1552.52
Band 54.1 (G)	54.1, 54.9 and 55.7, 56.5	1554.13, 1554.94 and 1555.75, 1556.55
Band 58.1 (H)	58.1, 58.9 and 59.7, 60.6	1558.17, 1558.98 and 1559.79, 1560.61

Table 2-3 AD-4C-xx.x Channel Sets

Band IDs	Add/Drop Channel IDs	Add/Drop Wavelengths (nm)
Band 30.3 (A)	30.3, 31.2, 31.9, 32.6	1530.33, 1531.12, 1531.90, 1532.68
Band 34.2 (B)	34.2, 35.0, 35.8, 36.6	1534.25, 1535.04, 1535.82, 1536.61
Band 38.1 (C)	38.1, 38.9, 39.7, 40.5	1538.19, 1538.98, 1539.77, 1540.56
Band 42.1 (D)	42.1, 42.9, 43.7, 44.5	1542.14, 1542.94, 1543.73, 1544.53
Band 46.1 (E)	46.1, 46.9, 47.7, 48.5	1546.12, 1546.92, 1547.72, 1548.51
Band 50.1 (F)	50.1, 50.9, 51.7, 52.5	1550.12, 1550.92, 1551.72, 1552.52
Band 54.1 (G)	54.1, 54.9, 55.7, 56.5	1554.13, 1554.94, 1555.75, 1556.55
Band 58.1 (H)	58.1, 58.9, 59.7, 60.6	1558.17, 1558.98, 1559.79, 1560.61

Table 2-4 AD-4B-xx.x Channel Sets

Band IDs	Add/Drop Channel IDs	Add/Drop Wavelengths (nm)
Band 30.3 (A)	B30.3	1530.33
Band 34.2 (B)	B34.2	1534.25
Band 38.1 (C)	B38.1	1538.19
Band 42.1 (D)	B42.1	1542.14
Band 46.1 (E)	B46.1	1546.12
Band 50.1 (F)	B50.1	1550.12

Table 2-4 AD-4B-xx.x Channel Sets

Band IDs	Add/Drop Channel IDs	Add/Drop Wavelengths (nm)
Band 54.1 (G)	B54.1	1554.13
Band 58.1 (H)	B58.1	1558.17

- Transponder (TXP) and muxponder (MXP) cards convert the “gray” optical client interface signals into trunk signals that operate in the “colored” DWDM wavelength range. Transponding or muxponding is the process of converting the signals between the client and trunk wavelengths.

  A muxponder generally handles several client signals. It aggregates, or multiplexes, lower- rate client signals together and sends them out over a higher-rate trunk port. Likewise, a muxponder demultiplexes optical signals coming in on a trunk and sends the signals out to individual client ports. A transponder converts a single client signal to a single trunk signal and converts a single incoming trunk signal to a single client signal.

  All of the TXP and MXP cards perform optical-to-electrical-to-optical (OEO) conversion. As a result, they are not optically transparent cards. OEO conversion is necessary because the cards must operate on the signals passing through the cards.

  However, the termination mode for all TXPs and MXPs can be configured as transparent (termination is performed at the electrical level). In a transparent termination, neither the Line nor the Section overhead is terminated. The cards can also be configured so that Line overhead, Section overhead, or both Line and Section overhead can be terminated.

Note When configured in the transparent termination mode, the MXP_2.5G_10G card does terminate some bytes by design.

Table 2-5 describes the Cisco ONS 15454 DWDM cards. Client-facing gray optical signals generally operate at shorter wavelengths, whereas DWDM colored optical signals are in the longer wavelength range (for example, 1490 nm = violet; 1510 nm = blue; 1530 nm = green; 1550 nm = yellow; 1570 nm = orange; 1590 nm = red; 1610 nm = brown). Some of the newer client-facing SFPs, however, operate in the colored region.

Table 2-5 Cisco ONS 15454 DWDM Cards

Card	Part Number	Description
Optical Service Channel Cards		
OSCM	15454-OSCM=	The OSCM card has one set of optical ports and one Ethernet port located on the faceplate. The card operates in Slots 8 and 10. An OSC is a bidirectional channel connecting all the nodes in a ring. The channel transports OSC overhead that is used to manage ONS 15454 DWDM networks. The OSC uses the 1510 nm wavelength and does not affect client traffic. The primary purpose of this channel is to carry clock synchronization and orderwire channel communications for the DWDM network. It also provides transparent links between each node in the network. The OSC is an OC-3 formatted signal. The OSCM is used in amplified nodes that include the OPT-BST booster amplifier. The OPT-BST includes the required OSC wavelength combiner and separator component. The OSCM cannot be used in nodes where you use OC-N cards, electrical cards, or cross-connect cards. The OSCM uses Slots 8 and 10 when the ONS 15454 is configured in a DWDM network.
OSC-CSM	15454-OSC-CSM=	The OSC-CSM card has three sets of optical ports and one Ethernet port located on the faceplate. The card operates in Slots 1 to 6 and 12 to 17. The OSC-CSM is identical to the OSCM, but also contains a combiner and separator module in addition to the OSC module. The OSC-CSM is used in unamplified nodes. This means that the booster amplifier with the OSC wavelength combiner and separator is not required for OSC-CSM operation. The OSC-CSM can be installed in Slots 1 to 6 and 12 to 17 when the ONS 15454 is configured in a DWDM network.
Optical Amplifiers		
OPT-PRE	15454-OPT-PRE=	The OPT-PRE card is designed to support 64 channels at 50 GHz channel spacing. The OPT-PRE is a C-band DWDM, two-stage EDFA with mid-amplifier loss (MAL) for allocation to a DCU. To control the gain tilt, the OPT-PRE is equipped with a built-in variable optical attenuator (VOA). The VOA can also be used to pad the DCU to a reference value. You can install the OPT-PRE in Slots 1 to 6 and 12 to 17 when the ONS 15454 is configured in a DWDM network.
OPT-BST	15454-OPT-BST=	The OPT-BST card is designed to support up to 64 channels at 50 GHz channel spacing. The OPT-BST is a C-band DWDM EDFA with OSC add-and-drop capability. When an ONS 15454 DWDM has an OPT-BST installed, it is only necessary to have the OSCM to process the OSC. The card has a maximum output power of 17 dBm. To control the gain tilt, the OPT-BST is equipped with a built-in VOA. You can install the OPT-BST in Slots 1 to 6 and 12 to 17 when the ONS 15454 is configured in a DWDM network.

Table 2-5 Cisco ONS 15454 DWDM Cards (continued)

Card	Part Number	Description
OPT-BST-E	15454-OPT-BST-E=	The OPT-BST-E card is designed to support up to 64 channels at 50 GHz channel spacing. It is a C-band DWDM EDFA with OSC add-and-drop capability. Its maximum output power is 21 dBm. To control the gain tilt, the OPT-BST-E is equipped with a built-in VOA. You can install the OPT-BST-E in Slots 1 to 6 and 12 to 17 when the ONS 15454 is configured in a DWDM network.
OPT-BST-L	15454-OPT-BST-L=	The OPT-BST-L card is designed to support up to 64 channels at 50 GHz channel spacing. It is an L-band DWDM EDFA with OSC add-and-drop capability. Its maximum output power is 17 dBm. To control the gain tilt, the OPT-BST-L is equipped with a built-in VOA. You can install the OPT-BST-L in Slots 1 to 6 and 12 to 17 when the ONS 15454 is configured in a DWDM network.
OPT-AMP-L	15454-OPT-AMP-L=	The OPT-AMP-L card is designed to support 64 channels at 50 GHz channel spacing. The OPT-AMP-L is a L-band DWDM, two-stage EDFA with MAL for allocation to a DCU. Its maximum output power is 20 dBm. To control the gain tilt, the OPT-AMP-L is equipped with a built-in VOA. The VOA can also be used to pad the DCU to a reference value. OPT-AMP-L is a double-slot card. You can install the OPT-AMP-L in Slots 1-2, 3-4, 5-6, or in Slots 12-13, 14-15, or 16-17.
Multiplexer and Demultiplexer Cards		
32MUX-O	15454-32MUX-O=	The 32MUX-O card multiplexes 32 100 GHz-spaced channels identified in the channel plan. The 32MUX-O card takes up two slots in an ONS 15454 DWDM and can be installed in Slots 1 to 5 and 12 to 16.
32DMX-O	15454-32DMX-O=	The 32DMX-O card demultiplexes 32 100-GHz-spaced channels identified in the channel plan. The 32DMX-O takes up two slots in an ONS 15454 DWDM and can be installed in Slots 1 to 5 and 12 to 16.
32DMX	15454-32DMX=	The 32DMX card is a single-slot optical demultiplexer. The card receives an aggregate optical signal on its COM RX port and demultiplexes it into to 32 100-GHz-spaced channels. The 32DMX card can be installed in Slots 1 to 6 and in Slots 12 to 17.
32DMX-L	15454-32DMX-L=	The 32DMX-L card is a single-slot optical L-band demultiplexer. The card receives an aggregate optical signal on its COM RX port and demultiplexes it into to 32 100 GHz-spaced channels. The 32DMX card can be installed in Slots 1 to 6 and in Slots 12 to 17.
4MD-xx.x	15454-4MD-xx.x=	The 4MD-xx.x card multiplexes and demultiplexes four 100 GHz-spaced channels identified in the channel plan. The 4MD-xx.x card is designed to be used with band OADMs (both AD-1B-xx.x and AD-4B-xx.x). There are eight versions of this card that correspond with the eight subbands specified in Table 2-1 on page 2-2. The 4MD-xx.x can be installed in Slots 1 to 6 and 12 to 17 when the ONS 15454 is configured in a DWDM network.
Optical Add/Drop Multiplexer Cards		

Table 2-5 Cisco ONS 15454 DWDM Cards (continued)

Card	Part Number	Description
AD-1C-xx.x	15454-AD-1C-xx.x=	The AD-1C-xx.x card passively adds or drops one of the 32 channels utilized within the 100 GHz-spacing of the DWDM card. There are thirty-two versions of this card, each designed only for use with one wavelength. Each wavelength version of the card has a different part number. The AD-1C-xx.x can be installed in Slots 1 to 6 and 12 to 17 when the ONS 15454 is configured in a DWDM network.
AD-2C-xx.x	15454-AD-2C-xx.x=	The AD-2C-xx.x card passively adds or drops two adjacent 100-GHz channels within the same band. There are sixteen versions of this card, each designed for use with one pair of wavelengths. The card bidirectionally adds and drops in two different sections on the same card to manage signal flow in both directions. Each version of the card has a different part number. The AD-2C-xx.x cards are provisioned for the channel pairs in Table 2-2 on page 2-2. In this table, channel IDs are provided instead of wavelengths. The AD-2C-xx.x can be installed in Slots 1 to 6 and 12 to 17 when the ONS 15454 is configured in a DWDM network.
AD-4C-xx.x	15454-AD-4C-xx.x=	The AD-4C-xx.x card passively adds or drops all four 100 GHz-spaced channels within the same band. There are eight versions of this card, each designed for use with one band of wavelengths. The card bidirectionally adds and drops two different sections on the same card to manage signal flow in both directions. Each version of this card has a different part number. The AD-4C-xx.x cards are provisioned for the channel pairs in Table 2-3 on page 2-3. In this table, channel IDs are given rather than wavelengths. The AD-4C-xx.x can be installed in Slots 1 to 6 and 12 to 17 when the ONS 15454 is configured in a DWDM network.
AD-1B-xx.x	15454-AD-1B-xx=	The AD-1B-xx.x card passively adds or drops a single band of four adjacent 100 GHz-spaced channels. There are eight versions of this card with eight different part numbers, each version designed for use with one band of wavelengths. The card bidirectionally adds and drops in two different sections on the same card to manage signal flow in both directions. This card can be used when there is asymmetric adding and dropping on each side (east or west) of the node; a band can be added or dropped on one side but not on the other. The AD-1B-xx.x can be installed in Slots 1 to 6 and 12 to17 when the ONS 15454 is configured in a DWDM network.
AD-4B-xx.x	15454-AD-4B-xx=	The AD-4B-xx.x card passively adds or drops four bands of four adjacent 100 GHz-spaced channels. There are two versions of this card with different part numbers, each version designed for use with one set of bands. The card bidirectionally adds and drops in two different sections on the same card to manage signal flow in both directions. This card can be used when there is asymmetric adding and dropping on each side (east or west) of the node; a band can be added or dropped on one side but not on the other. The AD-4B-xx.x cards are provisioned for the channel pairs in Table 2-4 on page 2-3. In this table, channel IDs are given rather than wavelengths. The AD1B-xx.x can be installed in Slots 1 to 6 and 12 to 17 when the ONS 15454 is configured in a DWDM network.

Table 2-5 Cisco ONS 15454 DWDM Cards (continued)

Card	Part Number	Description
32WSS	15454-32WSS=	The 32WSS card has seven sets of ports located on the faceplate. The card takes up two slots and operates in Slots 1-2, 3-4, 5-6, 12-13, 14-15, or 16-17. The 32WSS card performs channel add/drop processing within the ONS 15454 DWDM node. The 32WSS card works in conjunction with the 32DMX card to implement ROADM functionality. Equipped with ROADM functionality, the ONS 15454 DWDM can be configured to add or drop individual optical channels using Cisco Transport Controller (CTC), Cisco MetroPlanner, and Cisco Transport Manager (CTM). A ROADM network element utilizes two 32WSS cards (two slots each) and two 32DMX cards (one slot each), for a total of six slots in the chassis.
32WSS-L	—	The 32WSS-L card has seven sets of ports located on the faceplate. The card takes up two slots and operates in Slots 1-2, 3-4, 5-6,12-13, 14-15, or 16-17. The 32WSS-L card performs channel add/drop processing in the L band. The 32WSS-L card works in conjunction with the 32DMX-L card to implement ROADM functionality. Equipped with ROADM functionality, the ONS 15454 DWDM can be configured to add and drop or pass through each individual optical channel.
MMU	—	The MMU card supports multiring and mesh upgrades for ROADM nodes in both the C band and the L band. Mesh/multiring upgrade is the capability to optically bypass a given wavelength from one section of the network or ring to another one without requiring 3R regeneration. In each node, you need to install two MMU cards, one on the east side and one on the west side. The MMU card has six sets of ports located on the faceplate. It operates in Slots 1 to 6 and 12 to 17.
Transponder and Muxponder Cards		
TXP_MR_10G	15454-10T-L1-xx.x=	The 10 Gbps Transponder-100 GHz-Tunable xx.xx-xx.xx card (TXP_MR_10G) has two sets of ports located on the faceplate and can be in Slots 1 to 6 and 12 to 17. It processes one 10-Gbps signal (client side) into one 10-Gbps, 100-GHz DWDM signal (trunk side). It provides one 10-Gbps port per card that can be provisioned for an STM64/OC-192 short reach (1310 nm) signal, compliant with ITU-T G.707, ITU-T G.709, ITU-T G.691, and Telcordia GR-253-CORE, or to 10GE-BASE-LR, compliant with IEEE 802.3. Each version of this card has a different part number. The TXP_MR_10G card is tunable over two neighboring wavelengths in the 1550 nm, ITU 100 GHz range. It is available in sixteen different versions, covering thirty-two different wavelengths in the 1550 nm range.

Table 2-5 Cisco ONS 15454 DWDM Cards (continued)

Card	Part Number	Description
TXP_MR_10E	15454-10E-L1-xx.x=	The 10 Gbps Transponder-100 GHz-Tunable xx.xx-xx.xx (TXP_MR_10E) card has two sets of ports located on the faceplate and can be installed in Slots 1 to 6 and Slots 12 to 17. It is a multirate transponder for the ONS 15454 platform. It processes one 10-Gbps signal (client side) into one 10-Gbps, 100-GHz DWDM signal (trunk side) that is tunable on four wavelength channels (ITU-T 100-GHz grid). Each version of this card has a different part number. You can provision this card in a linear configuration, bidirectional line switched ring (BLSR), a path protection, or a hub. The card can be used in the middle of BLSR or 1+1 spans when the card is configured for transparent termination mode. The TXP_MR_10E port features a 1550-nm laser for the trunk port and an ONS-XC-10G-S1 XFP module for the client port and contains two transmit and receive connector pairs (labeled) on the card faceplate. The TXP_MR_10E card is tunable over four wavelengths in the 1550 nm ITU 100 GHz range. They are available in eight versions, covering thirty-two different wavelengths in the 1550 nm range.
TXP_MR_10E-C	15454-10E-L1-C=	This transponder has the same features as the TXP_MR_10E card, but its trunk interface can be tuned over the entire C band.
TXP_MR_10E-L	15454-10E-L1-L=	This transponder has the same features as the TXP_MR_10E card, but its trunk interface can be tuned over the entire L band.
TXP_MR_2.5G	15454-MR-L1-xx.x=	The 2.5 Gbps Multirate Transponder-100 GHz-Tunable xx.xx-xx.xx (TXP_MR_2.5G) card has two sets of ports located on the faceplate and can be installed in Slots 1 to 6 and Slots 12 to 17. It processes one 8 Mbps to 2.488 Gbps signal (client side) into one 8 Mbps to 2.5 Gbps, 100-GHz DWDM signal (trunk side). It provides one long-reach STM-16/OC-48 port per card, compliant with ITU-T G.707, ITU-T G.709, ITU-T G.957, and Telcordia GR-253-CORE. Each version of this card has a different part number. The TXP_MR_2.5G card is tunable over four wavelengths in the 1550 nm ITU 100-GHz range. The card is available in eight versions, covering thirty-two different wavelengths in the 1550 nm range. The TXP_MR_2.5G card supports 2R (reshape and regenerate) and 3R (retime, reshape and regenerate) modes of operation where the client signal is mapped into a ITU-T G.709 frame.

Table 2-5 Cisco ONS 15454 DWDM Cards (continued)

Card	Part Number	Description
TXPP_MR_2.5G	15454-MRP-L1-xx.x=	The 2.5 Gbps Multirate Transponder-Protected-100 GHz-Tunable xx.xxxx. xx (TXPP_MR_2.5G) card has three sets of ports located on the faceplate and can be installed in Slots 1 to 6 and Slots 12 to 17. It processes one 8 Mbps to 2.488 Gbps signal (client side) into two 8 Mbps to 2.5 Gbps, 100-GHz DWDM signals (trunk side). It provides two long-reach STM-16/OC-48 ports per card, compliant with ITU-T G.707, ITU-T G.957, and Telcordia GR-253-CORE. Each version of this card has a different part number. The TXPP_MR_2.5G card is tunable over four wavelengths in the 1550 nm ITU 100-GHz range. The card is available in eight versions, covering thirty-two different wavelengths in the 1550 nm range. The TXPP_MR_2.5G card support 2R and 3R modes of operation where the client signal is mapped into a ITU-T G.709 frame.
MXP_2.5G_10G	15454-10M-L1-xx.x=	The 2.5 Gbps-10 Gbps Muxponder-100 GHz-Tunable xx.xx-xx.xx (MXP_2.5G_10G) card has 9 sets of ports located on the faceplate and can be installed in Slots 1 to 6 and Slots 12 to 17. It multiplexes/demultiplexes four 2.5-Gbps signals (client side) into one 10-Gbps, 100-GHz DWDM signal (trunk side). It provides one extended long-range STM-64/OC-192 port per card on the trunk side (compliant with ITU-T G.707, ITU-T G.709, ITU-T G.957, and Telcordia GR-253-CORE) and four intermediate- or short-range OC-48/STM-16 ports per card on the client side. The port operates at 9.95328 Gbps over unamplified distances up to 80 km (50 miles) with different types of fiber such as C-SMF or dispersion compensated fiber limited by loss and/or dispersion. The port can also operate at 10.70923 Gbps in ITU-T G.709 Digital Wrapper/FEC mode. Each version of this card has a different part number. Client ports on the MXP_2.5G_10G card are also interoperable with OC-1 (STS-1) fiber-optic signals defined in Telcordia GR-253-CORE. An OC-1 signal is the equivalent of one DS-3 channel transmitted across optical fiber. OC-1 is primarily used for trunk interfaces to phone switches in the United States. The MXP_2.5G_10G card is tunable over two neighboring wavelengths in the 1550 nm, ITU 100-GHz range. It is available in sixteen different versions, covering thirty-two different wavelengths in the 1550 nm range.
MXPP_2.5G_10G	15454-	

Table 2-5 Cisco ONS 15454 DWDM Cards (continued)

Card	Part Number	Description
MXP_2.5G_10E	15454-10ME-xx.x=	The 2.5 Gbps-10 Gbps Muxponder-100 GHz-Tunable xx.xx-xx.xx (MXP_2.5G_10E) card has nine sets of ports located on the faceplate and can be installed in Slots 1 through 6 and 12 through 17. It is a DWDM muxponder for the ONS 15454 platform that supports full optical transparency on the client side. The card multiplexes four 2.5 Gbps client signals (4 x OC48/STM-16 SFP) into a single 10-Gbps DWDM optical signal on the trunk side. The MXP_2.5G_10E card provides wavelength transmission service for the four incoming 2.5 Gbps client interfaces. It passes all SONET overhead bytes transparently. Each version of this card has a different part number. The MXP_2.5G_10E works with Optical Transparent Network (OTN) devices defined in ITU-T G.709. The card supports Optical Data Channel Unit 1 (ODU1) to Optical Channel Transport Unit (OTU2) multiplexing, an industry standard method for asynchronously mapping a SONET/SDH payload into a digitally wrapped envelope. The MXP_2.5G_10E card is tunable over four neighboring wavelengths in the 1550 nm, ITU 100-GHz range. It is available in eight different versions, covering thirty-two different wavelengths in the 1550 nm range. It is not compatible with the MXP_2.5G_10G card, which does not supports full optical transparency. The faceplate designation of the card is “4x2.5G 10E MXP.”
MXP_2.5G_10E-C	15454-10ME-C=	This muxponder has the same features as the MXP_2.5G_10E card, but its trunk interface can be tuned over the entire C band.
MXP_2.5G_10E-L	15454-10ME-L=	This muxponder has the same features as the MXP_2.5G_10E card, but its trunk interface can be tuned over the entire L band.
MXP_MR_2.5G	15454-Datamux2.5GDM	The MXP_MR_2.5G card has nine sets of ports located on the faceplate. The MXP_MR_2.5G card aggregates a mix and match of client Storage Area Network (SAN) service client inputs (GE, FICON, Fibre Channel, and ESCON) into one 2.5 Gbps STM-16/OC-48 DWDM signal on the trunk side. It provides one long-reach STM-16/OC-48 port per card and is compliant with Telcordia GR-253-CORE.
MXPP_MR_2.5G	15454-Datamux2.5GDMP	The MXPP_MR_2.5G card has ten sets of ports located on the faceplate. The 2.5-Gbps Multirate Muxponder-Protected-100 GHz-Tunable 15xx.xx-15yy.yy (MXPP_MR_2.5G) card aggregates various client SAN service client inputs (GE, FICON, Fibre Channel, and ESCON) into one 2.5 Gbps STM-16/OC-48 DWDM signal on the trunk side. It provides two long-reach STM-16/OC-48 ports per card and is compliant with ITU-T G.957 and Telcordia GR-253-CORE.

Table 2-5 Cisco ONS 15454 DWDM Cards (continued)

Card	Part Number	Description
MXP_MR_10DME_C	15454-10DME-C=	The MXP_MR_10DME_C and MXP_MR_10DME_L cards aggregate a mix of client SAN service client inputs (GE, FICON, and Fibre Channel) into one 10-Gbps STM-64/OC-192 DWDM signal on the trunk side. It provides one long-reach STM-64/OC-192 port per card and is compliant with Telcordia GR-253-CORE and ITU-T G.957. They pass all SONET/SDH overhead bytes transparently. The ITU-T G.709 compliant digital wrapper function formats the DWDM wavelength so that it can be used to set up generic communications channels (GCCs) for data communications, enable forward error correction (FEC), or facilitate performance monitoring (PM). The cards work with the OTN devices defined in ITU-T G.709. The cards support ODU1 to OTU2 multiplexing, an industry standard method for asynchronously mapping a SONET/SDH payload into a digitally wrapped envelope. You can install MXP_MR_10DME_C and MXP_MR_10DME_L cards in Slots 1 to 6 and 12 to 17. The MXP_MR_10DME_C card features a tunable 1550-nm C-band laser on the trunk port. The laser is tunable across 82 wavelengths on the ITU grid with 50-GHz spacing between wavelengths. The MXP_MR_10DME_L features a tunable 1580-nm L-band laser on the trunk port. The laser is tunable across 80 wavelengths on the ITU grid, also with 50-GHz spacing. Each card features four 1310-nm lasers on the client ports and contains five transmit and receive connector pairs (labeled) on the card faceplate. The cards use dual LC connectors on the trunk side and use SFP modules on the client side for optical cable termination. The SFP pluggable modules are SR or IR and support an LC fiber connector.
MXP_MR_10DME_L	15454-10DME-L=	

2.2 Card Specifications

Refer to the “Card Reference” chapter in the *Cisco ONS 15454 DWDM Reference Manual* for a detailed description of each card.

2.2.1 Common Control Cards

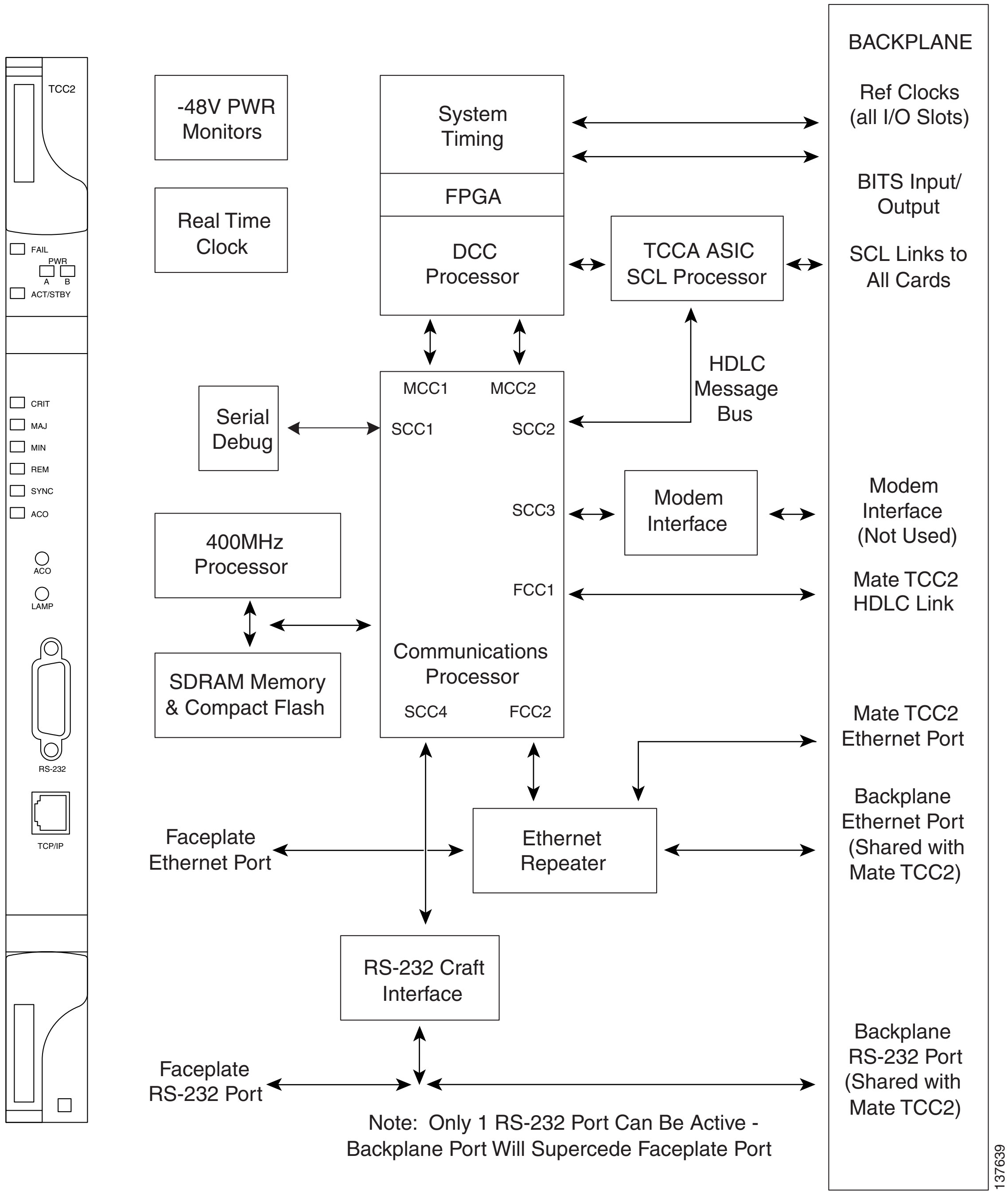
This section describes the common control cards (TCC2, TCC2P, AIC-I, and MS-ISC-100T).

2.2.1.1 TCC2 Card

The Advanced Timing, Communications, and Control (TCC2) card performs system initialization, provisioning, alarm reporting, maintenance, diagnostics, IP address detection/resolution, SONET section overhead (SOH) data communications channel/generic communications channel (DCC/GCC) termination, optical service channel (OSC) DWDM data communications network (DCN) termination, and system fault detection for the ONS 15454. The TCC2 also ensures that the system maintains Stratum 3 (Telcordia GR-253-CORE) timing requirements. It monitors the supply voltage of the system.

Figure 2-1 shows the faceplate and block diagram for the TCC2.

Figure 2-1 TCC2 Block Diagram and Faceplate



The TCC2 card terminates up to 32 DCCs. The TCC2 hardware is prepared for up to 84 DCCs, which will be available in a future software release.

The node database, IP address, and system software are stored in TCC2 nonvolatile memory, which allows quick recovery in the event of a power or card failure.

The TCC2 performs all system-timing functions for each ONS 15454. The TCC2 monitors the recovered clocks from each traffic card and two building integrated timing supply (BITS) ports for frequency accuracy. The TCC2 selects a recovered clock, a BITS, or an internal Stratum 3 reference as the system-timing reference. You can provision any of the clock inputs as primary or secondary timing sources. A slow-reference tracking loop allows the TCC2 to synchronize with the recovered clock, which provides holdover if the reference is lost.

The TCC2 monitors both supply voltage inputs on the shelf. An alarm is generated if one of the supply voltage inputs has a voltage out of the specified range.

Install TCC2 cards in Slots 7 and 11 for redundancy. If the active TCC2 fails, traffic switches to the protect TCC2.

The TCC2 card has two built-in interface ports for accessing the system: an RJ-45 10BaseT LAN interface and an EIA/TIA-232 ASCII interface for local craft access. It also has a 10BaseT LAN port for user interfaces via the backplane.

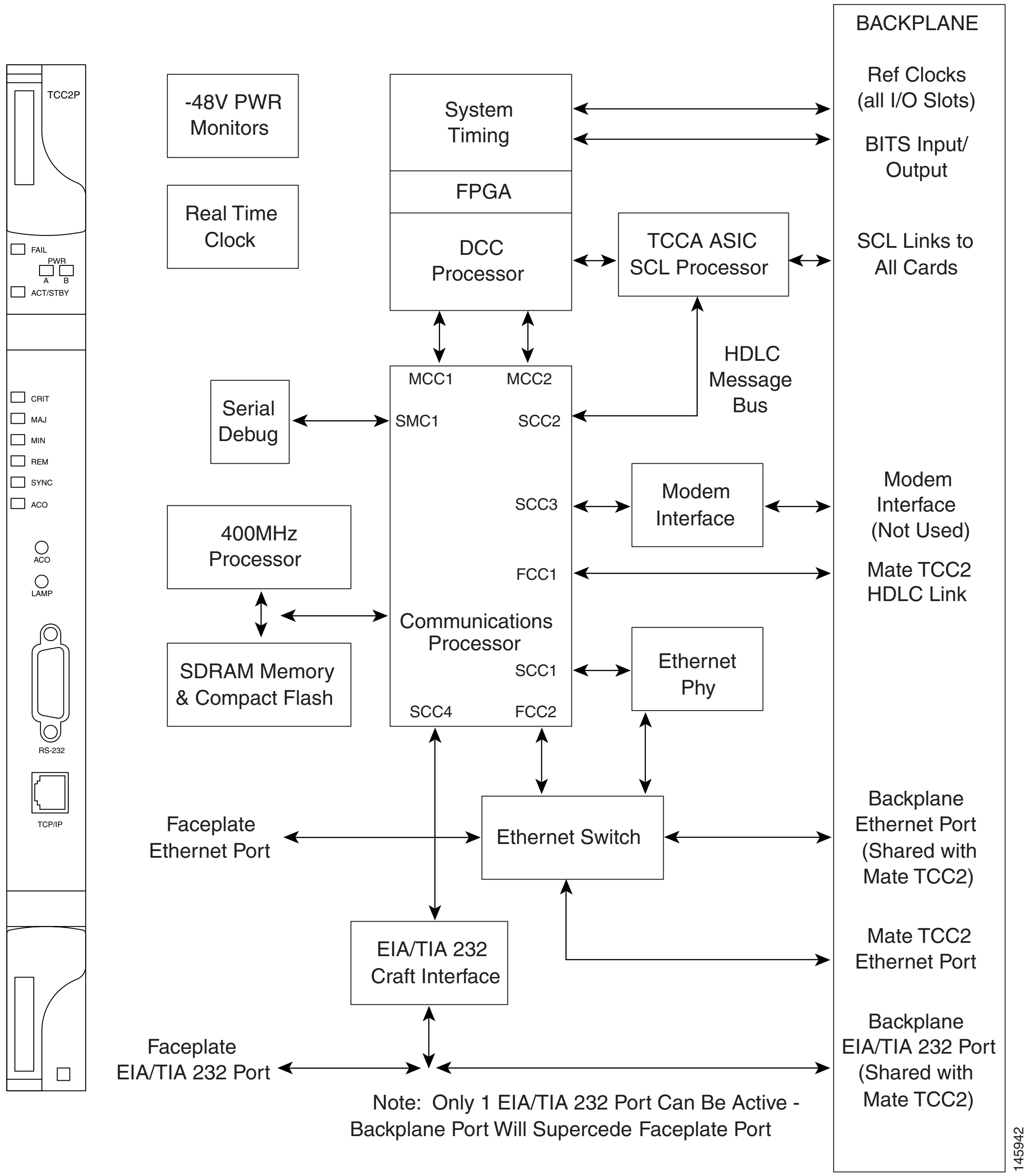
2.2.1.2 TCC2P Card

The Advanced Timing, Communications, and Control Plus (TCC2P) card is an enhanced version of the TCC2 card. The primary enhancements are Ethernet security features and 64K composite clock BITS timing.

The TCC2P card performs system initialization, provisioning, alarm reporting, maintenance, diagnostics, IP address detection/resolution, SONET SOH DCC/GCC termination, and system fault detection for the ONS 15454. The TCC2P also ensures that the system maintains Stratum 3 (Telcordia GR-253-CORE) timing requirements. It monitors the supply voltage of the system.

Figure 2-2 shows the faceplate and block diagram for the TCC2P card.

Figure 2-2 TCC2P Block Diagram and Faceplate



The TCC2P card supports multichannel, high-level data link control (HDLC) processing for the DCC. Up to 84 DCCs can be routed over the TCC2P card and up to 84 section DCCs can be terminated at the TCC2P card (subject to the available optical digital communication channels). The TCC2P selects and processes 84 DCCs to facilitate remote system management interfaces.

The TCC2P card also originates and terminates a cell bus carried over the module. The cell bus supports links between any two cards in the node, which is essential for peer-to-peer communication. Peer-to-peer communication accelerates protection switching for redundant cards.

The node database, IP address, and system software are stored in TCC2P card nonvolatile memory, which allows quick recovery in the event of a power or card failure.

The TCC2P card performs all system-timing functions for each ONS 15454. The TCC2P card monitors the recovered clocks from each traffic card and two BITS ports for frequency accuracy. The TCC2P card selects a recovered clock, a BITS, or an internal Stratum 3 reference as the system-timing reference. You can provision any of the clock inputs as primary or secondary timing sources. A slow-reference tracking loop allows the TCC2P card to synchronize with the recovered clock, which provides holdover if the reference is lost.

The TCC2P card supports 64/8K composite clock and 6.312 MHz timing output. The TCC2P card monitors both supply voltage inputs on the shelf. An alarm is generated if one of the supply voltage inputs has a voltage out of the specified range.

Install TCC2P cards in Slots 7 and 11 for redundancy. If the active TCC2P card fails, traffic switches to the protect TCC2P card. All TCC2P card protection switches conform to protection switching standards when the bit error rate (BER) counts are not in excess of 1 * 10 exp - 3 and completion time is less than 50 ms.

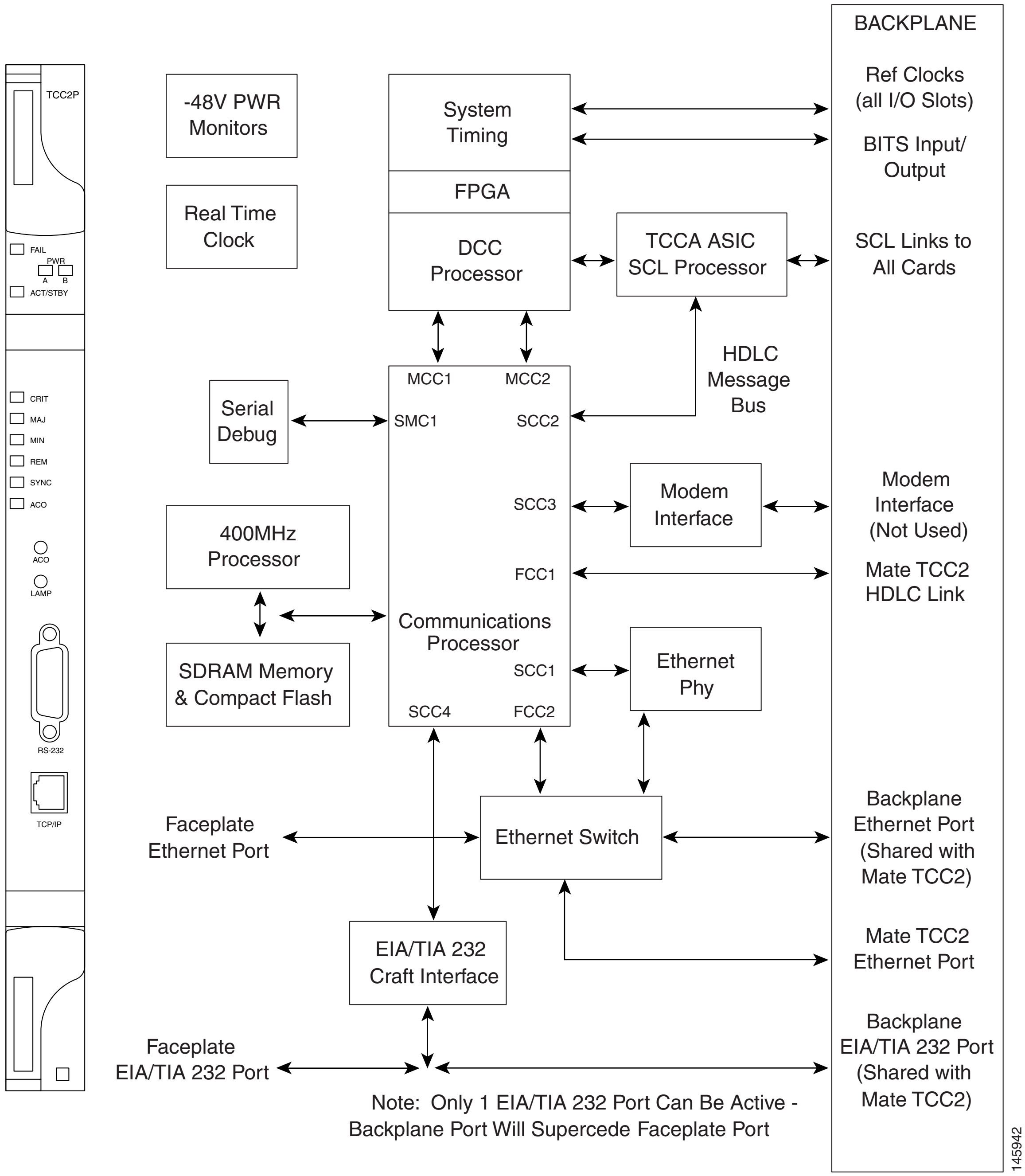
The TCC2P card has two built-in Ethernet interface ports for accessing the system: one built-in RJ-45 port on the front faceplate for on-site craft access and a second port on the backplane. The rear Ethernet interface is for permanent LAN access and all remote access via TCP/IP as well as for Operations Support System (OSS) access. The front and rear Ethernet interfaces can be provisioned with different IP addresses using CTC.

Two EIA/TIA-232 serial ports, one on the faceplate and a second on the backplane, allow for craft interface in TL1 mode.

2.2.1.3 MS-ISC-100T Card

The MS-ISC-100T Ethernet LAN card (see Figure 2-3), which is a 12-port NEBS3 Ethernet Switch running Cisco IOS. The MS-ISC-100T card must be equipped in an NC shelf; the preferred slots are 6 and 12. MS-ISC-100T Cisco IOS configuration is part of the software package and is automatically loaded to the card at start-up. This configuration can be modified using the Cisco IOS command-line interface (CLI) only. The CLI is disabled by default, but it can be enabled from the Cisco Transport Controller (CTC) interface. All MS-ISC-100T ports are turned on by default. Using the CLI, you can turn off ports that are not used.

Figure 2-3 MS-ISC-100T Faceplate and Block Diagram



The MS-ISC-100T separates internal and external traffic using a VLAN.

A Cisco IOS configuration file assigns a specific role to each of MS-ISC-100T ports that are shown on the card faceplates. They are as follows:

- DCN Port: Connected to external supervision
- SSC Port: Connected to a TCC2/TCC2P equipped in a subtended shelf
- NC Port: Connected to a TCC2/TCC2P equipped in an NC shelf

- PROT: Connected to the other MS-ISC-100T ports

The TCC is connected to the MS LAN by its front panel port. The back panel Ethernet port is disabled and cannot be used in the MS node.

2.2.2 Optical Service Channel Cards

The Optical Service Channel (OSC) is a bidirectional channel that connects all the nodes in a DWDM ring that transports general-purpose information without affecting client traffic. In its primary application, this channel carries data sub-channels for telemetry (supervisory) services for an optical system, provides orderwire applications, and provides transparent links between each node of the network for user-defined or proprietary functions.

The ONS 15454 has two OSC cards, the OSCM and the OSC-CSM.

Table 2-6 shows the optical specifications for the OSCM card.

Table 2-6 OSCM Card Optical Specifications

Parameter	**Condition**	**Min**	**Max**	**Unit**
OSC bandwidth at –0.5 dB	OSCRX -> TX – OSCTX	1500	1520	nm
Insertion loss	OSCRX -> TX – OSCTX	—	1.4	dB
OSC band chromatic dispersion	OSCRX -> TX – OSCTX	–10	+10	ps/nm
Polarization Mode Dispersion (PMD)	OSCRX -> TX – OSCTX	—	0.1	ps
Polarization Dependent Loss (PDL)	OSCRX -> TX – OSCTX	0-10dB	0.45	dB
Optical power setting accuracy	—	–0.5	+0.5	dB
Optical attenuation VOAosc power set resolution (granularity)	—	—	0.1	dB
Optical power stability	—	–0.2	+0.2	dB
Optical power setting time	—	—	200	ms
VOAosc dynamic range	—	30	—	dB
VOAosc off state	AVS state	39	—	dB
Directivity	—	40	—	dB
Return loss	—	40	—	dB

Table 2-7 shows the optical specifications for the OSC-CSM card.

Table 2-7 OSC-CSM Card Optical Specifications

Parameter	**Condition**	**Min**	**Max**	**Unit**
OSC (–0.5 dB bandwidth)	$LINE_{RX}$ – OSC_{TX} OSC_{RX} – $LINE_{TX}$	1500	1520	nm
Channels (–0,5 dB bandwidth)	$LINE_{RX}$ – COM_{TX} COM_{RX} – $LINE_{TX}$	1529	1605	nm

Table 2-7 OSC-CSM Card Optical Specifications (continued)

Parameter		Condition	Min	Max	Unit
Insertion loss		$LINE_{RX} – OSC_{TX}$	0.5	1.4	dB
		$LINE_{RX} – COM_{TX}$	0.4	1.2	dB
		$OSC_{RX} – LINE_{TX}$	1.2	2.2	dB
		$COM_{RX} – LINE_{TX}$	1.2	2.2	dB
OSC crosstalk		$LINE_{RX} – OSC_{TX}$ $OSC_{RX} – LINE_{TX}$	30	—	dB
Isolation		$LINE_{RX} – COM_{TX}$ $COM_{RX} – LINE_{TX}$	–15	—	dB
OSC band chromatic dispersion		$LINE_{RX} – OSC_{TX}$ $OSC_{RX} – LINE_{TX}$	–20	+20	ps/nm
Channel band chromatic dispersion		$LINE_{RX} – COM_{TX}$ $COM_{RX} – LINE_{TX}$	–20	+20	ps/nm
PMD		Each optical path	—	0.1	ps
PDL		$LINE_{RX} – COM_{TX}$ $LINE_{RX} – OSC_{TX}$ $COM_{RX} – LINE_{TX}$	—	0.2	dB
		$OSC_{RX} – LINE_{TX}$	—	0.5	
Optical power setting accuracy		VOA in closed loop	–0.5	+0.5	dB
Optical power setting time		VOA in closed loop	—	200	ms
VOAosc dynamic range		—	30	—	dB
VOAosc off state		AVS state	39	—	dB
Switch input lambda range		$COM_{RX} – LINE_{TX}$	1528	1605	nm
Switch open condition attenuation		$COM_{RX} – LINE_{TX}$	>40	—	dB
Switching time	Closed/Open	$COM_{RX} – LINE_{TX}$	—	5	ms
	Open/Closed		—	20	
Directivity		—	40	—	dB
Return loss		—	40	—	dB

2.2.3 Optical Add and Drop Cards

This section describes the internal parameter and performance information for the 32WSS, 32WSS-L, 32DMX, 32DMX-L, 32DMX-O, 32DMX-L, AD-1B-xx.x, AD-4B-xx.x, AD-1C-xx.x, AD-2C-xx.x, AD-4C-xx.x, and MMU cards.

2.2.3.1 32WSS Card

Table 2-8 defines internal parameter and performance details for the 32WSS card.

Table 2-8 32WSS Card Parameters and Performance

Parameter	Condition	Min	Typical	Max	Unit
Channel grid					
–0.5 dB bandwidth	EXP RX => COM TX	+/–115			pm
–0.5 dB bandwidth	Add 1, 32 => COM TX	+/–135			
Insertion loss	EXP RX => COM TX	—	—	11.3	dB
	COM RX => EXP TX	—	—	1.5	
	Add 1, 32 => COM TX	—	—	7.6	
	COM RX => DROP TX	6	—	8.5	
Adjacent crosstalk	Add 1, 32	23	—	—	dB
Multipath interference	EXP RX => COM TX	45	—	—	
Nonadjacent crosstalk	Add 1, 32	30	—	—	
PDL	EXP RX => COM TX	—	—	0.9	dB
	COM RX => EXP TX	—	—	0.1	
	Add 1, 32 => COM TX	—	—	0.5	
	COM RX => DROP TX	—	—	0.1	
In-band chromatic dispersion	All paths	–20	—	+20	ps/nm
Group delay ripple	All paths	–10	—	+10	ps
In-band PMD	All paths	—	—	0.5	ps
Optical power/VOA attenuation setting resolution	—	—	—	0.1	dB
Optical power setting accuracy	—	–0.5	—	+ 0.5	dB
Optical power setting precision	—	–0.1	—	+ 0.1	dB
Optical power/VOA attenuation settling time	—	—	—	200	ms
Optical switch state settling time	—	—	—	5	ms
	—	—	—	5	
VOA dynamic range	EXP RX => COM TX	20	—	—	dB
	Add 1, 32 => COM TX	25	—	—	
Channel shutoff attenuation (AVS)	EXP RX => COM TX	40	—	—	dB
	Add 1, 32 => COM TX		—	—	
	EXP RX => COM TX	40	—	—	
	Add 1, 32 => COM TX		—	—	
Optical port isolation	EXP RX => COM TX	32	—	—	dB
	Add 1, 32 => COM TX	42	45	—	

Table 2-8 32WSS Card Parameters and Performance (continued)

Parameter	Condition	Min	Typical	Max	Unit
Directivity	Add 1,32 <=> Add 1,32	40	—	—	dB
	Add 1, 32 <=> EXP RX				
Return loss	—	40	—	—	dB
Maximum optical input power	—	300	—	—	mW
Maximum AWG startup time	—	—	—	10	min.

2.2.3.2 32WSS-L Card

The 32WSS-L card is capable of operating bidirectionally over the L band of the optical spectrum (wavelengths from 1577 nm to 1605 nm).

In one line direction, the EXP-RX port receives the aggregate optical signal. The first arrayed wavelength grating (AWG) opens the spectrum and each wavelength goes through a 1x2 optical switch, where the same wavelength can be added from its ADD port. A dedicated per-channel VOA allows per-channel power regulation. The second AWG multiplexes all the wavelengths and the aggregate signal goes through the COM-TX output port.

In the other line direction, the aggregate optical signal comes in from the COM-RX port. An 80/20 splitter (80 Express/20 Drop) sends the optical signals on two output ports, the DROP-TX port for demultiplexing and dropping wavelengths, and the EXP-TX port for the next stage.

Each input and output port is equipped with either a real or a virtual photodiode. All VOAs for the 32 channels and switches are software-controlled for remote reconfiguration. Table 2-9 defines all optical internal parameters and performances details.

Table 2-9 32WSS-L Card Parameters and Performance

Parameter	Condition	Min	Typical	Max	Unit
–0.5 dB bandwidth	EXP RX => COM TX	+/–91	±116	—	pm
–0.5 dB bandwidth	Add 1, 32 => COM TX	+/–135	±161	—	
Insertion loss	EXP RX => COM TX	—	9.7	11.3	dB
	COM RX => EXP TX	—	1.4	1.6	
	Add 1, 32 => COM TX	—	6.2	8.0	
	COM RX => DROP TX	6	8	8.5	
Adjacent crosstalk	Add 1, 32	23	30	—	dB
Multi path interference	EXP RX => COM TX	41	49	—	
Nonadjacent crosstalk	Add 1, 32	30	42	—	
PDL	EXP RX => COM TX	—	0.5	0.9	dB
	COM RX => EXP TX	—	0.5	0.9	
	Add 1, 32 => COM TX	—	0.7	1.5	
	COM RX => DROP TX	—	0.7	1.3	

Table 2-9 32WSS-L Card Parameters and Performance (continued)

Parameter	Condition	Min	Typical	Max	Unit
In-band chromatic dispersion	All paths	–20	—	+20	ps/nm
Group delay ripple	All paths	–10	—	+10	ps
In-band PMD	All paths	—	—	1	ps
Optical power/VOA attenuation setting resolution	—	—	—	0.1	dB
Optical power setting accuracy	—	–0.7	0.1	+ 0.7	dB
Optical power setting precision	—	–0.4	0.1	+ 0.4	dB
Optical power/VOA attenuation settling time	—	—	—	200	ms
Optical switch state settling time	—	—	—	5	ms
	—	—	—	5	
VOA dynamic range	EXP RX => COM TX	20	25	—	dB
	Add 1, 32 => COM TX	25	25	—	
Channel shutoff attenuation (AVS)	EXP RX => COM TX	28	45	—	dB
	Add 1, 32 => COM TX			—	
	EXP RX => COM TX	39	50	—	
	Add 1, 32 => COM TX			—	
Optical port isolation	EXP RX => COM TX	27	33	—	dB
	Add 1, 32 => COM TX	36	50	—	
Directivity	Add 1,32 <=> Add 1,32	40	—	—	dB
	Add 1, 32 <=> EXP RX				
Return loss	—	40	—	—	dB
Maximum optical input power	—	300	—	—	mW
Maximum AWG startup time	—	—	—	10	min.

The 32WSS-L card supports OChSPRing protection. This implies that the optical plug-in module needs to perform a switch fast enough to allow a total unit switching time of less than 10 ms.

The 32WSS-L is a double-slot card that has three LEDs on its front panel.

2.2.3.3 32DMX Card

Table 2-10 defines the 32DMX card optical parameters and the maximum insertion loss allowed.

Table 2-10 32DMX Card Optical Parameters and Insertion Loss

Parameter	Condition	Min	Typical	Max	Unit
–1 dB Bandwidth	COM RX => TX 1, 32 (OUT)	+/–110	—	—	pm
–3 dB Bandwidth		+/–200	—	—	
Insertion Loss	COM RX => TX 1, 32	—	—	5.5	dB
Adjacent Crosstalk	COM RX => TX 1, 32	26	—	—	dB
Nonadjacent Crosstalk		34	—	—	
Total Crosstalk		20	—	—	
PDL	COM RX => TX 1, 32	—	—	0.5	dB
In Band Chromatic Dispersion	All paths	–20	—	+20	ps/nm
Group Delay Ripple	All paths	–10	—	+10	ps
In Band PMD	All paths	—	—	0.5	ps
VOA attenuation Setting Resolution	—	—	—	0.1	dB
VOA Attenuation Setting Accuracy	Attenuation range 0 – 10 dB	–0.5		+ 0.5	dB
VOA Attenuation Setting Precision	Attenuation range 0 – 10 dB	–0.1		+ 0.1	dB
Power Monitoring Indication Response Time Internal Cycle	All PDs (both real and virtual)	—	—	20	ms
Optical Power/VOA Attenuation Settling time	—	—	—	200	ms
VOA shut-off Attenuation (AVS)	COM RX => TX 1, 32	40	—	—	dB
Directivity	—	40	—	—	dB
Return Loss	—	40	—	—	dB
Maximum Optical input power	—	300	—	—	mW
Maximum AWG Start-up time	—	—	—	10	min.

2.2.3.4 32DMX-L Card

The 32DMX-L is a unidirectional unit that operates over the L band of the optical spectrum in wavelengths from 1577 nm to 1605 nm. The 32DMX-L card receives the aggregate optical signal through the COM-RX port and demultiplexes all 32 wavelengths onto its output ports. Every port has a photodiode for optical power monitoring. The common path is equipped with a common VOA for optical power regulation.

The single VOA on the common path is the main difference between the 32DMX-L card and the 32DMX-O card, which has 32 VOAs, one for each output port. The 32DMX-L cannot provide power regulation for each individual channel.

When output ports are connected to the client equipment, an external bulk attenuator might be required to match the receive (Rx) window of the interface. Table 2-11 defines the internal optical parameters.

Table 2-11 32DMX-L Card Optical Parameters

Parameter	Condition	Min	Typical	Max	Unit
–1 dB bandwidth	COM RX => TX 1, 32 (OUT)	+/–100	—	—	pm
–3 dB bandwidth		+/–200	—	—	
Insertion loss	COM RX => TX 1, 32	—	—	5.8	dB
Adjacent crosstalk	COM RX => TX 1, 32	25	—	—	dB
Nonadjacent crosstalk		34	—	—	
Total crosstalk		20	—	—	
PDL	COM RX => TX 1, 32	—	—	0.5	dB
In-band chromatic dispersion	All paths	–20	—	+20	ps/nm
Group delay ripple	All paths	–10	—	+10	ps
In-band PMD	All paths	—	—	0.5	ps
VOA attenuation setting resolution	—	—	—	0.1	dB
VOA attenuation setting accuracy	Attenuation range 0 – 10 dB	– 0.7	—	+ 0.7	dB
VOA attenuation setting precision	Attenuation range 0 – 10 dB	–0.1	—	+ 0.1	dB
Power monitoring indication response time internal cycle	All PDs (both real and virtual)	—	—	20	ms
Optical power/VOA attenuation settling time	—	—	—	200	ms
VOA shutoff attenuation (AVS)	COM RX => TX 1, 32	40	—	—	dB
Directivity	—	40	—	—	dB
Return loss	—	40	—	—	dB
Maximum optical input power	—	300	—	—	mW
Maximum AWG startup time	—	—	—	10	min.

2.2.3.5 32MUX-O Card

Table 2-12 defines the optical parameters for the 32MUX-O card.

Table 2-12 32MUX-O Card Optical Parameters

Parameter	Min	Typical	Max	Unit
–1 dB bandwidth	160	—	300	pm
In-band ripple	—	—	0.5	dB
Insertion loss	4	—	8.5	dB
Insertion loss disuniformity	—	—	1.5	dB
Adjacent crosstalk	23	—	—	dB
Nonadjacent crosstalk	30	—	—	dB
Total crosstalk	20	—	—	dB
PDL	—	—	1.5	dB
In-band chromatic dispersion	–20	—	+20	ps/nm
In-band PMD	—	—	0.5	ps
Optical power/VOA attenuation setting resolution	—	—	0.1	dB
Optical power setting accuracy	–0.5	—	+0.5	dB
VOA attenuation setting accuracy	–0.1	—	+0.1	dB
Power monitoring indication response time	—	—	20	ms
Optical power/VOA attenuation settling time	—	—	200	ms
Optical rise and fall time	—	—	200	ms
Optical over and undershoot	–1.5	—	+1.5	dB
VOA dynamic range	25	—	—	dB
VOA shutoff attenuation (AVS) with unit powered off	20	—	—	dB
VOA shutoff attenuation (AVS) with unit powered on	40	—	—	dB
Directivity	40	—	—	dB
Return loss	40	—	—	dB
Optical monitor tap splitting ratio on monitor port	19	—	21	dB
Maximum optical input power	300	—	—	mW
Maximum AWG startup time	—	—	10	min.

2.2.3.6 32DMX-O Card

Table 2-13 defines the optical parameters for the 32DMX-O card.

Table 2-13 32DMX-O Card Optical Parameters

Parameter	Min	Typical	Max	Unit
–1 dB bandwidth	160	—	300	pm
In-band ripple	—	—	0.5	dB
Insertion loss	4	—	8.5	dB
Insertion loss disuniformity	—	—	1.5	dB
Adjacent crosstalk	23	—	—	dB
Nonadjacent crosstalk	30	—	—	dB
Total crosstalk	20	—	—	dB
PDL	—	—	1.5	dB
In-band chromatic dispersion	–20	—	+20	ps/nm
In-band PMD	—	—	0.5	ps
Optical power/VOA attenuation setting resolution	—	—	0.1	dB
Optical power setting accuracy	–0.5	—	+0.5	dB
VOA attenuation setting accuracy	–0.1	—	+0.1	dB
Power monitoring indication response time	—	—	20	ms
Optical power/VOA attenuation settling time	—	—	200	ms
Optical rise and fall time	—	—	200	ms
Optical over and undershoot	–1.5	—	+1.5	dB
VOA dynamic range	25	—	—	dB
VOA shutoff attenuation (AVS) with unit Powered Off	20	—	—	dB
VOA shutoff attenuation (AVS) with unit powered on	40	—	—	dB
Directivity	40	—	—	dB
Return loss	40	—	—	dB
Optical monitor tap splitting ratio on monitor port	19	—	21	dB
Maximum optical input power	300	—	—	mW
Maximum AWG startup time	—	—	10	min.

2.2.3.7 4MD-xx.x Card

Table 2-14 defines optical parameters for the 4MD-xx.xx card.

Table 2-14 4MD-xx.x Card Optical Parameters

Optical Parameters	Value
Maximum insertion loss demultiplex section	3.2 dB
Maximum insertion loss multiplex section	3.6 dB at VOA min attenuation
Adjacent crosstalk	25 dB
Nonadjacent crosstalk	38 dB
VOA dynamic range	30 dB

2.2.3.8 C-Band OADM Filter Cards

Table 2-15 to Table 2-19 define optical parameters for the AD-1B-xx.x, AD-4B-xx.x, AD-1C-xx.x, AD-2C-xx.x, and AD-4C-xx.x cards.

Table 2-15 AD-1B-xx.x Card Optical Parameters

Optical Parameters	Value
Maximum insertion loss drop section	3 dB at VOA minimum attenuation
Maximum insertion loss add section	2.2 dB
Maximum insertion loss express section (Exp RX – COM TX)	1.6 dB
Maximum insertion loss express section (COM RX – Exp TX)	2.8 dB at VOA minimum attenuation
In-band ripple	0.3 dB
Out-of-band ripple (COM RX – Exp TX)	0.5 dB at VOA minimum attenuation
Out-of-band ripple (Exp RX – COM TX)	0.3 dB
Left/Right adjacent crosstalk	25 dB
First channel nonadjacent crosstalk	30 dB
Nonadjacent crosstalk	35 dB
Left/Right isolation drop path	–26 dB
Left/Right isolation add path	–13 dB

Table 2-16 AD-4B-xx.x Card Optical Parameters

Optical Parameters	Value
Maximum insertion loss drop section	4.5 dB at VOA minimum attenuation
Maximum insertion loss add section	3.5 dB
Maximum insertion loss express section (Exp RX – COM TX)	3 dB
Maximum insertion loss express section (COM RX – Exp TX)	4.8 dB at VOA minimum attenuation
In-Band Ripple	0.3 dB

Table 2-16 AD-4B-xx.x Card Optical Parameters (continued)

Optical Parameters	Value
In-band ripple	0.5 dB at VOA minimum attenuation
Out-of-band ripple (COM RX – Exp TX)	0.3 dB
Left/Right adjacent crosstalk	25 dB
First channel nonadjacent crosstalk	30 dB
Nonadjacent crosstalk	35 dB
Left/Right isolation drop path	–26 dB
Left/Right isolation add path	–13 dB

Table 2-17 AD-C-xx.x Card Optical Parameters

Optical Parameters	Value
Maximum insertion loss drop section	2 dB
Maximum insertion loss add section	2.6 dB at VOA minimum attenuation
Maximum insertion loss express section (Exp RX – COM TX)	1.1 dB
Maximum insertion loss express section (COM RX – Exp TX)	2.2 dB at VOA minimum attenuation
Adjacent crosstalk	25 dB
Nonadjacent crosstalk	35 dB
Isolation left/right	–14 dB
VOA dynamic range	30 dB

Table 2-18 AD-2C-xx.x Card Optical Parameters

Optical Parameters	Value
Maximum insertion loss drop section	2.4 dB
Maximum insertion loss add section	3.1 dB at VOA minimum attenuation
Maximum insertion loss express section (Exp RX – COM TX)	1.5 dB
Maximum insertion loss express section (COM RX – Exp TX)	2.7 dB at VOA minimum attenuation
Adjacent crosstalk	25 dB
Nonadjacent crosstalk	35 dB
Isolation left/right	–14 dB
VOA dynamic range	30 dB

Table 2-19 AD-4C-xx.x Card Optical Parameters

Optical Parameters	Value
Maximum insertion loss drop section	5.4 dB
Maximum insertion loss add section	4.9 dB at VOA min attenuation
Maximum insertion loss express section (Exp RX – COM TX)	1.2 dB
Maximum insertion loss express section (COM RX – Exp TX)	2.5 dB at VOA min attenuation
Adjacent crosstalk	25 dB
Nonadjacent crosstalk	38 dB
Isolation (COM RX – Exp TX)	–26 dB
Isolation (Exp RX – COM TX)	–13 dB
VOA dynamic range	30 dB

2.2.3.9 MMU Card

The MMU is a single-slot bidirectional card that operates over both the C-band and L-band optical spectrums. The MMU has six LC-PC-II optical connectors on its front panel. Table 2-20 shows the MMU specifications.

Table 2-20 MMU Card Optical Specifications

Parameter	Condition	Notes	Min	Typical	Max	Unit
Operating bandwidth	All paths	All SOP, including WDL and within whole operating temperature range, connectors included	1500 – 1605	—	—	nm
Insertion loss	EXP RX => COM TX		—	—	7.0	dB
	EXP A RX => COM TX		—	—	2.3	
	COM RX => EXP TX		—	—	0.8	
	COM RX => EXP A TX		—	—	14.8	
Wavelength dependent losses	C band only		—	—	0.3	dB
	L band only		—	—	0.3	
	C + L band		—	—	0.5	
PDL	C band only	—	—	—	0.2	dB
	L band only	—	—	—	0.2	
	C + L band	—	—	—	0.3	
Chromatic dispersion	All paths	—	–20	—	+20	ps/nm
PMD	All paths	—	—	—	0.1	ps

Table 2-20 MMU Card Optical Specifications (continued)

Parameter	Condition	Notes	Min	Typical	Max	Unit
Optical power reading resolution	All PDs (both real and virtual)	—	—	—	0.1	dB
Optical power reading precision		—	– 0.1	—	0.1	dB
Directivity	EXP RX => EXP A RX	All SOP, including WDL and within whole operating temperature range	40	—	—	dB
	EXP RX => EXP B RX					
	EXP A RX => EXP B RX					
Return loss	—	—	40	—	—	dB
Maximum optical input power	—	Maximum power handling	500	—	—	mW

2.2.4 Optical Amplifiers

The optical amplifier cards can be installed in Slots 1 through 6 and 12 through 17.

These cards contain three main modules:

- Optical plug-in module
- Microprocessor module (uP8260)
- DC/DC converter

The optical plug-in module has a built-in microcontroller for managing functionalities such as the optical power, laser current, and temperature control loops.

The microprocessor module (uP8260) manages the communication between the optical amplifier card and the TCC2/TCC2P card, and provides all the Operation, Administration, Maintenance, and Provisioning (OAM&P) functions (including controls and alarms). The DC/DC converter provides the power supply voltages for the cards.

The Cisco ONS 15454 has five optical amplifier cards:

- C-Band Preamplifier (OPT-PRE)
- C-Band Booster (OPT-BST)
- C-Band Booster Enhanced (OPT-BST-E)
- L-Band Amplifier (OPT-AMP-L)
- L-Band Booster (OPT-BST-L)

2.2.4.1 OPT-PRE Card

Table 2-21 provides the internal parameters and performance information for the OPT-PRE preamplifier card.

Table 2-21 OPT-PRE Card Standard Power and Gain Range

Parameter	Comment	Min	Typical	Max	Unit
Total input signal power range	Full channel load; see Figure 2-4 for a detailed Pin-Pout power mask	–4	—	12	dBm
	Single channel; see Figure 2-4 for a detailed Pin-Pout power mask	–22	—	–6	dBm
Maximum output signal power	Full channel load	17.0	—	17.5	dBm
	Single channel	–1.0	—	–0.5	dBm
Mid-stage loss range	—	3	—	9	dB
Maximum total mid-stage output power	—	—	—	15	dBm
Maximum per-channel mid-stage output power	At 32 channels	—	—	0	dBm
Maximum optical amplifier signal gain	With tilt controlled at 0 dB	—	—	21	dB
Standard gain range	With tilt controlled at 0 dB	5	—	21	dB

Figure 2-4 shows a graphical representation of a standard range power mask for OPT-PRE card.

Figure 2-4 OPT-PRE Standard Range Power Mask

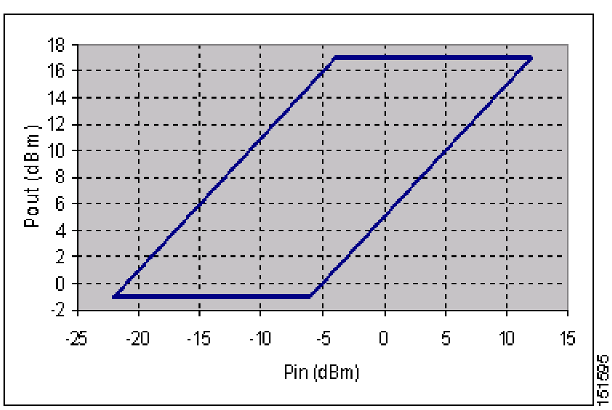


Table 2-22 indicates the extended power and gain range for OPT-PRE card.

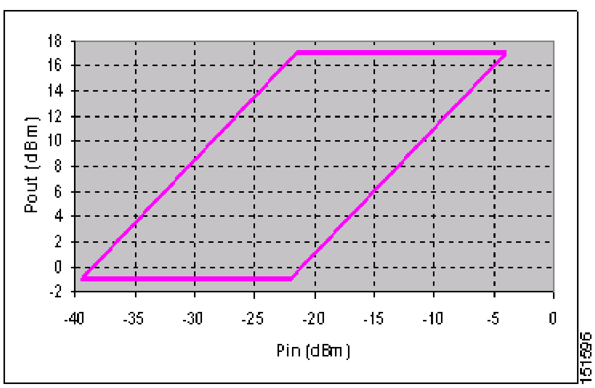
Table 2-22 OPT-PRE Extended Power and Gain Range

Parameter	Comment	Min	Typical	Max	Unit
Total input signal power range	Full channel load See Figure 2-5 for detailed P_{in}-P_{out} power mask	–21.5		–4	dBm
	Single channel See Figure 2-5 for detailed P_{in}-P_{out} power mask	–39.5		–22	dBm
Maximum output signal power	Full channel load	17.0	—	17.5	dBm
	Single channel	–1.0	—	–0.5	dBm
Extended gain range[1]	See Figure 2-5 Uncontrolled Tilt	21		38.5	dB

1. In the DWDM system, the amplifier will be used in Constant Gain mode for Gain <= 28 dB; in the region 28dB < Gain <= 38.5 dB, the operational mode will be Constant Output Power mode.

Figure 2-5 shows a graphical representation of an extended range power mask for an OPT-PRE card.

Figure 2-5 OPT-PRE Card Extended Range Power Mask



2.2.4.2 OPT-BST and OPT-BST-E Cards

Table 2-23 and Table 2-24 define all optical internal parameters and performance information for the OPT-BST and OPT-BST-E booster amplifier cards.

Table 2-23 OPT-BST Card Power and Gain Specification

Parameter	Comment	Min	Typical	Max	Unit
Total input signal power range	Full channel load; see Figure 2-6 for detailed Pin-Pout power mask	–3	—	12	dBm
	Single channel; see Figure 2-6 for detailed Pin-Pout power mask	–21	—	–6	dBm
Maximum output signal power	Full channel load	17.0	—	17.5	dBm
	Single channel	–1.0	—	–0.5	dBm
Maximum optical amplifier signal gain	With tilt controlled at 0 dB	—	—	20	dB
Gain range	Figure 44	5	—	20	dB
Gain tilt error at target gain tilt = 0 dB	—	—	—	0.5	dB

Figure 2-6 shows a graphical representation of the power mask for the OPT-BST card.

Figure 2-6 OPT-BST Card Power Mask

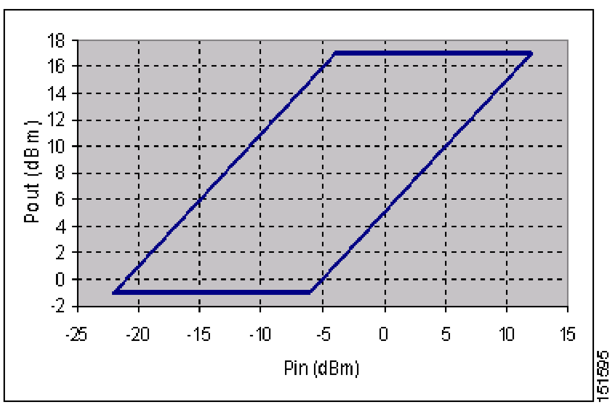


Table 2-24 defines the power and gain specifications for the OPT-BST-E card.

Table 2-24 OPT-BST-E Card Power and Gain Specifications

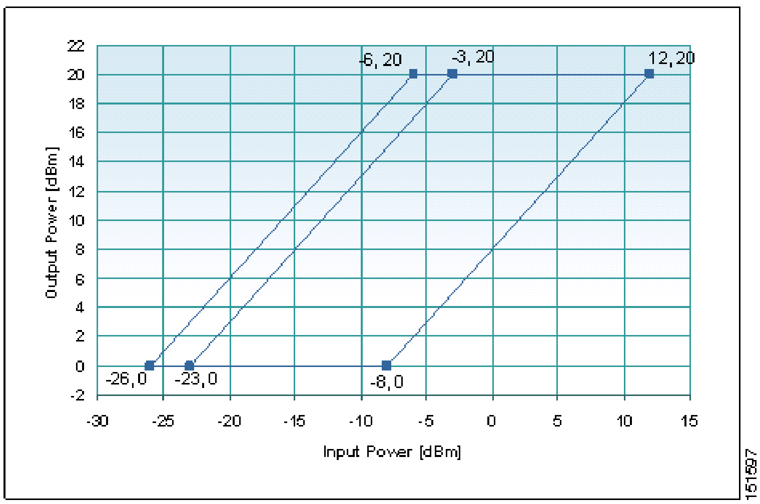
Parameter	Comment	Min	Typical	Max	Unit
Total input signal power range	Full channel load	–26	—	12	dBm
Maximum output signal power	Full channel load	20	—	20.5	dBm
Operative output power range	—	2	—	20	dBm

Table 2-24 OPT-BST-E Card Power and Gain Specifications (continued)

Parameter	Comment	Min	Typical	Max	Unit
Maximum optical amplifier signal gain	With tilt controlled at 0 dB	—	—	23	dB
Gain range	—	8	—	23	dB
Extended gain range	Gain range with tilt uncontrolled	23	—	26	dB
Gain tilt error at target gain tilt = 0 dB	—	—	—	+/– 0.5	dB

Figure 2-7 shows a graphical representation of standard extended gain range for the OPT-BST-E card.

Figure 2-7 OPT-BST-E Card Standard and Extended Gain Range



2.2.4.3 OPT-BST-L Card

The OPT-BST-L card is an L-band DWDM EDFA with OSC add/drop capability that can operate up to 64 optical transmission channels at 50-GHz channel spacing over the L band of the optical spectrum (wavelengths from 1570 nm to 1605 nm). To control gain tilt, the card is equipped with a built-in VOA managed by the card microprocessor. The OPT-BST-L provides the following features:

- True variable gain
- Fixed gain mode (with programmable tilt)
- Fast transient suppression
- Nondistorting low frequency transfer function
- Settable maximum output power
- Fixed output power mode (mode used during provisioning)
- Constant drive current mode (test mode)
- Amplified spontaneous emission (ASE) compensation in fixed gain mode

- Full monitoring and alarm handling capability with settable thresholds
- Supported optical safety functionality by signal loss detection and alarm, fast power down control, and reduced maximum output power in safe power mode

The OPT-BST-L card implements the following optical safety functions:

- Optical Safety Remote Interlock (OSRI)
- Automatic Laser Shutdown (ALS)

The OSRI function provides hardware and software capability for shutting down or reducing the output optical power to a safer level, whereas the ALS function provides a safety mechanism (automatic power reduction [APR]) for fiber cuts.

Table 2-25 defines all power and gain specifications for OPT-BST-L card:

Table 2-25 OPT-BST-L Card Power and Gain Specifications

Parameter	Comment	Min	Typical	Max	Unit
Operative input power range	Full channel load	–10	—	9	dBm
	Single channel	–37	—	–18	dBm
Maximum total output power	FW or HW limited	—	—	17.5	dBm
Signal output power range	Full channel load	—	—	17	dBm
	Single channel	–10	—		dBm
Standard gain range	Controllable gain tilt	8	—	20	dB
Extended gain range	Gain tilt uncontrolled	20	—	27	dB

Figure 2-8 shows the standard and extended gain range for the OPT-BST-L card. Red lines indicate the total measurement range accomplished by the photodiodes.

Figure 2-8 OPT-BST-L Card Standard and Extended Gain Range

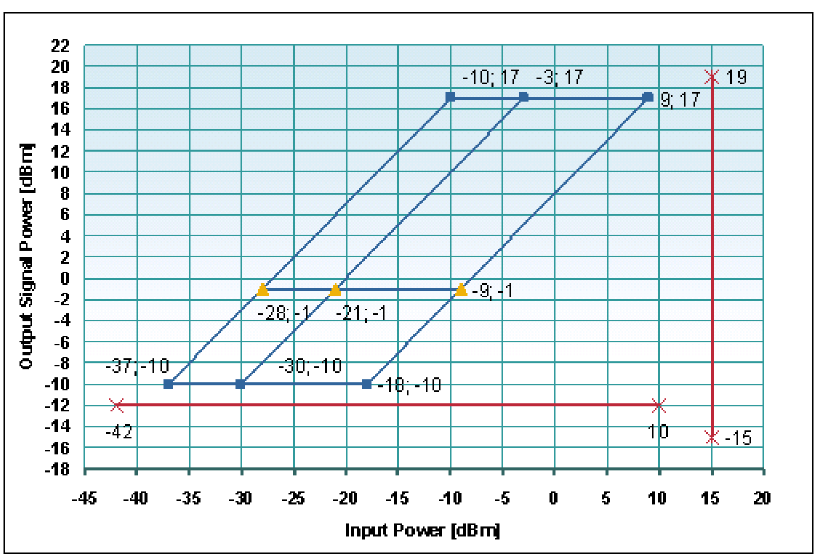


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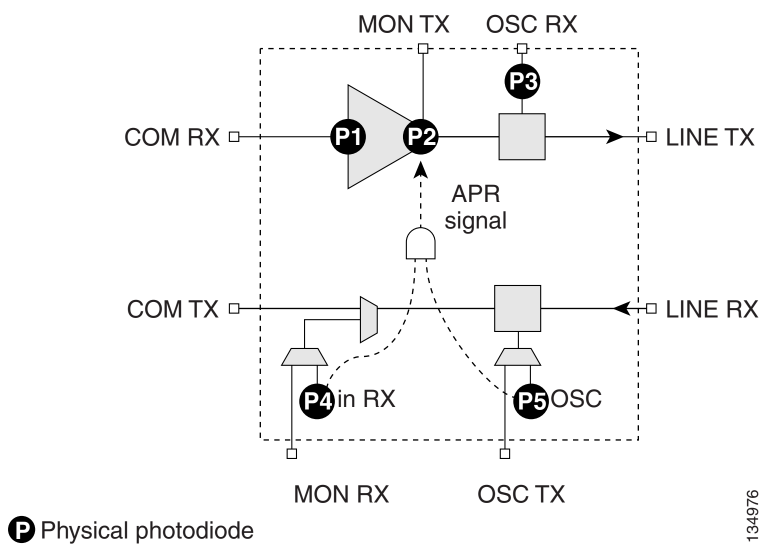
Figure 2-9 shows the internal functional structure for the OPT-BST-L card.

Figure 2-9 OPT-BST-L Card Functional Block Diagram



Optical loss (in dB) caused by the OPT-BST-L monitor ports is printed on the card faceplate. The OPT-BST-L is a single-slot bidirectional card with three LEDs and eight LC-PC-II optical connectors on the card faceplate.

2.2.4.4 OPT-AMP-L Card

The OPT-AMP-L preamplifier card can operate up to 64 optical transmission channels with 50-GHz channel spacing over the L-band optical spectrum (wavelengths from 1570 nm to 1605 nm). The OPT-AMP-L is an L-band DWDM optical amplifier module consisting of a two-stage EDFA with a MAL section for allocation of DCU and with the capability to add/drop the OSC. The OPT-AMP-L preamplifier is software configurable as a preamplifier or as a booster amplifier.

To control gain tilt, the card is equipped with a built-in VOA managed by the card's microprocessor. The VOA can also be used to pad the DCU to a reference value.

The OPT-AMP-L card provides the following features:

- True variable gain
- Fast transient suppression
- Nondistorting low frequency transfer function
- Settable maximum output power
- Fixed Output Power mode (mode used during provisioning)
- Constant drive current mode (test mode)
- MAL support for a fiber-based DCU
- ASE compensation in Fixed Gain mode
- Full monitoring and alarm handling capability with settable thresholds
- Supported optical safety functionality by means of signal loss detection and alarm, fast power down control and reduced maximum output power in safe power mode

The OPT-AMP-L card implements the following optical safety functions:

- OSRI
- ALS

The OSRI function provides hardware and software capability for shutting down optical power or reducing it to a safe level, whereas the ALS function provides an APR safety mechanism for fiber cuts.

Table 2-26 defines the standard and extended gain ranges for the OPT-AMP-L card.

Table 2-26 OPT-AMP-L Card Standard and Extended Gain Range

Parameter	Comment	Min	Typ	Max	Unit
Operative input power range	Full channel load	–15	—	8	dBm
	Single channel	–40	—	–17	dBm
Maximum total output power	FW or HW limited	—	—	21	dBm
Signal output power range	Full channel load	—	—	20	dBm
	Single channel	–5	—	—	dBm
Standard gain range	With full MSL range. Output gain tilt = 0 dB for: 0 dB MSL 12 dB	12	—	24	dB
Extended gain range	With full MSL range. Output gain tilt = 0 dB for: 0 dB MSL (36 – G) [dB]	24	—	35	dB

Figure 2-10 shows a graphical representation of standard and extended gain range for the OPT-AMP-L card.

Figure 2-10 OPT-AMP-L Card Standard and Extended Gain Range

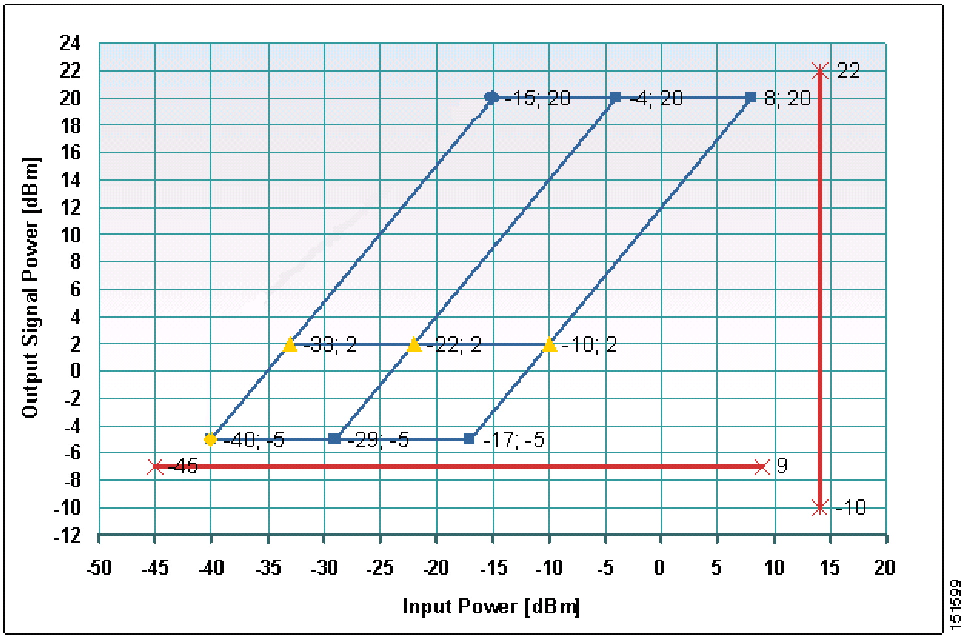
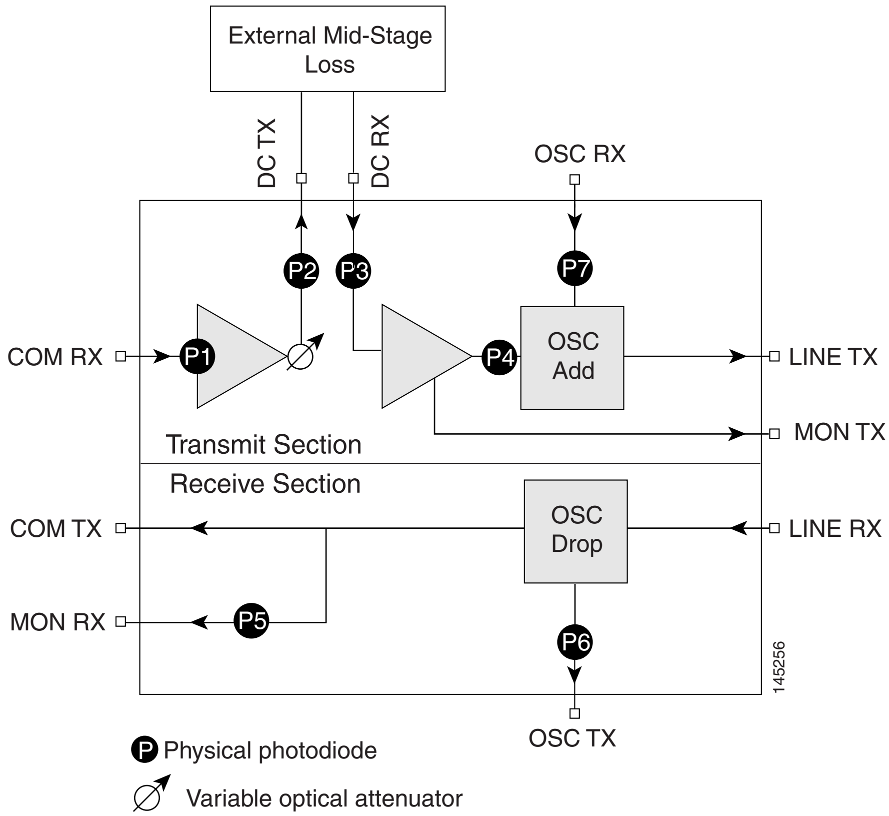


Figure 2-11 shows the internal functional structure of the OPT-AMP-L card.

Figure 2-11 OPT-AMP-L Card Functional Block Diagram



The card faceplate shows the optical loss (in dB) of the monitor ports provided by the OPT-AMP-L card. The OPT-AMP-L is a double-slot card with three LEDs on the faceplate.

2.2.5 Dispersion Compensation Units

Dispersion compensation units (DCUs) are installed in the ONS 15454 dispersion compensation shelf when optical preamplifier (OPT-PRE or OPT-AMP-L) cards are installed in the DWDM node.

Table 2-27 lists the DCUs used with the ONS 15454 DWDM configuration.

Table 2-27 Dispersion Compensation Units by Fiber Type

Fiber	DCU Description	C Band	L Band
SMF-28	SMF C-Band Dispersion Compensation Unit 100ps/nm	15216-DCU-100=	—
	SMF C-Band Dispersion Compensation Unit 350ps/nm	15216-DCU-350=	—
	SMF C-Band Dispersion Compensation Unit 450ps/nm	15216-DCU-450=	—
	SMF C-Band Dispersion Compensation Unit 550ps/nm	15216-DCU-550=	—
	SMF C-Band Dispersion Compensation Unit 750ps/nm	15216-DCU-750=	—
	SMF C-Band Dispersion Compensation Unit 950ps/nm	15216-DCU-950=	—
	SMF C-Band Dispersion Compensation Unit 1150ps/nm	15216-DCU-1150=	—
	SMF L-Band Dispersion Compensation Unit 300ps/nm	—	15216-DCU-L-300=
	SMF L-Band Dispersion Compensation Unit 600ps/nm	—	15216-DCU-L-600=
	SMF L-Band Dispersion Compensation Unit 700ps/nm	—	15216-DCU-L-700=
	SMF L-Band Dispersion Compensation Unit 800ps/nm	—	15216-DCU-L-800=
	SMF L-Band Dispersion Compensation Unit 1000ps/nm	—	15216-DCU-L-1000=
	SMF L-Band Dispersion Compensation Unit 1100ps/nm	—	15216-DCU-L-1100=
E-LEAF	—	15216-DCU-E-200=	—
	—	15216-DCU-E-350=	—
DS	DSF L-Band Dispersion Compensation Unit 100ps/nm	—	15216-DCU-DS-L100=
	DSF L-Band Dispersion Compensation Unit 200ps/nm	—	15216-DCU-DS-L200=
	DSF L-Band Dispersion Compensation Unit 300ps/nm	—	15216-DCU-DS-L300=

Each C-band DCU can compensate a maximum of 65 km of single-mode fiber (SMF-28). DCUs can be cascaded to extend the compensation to 130 km.

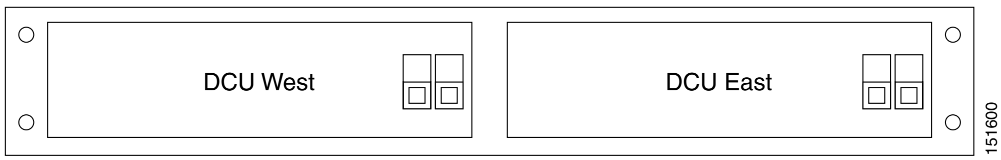
2.2.5.1 DCU Mechanical Specifications

The DCU subrack is designed to comply with all international standards. The DCU shelf is housed in a 1-RU 19" (482.6mm)/23” (584.2mm) rack-mounted shelf [17" (431.8mm) wide, 11" (279.4mm) deep, 1.75" (44.45mm) high] with all front access (fibers, management interfaces when applicable). The depth of the subrack, including cable management, does not exceed the 280 mm requirement.

For a bidirectional DCU, shown in Figure 2-12, the dimensions are 8” (205mm) wide, 9” (230 mm) deep, and 1.5” (38.5 mm) high.

The DCU has one optical adapter on its front panel that can house two LC-PC-II connectors.

Figure 2-12 DCU Front Panel



Refer to the *Cisco ONS 15216 System Dispersion Compensation Unit User Guide* for the Cisco ONS 15216 DCU mechanical specifications.

2.2.5.2 DCU Optical Specifications

Table 2-28 shows the optical specifications for ONS 15454 DCUs.

Table 2-28 Optical Specifications for ONS 15454 DCUs

Units		Specifications				
C Band	L Band	Insertion Loss [dB]	PMD [ps/nm]	PDL [dB]	ORL [dB]	Notes
15216-DCU-100=	—	<2.1	0.3	<0.1	<45	Wavelength range 1525 to 1565n
15216-DCU-350=	—	<3.5	0.55			
15216-DCU-450=	—	<3.5	0.65			
15216-DCU-550=	—	<3.9	0.7			
15216-DCU-750=	—	<5	0.8			
15216-DCU-950=	—	<5.5	0.9			
15216-DCU-1150=	—	<6	1			
15216-DCU-E-200=	—	<5.5	0.9	<0.1	<45	Wavelength range 1529.5 to 1561.6 nm
15216-DCU-E-350=	—	<7.0	1			

Table 2-28 Optical Specifications for ONS 15454 DCUs (continued)

Units		Specifications				
C Band	**L Band**	**Insertion Loss [dB]**	**PMD [ps/nm]**	**PDL [dB]**	**ORL [dB]**	**Notes**
—	15216-DCU-L-300=	<3	0.5	<0.1	<45	Wavelength range 1576 to 1605 nm
—	15216-DCU-L-600=	<4.2	0.6			
—	15216-DCU-L-700=	<4.6	0.6			
—	15216-DCU-L-800=	<5	0.7			
—	15216-DCU-L-1000=	<5.8	0.8			
—	15216-DCU-L-1100=	<6	0.8			
—	15216-DCU-DS-L100=	<3.6	0.5	<0.1	<45	
—	15216-DCU-DS-L200=	<4.4	0.6			
—	15216-DCU-DS-L300=	<5.2	0.7			

2.2.6 Transponder, Muxponder, and Optical Cards

For DWDM system interoperability, the operating center frequency (wavelength) of channels must be the same at the transmitting and receiving ends. Channel selection (center frequency) and channel width determine the number of nonoverlapping channels in the spectrum. Channel width, wavelength, bit rate, fiber type, and fiber length determine the amount of dispersion. Channel separation allows for a frequency deviation of approximately 2 GHz, caused by frequency drifts in the laser, filter, and amplifier devices to avoid interchannel interference.

The ITU-T currently recommends 81 channels in the C band, starting from 1528.77 nm and incrementing in multiples of 50 GHz to 1560.61 nm.

All C-band TXP and MXP cards support a range of wavelengths in increments of 100 GHz, as shown in Table 2-29.

Table 2-29 Supported C-Band Wavelengths for TXP/MXP Cards

		DWDM 10-Gbps TXP/MXP		DWDM 2.5-Gbps TXP/MXP	DWDM 10-Gbps TXP/MXP
Frequency (THz)	**Wavelength (nm)**	**(2 Ch Tunable)**	**(4 Ch Tunable)**	**(4 Ch Tunable)**	**(Full C-Band Tunable)**
196	1529.55	—	—	—	15454-10E-L1-C= 15454-10ME-C= 15454-10DME-C=
195.9	1530.33	15454-10M-L1-30.3= 15454-10T-L1-30.3=	15454-10E-L1-30.3= 15454-10ME-30.3=	15454-DM-L1-30.3=	
195.8	1531.12			15454-DMP-L1-30.3=	
195.7	1531.90	15454-10M-L1-31.9= 15454-10T-L1-31.9=		15454-MR-L1-30.3=	
195.6	1532.68			15454-MRP-L1-30.3=	

Table 2-29 Supported C-Band Wavelengths for TXP/MXP Cards (continued)

Frequency (THz)	Wavelength (nm)	DWDM 10-Gbps TXP/MXP (2 Ch Tunable)	DWDM 10-Gbps TXP/MXP (4 Ch Tunable)	DWDM 2.5-Gbps TXP/MXP (4 Ch Tunable)	DWDM 10-Gbps TXP/MXP (Full C-Band Tunable)
195.5	1533.47	—	—	—	
194.9	1538.19	15454-10M-L1-38.1=	15454-10E-L1-38.1=	15454-DM-L1-38.1=	
194.8	1538.98	15454-10T-L1-38.1=	15454-10ME-38.1=	15454-DMP-L1-38.1=	
194.7	1539.77	15454-10M-L1-39.7=		15454-MR-L1-38.1=	
194.6	1540.56	15454-10T-L1-39.7=		15454-MRP-L1-38.1=	
194.5	1541.35	—	—	—	
194.4	1542.14	15454-10M-L1-42.1=	15454-10E-L1-42.1=	15454-DM-L1-42.1=	
194.3	1542.94	15454-10T-L1-42.1=	15454-10ME-42.1=	15454-DMP-L1-42.1=	
194.2	1543.73	15454-10M-L1-43.7=		15454-MR-L1-42.1=	
194.1	1544.53	15454-10T-L1-43.7=		15454-MRP-L1-42.1=	
194	1545.32	—	—	—	
193.9	1546.12	15454-10M-L1-46.1=	15454-10E-L1-46.1=	15454-DM-L1-46.1=	
193.8	1546.92	15454-10T-L1-46.1=	15454-10ME-46.1=	15454-DMP-L1-46.1=	
193.7	1547.72	15454-10M-L1-47.7=		15454-MR-L1-46.1=	
193.6	1548.51	15454-10T-L1-47.7=		15454-MRP-L1-46.1=	
193.5	1549.32	—	—	—	

Table 2-29 Supported C-Band Wavelengths for TXP/MXP Cards (continued)

		DWDM 10-Gbps TXP/MXP		DWDM 2.5-Gbps TXP/MXP	DWDM 10-Gbps TXP/MXP
Frequency (THz)	**Wavelength (nm)**	**(2 Ch Tunable)**	**(4 Ch Tunable)**	**(4 Ch Tunable)**	**(Full C-Band Tunable)**
193.4	1550.12	15454-10M-L1-50.1=	15454-10E-L1-50.1= 15454-10ME-50.1=	15454-DM-L1-50.1=	
193.3	1550.92	15454-10T-L1-50.1=		15454-DMP-L1-50.1=	
193.2	1551.72	15454-10M-L1-50.1=		15454-MR-L1-50.1=	
193.1	1552.52	15454-10T-L1-50.1=		15454-MRP-L1-50.1=	
193	1553.33	—	—	—	
192.9	1554.13	15454-10M-L1-54.1=	15454-10E-L1-54.1= 15454-10ME-54.1=	15454-DM-L1-54.1=	
192.8	1554.94	15454-10T-L1-54.1=		15454-DMP-L1-54.1=	
192.7	1555.75	15454-10M-L1-55.7=		15454-MR-L1-54.1=	
192.6	1556.55	15454-10T-L1-55.7=		15454-MRP-L1-54.1=	
192.5	1557.36	—	—	—	
192.4	1558.17	15454-10M-L1-58.1=	15454-10E-L1-58.1= 15454-10ME-58.1=	15454-DM-L1-58.1=	
192.3	1558.98	15454-10T-L1-58.1=		15454-DMP-L1-58.1=	
192.2	1559.79	15454-10M-L1-59.7=		15454-MR-L1-58.1=	
192.1	1560.61	15454-10T-L1-59.7=		15454-MRP-L1-58.1=	
192	1561.42	—	—	—	

The TXP and MXP cards support the following L-band range of wavelengths in increments of 100 GHz.

Table 2-30 Supported L-Band Wavelengths for Transponder/Muxponder Cards

Frequency (THz)	Wavelength (nm)	DWDM 10-Gbps TXP/MXP (4 Ch Tunable)	DWDM 10-Gbps TXP/MXP (Full L-Band Tunable)
190.9	1570.42	—	15454-10E-L1-L= 15454-10ME-L= 15454-10DME -L=
190.8	1571.24	—	
190.7	1572.06	—	
190.6	1572.89	—	
190.5	1573.71	—	
190.4	1574.54	—	
190.3	1575.37	—	
190.2	1576.2	—	
190.1	1577.03	—	
190	1577.86	15454-10E-L1-77.4= 15454-10ME-77.4=	
189.9	1578.69		
189.8	1579.52		
189.7	1580.35		
189.6	1581.18	15454-10E-L1-80.7= 15454-10ME-80.7=	
189.5	1582.02		
189.4	1582.85		
189.3	1583.69		
189.2	1584.53	15454-10E-L1-84.1= 15454-10ME-84.1=	
189.1	1585.36		
189	1586.20		
188.9	1587.04		

Table 2-30 Supported L-Band Wavelengths for Transponder/Muxponder Cards (continued)

Frequency (THz)	Wavelength (nm)	DWDM 10-Gbps TXP/MXP (4 Ch Tunable)	DWDM 10-Gbps TXP/MXP (Full L-Band Tunable)
188.8	1587.88	15454-10E-L1-87.4= 15454-10ME-87.4=	
188.7	1588.73		
188.6	1589.57		
188.5	1590.41		
188.4	1591.26	15454-10E-L1-90.8= 15454-10ME-90.8=	
188.3	1592.10		
188.2	1592.95		
188.1	1593.79		
188	1594.64	—	
187.9	1595.49	—	
187.8	1596.34	—	
187.7	1597.19	—	
187.6	1598.04	—	
187.5	1598.89	—	
187.4	1599.75	—	
187.3	1600.6	—	
187.2	1601.46	—	
187.1	1602.31	—	
187	1603.17	—	
186.9	1604.03	—	
186.8	1604.88	—	
186.7	1605.74	—	

2.2.6.1 OC48 ITU-T Optics

The Cisco ONS 15454 supports a range of wavelengths in increments of 100 GHz and 200 GHz with its OC48 ITU-T optics, as shown in Table 2-31.

Table 2-31 OC48 ITU-T Channels Available for the ONS 15454

C-Band Spectrum		
15454 OC48 ELR 100 GHz ITU-T Cards	**Channel (nm)**	**Frequency (THz)**
X	1528.77	196.1
X	1529.55	196
X	1530.33	195.9
X	1531.12	195.8
X	1531.90	195.7

Table 2-31 OC48 ITU-T Channels Available for the ONS 15454 (continued)

C-Band Spectrum		
15454 OC48 ELR 100 GHz ITU-T Cards	**Channel (nm)**	**Frequency (THz)**
X	1532.68	195.6
X	1533.47	195.5
X	1534.28	195.4
X	1535.04	195.3
X	1535.82	195.2
X	1536.61	195.1
X	1538.19	194.9
X	1538.98	194.8
X	1539.77	194.7
X	1540.56	194.6
X	1541.35	194.5
X	1542.14	194.4
X	1542.94	194.3
X	1543.73	194.2
X	1544.53	194.1
X	1546.12	193.9
X	1546.92	193.8
X	1547.72	193.7
X	1548.51	193.6
X	1549.32	193.5
X	1550.12	193.4
X	1550.92	193.3
X	1551.72	193.2
X	1552.52	193.1
X	1554.13	192.9
X	1554.94	192.8
X	1555.75	192.7
X	1556.55	192.6
X	1557.36	192.5
X	1558.17	192.4
X	1558.98	192.3
X	1559.79	192.2
X	1560.61	192.1

The ONS 15454 OC48 ITU-T cards provide you with 37 separate ITU-T channels to choose from. These wavelengths conform to ITU-T 100-GHz and 200-GHz channel spacing, enabling compatibility with most DWDM systems. Integrating the ONS 15454 OC48 ITU-T cards with third-party DWDM products enables you to design a low-cost, scalable DWDM system with full add/drop capabilities.

2.2.6.2 OC192 ITU-T Optics

Table 2-32 lists the OC192 ITU-T channels available for the ONS 15454.

Table 2-32 OC192 ITU-T Channels Available for the ONS 15454

C-Band Spectrum		
15454 OC192 LR 100 GHz ITU-T Cards [1]	Channel (nm)	Frequency (THz)
—	1530.33	195.9
—	1531.12	195.8
—	1531.90	195.7
—	1532.68	195.6
X	1534.25	195.4
X	1535.04	195.3
X	1535.82	195.2
X	1536.61	195.1
X	1538.19	194.9
X	1538.98	194.8
X	1539.77	194.7
X	1540.56	194.6
X	1542.14	194.4
X	1542.94	194.3
X	1543.73	194.2
X	1544.53	194.1
X	1546.12	193.9
X	1546.92	193.8
X	1547.72	193.7
X	1548.51	193.6
X	1550.12	193.4
X	1550.92	193.3
X	1551.72	193.2
X	1552.52	193.1
X	1554.13	192.9
X	1554.94	192.8
X	1555.75	192.7

Table 2-32 OC192 ITU-T Channels Available for the ONS 15454 (continued)

C-Band Spectrum		
15454 OC192 LR 100 GHz ITU-T Cards [1]	**Channel (nm)**	**Frequency (THz)**
X	1556.55	192.6
X	1558.17	192.4
X	1558.98	192.3
X	1559.79	192.2
X	1560.61	192.1

1. These wavelengths are shorter lead-time cards and are recommended for deployment.

The ONS 15454 offers eight OC192 ITU-T cards. Each card provides a long-reach SONET compliant 9.95328 Gbps high-speed interface operating at a 100-GHz spaced, ITU-T compliant wavelength within the 1530 to 1562 nm frequency band. The primary application for the OC192 ITU-T card is for use in ultra high-speed metro interoffice facility (IOF) solutions interconnecting central offices and collocation sites over a DWDM-based transport network.

2.2.6.3 Client Side Interfaces

The TXP and MXP cards utilize small form-factor pluggables (SFPs) and 10-Gigabit SFPs (XFPs) to accommodate various client interface payloads. The SFP and XFP modules are inserted into matching connectors on the front panels of the cards and then connected to the client equipment with fiber-optic cables. Table 2-33 shows the SFP and XFP pluggable client modules available for each client service type.

Table 2-33 Client Services

Program Name	Client Service Type	Client Interface (SFP/XFP)	SFP/XFP Product ID (ANSI)	SFP/XFP Product ID (ETSI)
—	Gigabit Ethernet	1000Base-LX (IEEE 802.3) 1000Base-SX (IEEE 802.3)	15454-SFP-GE+-LX 15454-SFP-GEFC-SX	15454E-SFP-GE+-LX 15454E-SFP-GEFC-SX
	FibreChannel FICON 1G	100-SM-LC-L 100-M5-SN-I 100-M6-SN-I	15454-SFP-GE+-LX 15454-SFP-GEFC-SX 15454-SFP-GEFC-SX	15454E-SFP-GE+-LX 15454E-SFP-GEFC-SX 15454E-SFP-GEFC-SX
	FibreChannel 2G FICON 2G	200-SM-LC-L 200-M5-SN-I 200-M6-SN-I	15454-SFP-GE+-LX 15454-SFP-GEFC-SX 15454-SFP-GEFC-SX	15454E-SFP-GE+-LX 15454E-SFP-GEFC-SX 15454E-SFP-GEFC-SX
	OC-3	IR-1 (GR-253-CORE-Table 4-9)	15454-SFP3-1-IR	—
	OC-12	IR-1 (GR-253-CORE-Table 4-10)	15454-SFP12-4-IR	—
	OC-48	IR-1 (GR-253-CORE-Table 4-11) SR-1 (GR-253-CORE-Table 4-6)	15454-SFP-OC48-IR ONS-SE-2G-S1	—
	DV-6000	IR-1	15454-SFP-OC48-IR	15454E-SFP-L.16.1
	STM-1	S-1.1 (ITU-T G.957-Table 2)	—	15454E-SFP-L.1.1
	STM-4	S-4.1 (ITU-T G.957-Table 3)	—	15454E-SFP-L.4.1
—	STM-16	S-16.1 (ITU-T G.957-Table 4) I-16.1 (ITU-T G.957-Table 4)	—	15454E-SFP-L.16.1 ONS-SE-2G-S1
	ISC-COMPAT	100-SM-LC-L	15454-SFP-GE+-LX	15454E-SFP-GE+-LX
	ISC-PEER	100-SM-LC-L	15454-SFP-GE+-LX	15454E-SFP-GE+-LX
	ESCON Sysplex ETR Sysplex CLO	SBCON	15454-SFP-200	15454-SFP-200
	D1 Video SDI	ITU BT-1367	15454-SFP3-1-IR	15454E-SFP-L.1.1
	HDTV	ITU BT-1367	15454-SFP-GE+-LX	15454E-SFP-GE+-LX
	2R Any Rate	—	—	—

Table 2-33 Client Services (continued)

Program Name	Client Service Type	Client Interface (SFP/XFP)	SFP/XFP Product ID (ANSI)	SFP/XFP Product ID (ETSI)
15454-DM-L1- 15454-DMP-L1-	Gigabit Ethernet	1000Base-LX 1000Base-SX	15454-SFP-GE+-LX 15454-SFP-GEFC-SX	15454E-SFP-GE+-LX 15454E-SFP-GEFC-SX
	FibreChannel FICON 1G	100-SM-LC-L 100-M5-SN-I 100-M6-SN-I	15454-SFP-GE+-LX 15454-SFP-GEFC-SX 15454-SFP-GEFC-SX	15454E-SFP-GE+-LX 15454E-SFP-GEFC-SX 15454E-SFP-GEFC-SX
	FibreChannel 2G FICON 2G	200-SM-LC-L 200-M5-SN-I 200-M6-SN-I	15454-SFP-GE+-LX 15454-SFP-GEFC-SX 15454-SFP-GEFC-SX	15454E-SFP-GE+-LX 15454E-SFP-GEFC-SX 15454E-SFP-GEFC-SX
15454-10T-L1-	10GE	10GBASE-LR	No SFP	No SFP
	OC-192	SR-1	No SFP	No SFP
	STM-64	I-64.1	No SFP	No SFP
15454-10M-L1-	4xOC-48	IR-1 SR-1	15454-SFP-OC48-IR ONS-SE-2G-S1	—
	4xSTM-16	S-16.1 I.16.1	—	15454E-SFP-L.16.1 ONS-SE-2G-S1
15454-10E-L1-	10GE FibreChannel -10G	10GBASE-LR	ONS-XC-10G-S1	ONS-XC-10G-S1
	OC-192	SR-1	ONS-XC-10G-S1	—
	STM-64	I-64.1	—	ONS-XC-10G-S1
15454-10ME-	4xOC-48	IR-1 SR-1	15454-SFP-OC48-IR ONS-SE-2G-S1	—
	4xSTM-16	S-16.1 I.16.	—	15454E-SFP-L.16.1 ONS-SE-2G-S1

For more information on SFPs and XFPs, refer to the "SFP Specifications" and "XFP Specifications" sections in *Cisco ONS 15454 DWDM Reference Manual*.

2.2.7 Y-Cable Module

The two types of Y-cable module are the multimode splitter module and the single-mode splitter module. Both module types have 6 optical LC-LC adapters on the front panel. The adapter position and labeling are depicted in Figure 2-13.

Figure 2-13 Multimode Y-Cable Splitter Module

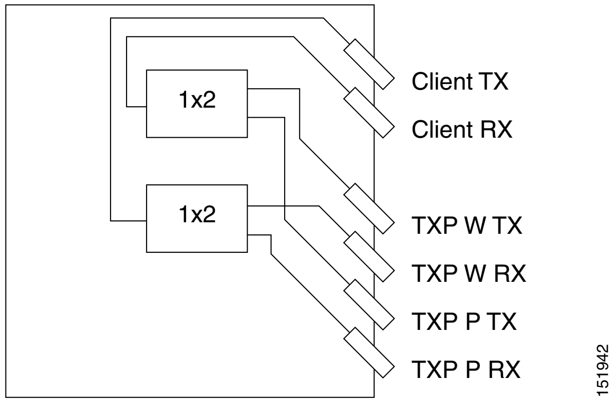


Table 2-34 shows operating parameters for a multimode Y-cable module.

Table 2-34 Multimode Y-Cable Module Operating Parameters

Parameter	Conditions	Min	Typical	Max	Unit
Wavelength range (WR)	—	770–1260		860–1380	nm
Insertion loss (IL)	In all wavelength ranges (both windows)	—	—	4.4	dB
Insertion loss uniformity	In all wavelength ranges (both windows)	—	—	0.7	dB
PDL	At both ports	—	—	0.1	dB
Optical return loss (RL)	—	40	—	—	dB
Directivity	—	40	—	—	dB
Operating temperature (Top)	—	–5	—	65	°C
Optical power	—	—	—	500	mW

Table 2-35 shows operating parameters for the single-mode Y-cable module.

Table 2-35 Single-Mode Y-Cable Module Operating Parameters

Parameter	Conditions	Min	Typical	Max	Unit
Wavelength range (WR)	—	1260–1430	—	1360–1580	nm
Insertion loss (IL)	In all wavelength ranges (both windows)	—	—	4.1	dB
Insertion loss uniformity	In all wavelength ranges (both windows)	—	—	1.1	dB
PDL	At both ports	—	—	0.1	dB
Optical return loss (RL)	—	50	—	—	dB
Directivity	—	50	—	—	dB
Operating temperature (Top)	—	–5	—	65	°C
Optical power	—	—	—	500	mW

2.2.8 Mechanical Equipment

The following section describes mechanical equipment such as the bay frame, optical shelf, dispersion compensation shelf, Y-cable shelf, fiber storage units, and 32-channel patch-panel units.

2.2.8.1 Bay Frame

DWDM cards use a generic standard bay frame, which is compliant with ANSI Standard Seismic 19-inch and 23-inch Bay Frames (Telcordia GR-63-CORE) and/or ETSI 600 mm x 300 mm (ETS 300-119, ETS 300-019, CEI EN 60917 and IEC 61587).

Floor mounting depends on the frame or cabinet that the customer chooses.

2.2.8.2 Optical Shelf

The shelf assemblies used in the ONS 15454 DWDM system and SONET/SDH systems are the same. The ONS 15454 is simple to engineer and flexible, in order to reduce the equipping rules as much as possible.

The system dimensions for an ONS 15454 ETSI rack are 617 mm(18.17") high x 432 mm (17") wide x 280 mm (11") deep. The dimensions of the ANSI system are 18.1" (461.6 mm) high x 17"(431.8 mm) wide x 12"(305.0 mm) deep. A total of four shelves fit into a standard ANSI rack. A total of three shelves fit into ETSI racks.

The subrack has 17 card slots, which are numbered from 1 starting at the left. Each slot is labeled with an icon that must match the icon on the plug-in card's faceplate. This enables easy identification of card/slot compatibility. Slots 7 through 11, indicated in white, are dedicated to system operations. These slots are known as common-control card slots. Slots 1 through 6 and 12 through 17, indicated in yellow and blue, are dedicated to traffic cards, such as OSC cards, optical add/drop cards, optical amplifier cards, and transponder/muxponder cards.

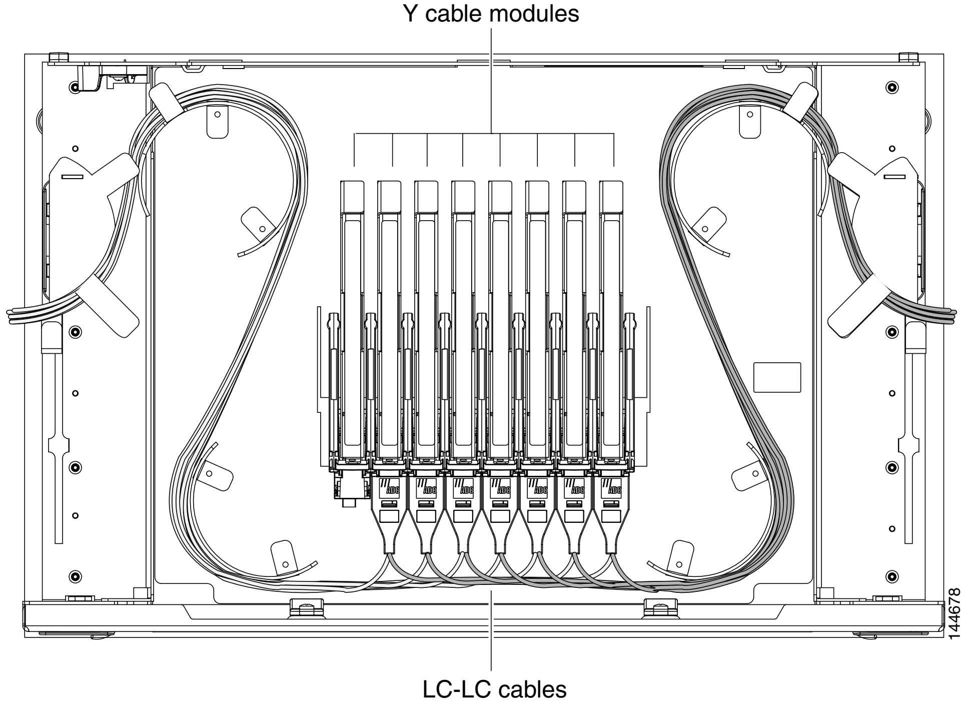
2.2.8.3 Dispersion Compensation Shelf

The dispersion compensation shelf is 1 RU in height. Two DCUs (one for each direction) can be housed in the dispersion compensation shelf. The shelf is not powered or cooled because the DCUs are optically passive.

2.2.8.4 Y-Cable Shelf

The Y-cable shelf houses up to eight Y-cable modules and all relevant patchcords. The Y-cable shelf has a height of 2 RU and can be installed in 19"(482.6 mm) ANSI or ETSI racks. See Figure 2-14.

Figure 2-14 Y-Cable Shelf Fiber Routing



2.2.8.5 Fiber Storage

The fiber storage tray has height of 1 RU and can be installed in 19” (482.6 mm) ANSI or ETSI racks.The fiber storage tray manages all incoming and outgoing fibers for a single ONS 15454 shelf. The minimum fiber bend radius is 1.5” (38.1 mm) or 20 times the cable diameter at any point, whichever is greater.

For more information on fiber management, refer to the *Cisco ONS 15454 DWDM Reference Manual.*

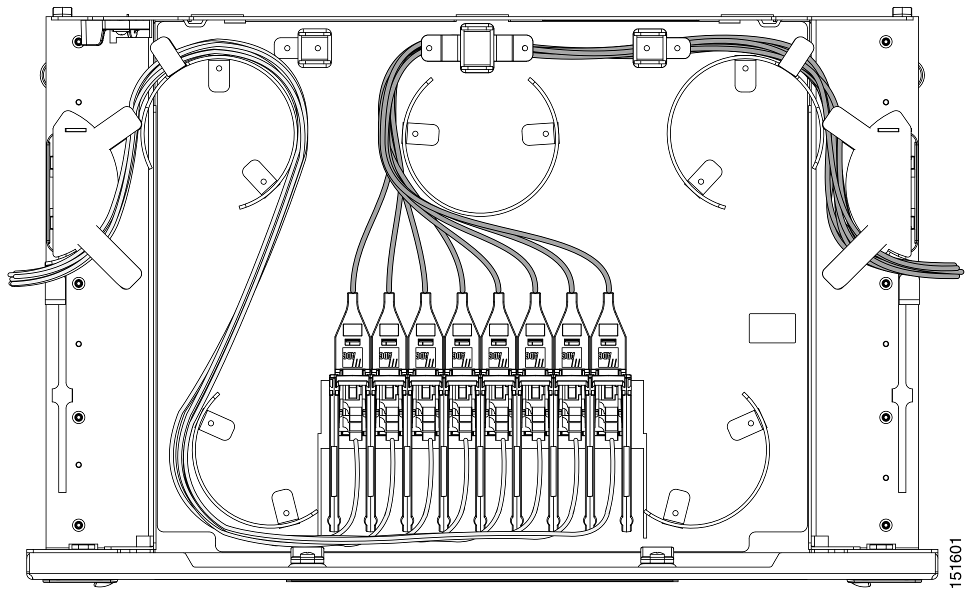
2.2.8.6 32 Channel Patch-Panel Trays

The ONS 15454 offers two patch panel trays that can be installed in 19” (482.6 mm) ANSI or ETSI shelves. The regular tray (15454-PP-64-LC) is 1 RU in height, and the deep tray is (PP-64) is 2 RU in height.

The deep patch panel tray (PP-64) manages the 32 channels that interconnect a ROADM node to relevant TXPs.

Table 2-35 shows fiber routing on the deep patch panel tray.

Figure 2-15 32-Channel Patch Panel Shelf Fiber Routing



The PP-64 contains 64 LC-LC adapters and manages up to eight multifiber cables. The minimum fiber bend radius is 1.5” (38.1 mm) or 20 times the cable diameter at any point, whichever is greater.

The PP-64 is used for both C-band and L-band systems. A label on the front panel enables identification of channel wavelength IDs during installation.

Node Configurations

This chapter describes the various configurations supported by DWDM applications in the Cisco ONS 15454.

The following topics are covered in this chapter:

3.1 Node Configurations

The ONS 15454 supports the following DWDM node configurations in the C-band:

- ROADM
- Line Amplifier
- OSC Regeneration Line
- OADM
- Anti-ASE
- Hub
- Terminal

The ONS 15454 supports the following DWDM node configurations in the L-band:

- ROADM
- Line Amplifier
- OSC Regeneration Line
- Hub
- Terminal

Note The Cisco MetroPlanner tool creates a plan for amplifier placement and proper node equipment.

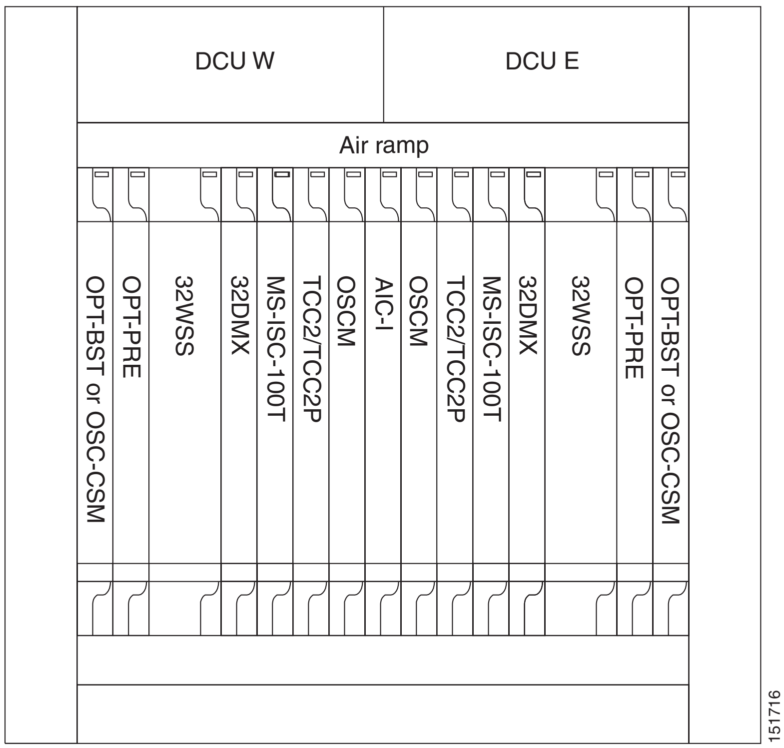
3.1.1 ROADM Node

The following sections describe the C-band and L-band ROADM nodes.

3.1.1.1 C-Band ROADM Node

A ROADM node can add and drop wavelengths without changing the physical fiber connections. ROADM nodes consist of two 32WSS cards. 32DMX or 32DMX-O demultiplexers are typically installed, but are not required. If amplification is not used, you can install TXPs and MXPs in any open slot. Figure 3-1 shows an example of an amplified ROADM node configuration.

Figure 3-1 ROADM Node with OPT-PRE, OPT-BST, 32WSS, and 32DMX Cards Installed



If the ROADM node receives a tilted optical signal, you can replace the single-slot 32DMX card with the double-slot 32DMX-O card to equalize the signal at the optical channel layer instead of the transport section layer. However, if 32DMX-O cards are installed, you cannot use Slots 6 and 12 for TXP or MXP cards.

Figure 3-2 shows an example of a ROADM node with 32DMX-O cards installed.

Figure 3-2 ROADM Node with OPT-PRE, OPT-BST, 32WSS, and 32DMX-O Cards Installed

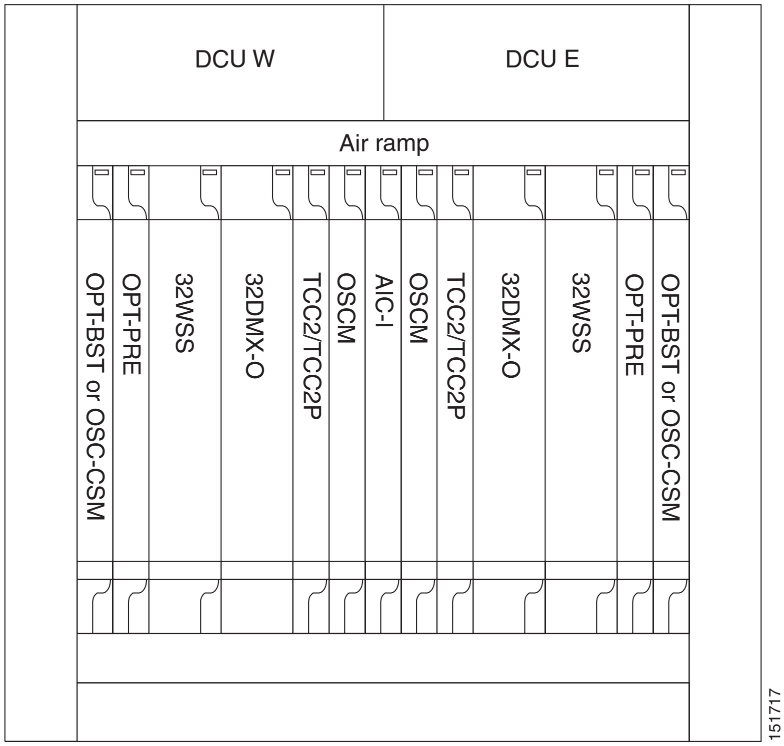
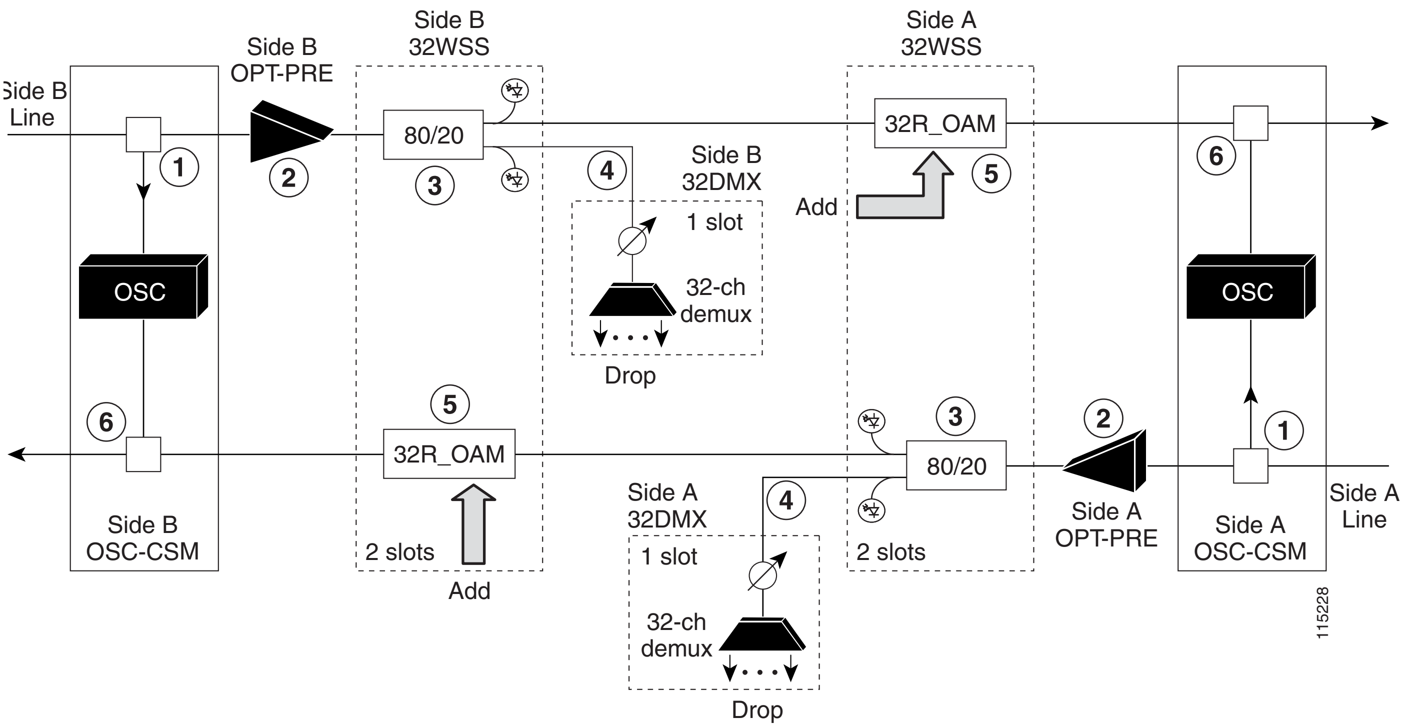


Figure 3-3 shows an example of a reconfigurable OADM east-to-west optical signal flow. The west-to-east optical signal flow follows an identical path through the west OSC-CSM and west 32WSS cards. In this example, OSC-CSM cards are installed, so OPT-BST cards are not needed.

Figure 3-3 ROADM Node with OPT-PRE, OPT-BST, 32WSS, and 32DMX-O Cards Installed

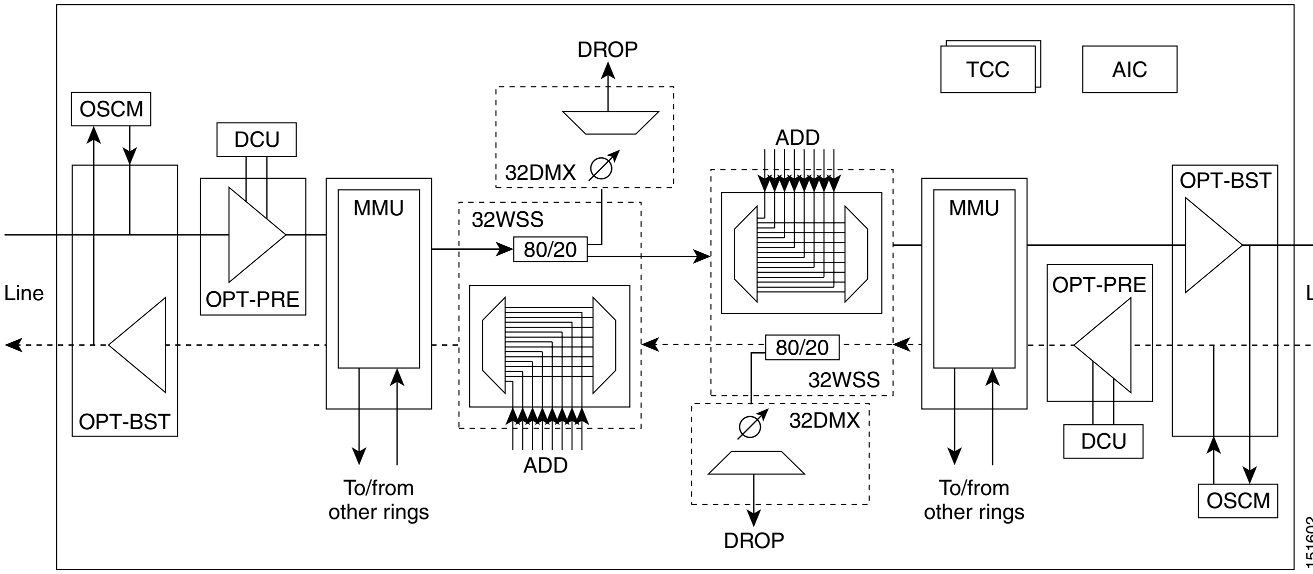


Legend	Description
1	The OSC-CSM card receives the optical signal. It separates the optical service channel from the optical payload and sends the payload to the OPT-PRE card.
2	The OPT-PRE card compensates for chromatic dispersion, amplifies the optical payload, and sends it to the 32WSS card.
3	The 32WSS card splits the signal into two components. One is sent to the DROP-TX port and the other is sent to the EXP-TX port.
4	The drop component goes to the 32DMX card where it is attenuated, demultiplexed, and dropped.
5	The express wavelength set goes to the 32WSS card on the other side where it is demultiplexed. Channels are stopped or forwarded based upon their switch states. Forwarded wavelengths are multiplexed and sent to the OSC-CSM card.
6	The OSC-CSM card combines the multiplexed payload with the OSC and sends the signal out the transmission line.

3.1.1.2 C-Band ROADM Node with MMU

Figure 3-4 is an example of a multi-ring/mesh node layout.

Figure 3-4 Multiring/Mesh C-Band Node



The OPT-PRE card amplifies the aggregate signal coming from the west line and the MMU card splits the signal to route the channels to other rings. The signal out of the MMU EXP port is then split by the west 32WSS card and sent to the 32DMX and the east 32WSS cards. This process multiplexes, equalizes, and transmits the relevant express channels and the added channel towards the east.

The multiplexed signal is then fed into the MMU card, which combines the channels with the new channel coming from other rings. The channel is then sent to the OPT-BST card, which amplifies the aggregated channels and combines the OSC. The resulting signal is launched into the east transmission fiber.

The transmit path for the other direction follows an identical path through the west 32WSS and the west OPT-BST card. The signal from the east fiber enters the east OPT-BST card, where the OSC signal is terminated. The aggregated DWDM signal is then fed into the east OPT-PRE card.

In the east OPT-PRE card, MAL performs the last chromatic dispersion compensation and then sends the signal to the MMU card, which splits the signal into two different paths. One of the signal paths is directly connected to the east 32WSS card, where the signal is split according to an 80/20 ratio. The other signal path is to the MMU EXP A port for future interconnection with other rings.

The Drop component from the east 32WSS enters the east 32DMX card, is attenuated by the VOA operating at the OTS layer, and is demultiplexed at the OCH layer.

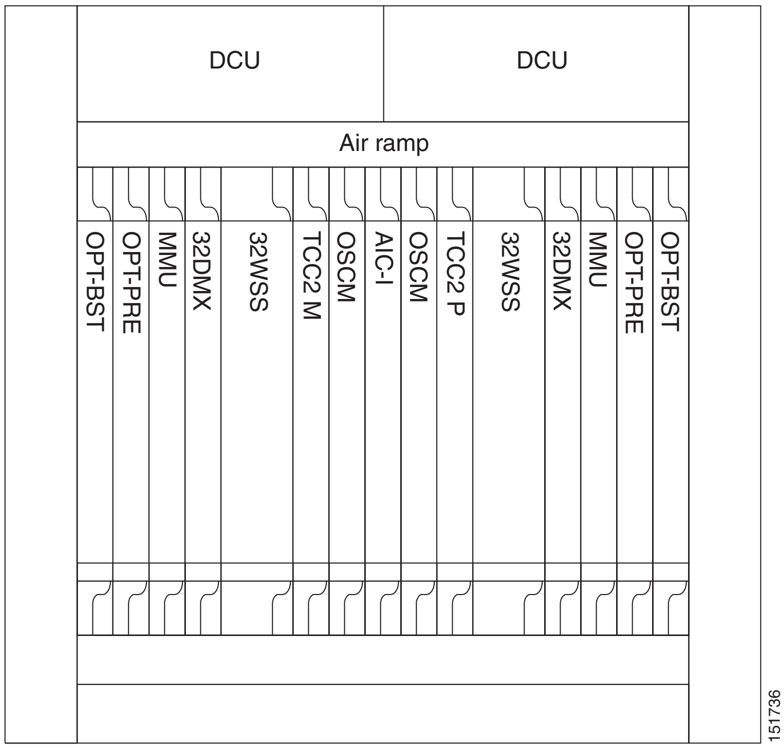
The Express component enters the west 32WSS card's OTS Rx port, is demultiplexed at the OCH layer, and stops or passes through according to the optical switch state.

The channels enter the west MMU and combine with the signals coming from the other rings. The OPT-BST card amplifies these signals and launches them into the west fiber.

All the cards that are used to build a multiring or mesh C-band node can be plugged into a single ONS 15454 shelf and a DCU shelf can be implemented if dispersion compensation is necessary.

Figure 3-5 shows a typical node configuration. The positions of the cards housed in Slots 1 through 6 and 12 through 17 are not mandatory. They can be swapped without any problem, but the common control cards have reserved slots in the middle of the shelf. You can equip TXP or MXP cards in configurations without preamplification, and you can install an OSC-CSM card in Slot 1 and 17 in configurations without booster amplification. You may leave Slot 8 and 10 empty in configurations without booster amplification.

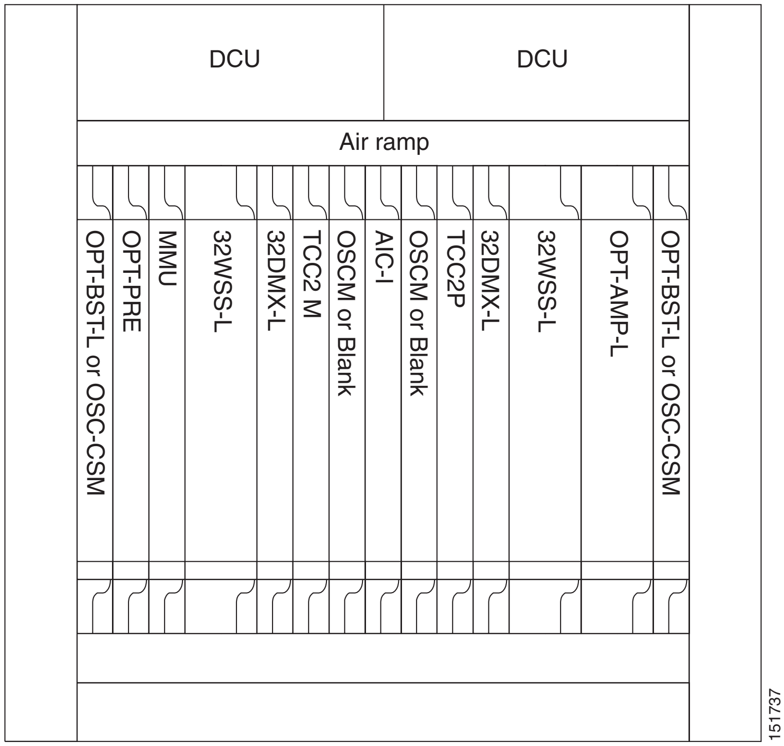
Figure 3-5 Multiring/Mesh C-Band Shelf Layout



3.1.1.3 L-Band ROADM Node

A ROADM node adds and drops wavelengths without changing the physical fiber connections. Figure 3-6 shows an example of an amplified ROADM node configuration.

Figure 3-6 L-Band ROADM Node



ROADM nodes are equipped with two 32WSS-L cards. 32DMX-L cards are typically installed, but are not required. You can install TXPs and MXPs in Slots 6 and 12 and, if amplification is not used, in any open slot.

3.1.2 Line Amplifier Node

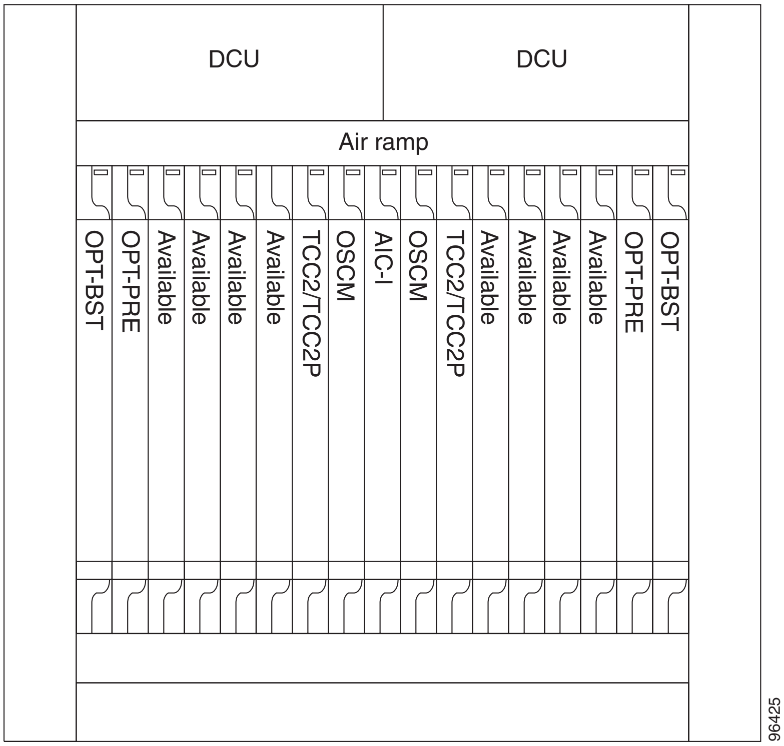
The following sections describe the various C-band and L-band amplifier nodes that are available.

3.1.2.1 C-Band Line Amplifier Node with Booster and Preamplifier

A line node is a single ONS 15454 node equipped with OPT-PRE amplifiers and OPT-BST amplifiers, two OSCM or OSC-CSM cards, and TCC2/TCC2P cards. Attenuators might also be required between each preamplifier and booster amplifier to match the optical input power value and to maintain the amplifier gain tilt value. Two OSCM or OSC-CSM cards are connected to the east or west ports of the booster amplifiers to multiplex the OSC signal with the pass-through channels.

Figure 3-7 shows an example of a line node configuration.

Figure 3-7 Line Node Configuration with Booster and Preamplifier

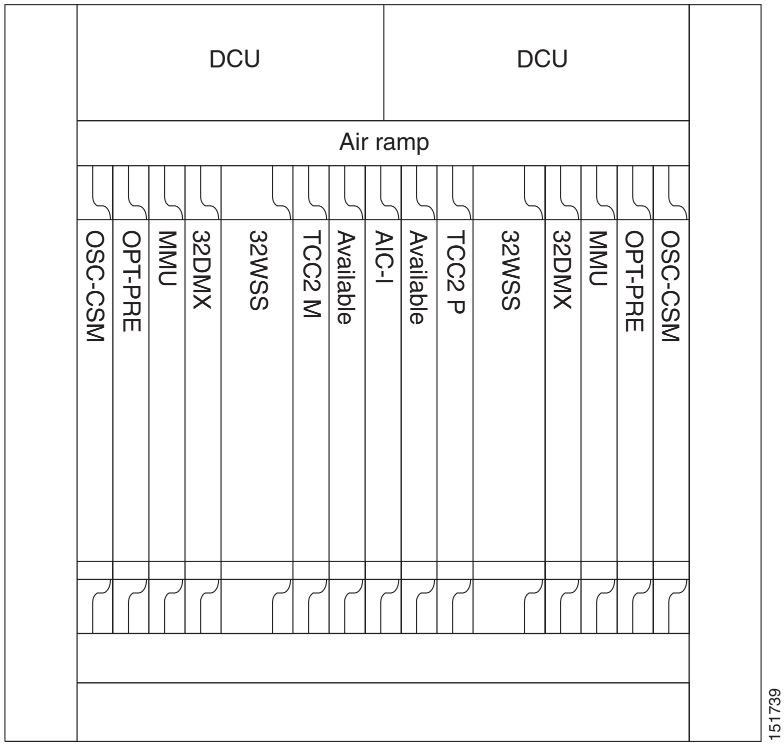


3.1.2.2 C-Band Line Amplifier Node with Preamplifier Only

A C-band line amplifier node contains a single ONS 15454 shelf equipped with two OPT-PRE or OPT-BST amplifiers, two OSCM or OSC-CSM cards, and two TCC2/TCC2P cards. If the node consists of two booster amplifiers only, the two OSCM cards are connected to the OSC ports of the booster amplifier to multiplex the OSC signal with the pass-through channels.

Figure 3-8 shows an example of a line node configuration.

Figure 3-8 Line Node Configuration with Preamplifier



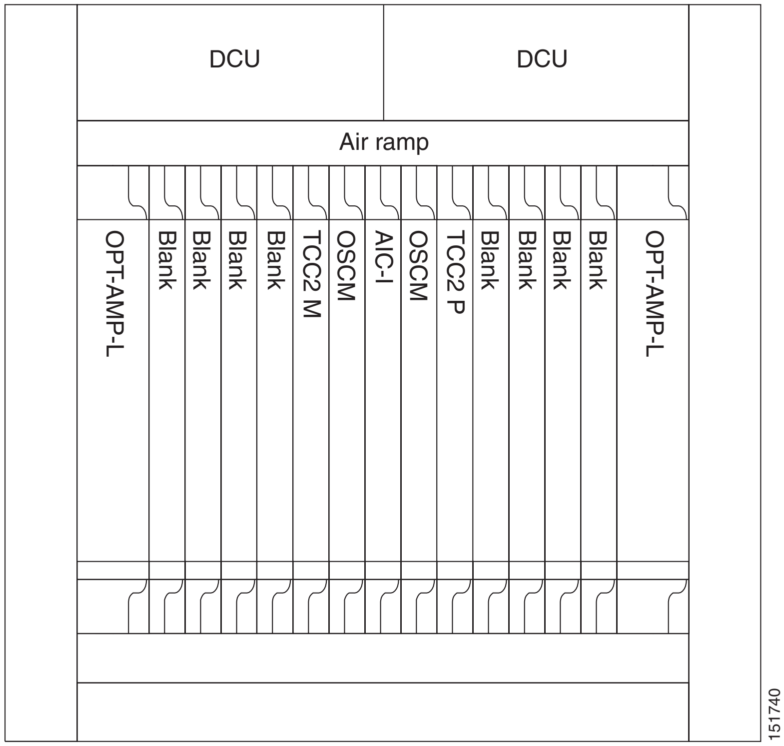
3.1.2.3 L-Band Line Amplifier Node

An L-band line amplifier node contains a single ONS 15454 shelf equipped with two OPT-AMP-L amplifiers or OPT-BST-L amplifiers, two OSCM or OSC-CSM cards, and two TCC2/TCC2P cards.

Two OSCM or OSC-CSM cards are connected to the OSC ports of the booster amplifiers to multiplex the OSC signal with the pass-through channels.

Figure 3-9 shows an example of a line node configuration.

Figure 3-9 Line Node Configuration with Amplifier



3.1.3 OSC Regeneration Node

An OSC regeneration node is added to DWDM networks for two reasons:

- To electrically regenerate the OSC channel whenever the span links have a 37 dB or longer loss and payload amplification and add/drop capabilities are not present. Cisco MetroPlanner places an OSC regeneration node in spans with greater than 37 dB loss. The greatest span loss between the OSC regeneration node and the next DWDM network site is 31 dB.
- To add data communications network (DCN) capability wherever needed within the network.

OSC regeneration nodes require two OSC-CSM cards, as shown in Figure 3-10.

Figure 3-10 OSC Regeneration Line Node Configuration

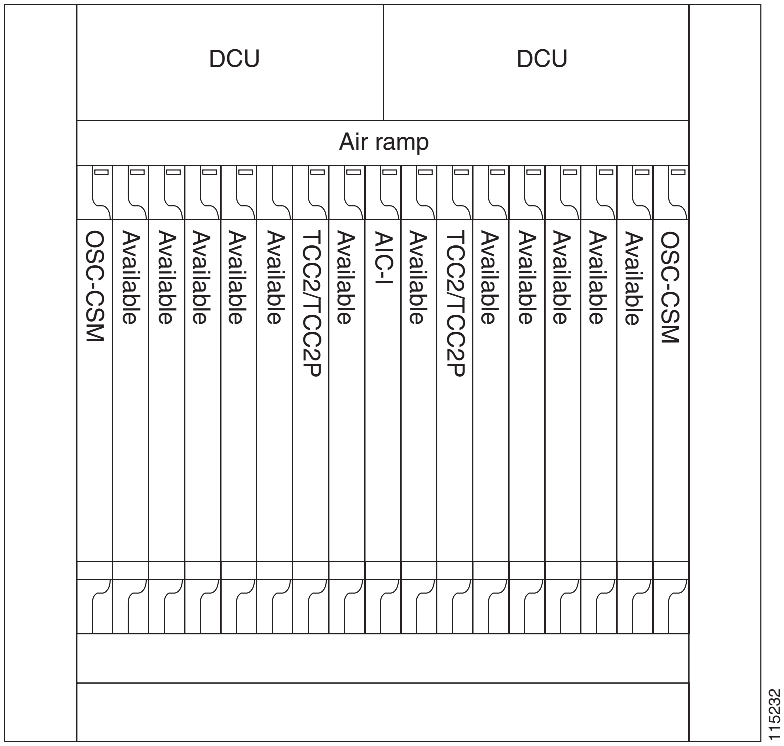
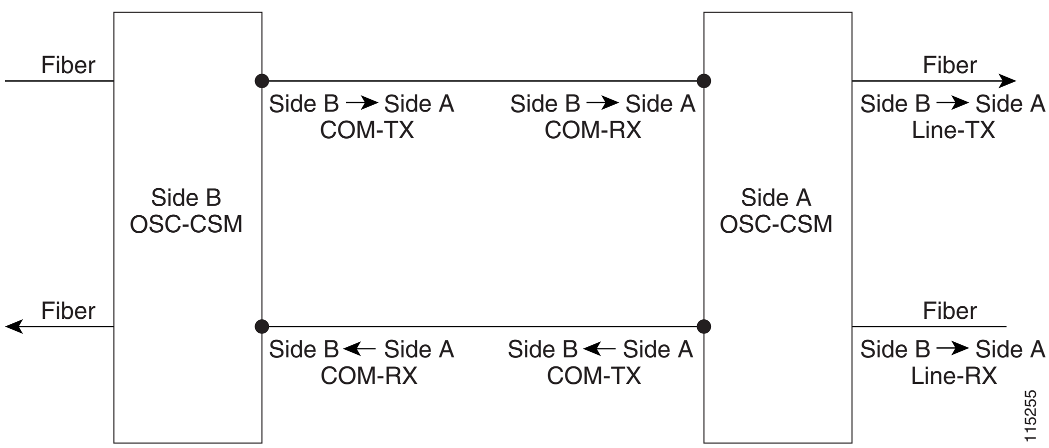


Figure 3-11 shows the OSC regeneration node OSC signal flow.

Figure 3-11 OSC Regeneration Line Site Example



3.1.4 C-Band OADM Node

An OADM node is a single ONS 15454 node equipped with at least one AD-xC-xx.x card or one AD-xB-xx.x card and two TCC2/TCC2P cards. The 32MUX-O or 32DMX-O cards cannot be provisioned. In an OADM node, channels can be added or dropped independently from each direction, passed through the reflected bands of all OADMs in the DWDM node (called express path), or passed through one OADM card to another OADM card without using a time-division multiplexing (TDM) ITU line card (called optical pass-through) if an external patchcord is installed.

Unlike express path, an optical pass-through channel can be converted later to an add/drop channel in an altered ring without affecting another channel. OADM amplifier placement and required card placement is determined by the Cisco MetroPlanner tool or your site plan.

There are different categories of OADM nodes, such as amplified, passive, and anti-ASE. For anti-ASE node information, see "3.1.5 C-Band Anti-ASE Node" section on page 3-15. Figure 3-12 shows an example of an amplified OADM node configuration.

Figure 3-12 OADM Node Configuration

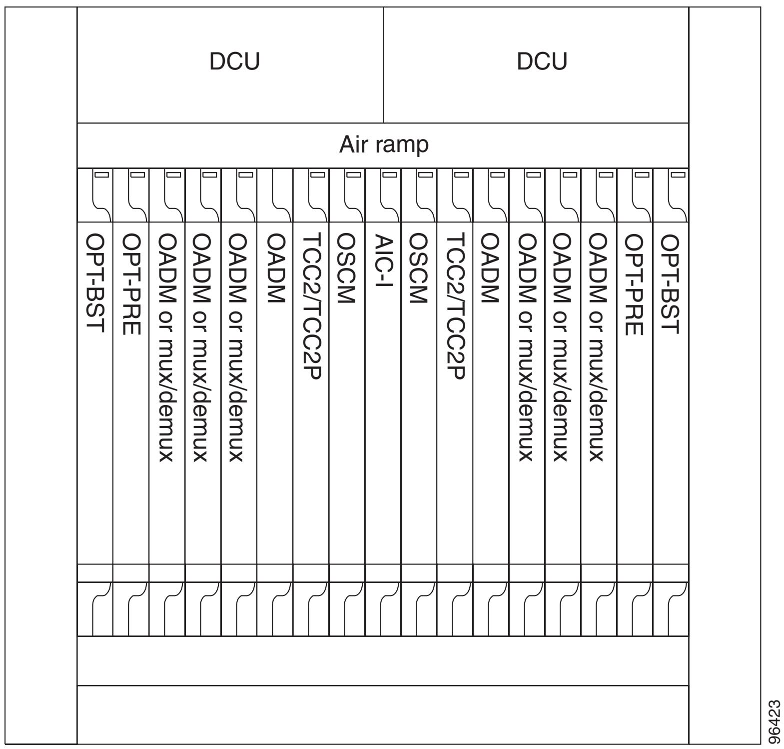


Figure 3-13 shows an example of the channel flow on the amplified OADM node. Because the 32 wavelength plan is based on eight bands (each band contains four channels), optical adding and dropping can be performed at the band level and/or at the channel level (meaning individual channels can be dropped).

Figure 3-13 Amplified OADM Node Channel Flow

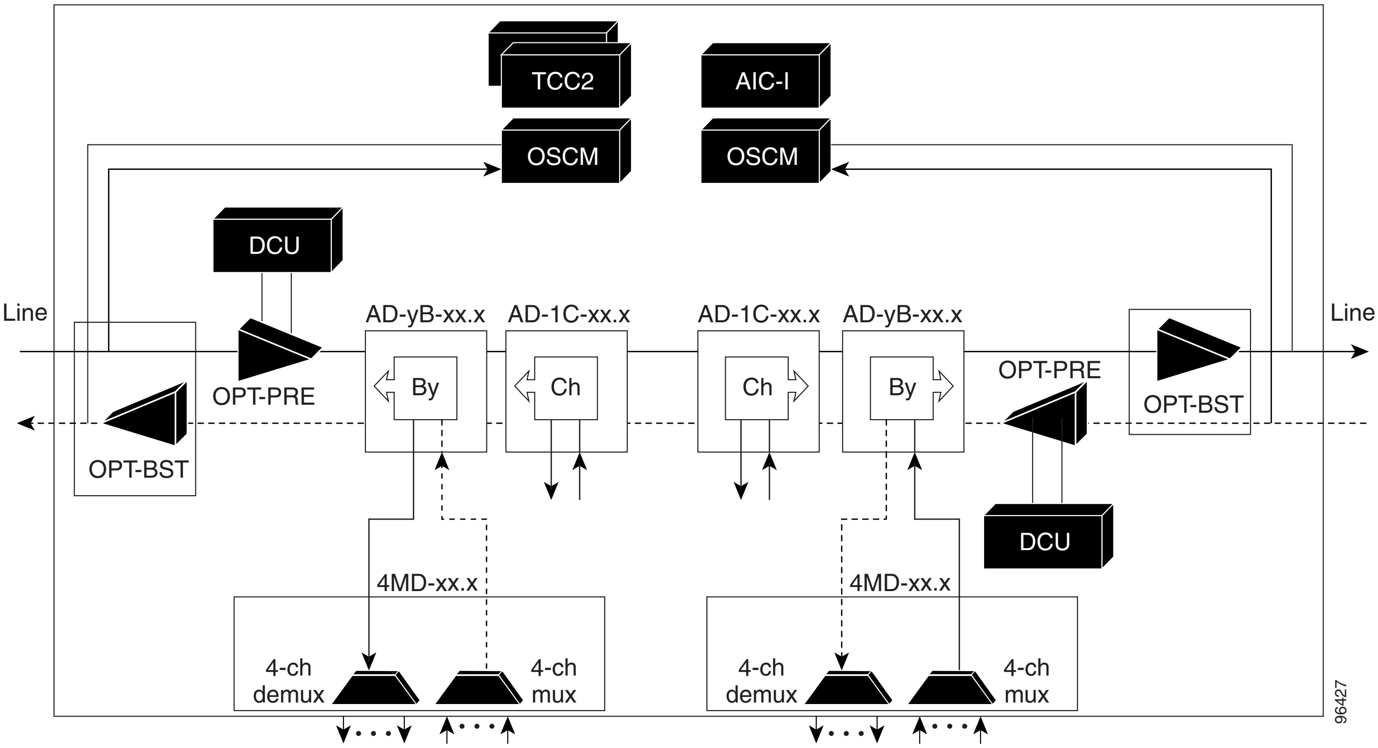


Figure 3-14 shows an example of a passive OADM node configuration. The passive OADM node is equipped with a band filter, one four-channel multiplexer/demultiplexer, and a channel filter on each side of the node.

Figure 3-14 Passive OADM Node Configuration

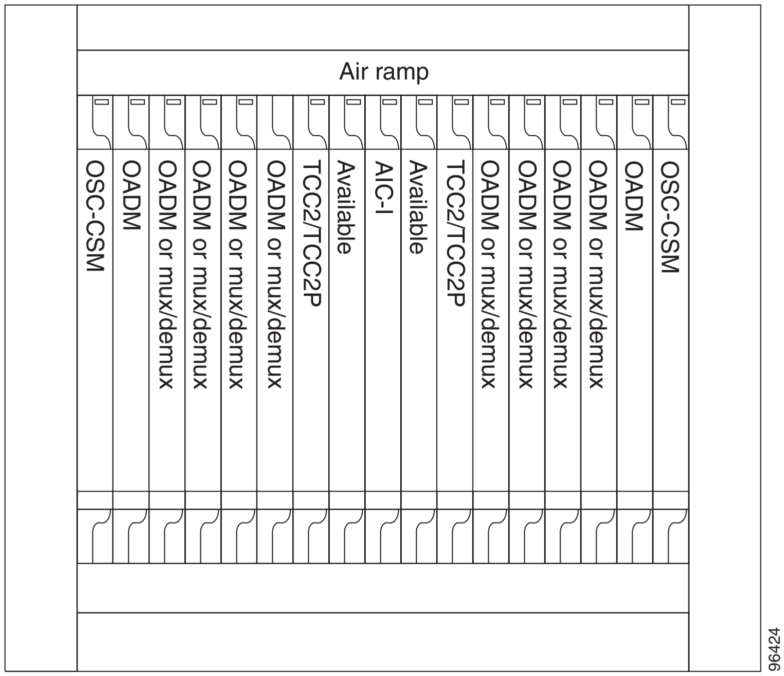
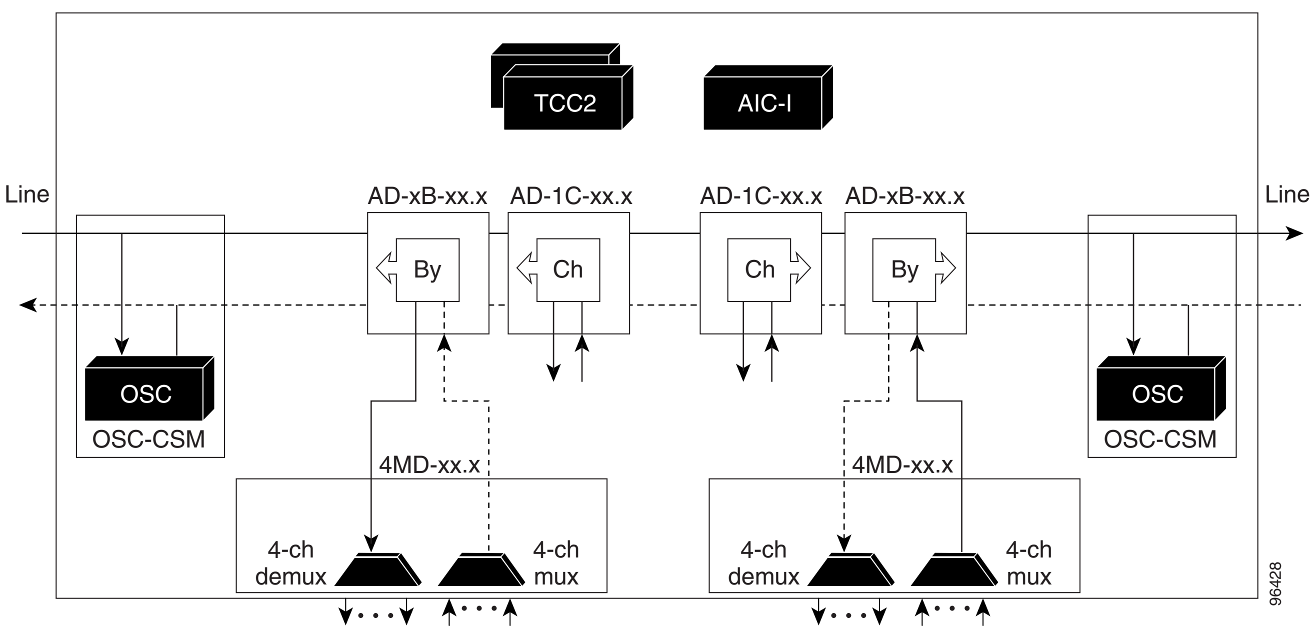


Figure 3-15 shows an example of traffic flow on the passive OADM node. The signal flow of the channels is the same as that described in Figure 3-13 except that the OSC-CSM card is being used instead of the OPT-BST amplifier and the OSCM card.

Figure 3-15 Passive OADM Node Channel Flow



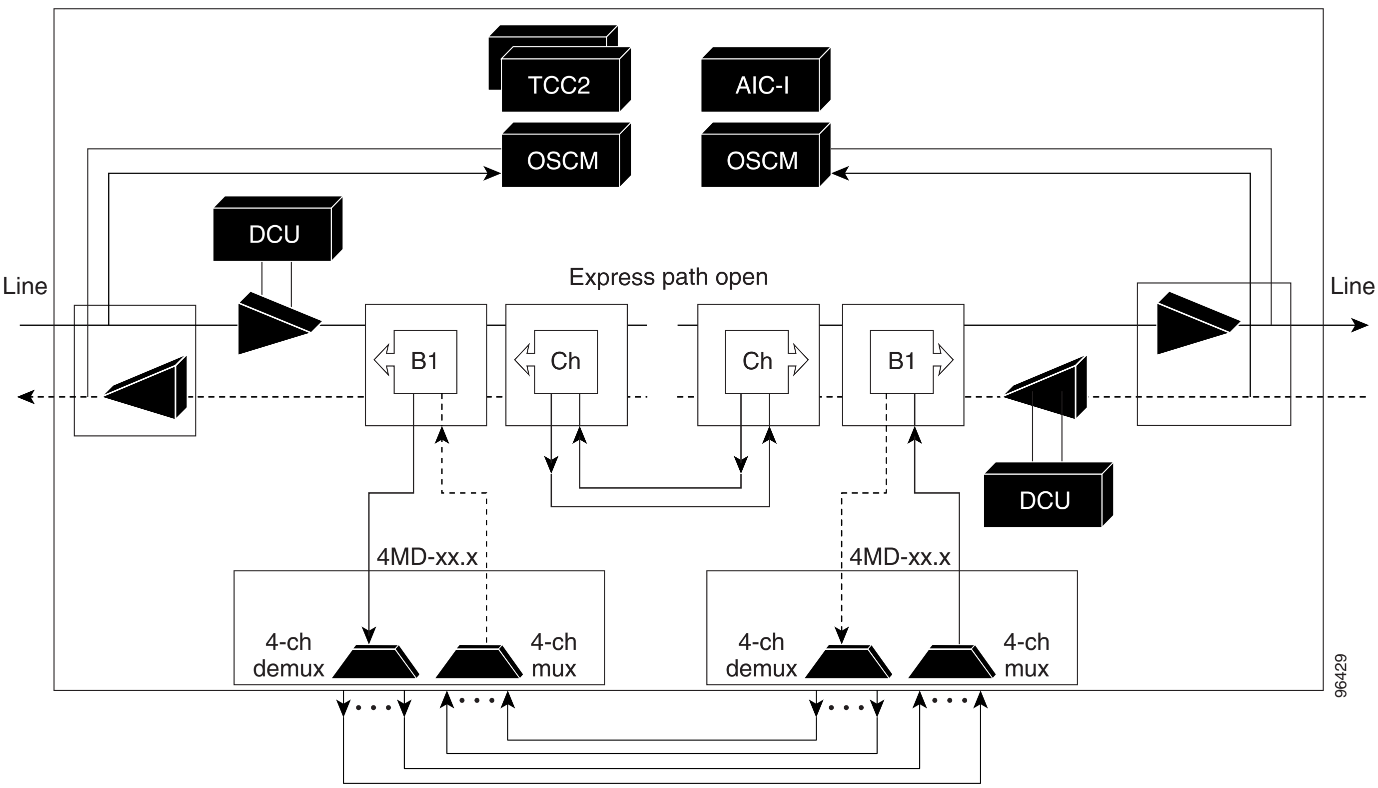
3.1.5 C-Band Anti-ASE Node

In a meshed ring network, the ONS 15454 requires a node configuration that prevents ASE accumulation and lasing. An anti-ASE node can be created by configuring a hub node or an OADM node with some modifications. No channels can travel through the express path, but they can be demultiplexed and dropped at the channel level on one side and added and multiplexed on the other side.

The hub node is the preferred node configuration when some channels are connected in pass-through mode. For rings that require a limited number of channels, combine AD-xB-xx.x and 4MD-xx.x cards, or cascade AD-xC-xx.x cards.

Figure 3-16 shows an example of traffic flow on an anti-ASE node that uses all wavelengths in the pass-through mode. Use Cisco MetroPlanner or another network planning tool to determine the best configuration for anti-ASE nodes.

Figure 3-16 Anti-ASE Node Channel Flow



3.1.6 Hub Node

This section describes C-band and L-band hub nodes.

3.1.6.1 C-Band Hub Node

A hub node is a single ONS 15454 node equipped with two TCC2/TCC2P cards, two OSCM or OSC-CSM cards, up to two OPT-BST or OPT-BST-E cards, up to two OPT-PRE cards, and one of the following combinations:

- Two 32MUX-O cards and two 32DMX-O or 32DMX cards
- Two 32WSS cards and two 32DMX or 32DMX-O cards

Note The 32WSS and 32DMX are normally installed in ROADM nodes, but they can be installed in hub and terminal nodes. If the cards are installed in a hub node, the 32WSS express ports (EXP RX and EXP TX) are not cabled.

A DCU can also be added, if necessary. The hub node does not support both DWDM and TDM applications since the DWDM slot requirements do not leave room for TDM cards. Figure 3-17 shows a hub node configuration with the 32MUX-O and 32DMX-O cards installed.

Note The OADM AD-xC-xx.x or AD-xB-xx.x cards are not part of a hub node because the 32MUX-O, 32DMX-O, 32WSS, and 32DMX cards drop and add all 32 channels; therefore, no other cards are necessary.

Figure 3-17 C-Band Hub Node Configuration

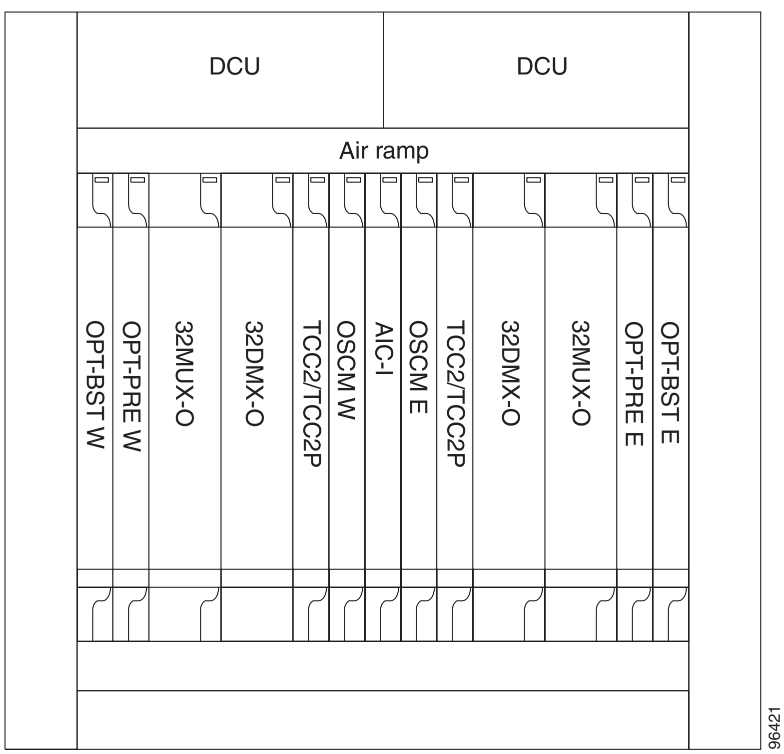
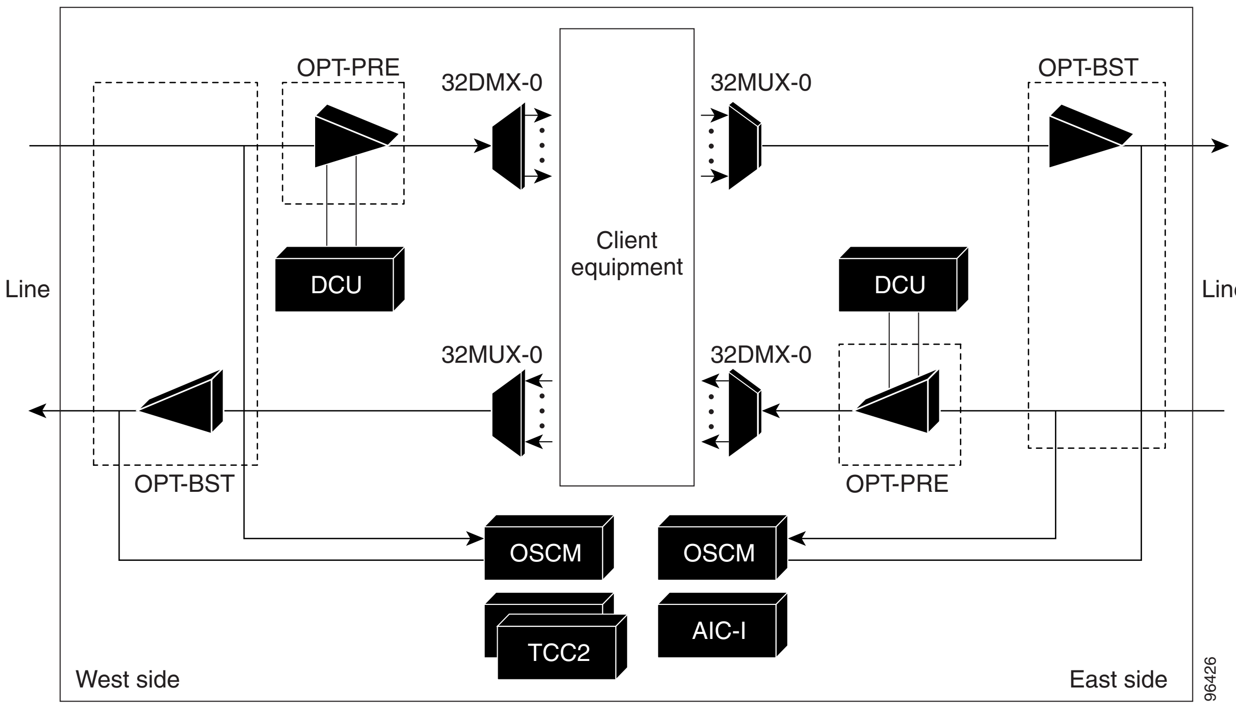


Figure 3-18 shows the channel flow for a hub node. Up to 32 channels from the client ports are multiplexed and equalized onto one fiber using the 32MUX-O card. Then, multiplexed channels are transmitted on the line in the eastward direction and fed to the OPT-BST amplifier. The output of this amplifier is combined with an output signal from the OSCM card, and transmitted toward the east line.

Received signals from the east line port are split between the OSCM card and an OPT-PRE amplifier. Dispersion compensation is applied to the signal received by the OPT-PRE amplifier, and it is then sent to the 32DMX-O card, which demultiplexes and attenuates the input signal. The west receive fiber path is identical through the west OPT-BST amplifier, the west OPT-PRE amplifier, and the west 32DMX-O card.

Figure 3-18 Hub Node Channel Flow



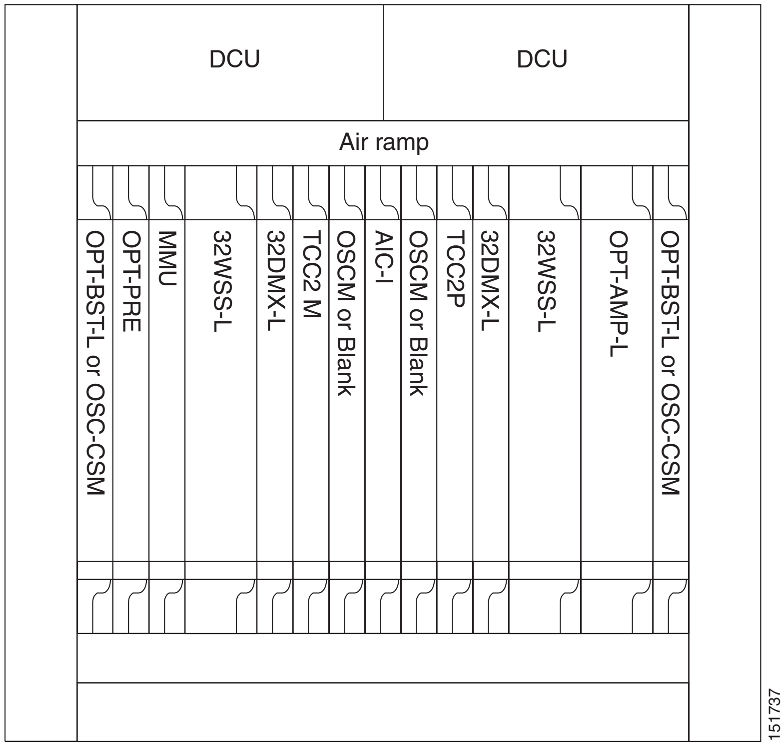
3.1.6.2 L-Band Hub Node

An L-band hub node is a single ONS 15454 node equipped with two TCC2/TCC2P cards, two OSCM or OSC-CSM cards, up to two OPT-BST-L cards, up to two OPT-PRE cards, two 32WSS-L cards, and two 32DMX-L cards.

Note The 32WSS-L and 32DMX-L are normally installed in ROADM nodes, but they can be installed in hub and terminal nodes. If the cards are installed in a hub node, the 32WSS-L express ports (EXP RX and EXP TX) are not cabled.

A DCU can also be added, if necessary. The hub node does not support both DWDM and TDM applications since the DWDM slot requirements do not leave room for TDM cards. Figure 3-19 shows a hub node configuration.

Figure 3-19 L-Band Hub Node



3.1.7 Terminal Node

This section explains the following nodes:

- C-band terminal node
- C-band scalable terminal node
- L-band terminal node

3.1.7.1 C-Band Terminal Node

A terminal node is a single ONS 15454 node equipped with two TCC2/TCC2P cards, an OSCM or OSC-CSM card, an OPT-BST or OPT-BST-E card, an OPT-PRE card, and one of the following combinations:

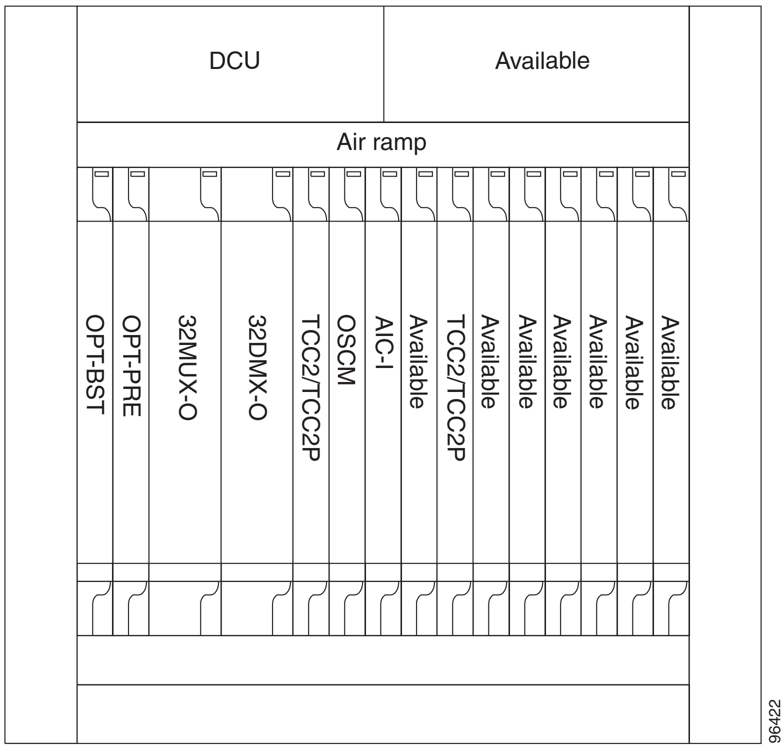
- One 32MUX-O card and one 32DMX-O card
- One 32WSS and either a 32DMX or a 32DMX-O card

Terminal nodes can be either east or west. In west terminal nodes, the cards are installed in the east slots (Slots 1 through 6). In east terminal nodes, cards are installed in the west slots (Slots 12 through 17). A hub node can be changed into a terminal node by removing either the east or west cards. Figure 3-20 shows an example of an east terminal configuration with 32MUX-O and 32DMX-O cards installed. The channel flow for a terminal node is the same as the hub node (see Figure 3-18).

Note AD-xC-xx.x or AD-xB-xx.x cards are not part of a terminal node because pass-through connections are not allowed.

If OPT-BST or OPT-BST-E cards are not required, the OSC-CSM card is used in place of the OSCM card to ensure the processing of the OSC along the network.

Figure 3-20 C-Band Terminal Node Configuration



3.1.7.2 C-Band Scalable Terminal Node

The scalable terminal node is a single ONS 15454 node equipped with a series of OADM cards and amplifier cards. This node type is more cost effective if a maximum of 16 channels are used (see Table 3-1). This node type does not support a terminal configuration exceeding 16 channels, because the 32-channel terminal site is more cost effective for 17 channels and beyond.

Table 3-1 Typical Add/Drop Configurations for Scalable Terminal Nodes

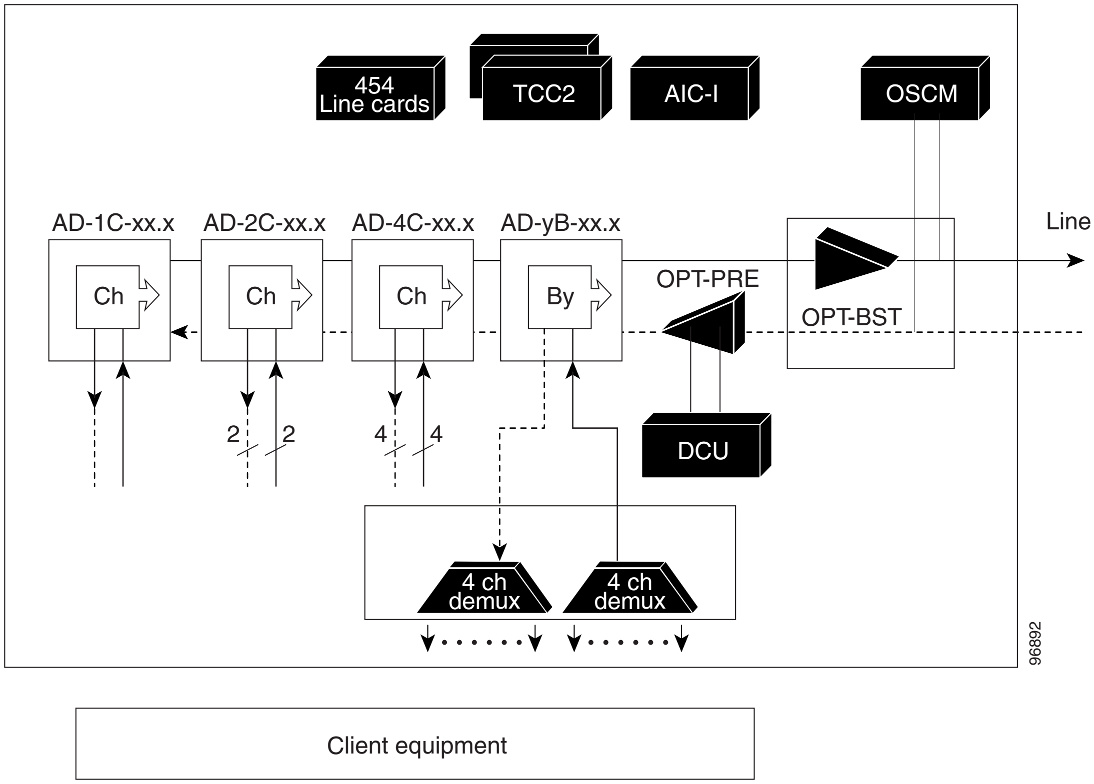
Number of Channels	Terminal Configuration Options	
	Option 1	**Option 2**
1	AD-1C-xx.x	—
2	AD-2C-xx.x	—
3	AD-4C-xx.x	AD-1B-xx.x + 4MD-xx.x
4	AD-4C-xx.x	AD-1B-xx.x + 4MD-xx.x

Table 3-1 Typical Add/Drop Configurations for Scalable Terminal Nodes (continued)

Number of Channels	Terminal Configuration Options	
	Option 1	**Option 2**
5	AD-1C-xx.x + AD-4C-xx.x	AD-1C-xx.x + AD-1B-xx.x + 4MD-xx.x
6	AD-2C-xx.x + AD-4C-xx.x	AD-2C-xx.x + AD-1B-xx.x + 4MD-xx.x
7	2 x AD-4C-xx.x	2 x (AD-1B-xx.x + 4MD-xx.x)
8	2 x AD-4C-xx.x	2 x (AD-1B-xx.x + 4MD-xx.x)
9	AD-1C-xx.x + (2 x AD-4C-xx.x)	AD-1C-xx.x + 2 x (AD-1B-xx.x + 4MD-xx.x)
10	AD-2C-xx.x + (2 x AD-4C-xx.x)	AD-2C-xx.x + 2 x (AD-1B-xx.x + 4MD-xx.x)
11	3 x AD-4C-xx.x	AD-4B-xx.x + (3 x 4MD-xx.x)
12	3 x AD-4C-xx.x	AD-4B-xx.x + (3 x 4MD-xx.x)
13	AD-4B-xx.x + (3 x 4MD-xx.x) + AD-1C-xx.x	AD-4B-xx.x + (3 x 4MD-xx.x)
14	AD-4B-xx.x + (3 x 4MD-xx.x) + AD-1C-xx.x	AD-4B-xx.x + (3 x 4MD-xx.x)
15	—	AD-4B-xx.x + (3 x 4MD-xx.x)
16	—	AD-4B-xx.x + (3 x 4MD-xx.x)

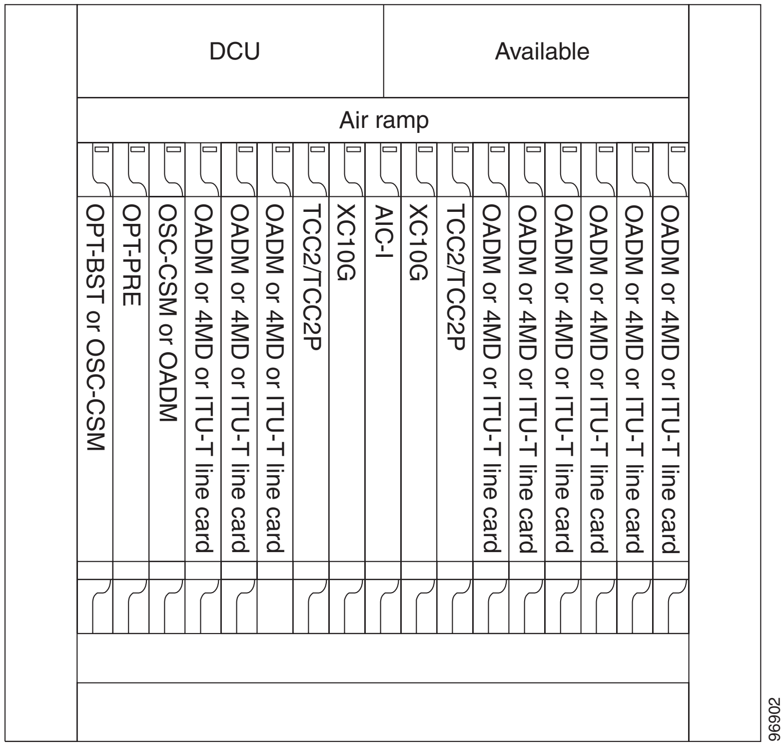
The OADM cards that can be used in this type of configuration are the AD-1C-xx.x, AD-2C-xx.x, AD-4C-xx.x, and AD-1B-xx.x. You can also use the AD-4B-xx.x card and up to four 4MD-xx.x cards. The OPT-PRE and/or OPT-BST amplifiers can be used. The OPT-PRE or OPT-BST configuration depends on the node loss and the span loss. When the OPT-BST is not installed, the OSC-CSM card must be used instead of the OSCM card. Figure 3-21 shows a channel flow example of a scalable terminal node configuration.

Figure 3-21 Scalable Terminal Channel Flow



A scalable terminal node can be created by using band and/or channel OADM filter cards. This node type is the most flexible of all node types, because the OADM filter cards can be configured to accommodate node traffic. If the node does not contain amplifiers, it is considered a passive hybrid terminal node. Figure 3-22 shows an example of a scalable terminal node configuration. This node type can be used without add or drop cards.

Figure 3-22 Scalable Terminal Node Configuration



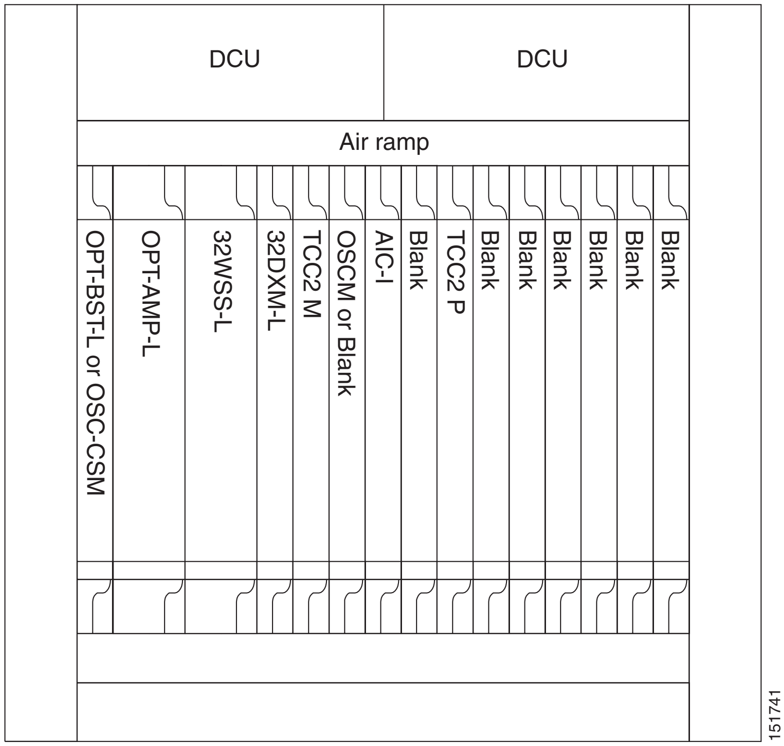
3.1.7.3 L-Band Terminal Node

A terminal node is a single ONS 15454 node equipped with two TCC2/TCC2P cards, an OSCM or OSC-CSM card, an OPT-BST-L card, an OPT-AMP-L card, one 32WSS-L card, and one 32DMX-L card.

Terminal nodes can be either east or west. In west terminal nodes, the cards are installed in the east slots (Slots 1 through 6). In east terminal nodes, cards are installed in the west slots (Slots 12 through 17). A hub node can be changed into a terminal node by removing either the east or west cards. Figure 3-20 shows an example of an east terminal configuration. The channel flow for a terminal node is the same as the hub node, as shown in Figure 3-18.

Note If OPT-BST or OPT-BST-E cards are not required, the OSC-CSM card is substituted for the OSCM card to ensure the processing of the OSC along the network.

Figure 3-23 L-Band 32-Channel Terminal Site Layout



3.1.8 DWDM and TDM Hybrid Node Configurations

The node configuration is determined by the type of card that is installed in an ONS 15454 hybrid node. The ONS 15454 supports the following DWDM and TDM hybrid node configurations:

- Hybrid terminal
- Hybrid OADM
- Hybrid line amplifier
- Amplified TDM

Note The Cisco MetroPlanner tool creates a plan for amplifier placement and proper equipment for DWDM node configurations. Although TDM cards can be used with DWDM node configurations, the Cisco MetroPlanner tool does not create a plan for TDM card placement. Cisco MetroPlanner will support TDM configurations in a future release.

3.1.8.1 Hybrid Terminal Node

A hybrid terminal node is a single ONS 15454 node equipped with at least one 32MUX-O card, one 32DMX-O card, two TCC2/TCC2P cards, and TDM cards. If the node is equipped with OPT-PRE or OPT-BST amplifiers, it is considered an amplified terminal node. The node becomes passive if the amplifiers are removed. The hybrid terminal node type is based on the DWDM terminal node type described in the "3.1.7 Terminal Node" section on page 3-18. Figure 3-24 shows an example of an amplified hybrid terminal node configuration.

Figure 3-24 Amplified Hybrid Terminal

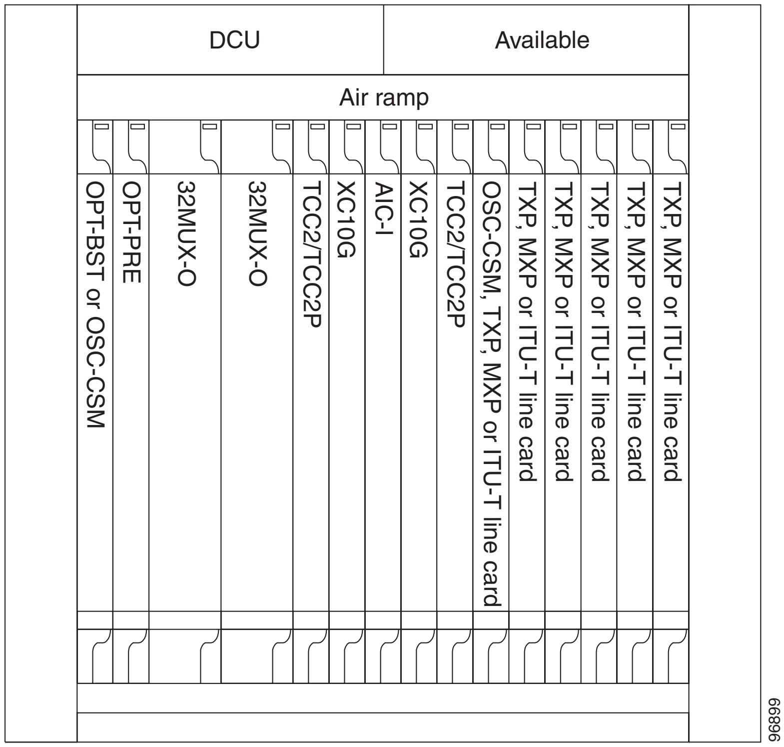
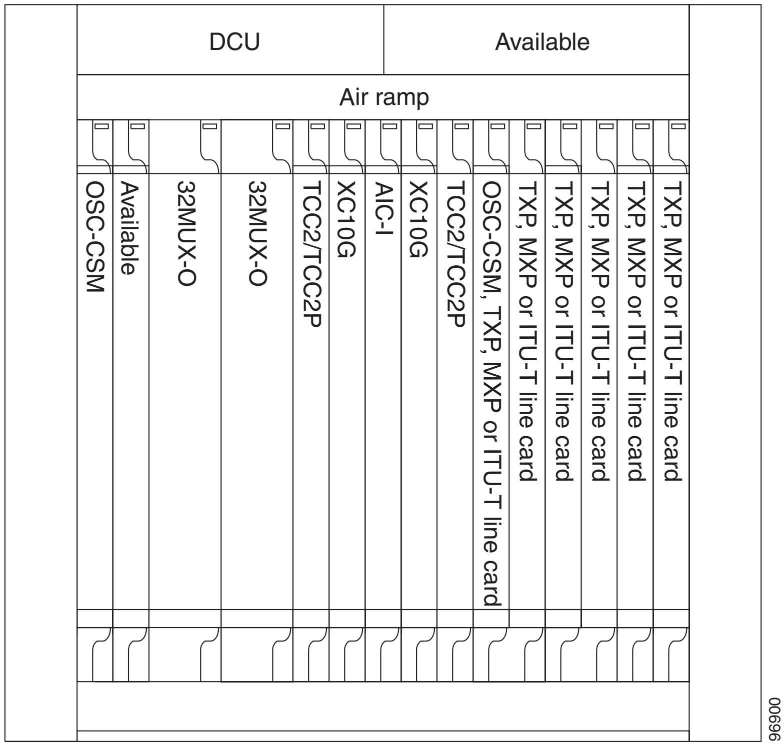


Figure 3-25 shows an example of a passive hybrid terminal node configuration.

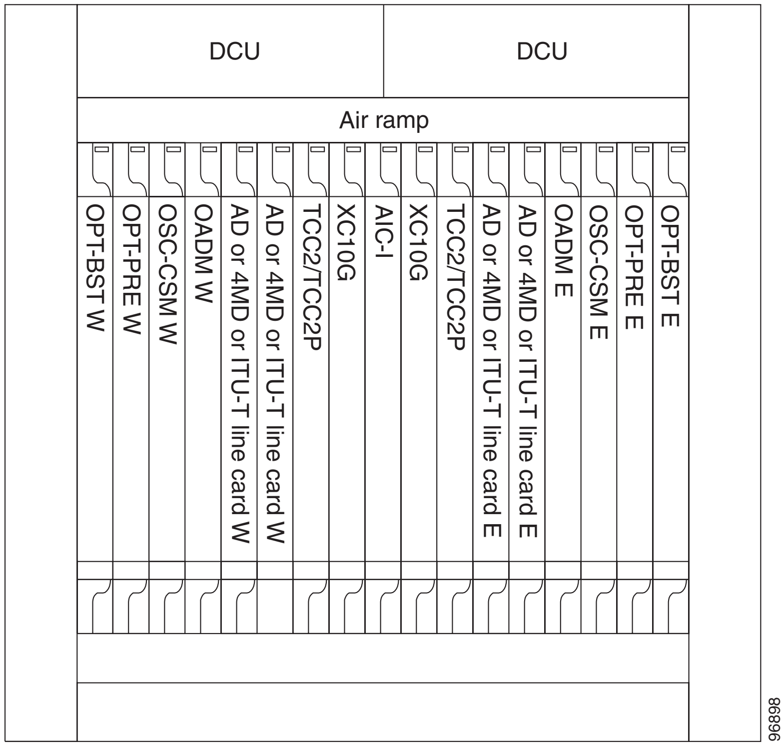
Figure 3-25 ***Passive Hybrid Terminal***



3.1.8.2 Hybrid OADM Node

A hybrid OADM node is a single ONS 15454 node equipped with at least one AD-xC-xx.x card or one AD-xB-xx.x card, and two TCC2/TCC2P cards. The hybrid OADM node type is based on the DWDM OADM node type previously described in the "3.1.4 C-Band OADM Node" section on page 3-11. TDM cards can be installed in any available multispeed slot. Review the plan produced by Cisco MetroPlanner to determine slot availability. Figure 3-26 shows an example of an amplified hybrid OADM node configuration. The hybrid OADM node can also become passive by removing the amplifier cards.

Figure 3-26 Hybrid Amplified OADM

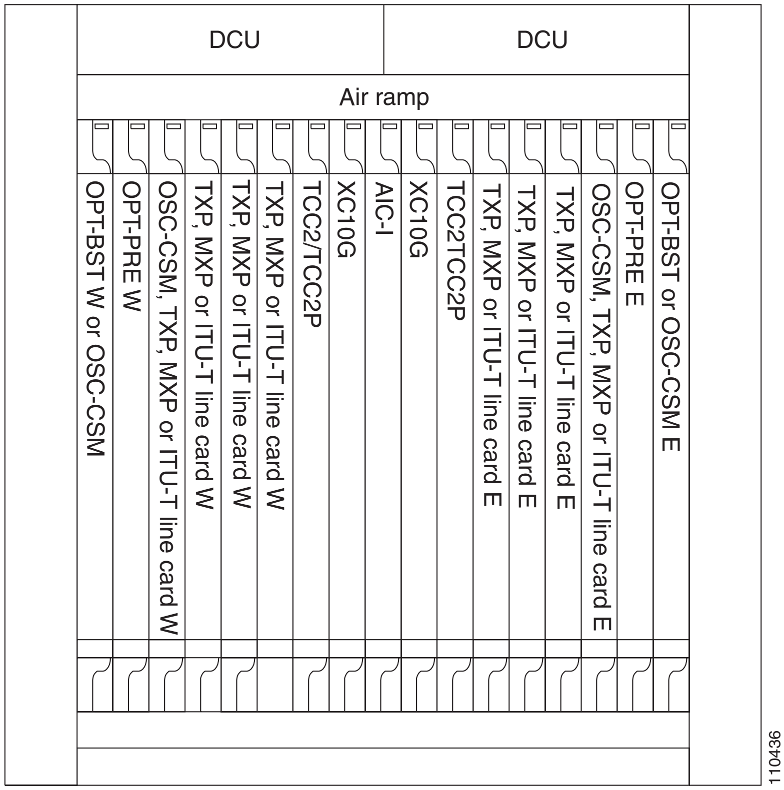


3.1.8.3 Hybrid Line Amplifier Node

A hybrid line amplifier node is a single ONS 15454 node with open slots for both TDM and DWDM cards. Figure 3-27 shows an example of a hybrid line amplifier node configuration.

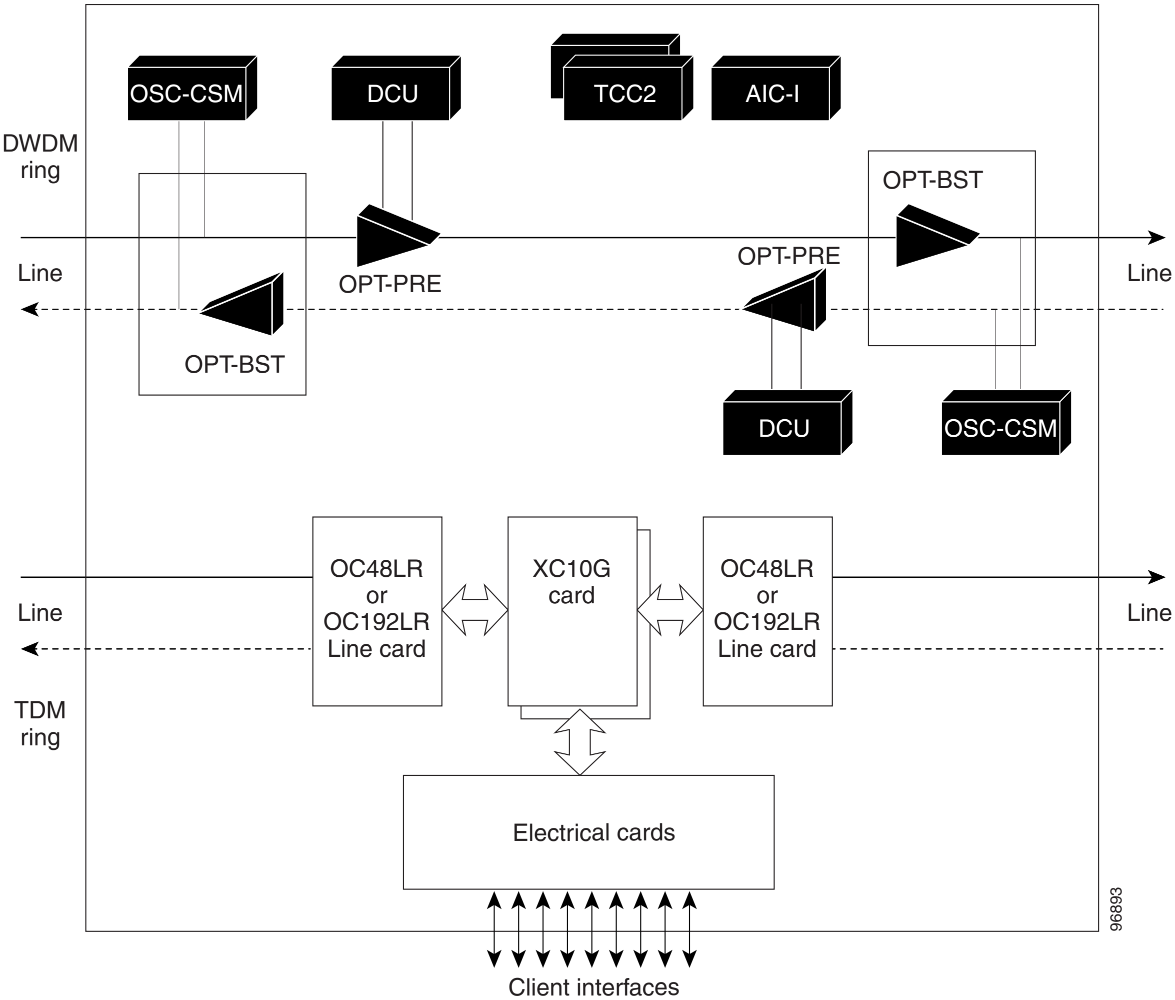
Note For DWDM applications, if the OPT-BST card is not installed in the node, the OSC-CSM card must be substituted for the OSCM card.

Figure 3-27 Hybrid Line Amplifier



A hybrid line node is another example of the hybrid line amplifier OADM node. A hybrid line node is single ONS 15454 node equipped with OPT-PRE amplifiers, OPT-BST amplifiers, and TCC2/TCC2P cards for each line direction. Both types of amplifiers can be used or just one type of amplifier. Attenuators might also be required between each preamplifier and booster amplifier to match the optical input power value and to maintain the amplifier gain tilt value. TDM cards can be installed in any available multispeed slot. Review the plan produced by Cisco MetroPlanner to determine slot availability. Figure 3-28 shows a channel flow example of a hybrid line node configuration. Since this node contains both TDM and DWDM rings, both TDM and DWDM rings should be terminated even if no interactions are present between them.

Figure 3-28 Hybrid Line Amplifier Channel Flow



3.1.8.4 Amplified TDM Node

An amplified TDM node is a single ONS 15454 node that increases the span length between two ONS 15454 nodes that contain TDM cards and optical amplifiers. There are three possible configurations for an amplified TDM node:

- Configuration 1 uses client cards and OPT-BST amplifiers.
- Configuration 2 uses client cards, OPT-BST amplifiers, OPT-PRE amplifiers, and FlexLayer filters.
- Configuration 3 uses client cards, OPT-BST amplifiers, OPT-PRE amplifiers, AD-1Cxx.x cards, and OSC-CSM cards.

The client cards that can be used in an amplified TDM node are:

- TXP_MR_10G
- MXP_2.5G_10G
- TXP_MR_2.5G
- TXPP_MR_2.5G

- OC-192 LR/STM 64 ITU 15xx.xx
- OC-48 ELR/STM 16 EH 100 GHz

Figure 3-29 shows the first amplified TDM node configuration with an OPT-BST amplifier.

Figure 3-29 Amplified TDM Example with an OPT-BST Amplifier

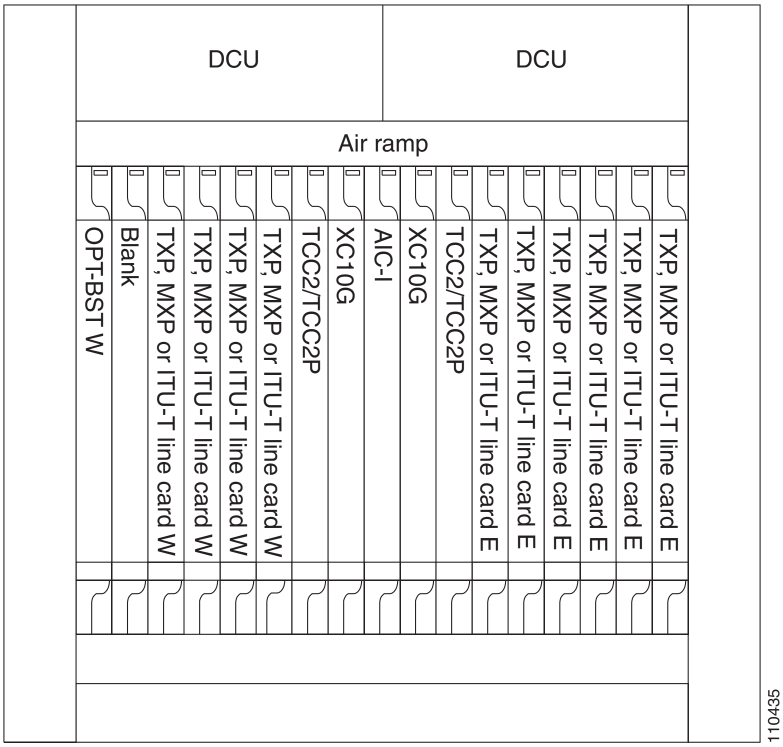


Figure 3-30 shows the first amplified TDM node channel flow configuration with OPT-BST amplifiers.

Figure 3-30 Amplified TDM Channel Flow Example With OPT-BST Amplifiers

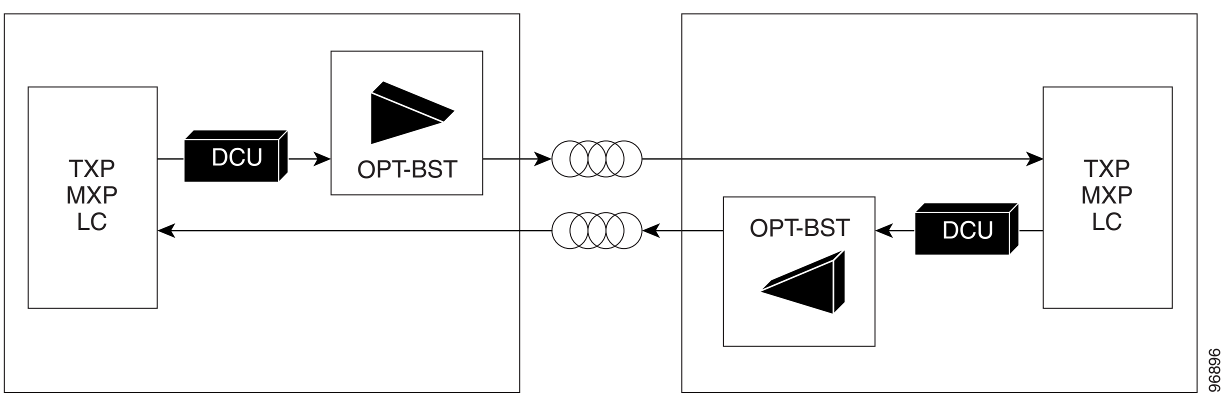


Figure 3-31 shows the second amplified TDM node configuration with client cards, AD-1C-xx.x cards, OPT-BST amplifiers, OPT-PRE amplifiers, and FlexLayer filters.

Figure 3-31 Amplified TDM Example with FlexLayer Filters

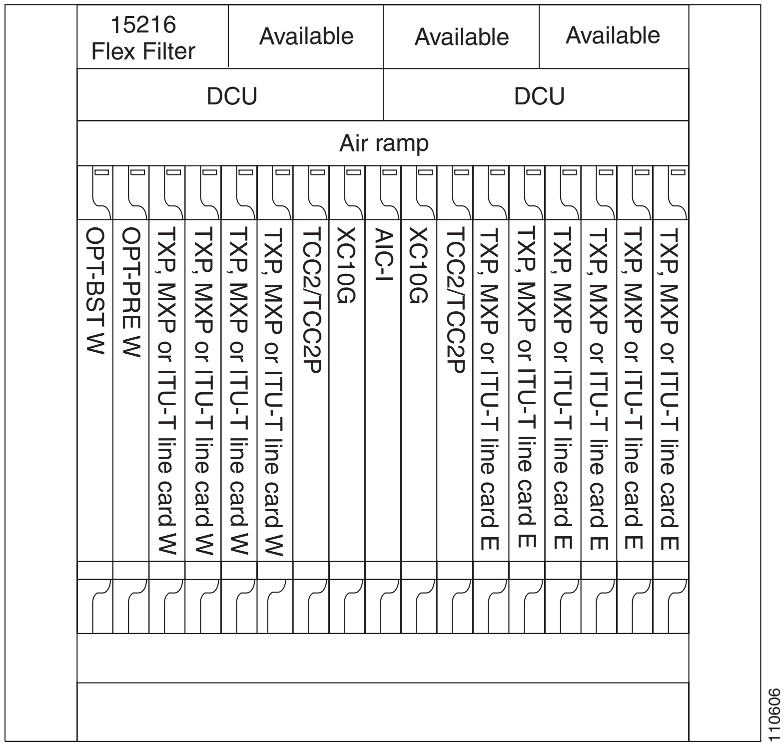


Figure 3-32 shows the second amplified TDM node channel flow configuration with client cards, OPT-BST amplifiers, OPT-PRE amplifiers, and FlexLayer filters.

Figure 3-32 Amplified TDM Channel Flow Example With FlexLayer Filters

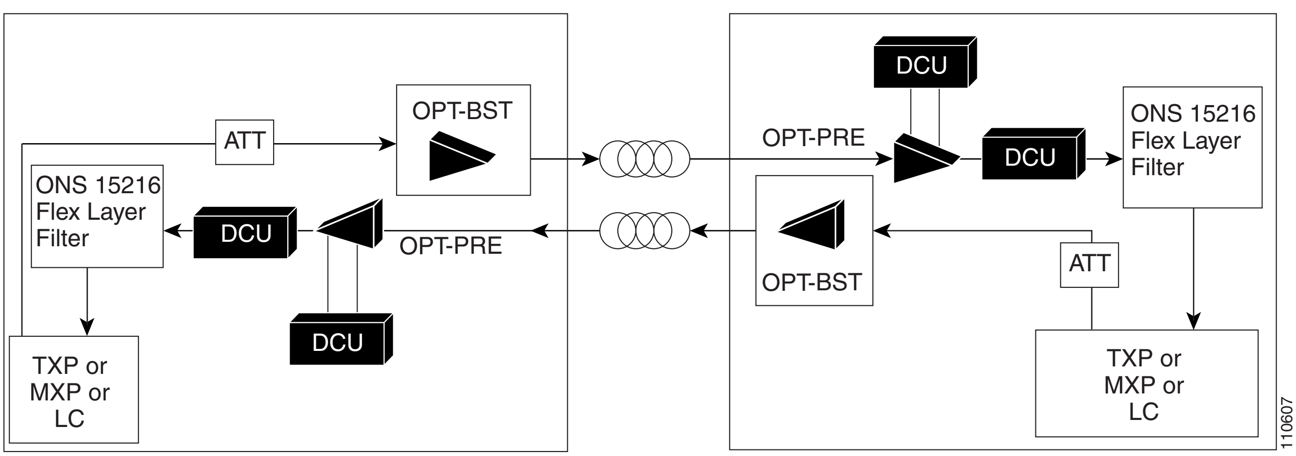
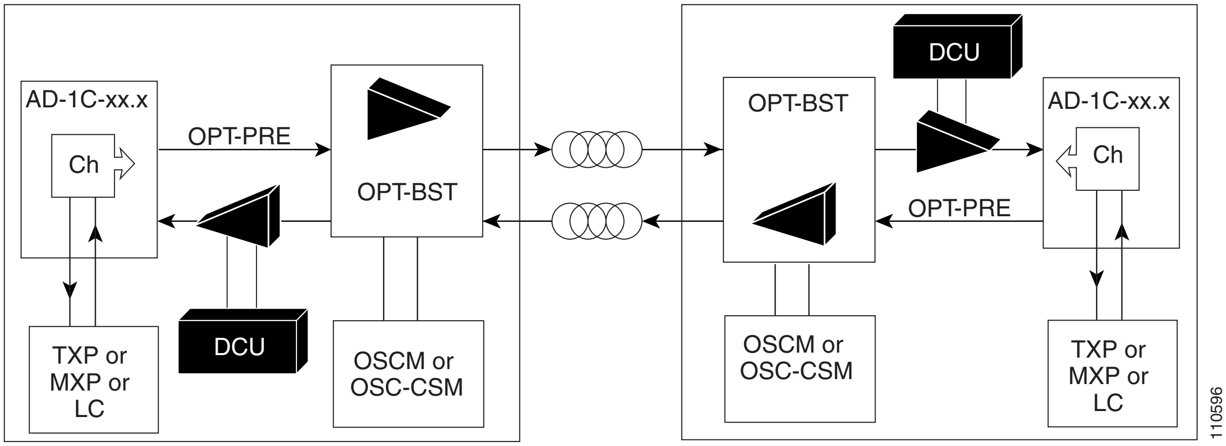


Figure 3-33 shows the third amplified TDM channel flow configuration with client cards, OPT-BST amplifiers, OPT-PRE amplifiers, AD-1C-xx.x cards, and OSC-CSM cards.

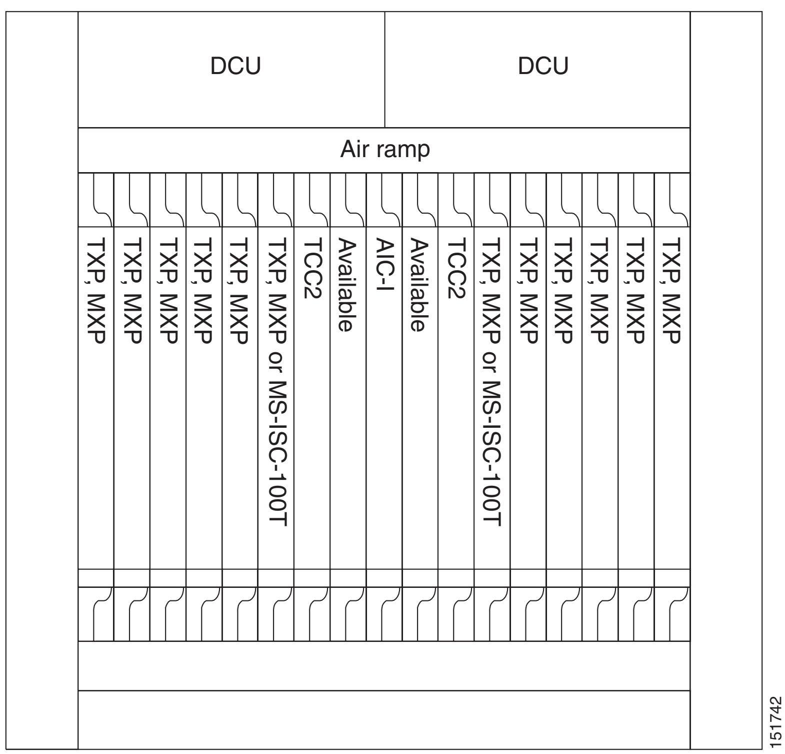
Figure 3-33 Amplified TDM Channel Flow Example With Amplifiers, AD-1C-xx.x Cards, and OSC-CSM Cards



3.1.9 Transponder (Client) Shelf Layout

Transponder and muxponder cards can be installed in any ONS 15454 slot that is marked with the orange circle symbol. Figure 3-34 shows transponder shelf layout.

Figure 3-34 Transponder Shelf Layout



3.1.10 Inter-Shelf Communications

A typical Multiservice Transport Platform (MSTP) node foresees a number of units that cannot be equipped in a single shelf. It might not be possible to manage the optical shelf and the transponder shelf as different nodes.

A multishelf (MS) node can aggregate up to eight shelves, none of them equipped with cross-connect (XC) cards. All these shelves must be collocated at the same site at a maximum distance of 328 feet (100 m) from the Ethernet switches that are used to support the communication LAN.

The MS feature is not supported for the Multiservice Provisioning Platform (MSPP). Multishelf nodes carry a single public IP address. All aggregated shelves have a common management interface (CTC/CTM/TL1/SNMP/HTTP).

3.1.10.1 Definitions

The following definitions are applicable to inter-shelf communications:

- Node Controller (NC): The main shelf, equipped with a TCC2/TCC2P card that runs node functions.
- Subtended Shelf: One of the aggregated shelves. The TCC2/TCC2P equipment in a subtended shelf is called the Subtended Shelf Controller, which runs shelf functions.
- Shelf ID: A number used to address a shelf in the MS node. It is a number between 1 and 8, assigned by the user. Shelf ID 1 is reserved for the NC.

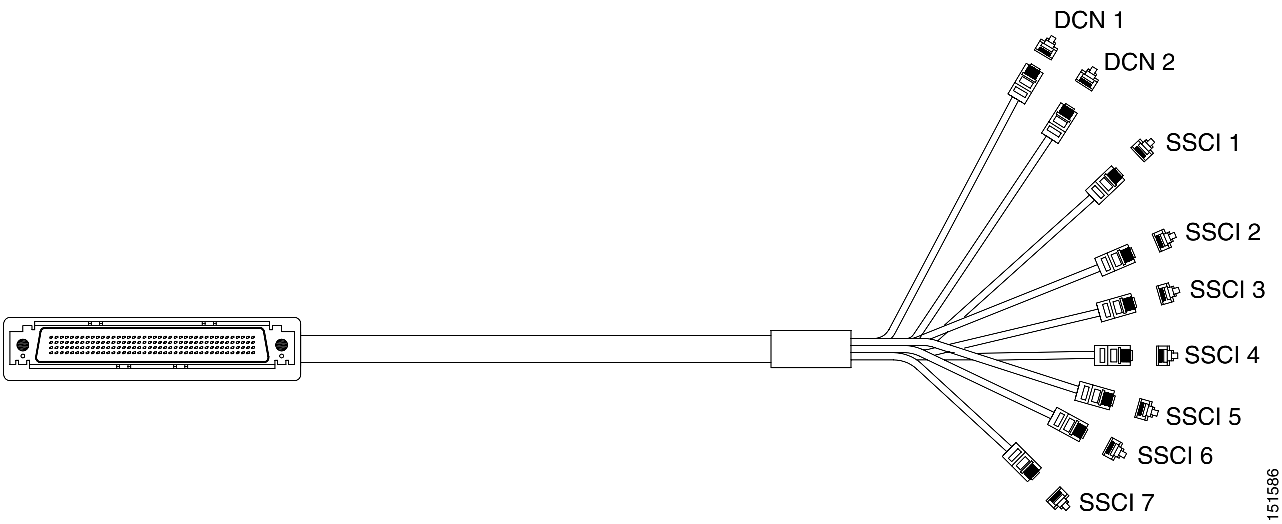
3.1.10.2 Communication Layer

Supervision of an MS mode is distributed among TCC2/TCC2Ps in different shelves. The TCCs require communication channel between them, which is accomplished with an Ethernet LAN.

For physical connections between PROT ports, and between an MS-ISC-100T NC port and a TCC2/TCC2P FP port, you must use common CAT-5 Ethernet cables. These cables are internal to the NC shelf and are part of the MS bundle.

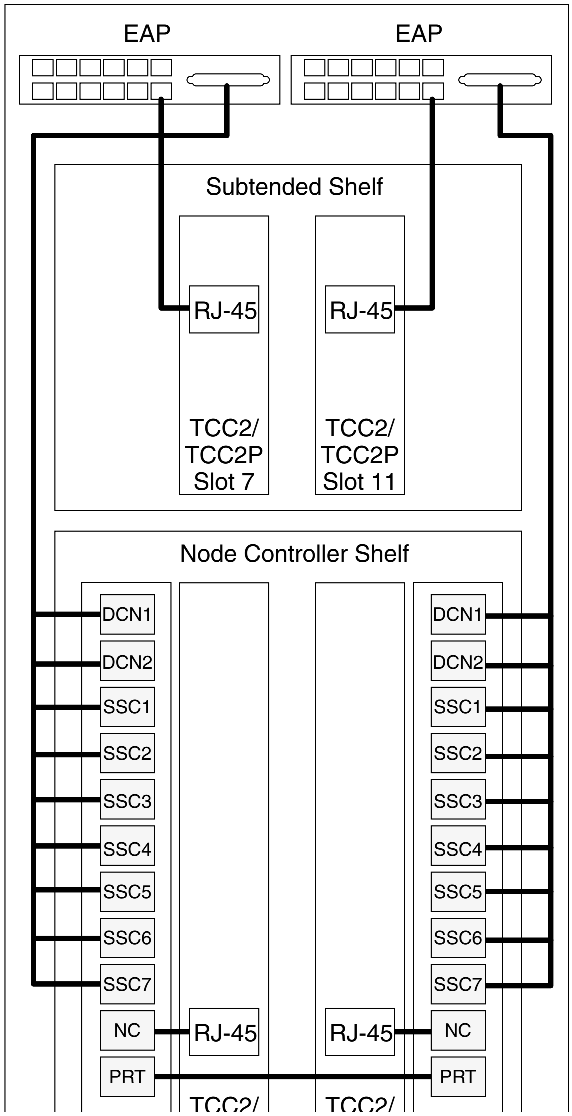
Physical connection starting from DCN and SSC ports use a special multiport cable that must be installed (see Figure 3-35).

Figure 3-35 Ethernet Adapter Cable



User interfaces (TCC, CTM, Tl1 OSS) and SSC ports must be connected to the patch panel using common CAT-5 Ethernet cables. Patch-panel ports are labeled as MS-ISC-100T ports, which use the same color code. Figure 3-36 shows a rack with two shelves in it. It follows the cabling rules described in this section.

Figure 3-36 Connecting the EAP to the Node Controller and Subtending Shelf



A multishelf node can use both TCC2 and TCC2P cards. A mix of TCC2 and TCC2P is supported in both NC and SSC shelves.

3.1.10.3 Multishelf Layout

MS mode does not impose any constraint about layout apart from equipping MS-ISC-100T cards in the NC shelf. The following are the most common configurations:

- Typical: All optical units are equipped in the NC shelf and TXPs/MXPs are equipped in the aggregated subtended shelves.
- East/West protected: All optical units facing west are equipped in one shelf; all the optical units facing east are equipped in another shelf.

These are the recommended configurations and are designed by Cisco MetroPlanner. Considering the first case, all empty slots in the NC shelves can be equipped with TXPs/MXPs.

These layouts are automatically detected by the CTC software. In these two cases, you can create the node patchcord tree without any manual intervention. This feature is not supported if units are provisioned or equipped according to different rules.

In Software Release 7.0, the patchcord tree has been extended to include a link between the TXP/MXP OCH Trunk port a nd the OCH-Filter port. This patchcord can be automatically created only if a TXP/MXP has been previously tuned on one of the supported wavelengths.

In the east/west protected layout, you must implement configurations that are reliable against electrical power outages. Neither east nor west terminated traffic will be lost in case of a single shelf shut down.

In a typical layout, TXPs or MXPs facing east and west can be equipped in three different ways:

- Protected Transponder (OSMINE Configuration): The working and protect cards are equipped near each other, starting from the first free slot. The TXP facing west is the one with the lower slot ID.
- Protected Transponder (not OSMINE Configuration): TXPs facing west are always equipped in west side slots (1 to 6), while TXPs facing east are equipped in east side slots (12 to 17).
- Unprotected Transponder: A TXP is equipped starting from the first free slot.

These rules are also implemented by Cisco MetroPlanner 7.0.

ANSI and ETSI racks can equip a number of 15454 shelves. An ANSI rack can equip four 15454 shelves, while an ETSI rack can equip three 15454 shelves. Fully-equipped racks do not have space for an ONS 15216 DCU Shelf (1 RU), a Patch Panel Shelf (1 RU), a Fiber Storage (1 RU), an ONS 15216 Y-Cable Shelf (1 RU), or an Air Ramp (1 RU).

To create space for one of these service shelves, the number of 15454 shelves must be reduced to three in an ANSI rack and to two in an ETSI rack. In all layouts, unallocated space for MSTP shelves can be used to install MSPP shelves. In this case, MSTP shelves will build a Multishelf Node Element (MSNE); each of the MSPP shelves will be a single-shelf node.

A fully equipped maximum MSNE configuration (32 bidirectional channels) requires eight shelves in an east/west protected layout, seven in all the others. These shelves can be equipped in different racks: a maximum of eight for protected configurations, seven for all others.

3.1.10.4 DCC/GCC/OSC Termination

A multishelf MSTP node provides the same DCN communication channels as a single-shelf node:

- OSC links terminated on OSCM or OSC-CSM cards
- GCC/data communications channel (DCC) links terminated on TXP or MXP cards

Support for intelligent network applications requires two OSC links between every two MSTP nodes. This assumption is still valid in an MS environment where an OSC-CSM or OSCM card is required for each of terminated spans. An OSC link between two nodes cannot be replaced by an equivalent GCC/DCC link terminated on the same set of nodes. OSC links are mandatory and they can be used to connect nodes to gateway network element (GNE). This implies that TXP shelves can be monitored remotely and this reduces the number of GCC/DCC links requested by DCN.

The maximum number of DCC/GCC/OSC terminations that are supported in a multishelf node is 48. These paths can be terminated in any of the aggregated shelves.

3.1.10.5 Circuit Overhead

Circuit overhead is extracted by AIC-I physical ports. In a multishelf environment, overhead byte circuits are not routed inside an MSNE node. To extract overhead bytes, the shelf must be equipped with an AIC-I card.

3.1.10.6 Timing Tree

Aggregating many shelves in a single multishelf network element (NE) does not imply any specific requirement related to timing. For timing, each shelf must have a single-shelf node that can be used as timing source line, TCC clock, or building integrated timing supply (BITS) source lines.

If you want to synchronize the entire MSNE with a single timing source, you must configure BITS IN and BITS OUT ports on different shelves correctly.

3.1.10.7 Automatic Node Provisioning

Cisco MetroPlanner provides a node bill of materials (BOM) and node layout, including the physical position (slot) of each card. The Automatic Node Provisioning file contains two main sections:

- Node layout
- Automatic node setup (ANS) provisioning parameters

A card parameter section is also available, though it is significant for L-band cards only. Node layout includes shelves, and the cards inside the shelves. In the DWDM > ANS tab, CTC provides a wizard that allows you to manage XML files. Cisco MetroPlanner prepares a single XML file for each designed network.

You can choose to perform node layout provisioning, ANS parameters provisioning, or both. Node layout provisioning includes the following components:

- Shelves
- Cards inside the shelves

You can preview provisioning data parameters before applying them. Provisioning results are displayed on the monitor, and are logged into a specified file.

The Import function that was available on the ANS-WDM > Provisioning tab is no longer supported because the wizard now provisions ANS parameters. The provisioning wizard is not backward compatible and hence cannot manage ANS files in the previous ASCII format.

The main provisioning report could have the following results:

- Applied: All units have been successfully provisioned.
- Slot not empty: One or more slots cannot be provisioned according to the enhanced state model (ESM) rules (for example, a card is already provisioned, or a card is already equipped and not in the deletion state).
- Setting Refused: The TCC2/TCC2P card did not accept a card or parameter provisioning.

3.2 Site Drawings

Typically, up to three ONS 15454 shelves can be mounted in a standard ANSI 7-foot bay (with a low-profile fuse panel) if a dispersion compensation shelf assembly is required. The remaining space can be used to install up to nine 1 rack unit (RU) shelves, including:

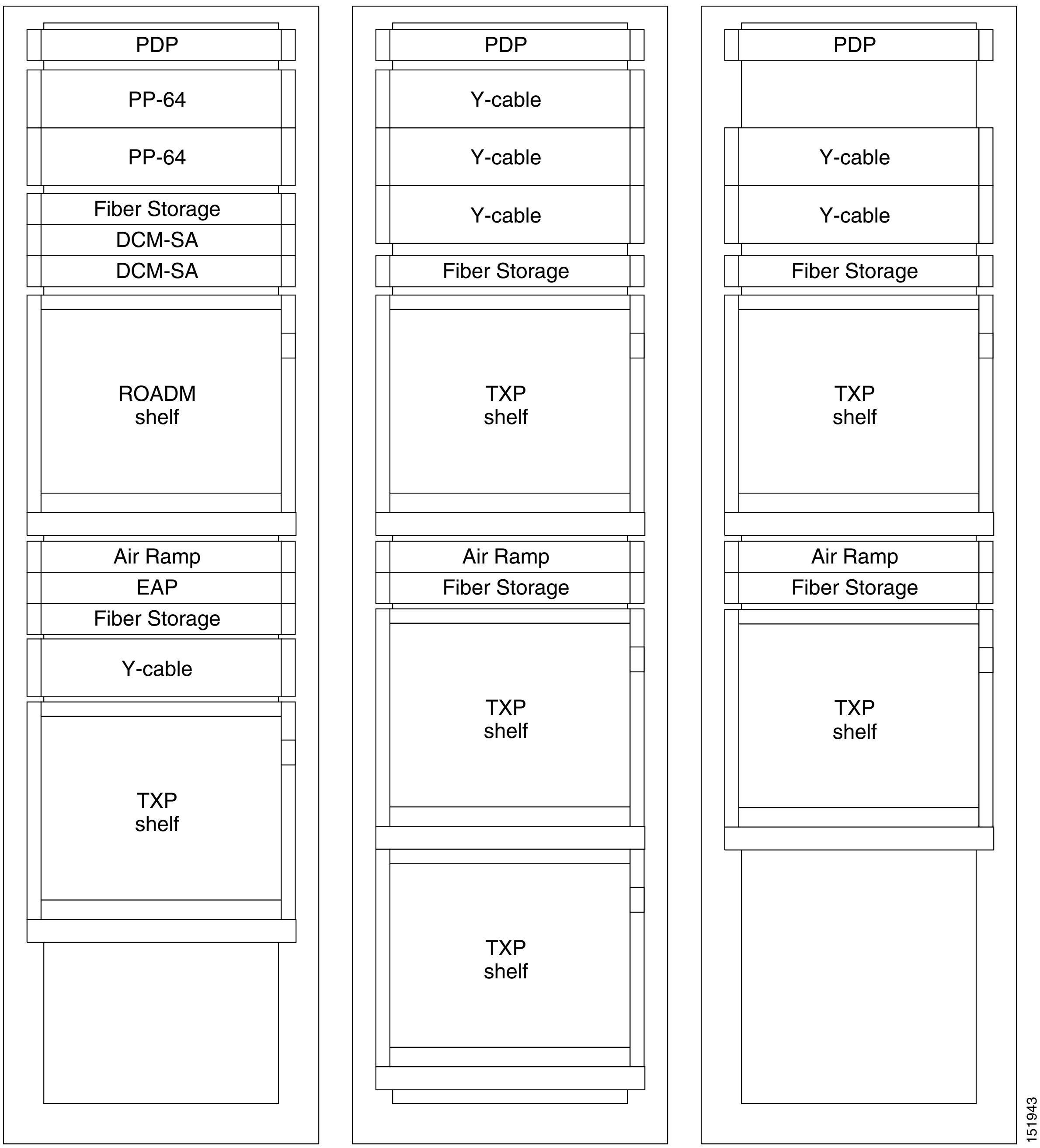
- 2 patch panels (2 RU high): Provide MPO to LC fan-out for 32 connections.
- Fiber Storage (1 RU high): Provides fiber storage inside the rack and inter-unit fiber connections.
- DCU-SA (1 RU high): Stores up to two dispersion compensation units (DCUs). Requires two DCU shelves if two DCUs will be cascaded.
- Air Ramp (1 RU high): Installed between a 1RU shelf and the ONS 15454 shelf.

- Ethernet Adapter Panel (1RU high): In a multishelf configuration, extends the Ethernet connections from the node controller shelf to the subtended shelves.

3.2.1 ROADM and Hub Node

Figure 3-37 shows the site configuration for an ROADM and hub node.

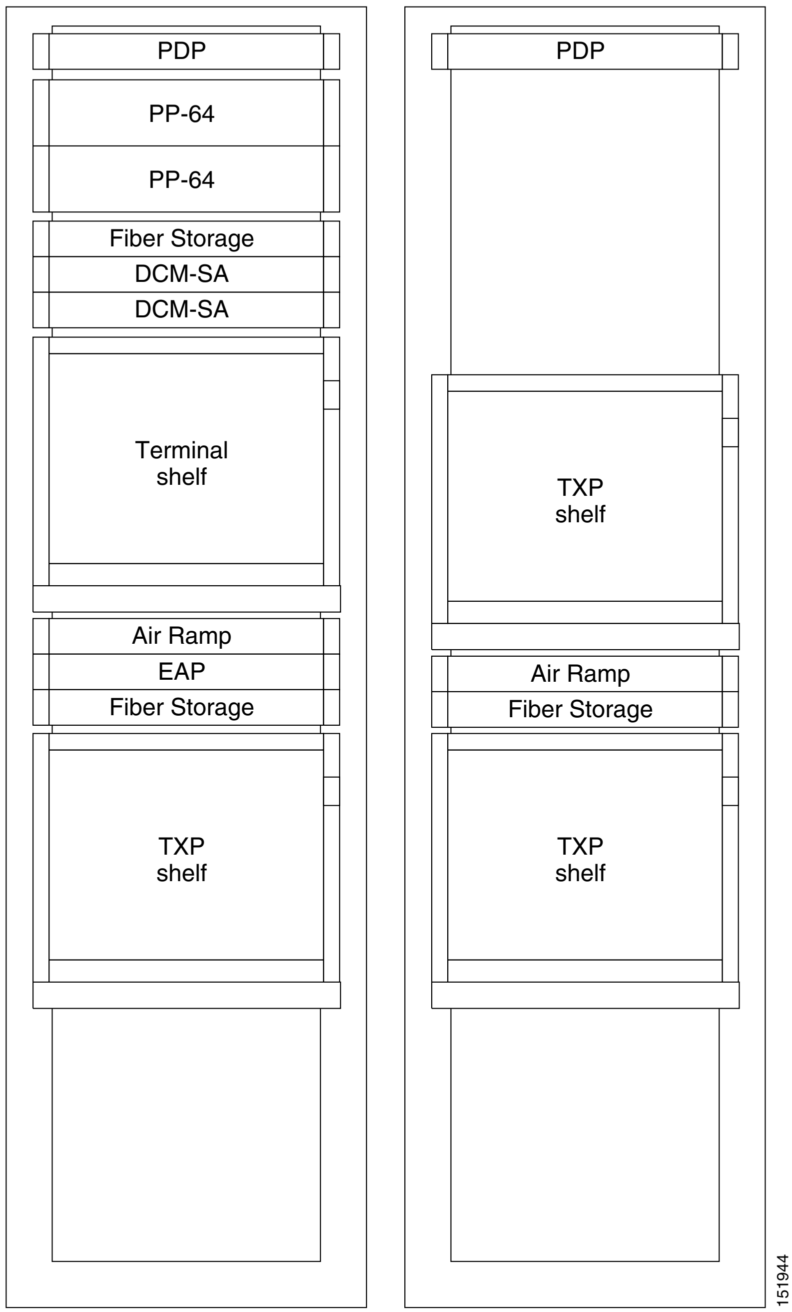
Figure 3-37 ROADM and Hub Node



3.2.2 Terminal Site

Figure 3-38 shows the configuration for a terminal site.

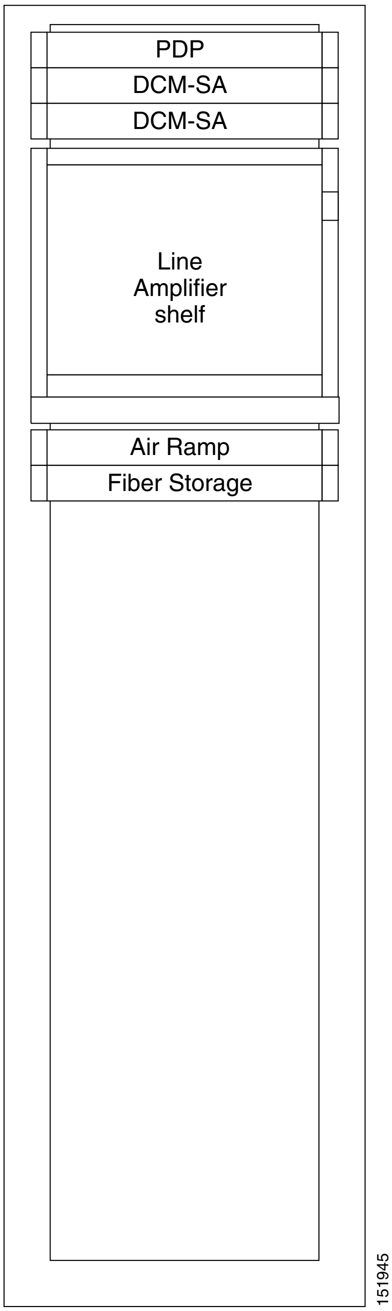
Figure 3-38 Terminal Site



3.2.3 Line Amplifier Site

Figure 3-39 shows the configuration for a line amplifier site.

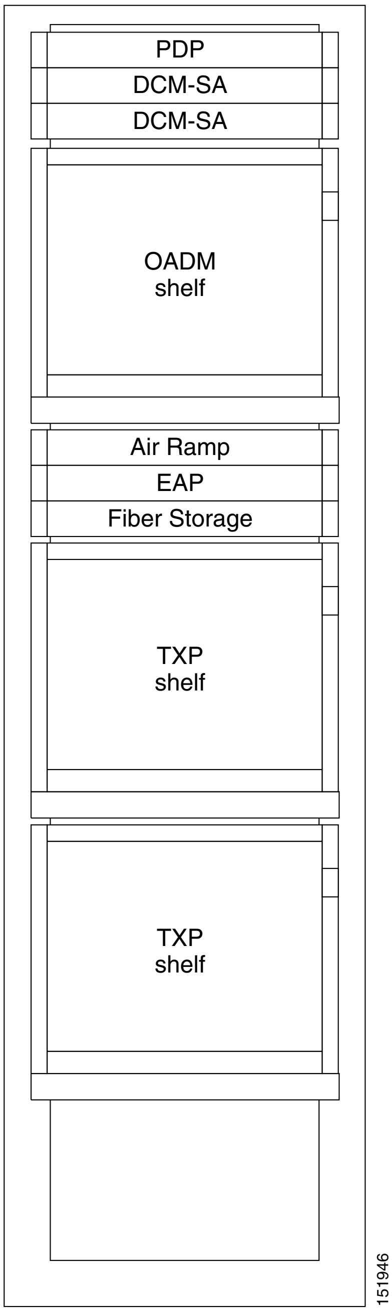
Figure 3-39 Line Amplifier Site



3.2.4 OADM Node

Figure 3-40 shows the configuration for an OADM node.

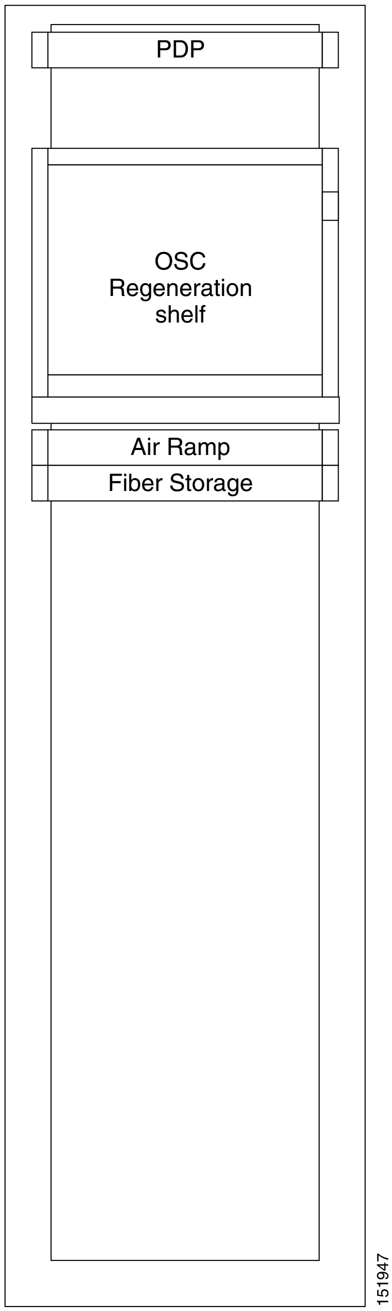
Figure 3-40 OADM Node



3.2.5 OSC Regeneration Site

Figure 3-41 shows the configuration for an optical service channel (OSC) regeneration site.

Figure 3-41 OSC Regeneration Site



CHAPTER 4

Topologies

The following Cisco ONS 15454 DWDM network topologies are described in this chapter:

4.1 Overview

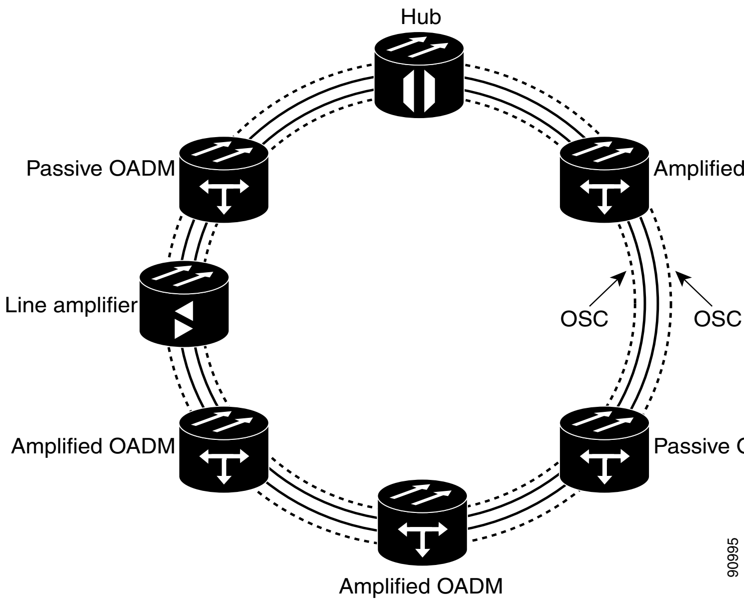
There are two main DWDM network types: Metro Core, where the channel power is equalized and dispersion compensation is applied, and Metro Access, where the channels are not equalized and dispersion compensation is not applied. Metro Core networks often include multiple spans and amplifiers, thus making optical signal-to-noise ratio (OSNR) the limiting factor for channel performance. Metro Access networks often include a few spans with very low span loss; therefore, the signal link budget is the limiting factor for performance.

4.2 Hubbed Rings

In the hubbed ring topology (Figure 4-1), a hub node terminates all the DWDM channels. A channel can be provisioned to support protected traffic between the hub node and any node in the ring. Both working and protected traffic use the same wavelength on both sides of the ring. Protected traffic can also be provisioned between any pair of optical add/drop multiplexer (OADM) nodes, except that either the working or the protected path must be regenerated in the hub node.

Protected traffic saturates a channel in a hubbed ring, which means that channel reuse is not available. However, the same channel can be reused in different sections of the ring by provisioning unprotected multihop traffic. From a transmission point of view, this network topology is similar to two bidirectional point-to-point links with OADM nodes.

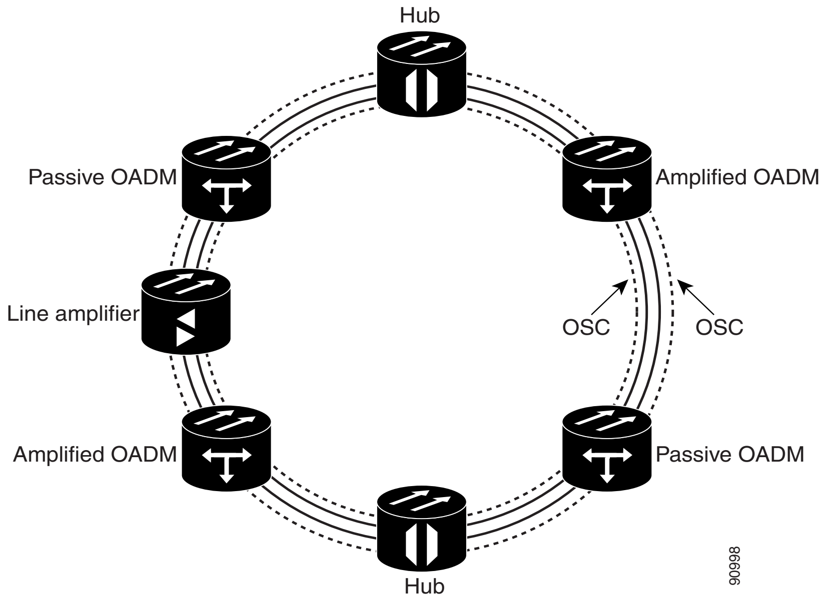
Figure 4-1 Hubbed Ring



4.3 Multihubbed Rings

A multihubbed ring (Figure 4-2) is based on the hubbed ring topology, except that two or more hub nodes are added to make a multihubbed ring. Protected traffic can only be established between the two hub nodes. Protected traffic can be provisioned between a hub node and any OADM node if the allocated wavelength channel is regenerated through the other hub node. Multihop traffic can be provisioned on this ring. From a transmission point of view, this network topology is similar to two or more point-to-point links with OADM nodes.

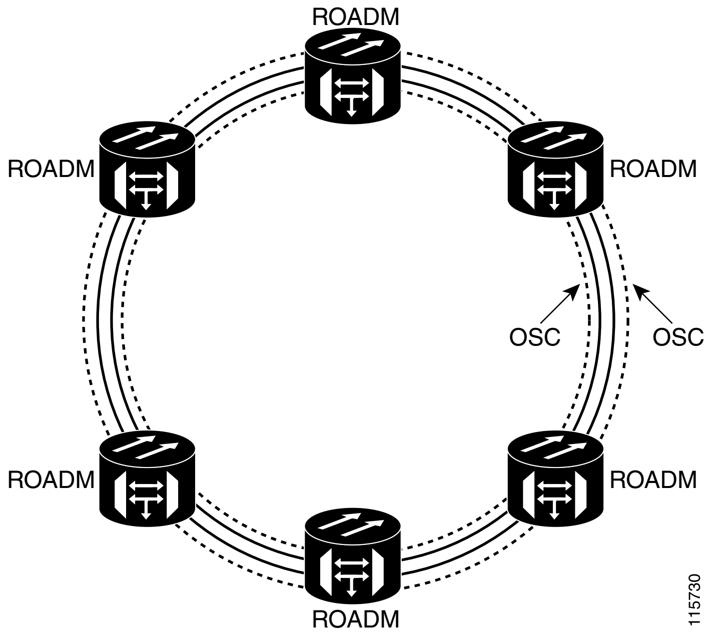
Figure 4-2 Multihubbed Ring



4.4 Any-to-Any Rings

The any-to-any ring topology shown in Figure 4-3 contains only reconfigurable OADM (ROADM) nodes, or ROADM nodes with optical service channel (OSC) regeneration or amplifier nodes. The any-to-any ring topology allows you to route every wavelength from any source to any destination node inside the network.

Figure 4-3 Any-to-Any Ring



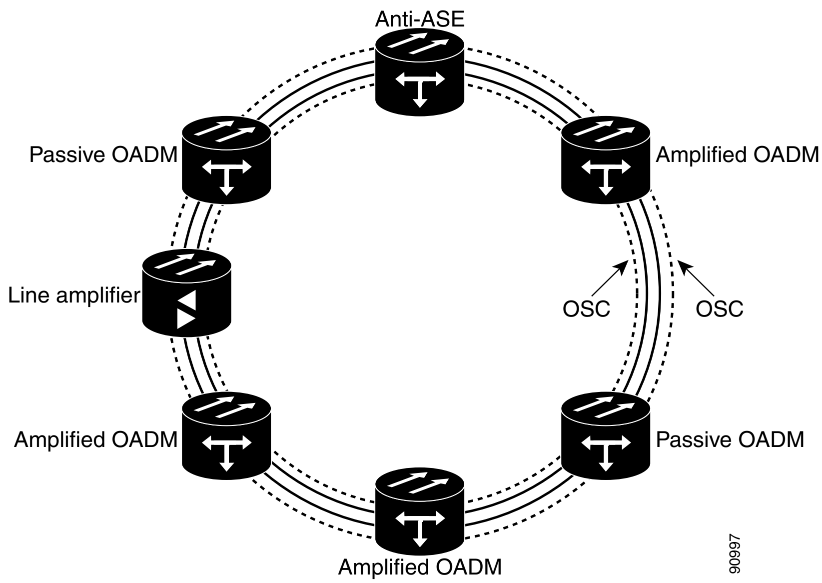
4.5 Meshed Rings

In a meshed ring topology (Figure 4-4), protected traffic can be provisioned between any two nodes; however, the selected channel cannot be reused in the ring. Unprotected multihop traffic can be provisioned in the ring. A meshed ring must be designed to prevent amplified spontaneous emission (ASE) lasing. ASE lasing is prevented by configuring a particular node as an anti-ASE node. An anti-ASE node can be created in two ways:

- Equip an OADM node with 32MUX-O cards and 32DMX-O cards. This solution is adopted when the total number of wavelengths deployed in the ring is higher than ten. OADM nodes equipped with 32MUX-O cards and 32DMX-O cards are called full OADM nodes.
- When the total number of wavelengths deployed in the ring is lower than ten, the anti-ASE node is configured by using an OADM node where all the channels that are not terminated in the node are configured as "optical pass-through." In other words, no channels in the anti-ASE node can travel through the express path of the OADM node.

Note The example in Figure 4-4 does not use hubbed nodes; only amplified and passive OADM nodes are present.

Figure 4-4 Meshed Ring



4.6 Linear Configurations

Linear configurations are characterized by the use of two terminal nodes (west and east). The terminal nodes must be equipped with a 32MUX-O card with a 32DMX-O card, or a 32WSS card with a 32DMX or 32DMX-O card. OADM or line amplifier nodes can be installed between the two terminal nodes. Only unprotected traffic can be provisioned in a linear configuration. Figure 4-5 shows five ONS 15454 nodes in a linear configuration with an OADM node.

Figure 4-5 Linear Configuration with an OADM Node

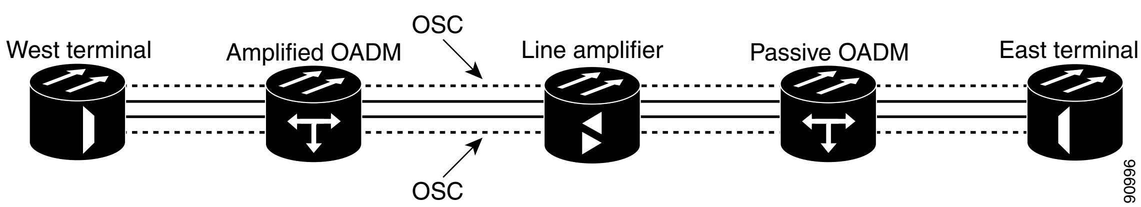
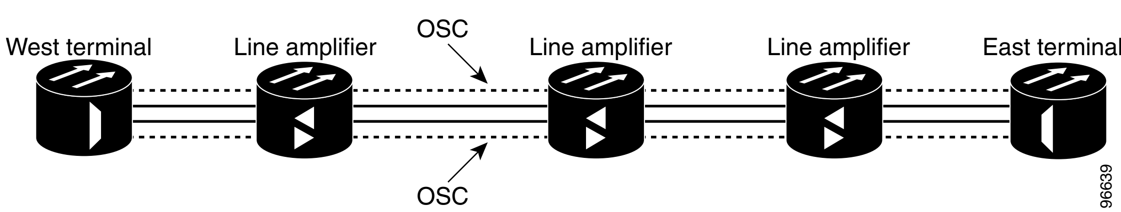


Figure 4-6 shows five ONS 15454 nodes in a linear configuration without an OADM node.

Figure 4-6 Linear Configuration without an OADM Node

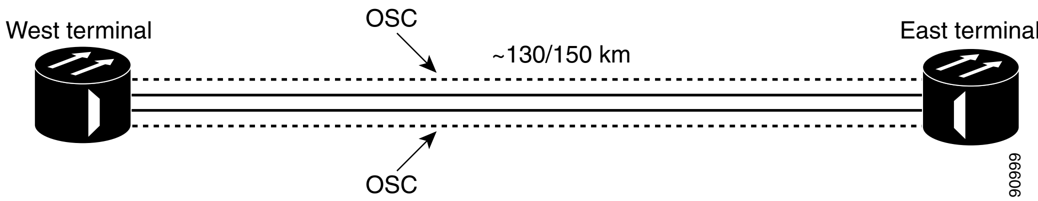


4.7 Single-Span Link

Single-span link is a type of linear configuration characterized by a single-span link with preamplification and post-amplification. A span link is also characterized by the use of two terminal nodes (west and east). The terminal nodes are usually equipped with a 32MUX-O card and a 32DMX-O card. However, a 32WSS card and a 32DMX or a 32DMX-O card can be installed. Single-span links with AD-4C-xx.x cards ar e also supported. Only unprotected traffic can be provisioned on a single-span link.

Figure 4-7 shows ONS 15454 nodes in a single-span link. Eight channels are carried on one span. Single-span link losses apply to OC-192 LR ITU cards. The optical performance values are valid if that the sum of the insertion losses and span losses for the passive OADM nodes does not exceed 35 dB.

Figure 4-7 Single-Span Link



4.8 1+1 Protected Single-Span Link

A 1+1 protected, single-span link configuration uses a single hub or OADM node connected directly to the far-end hub or OADM node through four-fiber links. This node configuration is used in a ring configured with two point-to-point links. The advantage of the 1+1 protected flexible terminal node configuration is that it provides path redundancy for 1+1 protected time division multiplexing (TDM) networks (two transmit paths and two receive paths) using half of the DWDM equipment that is usually required. In the example shown in Figure 4-8, one node transmits traffic to the other node on both the east side and the west side of the ring for protection purposes. If the fiber is damaged on one side of the ring, traffic still arrives safely through fiber on the other side of the ring.

Figure 4-8 Double Terminal Protection Configuration

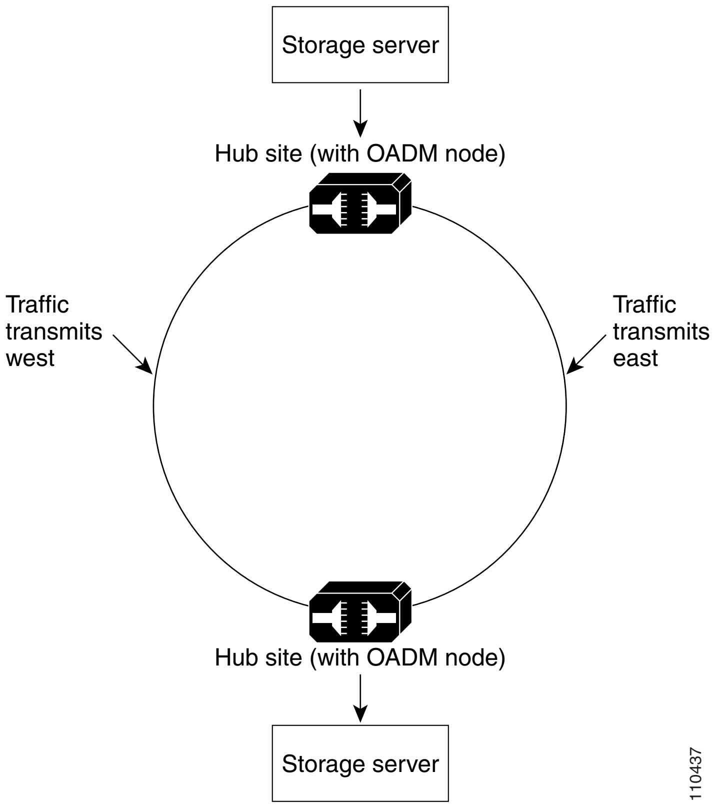


Figure 4-9 shows a functional block diagram of a 1+1 protected, single-span link with hub nodes. A 1+1 protected, single-span link with hub nodes cannot be used in a hybrid configurations.

Figure 4-9 1+1 Protected Single-Span Link with Hub Nodes

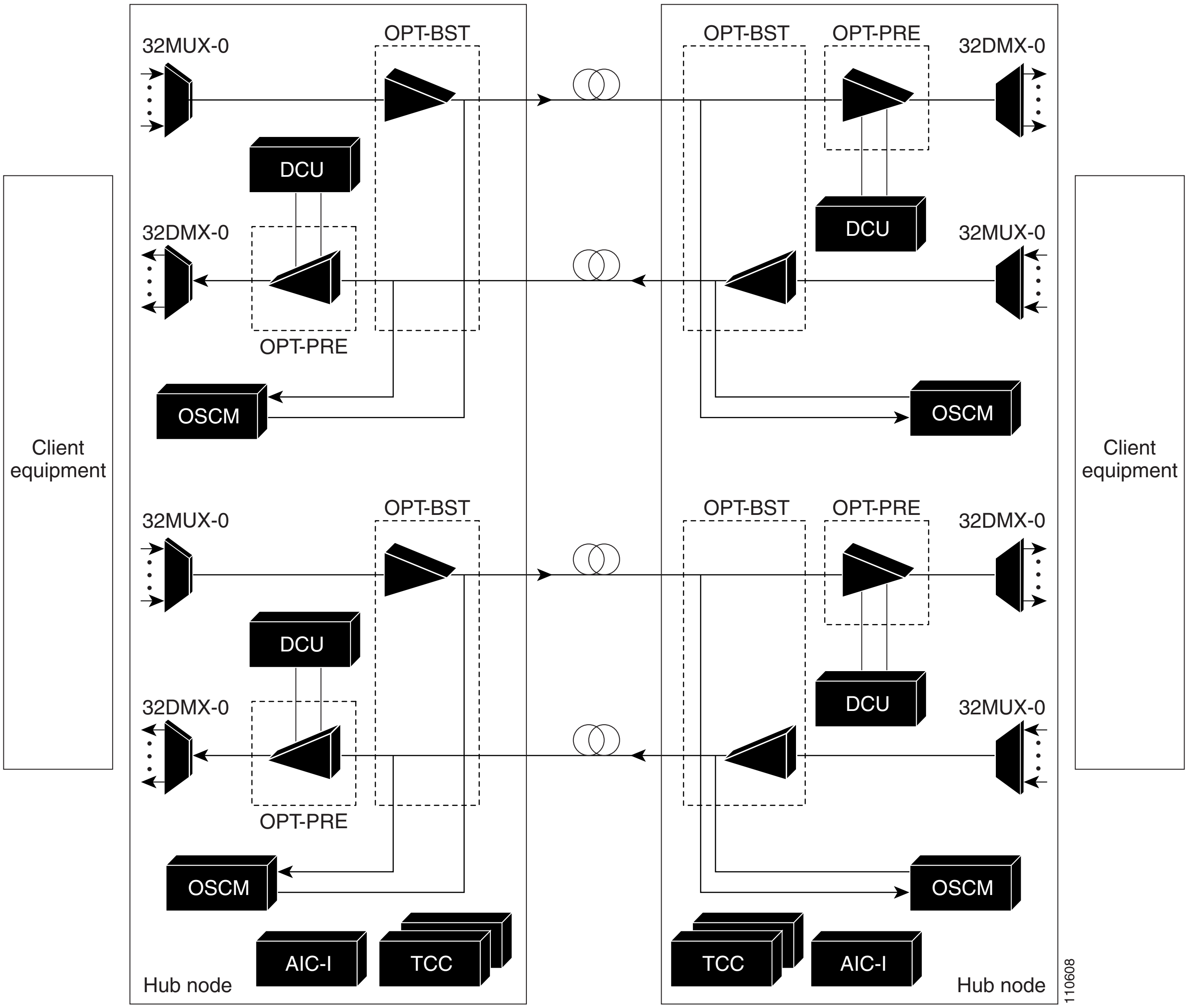


Figure 4-10 shows a functional block diagram of a 1+1 protected, single-span link with active OADM nodes. A 1+1 protected, single-span link with active OADM nodes can be used in a hybrid configurations.

Figure 4-10 1+1 Protected Single-Span Link with Active OADM Nodes

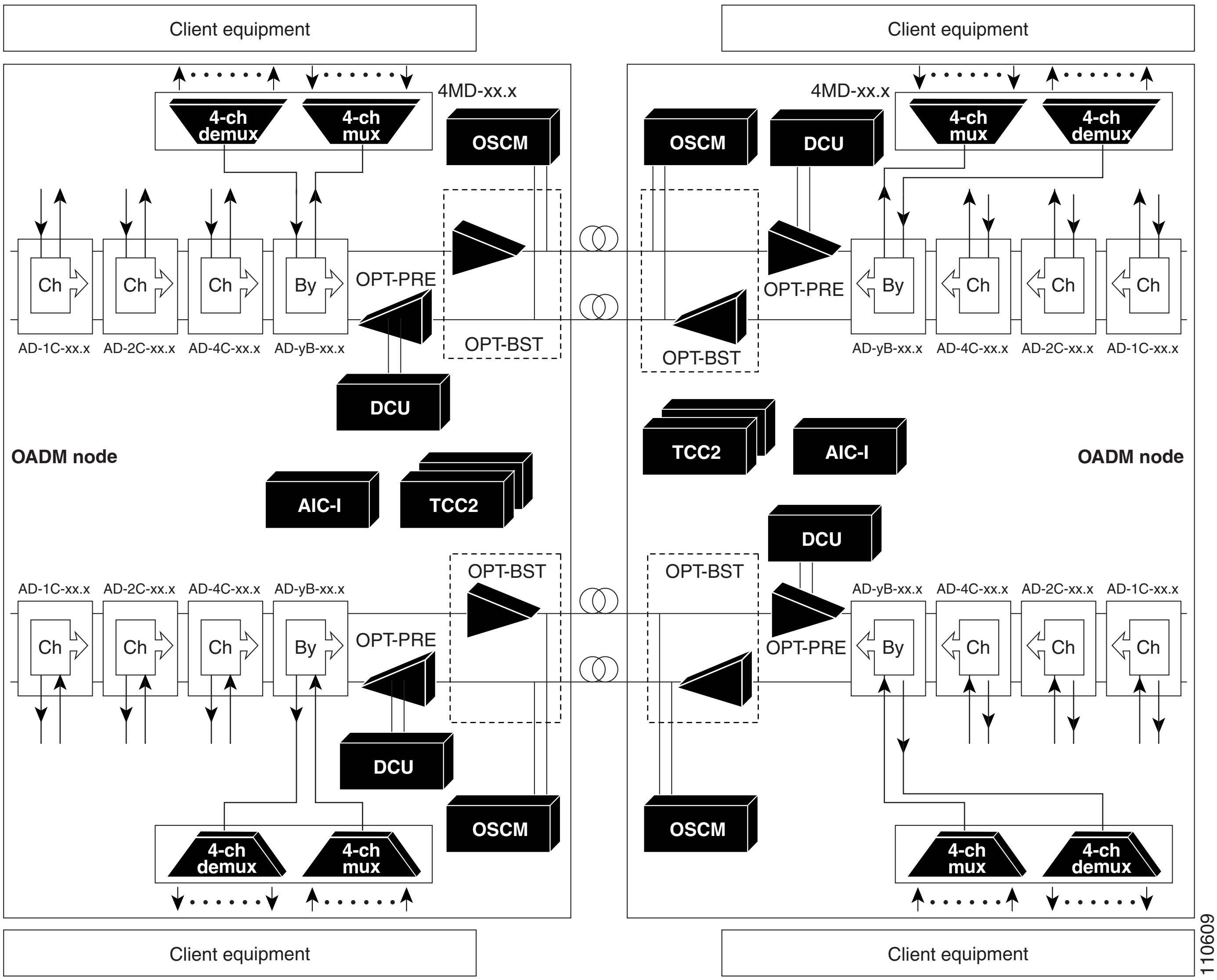
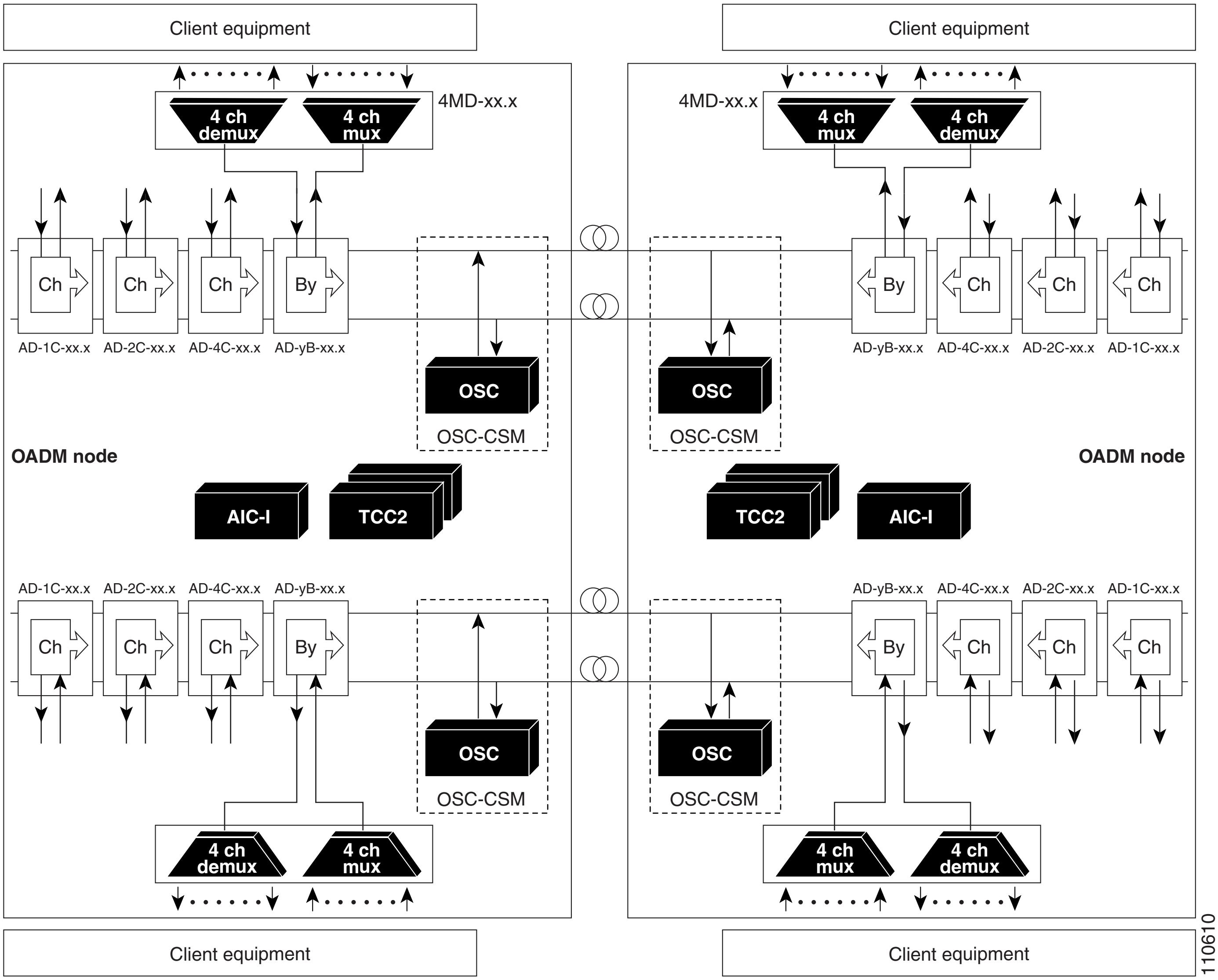


Figure 4-11 shows a functional block diagram of a 1+1 protected, single-span link with passive OADM nodes. 1+1 protected, single-span links with passive OADM nodes can be used in a hybrid configurations.

Figure 4-11 1+1 Protected Single-Span Link with Passive OADM Nodes

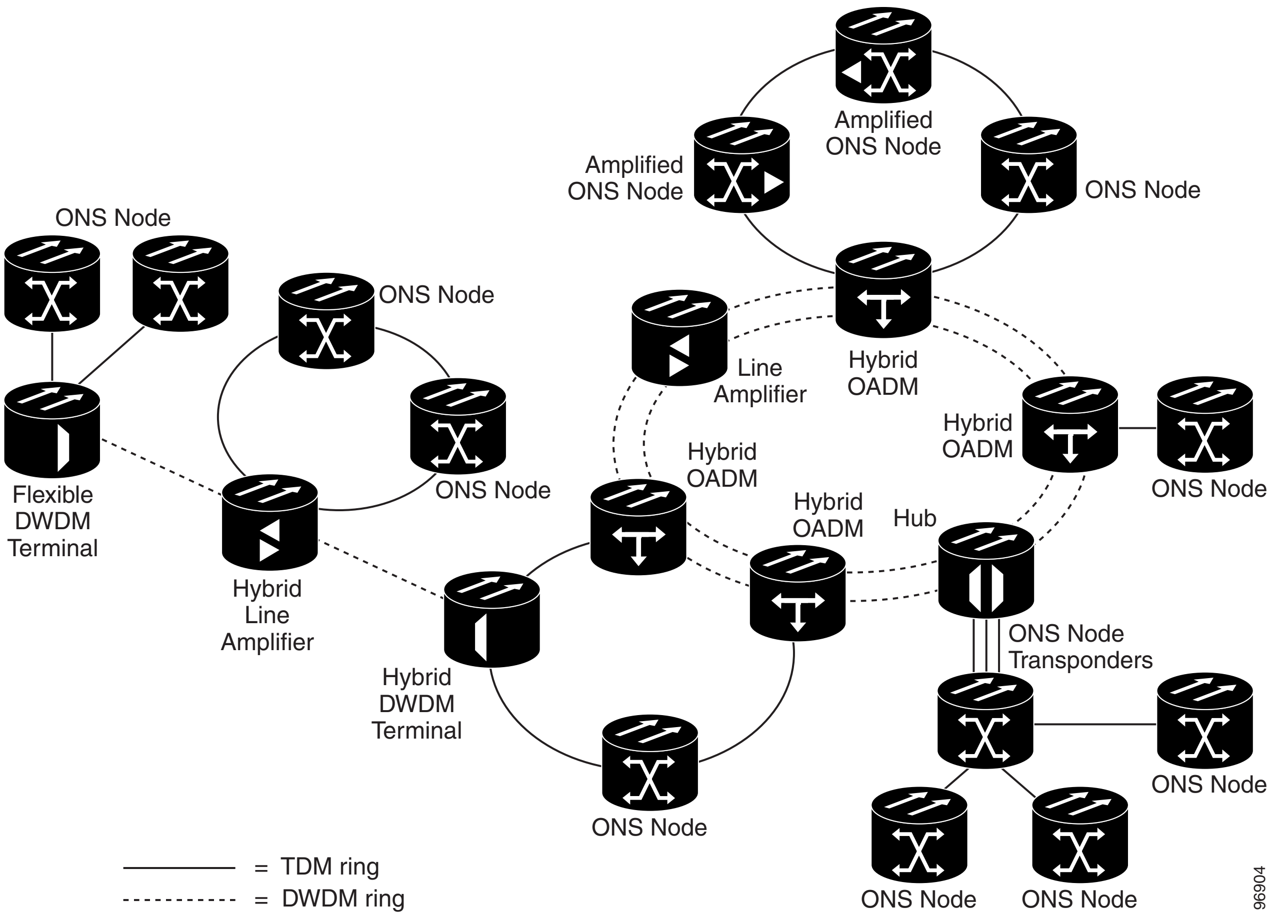


4.9 Hybrid Network

The hybrid network configuration is determined by the type of node that is used in an ONS 15454 network. Along with TDM nodes, the ONS 15454 supports the following hybrid node types: 1+1 protected flexible terminal, scalable terminal, hybrid terminal, hybrid OADM, hybrid line amplifier, and amplified TDM.

Figure 4-12 shows ONS 15454 nodes in a hybrid TDM and DWDM configuration.

Figure 4-12 Hybrid Network Example



DWDM and TDM layers can be mixed in the same node; however they operate and are provisioned independently. The following TDM configurations can be added to a hybrid network:

- Point-to-point
- Linear add/drop multiplexing (ADM)
- Bidirectional line switched ring (BLSR)
- Path Protection

Figure 4-13 shows ONS 15454 nodes in a hybrid point-to-point configuration.

Figure 4-13 Hybrid Point-to-Point Network Example

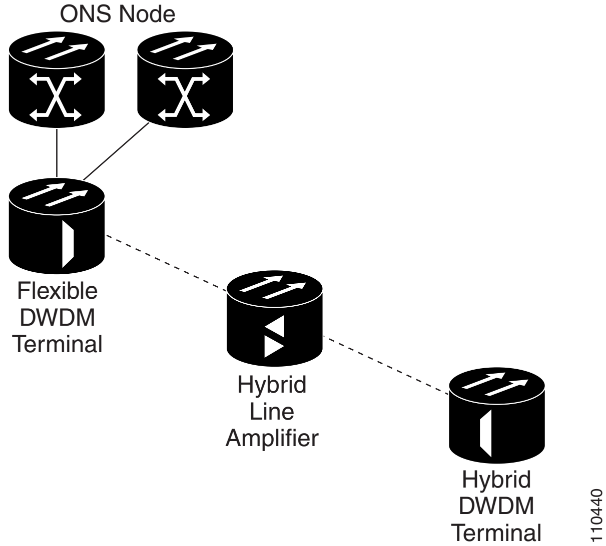


Figure 4-14 shows ONS 15454 nodes in a hybrid linear ADM configuration.

Figure 4-14 Hybrid Linear ADM Network Example

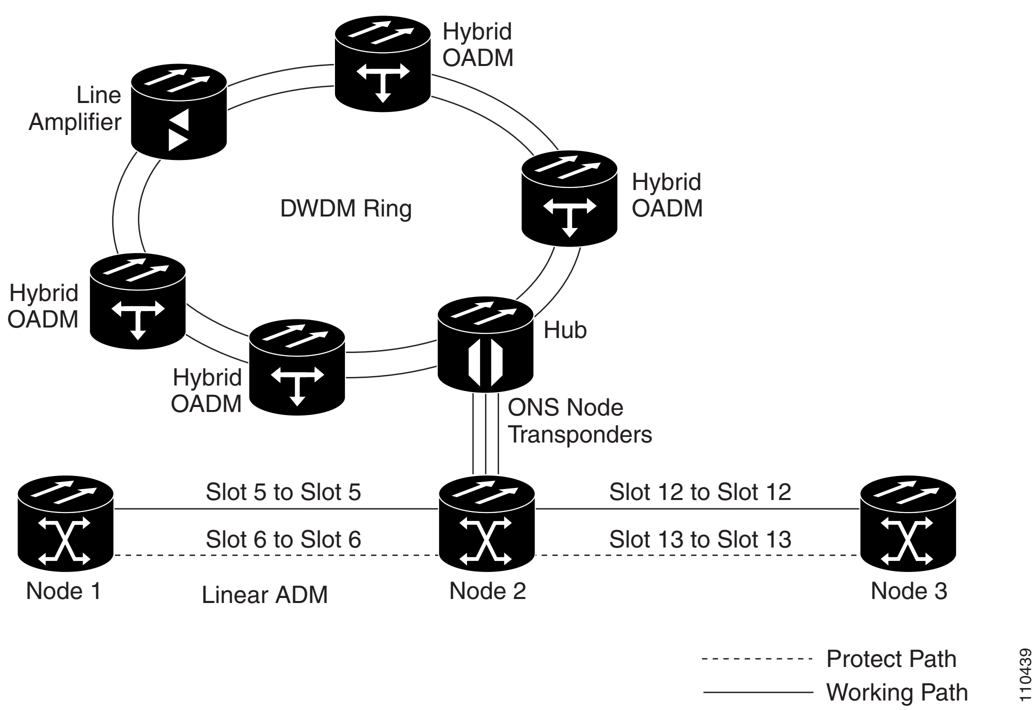


Figure 4-15 shows ONS 15454 nodes in a hybrid BLSR configuration.

Figure 4-15 Hybrid BLSR Network Example

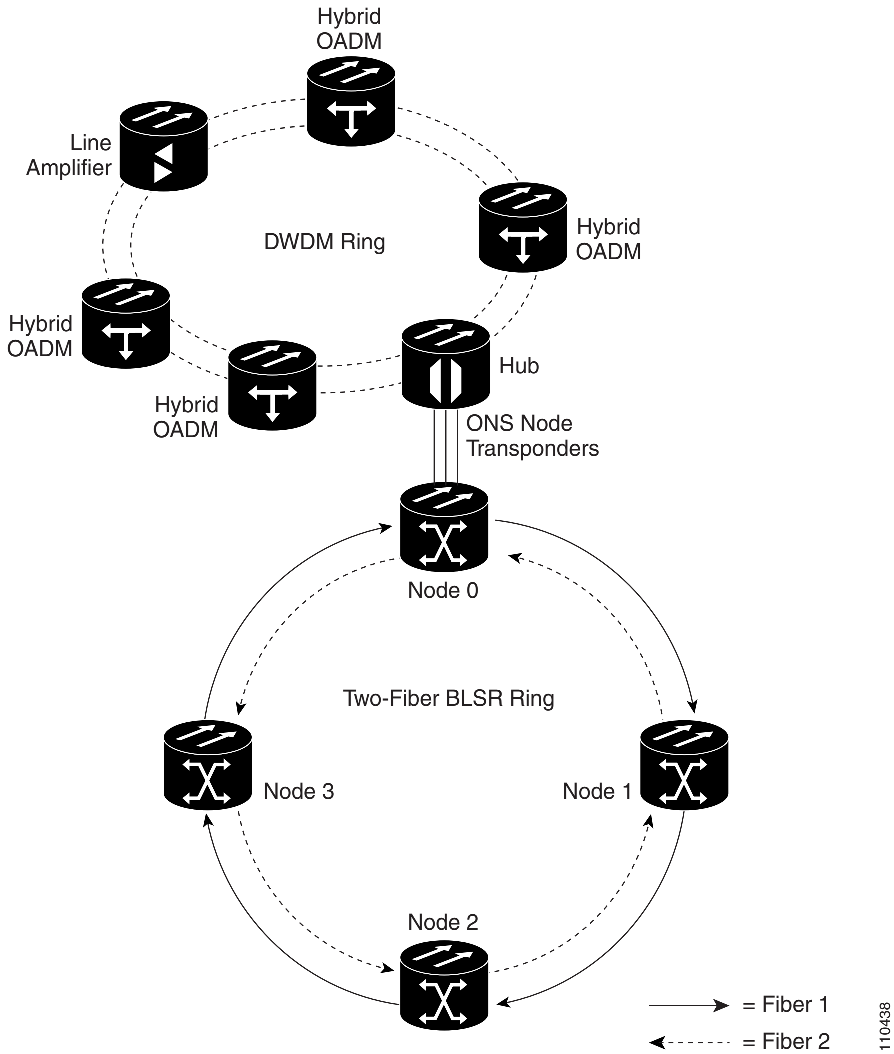
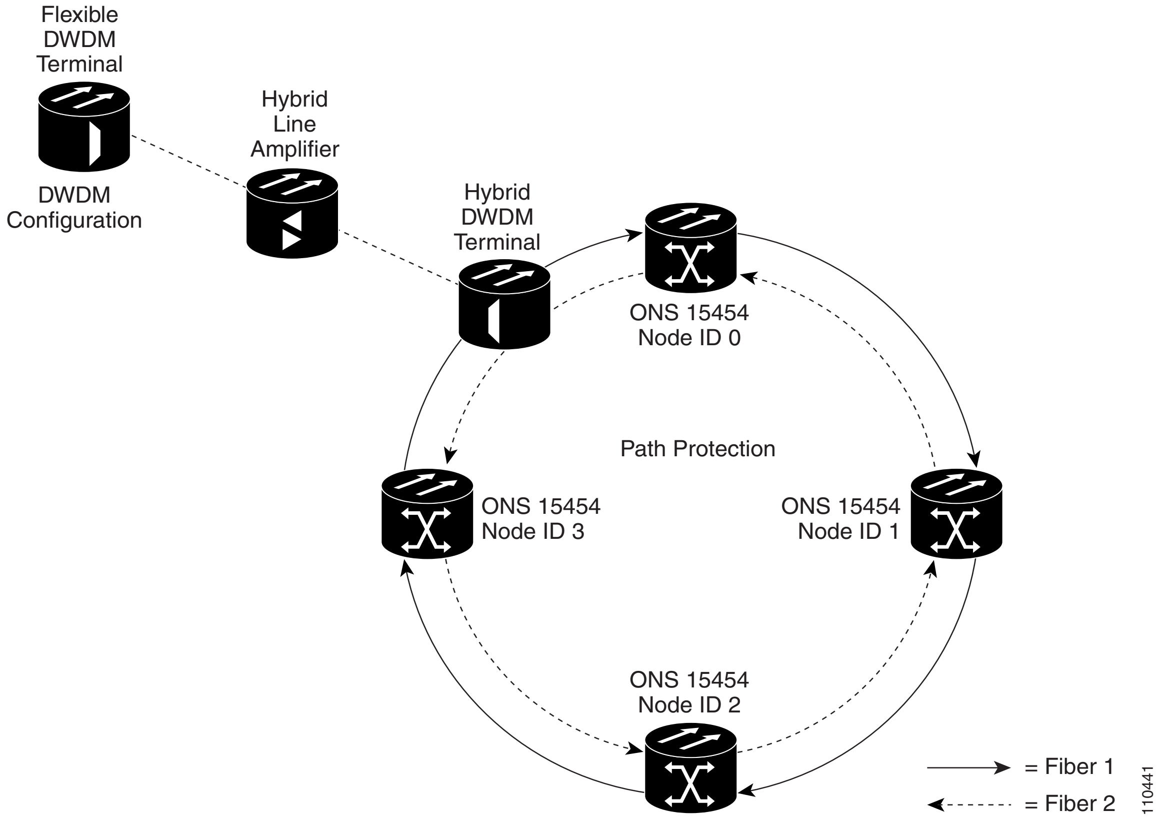


Figure 4-16 shows ONS 15454 nodes in a hybrid path protection configuration.

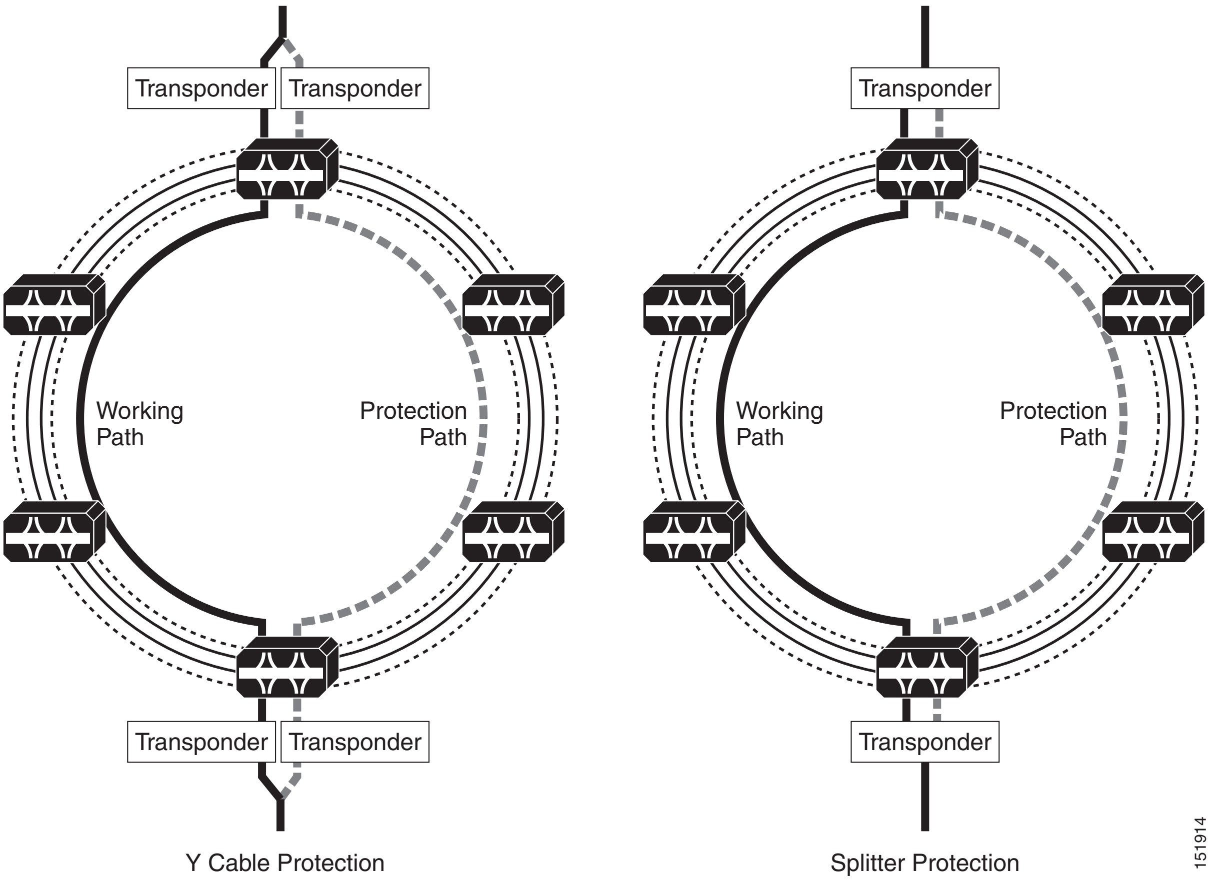
Figure 4-16 Hybrid Path Protection Network Example



4.10 Transponder and Muxponder Protection Topologies

The ONS 15454 supports Y-cable and splitter protection for transponder (TXP) and muxponder (MXP) cards. Figure 4-17 shows Y-cable and splitter protection.

Figure 4-17 Y-Cable and Splitter Protection



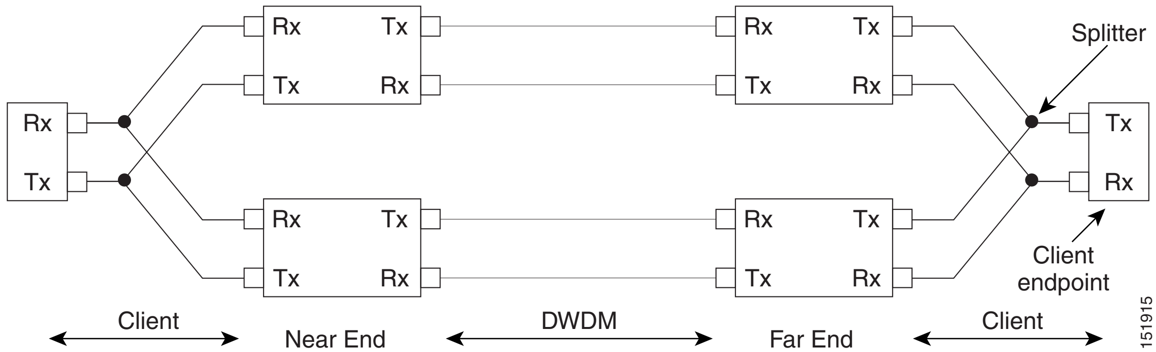
4.10.1 Y-Cable Protection

The Y-cable protection scheme employs two Y cables, which are hardware combiner/splitters. A signal injected into the stem of the Y is duplicated into both arms of the Y with 50 percent attenuation in each arm. Signals injected into the arms of the Y are summed into the stem of the Y.

A Y-cable protection group requires two DWDM cards with the arms of the Y-cables connected to the client ports on the DWDM cards, and the stems of the Y-cables connected to the client source, such as an OC-N card. When a TXP Y-cable protection group is required, the two TXP cards must be installed in the same shelf assembly in adjacent slots.

Figure 4-18 shows a functional block diagram of Y-cable protection.

Figure 4-18 Y-Cable Protection

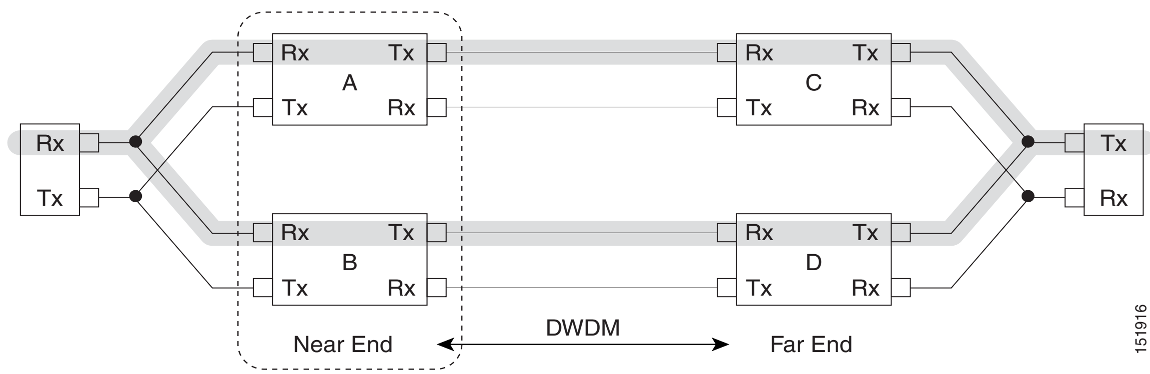


A Y-cable protection group has two paths:

- Transmit (TX) path, defined as the client RX and the trunk TX
- Receive (RX) path, defined as the trunk RX and the client TX

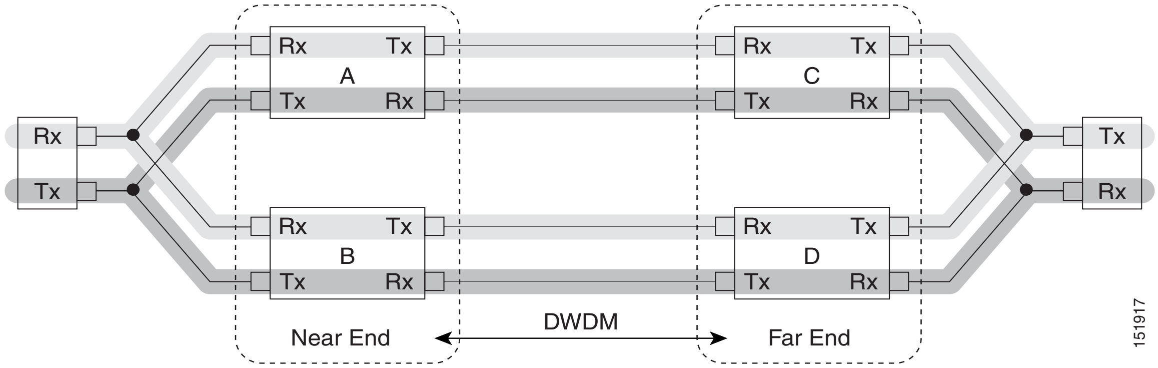
The basic behavior of the Y-cable group is that an incoming client signal is bridged to the two TX paths, and one RX path is selected for the outgoing client signal. Thus, a Y-cable protection group only protects against defects in the RX path. Figure 4-19 shows the RX path for the near-end Y-cable protection group.

Figure 4-19 Rx Path for Near-End Y-Cable Protection



To protect against all defects, a pair of Y-cable protection groups is required. Each protects against defects in its own RX path. Figure 4-20 shows how the near-end and the far-end jointly protect against defects.

Figure 4-20 Near-End and Far-End Y-Cable Protection



A Y-cable protection group is defined by two client ports on two different cards. One client port is designated as working and the other is designated as protect. Some of the rules in a Y-cable protection are as follows:

- The cards must have the same equipment type.
- The cards must have the same payload data type.
- The cards must have the same termination mode.
- The client ports must have the same payload type.
- The client ports must have the same facility number.

For example, a Y-cable protection group can include MXP Client 2 on the working and protect cards, but cannot include Client 2 on the working card if Client 3 is on the protect card. TXP cards have a single client (facility 1), so this requirement is satisfied by default.

Zero, one, two, or all of the client ports on an MXP card can be in Y-cable protection groups. Some clients can be in a protection group while others are unprotected.

The client ports on a card that are in Y-cable protection groups are either all working or all protect. You cannot mix working and protect client ports on the same card. For convenience, the trunk ports adopt the designation (working or protect) of the client ports.

The Y-cable protection groups on an MXP card switch independently. A Y-cable protection group performs protection switching by disabling the transmitter on the standby client port and enabling the active client port.

The protection group does not enable the active transmitter, because the active transmitter may have been disabled for other reasons. The port is disabled if it has an OOS-DBLD service state, is squelched, or is shutdown by automatic laser shutdown (ALS). The protection group releases a signal that the active transmitter is disabled. This activity changes the RX path but not the TX path. A Y-cable protection group can only protect its RX path.

A Y-cable protection group enables its client receivers unless the client facilities have an OOS-DSBLD service state. This means that client receivers (and trunk transmitters) are operational regardless of the active/standby status of the card. Traffic might not be lost if both client lasers in a Y-cable protection group are enabled. If the output powers of the two lasers are not identical, then the receiver at the stem of the Y-cable can opt for the stronger client laser and ignore the weaker signal.

4.10.2 Splitter Protection

A splitter protection group consists of a single 2.5-Gbps transponder splitter (TXPP_MR_2.5G card). The protection group is defined by the two trunk ports on the splitter card. One trunk port is designated working and the other is designated as protect. A splitter card has a single trunk laser and a hardware splitter that duplicates the trunk signal out of the card's two trunk ports. The switch in the card receives one of the two trunk input signals and the received signal is connected to the client ports.

A splitter protection group has two TX paths and two RX paths on the same card; the paths share client ports. The TX path is defined as the client RX and the trunk TX, and the RX path is defined as the trunk RX and the client TX. In a splitter group, an incoming client signal is bridged to the TX paths, and one RX path is selected for the outgoing client signal.

A splitter protection group performs switching by enabling the receiver of the active trunk port and then routing the active trunk traffic to the client ports. The protection group does not disable the transmitter on the standby trunk port.

4.10.3 Switch Criteria

Cisco Transport Controller (CTC), the ONS 15454 software interface, performs protection switches based on priority, trunk and client line conditions, switch commands, unidirectional/bidirectional switching, and other criteria.

4.10.3.1 Switch Priority

Switch priorities are defined in Table 4-1.

Table 4-1 Switch Priorities

Request/State	Abbreviation	Priority
Lockout of Protection	LO	8 (highest)
Forced Switch	FS	7
Signal Fail	SF	6
Signal Degrade	SD	5
Manual Switch	MS	4
Wait to Restore	WTR	3
Do Not Revert	DNR	2
No Request	NR	1 (lowest)

All switch criteria are assigned a numerical priority, which is reversed from ITU-T G.873.1 to avoid confusion when comparing priorities. In this document, a higher priority is numerically greater than a lower priority.

If the protection channel and the working channel have conditions with the same priority, and the priority is greater than Do Not Revert (DNR), then the condition on the protection channel takes precedence.

In practice, only two priorities can exist independently and simultaneously on the working and protection channels: signal fail (SF) and signal degrade (SD). This requirement means that if both channels have, for example, an SF condition without any higher conditions present, then the protection group chooses the working channel. Traffic switches away from the highest-priority condition.

4.10.3.2 Line Conditions on the Trunk

The following line conditions on the trunk generate the priorities given:

- OTUn-LOS on a trunk, if ITU-T G.709 is enabled, has an SF priority.
- OTUn-LOF on a trunk, if ITU-T G.709 is enabled, has an SF priority.
- OTUn-LOM on a trunk, if ITU-T G.709 is enabled, has an SF priority.
- OTUn-AIS on a trunk, if ITU-T G.709 is enabled, has an SF priority.
- ODUn-AIS on a trunk, if ITU-T G.709 is enabled, has an SF priority.
- OTU BER SF on a trunk, if ITU-T G.709 is enabled, has an SF priority.
- OTU BER SD on a trunk, if ITU-T G.709 is enabled, has an SD priority.
- TIM on OTU SM TTI on a trunk, if ITU-T G.709 is enabled, has an SF priority.
- TIM on ODU PM TTI on a trunk, if ITU-T G.709 is enabled, has an SF priority.
- S-LOF on a trunk, if ITU-T G.709 is disabled and the trunk is OCn, has an SF priority.
- S-LOS on a trunk, if ITU-T G.709 is disabled and the trunk is OCn, has an SF priority.
- SF on a trunk, if ITU-T G.709 is disabled and the trunk is OCn, has an SF priority.
- SD on a trunk, if ITU-T G.709 is disabled and the trunk is OCn, has an SD priority.
- AIS-L on a trunk, if ITU-T G.709 is disabled and the trunk is OCn, has an SF priority.
- RS-LOF on a trunk, if ITU-T G.709 is disabled and the trunk is STMn, has an SF priority.
- RS-LOS on a trunk, if ITU-T G.709 is disabled and the trunk is STMn, has an SF priority.
- SF on a trunk, if ITU-T G.709 is disabled and the trunk is STMn, has an SF priority.
- SD on a trunk, if ITU-T G.709 is disabled and the trunk is STMn, has an SD priority
- MS-AIS on a trunk, if ITU-T G.709 is disabled and the trunk is STMn, has an SF priority.
- TIMS-S on J0 on a trunk, if ITU-T G.709 is disabled and TIM is enabled, has an SF priority.
- RS-TIM-S on J0 on a trunk, if ITU-T G.709 is disabled and TIM is enabled, has an SF priority.
- CARLOSS on a trunk, if ITU-T G.709 is disabled and the payload is GigE, has an SF priority.
- SIGLOSS on a trunk, if ITU-T G.709 is disabled and the payload is Fibre Channel (any speed), has an SF priority.
- GE-OOSYNC on a trunk, if ITU-T G.709 is disabled and the payload is 10GigE, has an SF priority.
- OOS on a trunk, if ITU-T G.709 is disabled and the payload is GigE, has an SF priority.
- OOS on a trunk, if ITU-T G.709 is disabled and the payload is Fibre Channel, has an SF priority.
- SYNCLOS on a trunk, if ITU-T G.709 is disabled and the payload is Fibre Channel, has an SF priority.

4.10.3.3 Line Conditions on the Client

Most of the defects on client ports are corrected by switching at the far-end protection group.

In a Y-cable protection group, a line alarm indication signal (AIS-L) on the client signal has an SF priority if generic framing procedure (GFP) is not used and the client framing is SONET.

4.10.3.4 Switch Commands

Switch commands have the following priorities:

- A Lockout of Protect (Lockon Working) switch command has an LO priority on the protect port.
- A Force From Working (Force to Protect) switch command has an FS priority on the working port.
- A Force From Protect (Force To Working) switch command has an FS priority on the protect port.
- A Manual From Working (Manual To Protect) switch command has an MS priority on the working port.
- A Manual From Protect (Manual To Working) switch command has an MS priority on the protect port.
- A Clear command cancels (unlocks) any switch command.

4.10.3.5 Unidirectional and Bidirectional Switching

Y-cable and splitter protection support unidirectional switching. In unidirectional switching, the near-end protection group switches without regard for the status of the far-end protection group.

Therefore, the near-end working facilities can be active at the same time the far-end protection facilities are in standby. This does not mean that a defect at the far end will not cause a near-end switch. A defect at the far end might result in a condition at the near end, which then causes a switch, but the switch is caused by the near-end condition.

Bidirectional protection cannot be provisioned unless the near end and far end have the same hardware and data modes and the trunks are connected as working-to-working and protect-to-protect.

Any other configuration results in an undefined behavior. Y-cable and splitter protection groups are not required to detect misconfigured bidirectional protection.

A Y-cable or splitter protection group switches unidirectionally unless at least one trunk signal is intact and there is an operational card terminating the trunk signal at the far end.

4.10.3.6 Other Switch Criteria

This section details switch criteria other than line conditions. A card is said to become operational after it has received and processed the first provisioning message after a warm or cold boot. A card ceases to be operational when it is reset, either with a soft reset request or a hardware reset.

A soft reset of a card does not cause a protection switch or a traffic disruption greater than the disruption induced by the soft reset of an unprotected card. If one or both cards are not operational, then any disruption of traffic on the active card will cause traffic loss until both cards have become operational again.

Switch conditions with a priority lower than FS are ignored by a Y-cable protection group unless both cards are operational. Switch conditions cannot be used to restore traffic while one member of the protection group is reset. For instance, if the working/active card is soft reset and a Forced Switch to the protect card is issued, the protect client laser will turn on but the working client laser will not turn off. Traffic will be lost until the working card becomes operational and can process the Forced Switch request.

The LO and FS switch conditions are accepted by the shelf regardless of the operational status of the cards in a Y-cable protection group or a splitter protection group. A nonoperational card cannot process the switch condition; the provisioning has been accepted by the shelf controller and will be issued to the cards when it becomes operational.

The LO and FS switch conditions are implemented immediately by the operational cards in a Y-cable protection group even if one card is nonoperational. This might cause traffic loss.

Y-cable protection switching is inhibited during a shelf controller reset. Protection switching does not resume until the cards receive their first provisioning message from the active shelf controller.

Each card in a Y-cable protection group begins its provisioning hold-off timer after processing the first provisioning message. For proper behavior, both cards should be provisioned within the provisioning hold-off timer interval. A card missing condition has an SF+ priority. This gives the card missing condition a higher priority than any span alarm.

- A card MEA condition has an SF priority.
- An SFP failure condition has an SF priority.
- An SFP mismatch (failure to support the data rate or mode) condition has an SF priority.
- An SFP missing condition has an SF priority.
- A wavelength mismatch condition has an SF priority.
- A port that is OOS-DSBLD has an SF+ priority.
- The OOS-DSBLD condition has a higher priority than any span alarm.
- A port that is shutdown by ALS has an SF priority.

4.10.3.7 Switch Stability

Y-cable and splitter protection groups use a variety of timers to prevent oscillation, as detailed in the following requirements. No timer is provisionable.

The protection groups implement soak-to-clear timers. A soak-to-clear timer starts when a switch condition clears. While the timer is running, the protection group behaves as though the switch condition is still present. If the switch condition recurs before the timer has expired, the timer is canceled. When the switch condition clears, the timer is restarted.

The durations of soak-to-clear timers are not user-provisionable and are unrelated to the soak times for alarms and conditions. A soak-to-clear timer is not started when a switch condition clears if the switch condition has a lower priority than the currently active switch condition For example, an SD BER soak-to-clear timer will not start if SD BER clears while AIS is present, since AIS has a higher priority than SD BER. All line defects with an SF priority, except for SF BER, share a single one-second soak-to-clear timer. SF BER and SD BER line conditions have a 10-second soak-to-clear timer.

The protection group does not switch sooner than 1.5 seconds after the last switch (the switch hold-off timer). This timer prevents rapid oscillation of the protection group.

A Y-cable protection group does not switch for the first 5 seconds after it is created unless both cards in the protection group become active before 5 seconds elapses.This delay allows both cards in the protection group to be provisioned before any switching decisions are made.

A Y-cable protection group does not switch sooner than 0.5 seconds after a client or trunk facility moves from the OOS-SDBLD state. This hold-off timer allows the cards to ignore transients caused by a port going in-service. The ALS condition has a 3 second soak-to-clear timer.

4.10.3.8 Revertive and Nonrevertive Attributes

Both revertive and nonrevertive switching is supported; the default switch mode is nonrevertive.

Network element (NE) defaults contain a revertive attribute for Y-cable and splitter protection. When applicable in revertive mode, the revert delay timer, also called the Wait-To-Restore (WTR) timer, is software provisionable for Y-cable and splitter protection. The WTR timer is provisionable between 0.5 and 12 minutes, in 0.5 minute increments, and it has a default value of 5 minutes.

When applicable, the NE defaults contain a WTR attribute for Y-cable and splitter protection. When a Y-cable protection group is deleted, a dialog box will appear warning of possible traffic loss.

4.10.3.9 Communications Channels

In a Y-cable protection group, only the working client cam be provisioned with a section data communications channel (SDCC) or line data communications channel (LDCC), and only the working client port can be provisioned as a timing reference (as permitted by payload). The working and protect trunks can be provisioned separately with communication channels (SDCC, LDCC, or generic communications channel [GCC], as permitted by payload type). The communication channels are not protected.

4.10.3.10 Inherited Port Properties

Selected port properties of the protection port are inherited from the working port. In this section, the word port refers to a Y-cable client port or a splitter trunk port:

- The maximum Ethernet Frame Size of the protect port is inherited from the working port.
- The Port Type (SONET or SDH) of the protect port is inherited from the working port.
- The Termination Mode of the protect port is inherited from the working port.
- The SF BER threshold of the protect port is inherited from the working port.
- The SD BER threshold of the protect port is inherited from the working port.
- The SyncMsgIn and SendDoNotUse attributes of the protect port are inherited from the working port.
- Section trace provisioning of the protect port is inherited from the working port.
- The line thresholds of the protect port are inherited from the working port.
- The SDCC/LDCC/GCC provisioning of the protect port is inherited from the working port.
- The ALS provisioning of the protect port is inherited from the working port.

ALS is not permitted on the client ports of Y-cable protection groups. This requirement applies only to splitter protection groups.

4.10.3.11 Switch Status Reporting

Y-cable and splitter protection groups indicate to management software the active/standby status of facilities and cards involved in the protection group. A facility has an active/standby status within the protection group and it has a status that is reported to the management software. These two do not always coincide. Internally, the protection group always has one active facility and one standby facility. In some circumstances, the protection group reports both facilities as standby.

The reported status of any port on a nonoperational card is undefined. While a card is reset, its status might or might not be reported properly. Because the card does not report any status, the report to the user is a function of the management software, not the protection group.

A Y-cable protection group reports a separate status for the TX path and the RX path, for every facility. The active/standby status of the protection group is reported as the status of the RX path. If the status of the far-end protection group is known, then the status of the far-end protection group is reported as the status of the near-end TX path.

The ability of a protection group to know the status of the far-end protection group is a function of the equipment type and the trunk type. If the status of the far-end protection group is not known, the status of the near-end protection group shall be reported as the status of the TX path.

A Y-cable protection group has at most one active client port. A port in a Y-cable or splitter protection group is reported as standby if it has an OOS-DSBLD service state, regardless of its status within the protection group. A port in a Y-cable or splitter protection group is reported as active if it does not have an OOS-DSBLD state and if it carries overhead traffic (GCC, SDCC, LDCC, or E1 bytes), regardless of its status within the protection group.

A client port in a Y-cable protection group is reported as active if it does not have an OOS-DSBLD service state and if it is active within the protection group. A trunk port in a Y-cable protection group is reported as active if it does not have an OOS-DSBLD service state and if any client port on the same card is active.

Transponders have exactly one client port, and the relationship of client to trunk is clear. Muxponder cards have multiple client ports, which means that multiple protection groups are present. If any client port on a muxponder is active, and if the trunk is in-service, the trunk is also reported as active.

Client ports and trunk ports on unprotected cards (cards not part of any protection group) are reported as active if they do not have an OOS-DSBLD service state.

4.10.3.12 Switch Conditions

Protection groups generate conditions and transient conditions to provide a status to the node management software. Common conditions include:

- The protection group raises a MAN-REQ condition against the working facility while a Manual Switch to Protection switch command is in effect.
- The protection group raises a MAN-REQ condition against the protection facility while a Manual Switch to Working switch command is in effect.
- The protection group raises a FORCED-REQ condition against the working facility while a Forced Switch to Protection switch command is in effect.
- The protection group raises a FORCED-REQ condition against the protection facility while a Forced Switch to Working switch command is in effect.
- The protection group raises a LOCKOUT-REQ condition against the protection facility while a Lockout of Protection switch command is in effect.
- The protection group signals an APS-CLEAR condition when a switch command is preempted by a higher-priority switch condition.
- The protection group signals a FAILTOSW condition while a switch command is inhibiting a protection switch due to a lower-priority line condition.
- The protection group raises a WTR condition against the working facility while the Wait To Restore timer is running.
- The protection group, if it is in revertive mode, raises a WKSWPR condition against the working facility while the protection facility is active.
- The protection group, if it is in nonrevertive mode, signals a WKSWPR condition against the working facility when the protection facility becomes active.

- The protection group, if it is nonrevertive, signals a WKSWBK condition against the working facility when the working facility becomes active.

4.10.3.13 Protection Switching Performance Requirements

Protection switching is executed within 50 ms of a defect appearing at the near end. Loss of light on the client outputs of a Y-cable protection group does not exceed 20 ms during a switch.

During a protection switch, the standby client transmitter turns off, and the active client transmitter turns on. If the standby transmitter turns off before the active transmitter is fully on, a loss of light occurs at the stem of the Y-cable. This loss of light does not last longer than 20 ms. If a payload cannot tolerate a loss of light less than 20 ms, then that payload cannot be used with Y-cable protection.

4.10.4 Usability Requirements

The following section discusses regeneration groups, automatic laser shutdown, and client signal failures.

4.10.4.1 Regeneration Groups

A regeneration group boosts the power and improves the signal-to-noise (S/N) ratio in a DWDM signal. The purpose is to extend the reach of a DWDM signal between two termination points. In an ideal condition, regeneration is totally transparent to the endpoints. However, some regeneration techniques fall short of this ideal condition and might modify, delay, or even drop overhead signals (ITU-T G.709, GFP, or other section-level signaling protocols).

The behavior of Y-cable and splitter protection groups is unchanged by the presence of a single peer-to-peer regeneration group in one or both of the DWDM spans. This requirement cannot be met if the regeneration corrupts the overhead bytes that are necessary for protection switching.

4.10.4.2 Automatic Laser Shutdown

ALS disables the transmitter of a facility if the receiver of the same facility detects a loss of light. ALS exists as a human-safety standard. After ALS shuts down the transmitter, it is not restarted until the loss of light condition clears. To facilitate restarting lasers when both ends of a span are shut down by ALS, the facility can be provisioned to send short test pulses of light. ALS is not permitted on the client ports of a Y-cable protection group.

4.10.4.3 Client Signal Failures

Y-cable protection groups can protect against failures of the client RX signal at the end. The far-end client RX failure can be in the fiber (in an "arm" of the Y), in the equipment (for example, the SFP), or in the provisioning (client OOS-DSBLD). These failure types require special handling because they are out-of-band with respect to the normal client payload. The term used for these failures is client signal fail (CSF). This has the same meaning as GFP-CSF, but does not imply that GFP-CSF is used for the signaling. Client signal failures include:

- An S-LOF on a client port, if the client is OC-N, is signaled to the downstream client port as a CSF.
- An S-LOS on a client port, if the client is OC-N, is signaled to the downstream client port as a CSF.

- An RS-LOF on a client port, if the client is STM-N, is signaled to the downstream client port as a CSF.
- An RS-LOS on a client port, if the client is STM-N, is signaled to the downstream client port as a CSF.
- A GE-OOSYNC on a client port, if the client is GigE or 10GigE, is signaled to the downstream client port as a CSF.
- An SFP missing condition on a client port is signaled to the downstream silent port as a CSF.
- An SFP mismatch (failure to support client data rate) condition on a client port is signaled to the downstream client port as a CSF.
- An SFP failure condition on a client port is signaled to the downstream client port as a CSF.
- An OOS-DSBLD condition on a client port is signaled to the downstream client port as a CSF.

4.10.5 In-service Upgrade

A Y-cable group switches normally during a software activation or software revert if both cards in the Y-cable group are running the same software release.

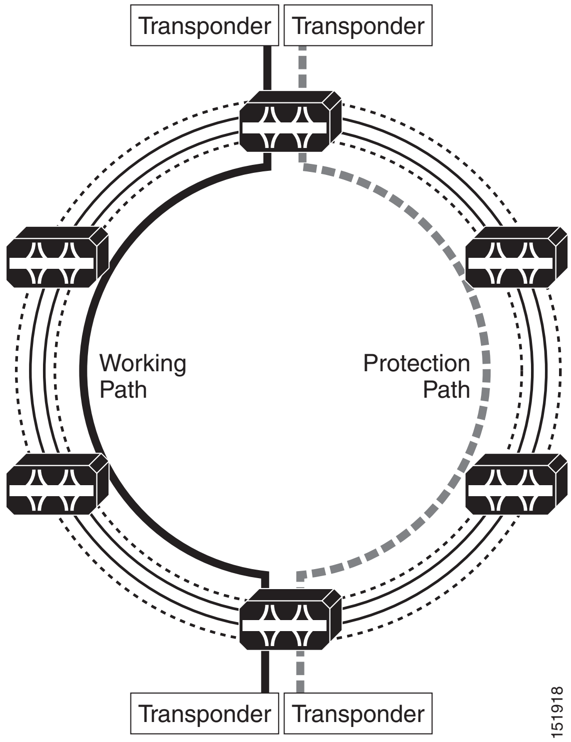
This behavior is different from that of OC-N 1+1 protection groups, which will not switch until the software activation is complete. The Y-cable group is able to switch before either card has booted to the new release and after both cards have booted to the new release. This requirement does not preempt the other requirements that both cards be operational and that an active TCC2/TCC2P be installed.

4.11 Path Diversion Support for Client Protection

The ONS 15454 DWDM system provides the capability to provision unprotected wavelengths on a per-wavelength basis and supports the reuse of unprotected wavelengths on adjacent spans.

Figure 4-21 provides examples of unprotected wavelengths.

Figure 4-21 Example of Unprotected Wavelengths



System Engineering

This chapter provides the basic planning and engineering information required to configure an ONS 15454 node for DWDM deployment.

The following topics are covered in this chapter:

5.1 Client Interfaces

Table 5-1 lists all DWDM cards and their assigned class.

Table 5-1 Cards, Protection Type, and Class

Product ID	Card Type	Protection Type	Card Name	Card Description	Class
15454-O48E-1-xx.x	2.5 Gbps	Client 1+1	OC-48 (ANSI)	OC48 ELR/STM16EH 100 GHz -15xx.xxnm	G
15454E-EL16HSxx.xx (ETSI)			STM16 (ETSI)		
15454-MRP-L1-xx.x (ANSI Fiber Switched) 15454-MRP-I-xx.x (ETSI Fiber Switched) 15454-MR-L1-xx.x (ANSI) 15454E-MR-1-xx.x (ETSI)	2.5G MR TXP w/FEC[1] (ISC-1 Not Supported)	Client 1+1 Y-Cable Fiber-Switched	TXPP_MR_2.5G TXP_MR_2.5G	2.5-Gbps Multirate Transponder-Protected 100-GHz-Tunable xx.xx-xx.xx 2.5-Gbps Multirate Transponder 100-GHz-Tunable xx.xx-xx.xx	D/E/F
	2.5G MR TXP w/o FEC	Client 1+1 Y-Cable (No ISC-I) Fiber-Switched (No ISC-I)			
	2.5G MR TXP 2R[2] Mode	Client 1+1 Y-Cable (No ETR/CLO) (No ISC-3) Fiber-Switched (No ETR/CLO) (No ISC-I)			

Table 5-1 Cards, Protection Type, and Class (continued)

Product ID	Card Type	Protection Type	Card Name	Card Description	Class
15454-192L-1-xx.x (ANSI) 15454E-64L-1-xx.x (ETSI)	10-Gbps LR[3] ITU-T	Client 1+1	OC-192(ANSI) STM-64 (ETSI)	OC-192 LR/STM64 LH ITU 15xx.xx	C
15454 10T-L1-xx.xx (ANSI) 15454E 10T-xx.xx (ETSI)	10G MR TXP w/FEC 10G MR TXP w/o FEC	Client 1+1 Y-Cable	TXP_MR_10G	10-Gbps Transponder-100-GHz - Tunable xx.xx-xx.xx	A/B/C
15454-10M-L1-xx.xx (ANSI) 15454E-10M-xx.xx (ETSI)	4x2.5-Gbps MXP w/FEC 4x2.5-Gbps MXP w/o FEC	Client 1+1 Y-Cable	MXP_2.5G_10G	2.5-Gbps-10-Gbps Muxponder-100-GHz-Tunable xx.xx-xx.xx	A/B/C
15454-DMP-L1-xx.xx (ANSI Fiber-switched) 15454-DMP-1-xx.x (ETSI Fiber Switched) 15454-DM-L1-xx.x (ANSI) 15454-DM-1-xx.x (ETSI)	2.5G Data MXP w/o FEC	Client 1+1 Y-Cable Fiber-Switched	MXPP_MR_2.5G MXP_MR_2.5G	2.5-Gbps Multirate Muxponder-Protected-100-GHz-Tunable 15xx.xx-15yy.yy 2.5-Gbps Multirate Muxponder - 100-GHz-Tunable 15xx.xx-15yy.yy	E
15454-10E-L1-xx.xx (ANSI) 15454E-10E-1-xx.xx (ETSI)	10G Enh MR TXP w/ FEC 10G Enh MR TXP w/ FEC 10G Enh MR TXP w/o FEC	Client 1+1 Y-Cable	TXP_MR_10E	10-Gbps Transponder 100-GHz-Enhanced-Tunable xx.xx-xx.xx	A/C/I
15454-10ME-xx.x (ANSI) 15454E-10ME-xx.x (ETSI)	4x2.5-Gbps Enh MXP w/ EFEC[4] 4x2.5-Gbps Enh MXP w/ FEC	Client 1+1 Y-Cable	MXP_2.5G_10E	10-Gbps Muxponder - 100-GHz-Enhanced FEC -Tunable xx.x-xx.x	A/C/I

Table 5-1 Cards, Protection Type, and Class (continued)

Product ID	Card Type	Protection Type	Card Name	Card Description	Class
15454-10E-L1-C=	10G Enh MR TXP w/ FEC	Client 1+1 Y-Cable	TXP_MR_10E	10-Gbps Transponder Full C-Band Tunable	A/C/I
15454-10E-L1-L=	10G Enh MR TXP w/ FEC 10G Enh MR TXP w/o FEC			10-Gbps Transponder Full L-Band Tunable	
15454-10ME-L1-C=	10G Enh MR MXP w/ EFEC		MXP_2.5G_10E	10-Gbps Muxponder Full C-Band Tunable	
15454-10ME-L1-L=	10G Enh MR MXP w/ FEC 10G Enh MR MXP w/o FEC			10-Gbps Muxponder Full L-Band Tunable	
15454-10DME-C=	10G Enh DATA MXP w/ EFEC		MXP_MR_10DME	10-Gbps Data Muxponder Full C-Band Tunable	
15454-10DME-L=	10G Enh DATA MXP w/ FEC 10G Enh DATA MXP w/o FEC			10-Gbps Data Muxponder Full L-Band Tunable	
15454-GBIC-xx.x (ANSI) 15454E-GBIC-xx.x (ETSI)	GE WDM[5] GBIC[6]	Client 1+1	WDM GBIC xx.x	GBIC xx.x WDM 100GHz	G
15530-ITU2-xx10 (w/splitter) 15530-ITU2-xx20 (no splitter)	10Gbps Aggregation (w/splitter) 10Gbps Aggregation	Client 1+1 Fiber-switched/ Splitter	ONS 15530 Ch x 10-Gbps ITU Trunk Card MU w/ Splitter ONS 15530 Ch x 10-Gbps ITU Trunk Card MU w/o Splitter	ONS 15530 10-Gbps ITU Trunk Card with splitter ONS 15530 10-Gbps ITU Trunk Card without splitter	C
15530 -ITU3-xx10 (w/splitter) 15530-ITU3-xx20 (no splitter)	2.5 Gbps Aggregation (w/ splitter) 2.5 Gbps Aggregation	Client 1+1 Fiber-switched/ Splitter	15530-ITU3-xx10 15530 ITU3-xx 20	ONS 15530 Ch x/y 2.5-Gbps ITU Trunk Card MU w/ Splitter ONS 15530 Ch x/y 2.5-Gbps ITU Trunk Card MU w/o Splitter	J

Table 5-1 Cards, Protection Type, and Class (continued)

Product ID	Card Type	Protection Type	Card Name	Card Description	Class
15530-TSP1-xx11 (MM[7] w/splitter) 15530-TSP1-xx12 (SM[8] w/splitter) 15530-TSP1-xx21 (MM, no splitter) 15530-TSP1-xx22 (SM, no splitter)	MR MM Transponder (w/ splitter) MR SM Transponder (w/ splitter) MR MM Transponder MR SM Transponder	Client 1+1 Y-Cable Fiber-switched/ Splitter	15530-TSP1-xx11 15530-TSP1-xx12 15530-TSP1-xx21 15530-TSP1-xx22	ONS 15530 Transponder Ch x/y - 1310 nm MM SC w/splitter ONS 15530 Transponder Ch x/y - 1310 nm SM SC w/splitter ONS 15530 Transponder Ch x/y - 1310 nm MM SC w/o splitter ONS 15530 Transponder Ch x/y - 1310 nm SM SC w/o splitter	J
15530-MSMP-xx12 (w/ splitter) 15530-MSMP-xx22 (no splitter)	Data Muxponder (w/splitter) Data Muxponder	Client 1+1 Fiber-switched/ splitter	15530 MSMP-xx12 15530 MSMP-xx22	MR Data Muxponder (w/ splitter) MR Data Muxponder (w/o splitter)	J

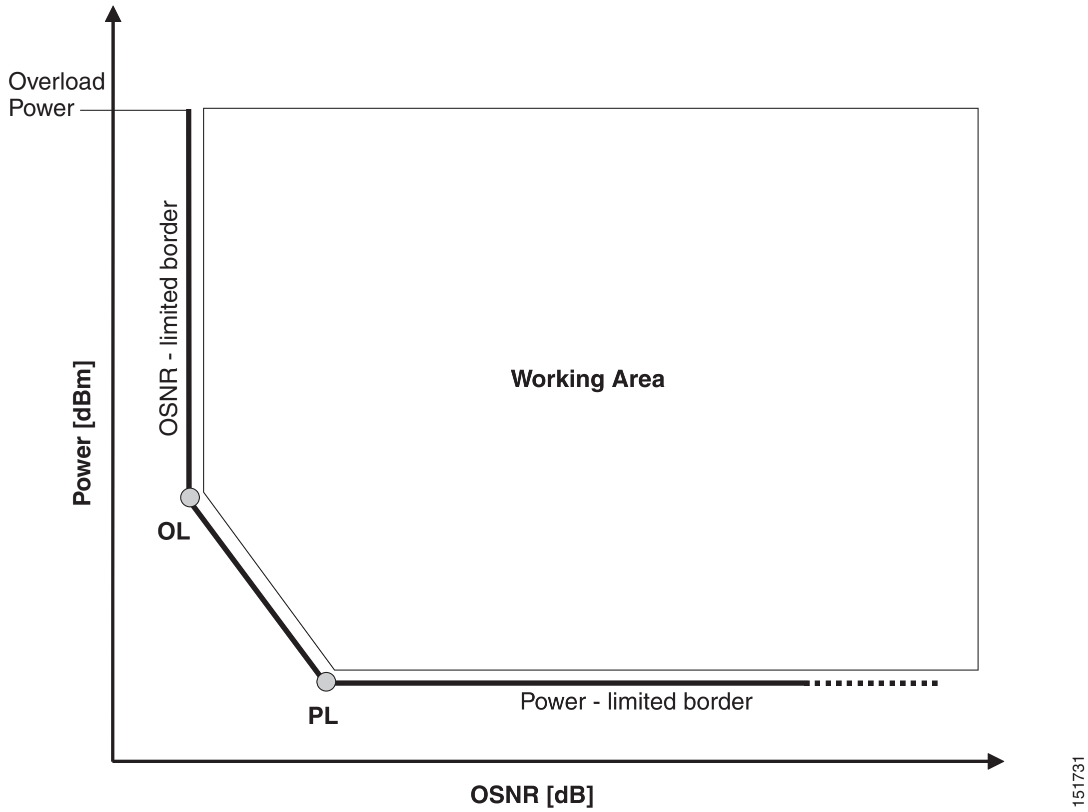
1. FEC: Forward Error Correction
2. 2R: reshape and regenerate
3. LR: Long Range
4. EFEC: Enhanced FEC
5. WDM: Wavelength division multiplexing
6. GBIC: Gigabit Interface Converter
7. MM: Multimode
8. SM: Single mode

Client interfaces (cards) have been grouped in ten classes (Class A through Class J). All client interfaces supported by DWDM can be specified in terms of their ISO-BER curve.

The operative area of an interface is defined on a two-dimensional Cartesian plane where the X axis is the optical signal-to-noise ratio (OSNR) value [in dB] and the Y axis is the power value [in dBm], as shown in Figure 5-1.

The limits to the operative area are three lines that result from a simple approximation of an ISO-BER line. The original ISO-BER line has two points, OSNR Limited (OL) and Power Limited (PL), that define the two main borders of the simplified working area. The two main borders are "OSNR Limited" and "Power Limited." OL and OP are defined by two sets of coordinates, namely OLOSNR/OLPower and PLOSNR/PLPower, whose initial values are defined in Table 5-2, Table 5-3, and Table 5-4.

Figure 5-1 Client Interface ISO BER Curve and Rectangle Definition for Specifying Performance



The upper limit of the "OSNR limited" border is the interface power overload, which also draws an upper limit to the working area. Theoretically, there is no upper limit to the OSNR value, but physical constraints limit this value to 35 to 40 dB.

Table 5-2 Optical Performance in the 10-Gbps Interface Classes A, B, C, and I

	Class A		Class B		Class C	Class I		
Parameter	**Power Limited**	**OSNR Limited**	**Power Limited**	**OSNR Limited**	**OSNR Limited**	**Power Limited**	**OSNR Limited**	**Unit**
Maximum bit rate	10		10		10	10		Gbps
Regeneration	3R		3R		3R	3R		
FEC	Yes		No		No	Yes (E-FEC)		
Threshold	Optimum		Average		Average	Optimum		
Maximum BER	10^{-15}		10^{-12}		10^{-12}	10^{-15}		
OSNR sensitivity	23	9	23	19	19	20	6	dB
Power sensitivity	–24	–18	–21	–20	–22	–26	–18	dBm
15530-ITU2-xx10 power sensitivity	—	—	—	—	–20.5	—	—	dBm
Power overload	–8		–8		–9	–8		dBm

Table 5-2 Optical Performance in the 10-Gbps Interface Classes A, B, C, and I (continued)

Parameter		Class A		Class B		Class C	Class I		Unit
		Power Limited	OSNR Limited	Power Limited	OSNR Limited	OSNR Limited	Power Limited	OSNR Limited	
Transmitted power range	TXP_MR_10G MXP_2.5G_10G	+2.5 / +3.5		+2.5 / +3.5		—	—		dBm
	OC192_LR	—		—		+3 / +6	—		dBm
	TXP_MR_10E MXP_2.5G_10E	+3 / +6		—		+3 / +6	+3 / +6		dBm
	15530-ITU2-xx20	—		—		+3 / +6	—		dBm
	15530-ITU2-xx10	—		—		–1.2 / +1.8	—		dBm
Dispersion compensation tolerance		+/– 800		+/– 1000		+/– 1000	+/– 1000	+/– 800	ps/nm

Table 5-3 Optical Performance in the 2.5-Gbps Interface Classes D, E, F and G

Parameter		Class D		Class E		Class F	Class G		Unit
		Power Limited	OSNR Limited	Power Limited	OSNR Limited	OSNR Limited	Power Limited	OSNR Limited	
Maximum bit rate		2.5		2.5		2.5	2.5		Gbps
Regeneration		3R		3R		2R	3R		
FEC		Yes		No		No	No		
Threshold		Average		Average		Average	Average		
Maximum BER		10^{-15}		10^{-12}		10^{-12}	10^{-12}		
OSNR sensitivity		14	6	14	10	15	14	11	dB
Power sensitivity		–31	–25	–30	–23	–24	–27	–23	dB
Power overload		–9		–9		–9	–9		dBm
Transmitted power range	TXP_MR_2.5G	–1 / +1		–1 / +1		–1 / +1	–2 / 0		dBm
	TXPP_MR_2.5G	–4.5 / –2.5		–4.5 / –2.5		-4.5 / –2.5			dBm
	MXP_MR_2.5G	—		+2 / +4		—			dBm
	MXPP_MR_2.5G	—		–1.5 / +0.5		—			dBm
Dispersion compensation tolerance		–1200 + 5400		–1200 + 5400		–1200 +3300	–1200 +5000		ps/nm

Table 5-4 Optical Performance in the 2.5-Gbps Interface Classes H and J

Parameter	Class H		Class J	Unit
	Power Limited	OSNR Limited	Power Limited	
Maximum bit rate	1.25		2.5	Gbps
Regeneration	3R		3R	
FEC	No		No	

Table 5-4 Optical Performance in the 2.5-Gbps Interface Classes H and J (continued)

Parameter		Class H Power Limited	Class H OSNR Limited	Class J Power Limited	Unit
Threshold		Average		Average	
Maximum BER		10^{-12}		10^{-12}	
OSNR sensitivity		13	8	12	dB
Power sensitivity		–28	–18	–26	dBm
15530-ITU3-xx10 15530-TSP1-xx11 15530-TSP1-xx12 Power sensitivity		—		–24.5	
Power overload		–7		–17	dBm
Transmitted power range	DWDM-GBIC	0 / +3		—	dBm
	15530-ITU3-xx20 15530-TSP1-xx21 15530-TSP1-xx22 15530-MSMP-xx22	—		+5 / +10	
	15530-ITU3-xx10 15530-TSP1-xx11 15530-TSP1-xx12 15530-MSMP-xx12	—		+0.8 / +5.8	
Dispersion compensation tolerance		–1000 / +3600		–1000 / +3200	ps/nm

5.2 System Optical Performance

This section discusses the optical performance parameters of a Cisco ONS 15454 DWDM system.

5.2.1 Maximum Number of Nodes

The Network Wizard in the Cisco MetroPlanner tool allows you to create a ring or a linear topology with a maximum of 60 locations. Up to 20 of these 60 locations can be equipped with optical amplifier cards (OPT-PRE and/or OPT-BST) and optical service channel cards (OSCM and/or OSC-CSM cards). Up to 16 of those 20 locations can be equipped with optical add/drop multiplexer (OADM) cards.

The entire network cannot include more than 40 amplifiers in each direction [clockwise(CW)/counter clockwise(CCW)], which relates to the 20 locations that can be equipped with optical amplifier cards and optical service channel cards.

Before 3R regeneration occurs, individual optical connections cannot include more than 30 amplifiers per direction (CW/CCW), which relates to the number of OADM nodes you can have in the network, assuming that there are a maximum of two optical amplifiers in the same node.

5.2.2 Optical Performance (OSNR Limited)

A network configuration, whether ring or linear, is created by a general combination of spans and nodes with unequal losses. Cisco MetroPlanner requires that the design of a network (in terms of amplifier and OADM card placement) must satisfy the traffic demand between the nodes. This section contains optical performance information from a limited number of reference cases characterized by configurations with equal span and node losses.

The optical performance examples provided in the "5.2.3 C-Band Optical Performance" section on page 5-8 and the "5.2.4 L-Band Optical Performance" section on page 5-18 are calculated for the worst channel path that can be provisioned with regard to the number of amplified nodes multiplied by the span loss (assuming equal spans and node losses in a link). For example, saying that a referenced optical performance is 5x20 dB means that the longest channel path on a ring can pass through five amplified nodes with a maximum of 20 dB loss for each span.

Note The span losses specified in this section are end-of-life values including margins for cable aging and repairs.

Note The optical performance examples are given for the Metro Core applications only.

5.2.3 C-Band Optical Performance

Table 5-5 details the target system performance of an ONS 15454 DWDM C-band system.

Table 5-5 C-Band Supported Topologies and Node Types

Number of Channels	Fiber Type	Topologies	Node Type
32	SMF-28[1] E-LEAF[2] TW-RS[3]	Ring Linear Linear without OADM	Hub Active OADM Passive OADM ROADM Terminal Line OSC regeneration
16	SMF-28	Ring Linear Linear without OADM	Hub Active OADM Passive OADM ROADM Terminal Line OSC regeneration

Table 5-5 C-Band Supported Topologies and Node Types (continued)

Number of Channels	Fiber Type	Topologies	Node Type
8	SMF-28	Linear without OADM	Terminal Line

1. SMF-28 = single-mode fiber 28
2. E-LEAF = enhanced large effective area fiber
3. TW-RS = TrueWave reduced slope fiber

For a description of rings and linear configurations with fixed OADM nodes and without OADM nodes, refer to the “Network Reference” chapter in the *Cisco ONS 15454 DWDM Reference Manual*. For optical performance information for ROADM rings and single-span networks, also refer to the “Network Reference” chapter in the *Cisco ONS 15454 DWDM Reference Manual*.

5.2.3.1 Optical Performance for Rings and Linear Networks with OADM Nodes

The following tables provide optical performance estimates for open and closed ONS 15454 rings and linear networks with OADM nodes.

Table 5-6 shows the optical performance for 32-channel networks using SMF fiber. Span losses shown in the table assume:

- OADM nodes have a loss of 16 dB and equal span losses.
- The dispersion compensation unit (DCU) loss is 9 dB.
- OPT-PRE and OPT-BST/OPT-BST-E amplifiers are installed in all nodes.
- The OPT-PRE amplifier switches to control power whenever the span loss is higher than 27 dB.

Table 5-6 Span Loss for 32-Channel Ring and Linear Networks with OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	29 dB	21 dB	20 dB	30 dB	31 dB	27 dB	25 dB	26 dB	28 dB	25 dB
3	26 dB	17 dB	15 dB	28 dB	29 dB	25 dB	23 dB	24 dB	26 dB	23 dB
4	24 dB	—	—	25 dB	26 dB	23 dB	20 dB	22 dB	24 dB	20 dB
5	23 dB	—	—	24 dB	25 dB	22 dB	16 dB	20 dB	23 dB	16 dB
6	21 dB	—	—	23 dB	24 dB	19 dB	—	17 dB	21 dB	—
7	20[1] dB	—	—	22 dB	23 dB	16 dB	—	—	19 dB	—

1. 0.5 dB of OSNR impairment recovered by FEC margin @ BER > 10-6

Table 5-7 shows the optical performance for 16-channel networks using SMF fiber. Span loss values assume the following:

- OADM nodes have a loss of 16 dB and equal span losses.
- The DCU loss is 9 dB.
- All nodes have OPT-PRE and OPT-BST/OPT-BST-E amplifiers installed.

- The OPT-PRE amplifier switches to control power whenever the span loss is higher than 27 dB.

Table 5-7 Span Loss for 16-Channel Ring and Linear Networks with OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	37 dB	29 dB	28 dB	37 dB	37 dB	36 dB	33 dB	35 dB	37 dB	33 dB
2	32 dB	24 dB	24 dB	34 dB	35 dB	31 dB	28 dB	30 dB	32 dB	28 dB
3	29 dB	22 dB	21 dB	31 dB	32 dB	28 dB	25 dB	27 dB	29 dB	25 dB
4	27 dB	19 dB	17 dB	29 dB	30 dB	26 dB	23 dB	25 dB	27 dB	23 dB
5	26 dB	—	—	27 dB	28 dB	24 dB	22 dB	24 dB	25 dB	22 dB
6	25 dB	—	—	26 dB	27 dB	23 dB	21 dB	23 dB	24 dB	21 dB
7	24 dB	—	—	25 dB	256dB	23 dB	19 dB	22 dB	23 dB	19 dB

Table 5-8 shows the optical performance for 32-channel networks using TW-RS fiber. Span loss values assume the following:

- OADM nodes have a loss of 16 dB and equal span losses.
- The DCU is 550 ps with 4 dB loss.
- All nodes have OPT-PRE and OPT-BST/OPT-BST-E amplifiers installed.
- The OPT-PRE amplifier switches to control power whenever the span loss is higher than 27 dB.

Table 5-8 Span Loss for 32-Channel Ring and Linear Networks with OADM Nodes Using TW-RS Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	29 dB	21 dB	20 dB	31 dB	32 dB	28 dB	26 dB	27 dB	29 dB	26 dB
3	27 dB	17 dB	15 dB	29 dB	30 dB	26 dB	23 dB	25 dB	27 dB	23 dB
4	25 dB	—	—	27 dB	28 dB	23 dB	20 dB	22 dB	24 dB	20 dB
5	23 dB	—	—	26 dB	27 dB	22 dB	16 dB	20 dB	23 dB	16 dB
6	21 dB	—	—	24 dB	25 dB	19 dB	—	17 dB	21 dB	—
7	20 dB	—	—	22 dB	24 dB	16 dB	—	—	19 dB	—

Table 5-9 shows the optical performance for 32-channel networks using E-LEAF fiber. Span loss values assume the following:

- OADM nodes have a loss of 16 dB and equal span losses.
- The DCU is 550 ps with 4 dB loss.
- All nodes have OPT-PRE and OPT-BST/OPT-BST-E amplifiers installed.
- The OPT-PRE amplifier switches to control power whenever the span loss is higher than 27 dB.

Table 5-9 Span Loss for 32-Channel Ring and Linear Networks with OADM Nodes Using E-LEAF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	29 dB	21 dB	20 dB	31 dB	32 dB	28 dB	26 dB	27 dB	29 dB	26 dB
3	27 dB	17 dB	15 dB	29 dB	30 dB	26 dB	23 dB	25 dB	27 dB	23 dB
4	24 dB	—	—	26 dB	28 dB	23 dB	20 dB	22 dB	24 dB	20 dB
5	22 dB	—	—	24 dB	27 dB	22 dB	16 dB	20 dB	23 dB	16 dB
6	20 dB	—	—	22 dB	25 dB	19 dB	—	17 dB	21 dB	—
7	17 dB	—	—	20 dB	24 dB	16 dB	—	—	19 dB	—

5.2.3.2 Optical Performance for Linear Networks Without OADM Nodes

The following tables list the reference optical performances for linear networks without OADM nodes.

Table 5-10 shows the optical performance for 32-channel linear networks using SMF fiber. Span loss values assume the following:

- No OADM nodes are installed and span losses are equal.
- The DCU loss is 9 dB.
- Only OPT-PRE amplifiers are installed.

Table 5-10 Span Loss for 32-Channel Linear Networks without OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	27 dB	20 dB	19 dB	29 dB	30 dB	26 dB	23 dB	25 dB	26 dB	23 dB
3	24 dB	17 dB	17 dB	25 dB	26 dB	23 dB	20 dB	22 dB	23 dB	20 dB
4	22 dB	15 dB	14 dB	23 dB	24 dB	21 dB	19 dB	20 dB	22 dB	19 dB
5	21 dB	—	—	22 dB	22 dB	20 dB	18 dB	19 dB	20 dB	18 dB
6	20 dB	—	—	21 dB	21 dB	19 dB	17 dB	18 dB	19 dB	17 dB
7	19 dB	—	—	20 dB	20 dB	18 dB	16 dB	18 dB	19 dB	16 dB

Table 5-11 shows the optical performance for 32-channel linear networks using TW-RS fiber. Span loss values assume the following:

- No OADM nodes are installed and span losses are equal.
- The DCU is 550 ps with 4 dB loss.
- Only OPT-PRE amplifiers are installed.

Table 5-11 Span Loss for 32-Channel Linear Networks without OADM Nodes Using TW-RS Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	28 dB	20 dB	20 dB	30 dB	31 dB	27 dB	24 dB	26 dB	27 dB	24 dB
3	26 dB	18 dB	17 dB	27 dB	28 dB	24 dB	22 dB	23 dB	25 dB	22 dB
4	24 dB	15 dB	14 dB	25 dB	26 dB	23 dB	21 dB	22 dB	24 dB	20 dB
5	23 dB	—	—	24 dB	25 dB	22 dB	19 dB	21 dB	22 dB	19 dB
6	22 dB	—	—	23 dB	24 dB	20 dB	17 dB	19 dB	21 dB	17 dB
7	21 dB	—	—	23 dB	23 dB	19 dB	16 dB	18 dB	20 dB	16 dB

Table 5-12 shows the optical performance for 32-channel linear networks using E-LEAF fiber. Span loss values assume the following:

- No OADM nodes are installed and span losses are equal.
- The DCU is 550 ps with 4 dB loss.
- Only OPT-PRE amplifiers are installed.

Table 5-12 Span Loss for 32-Channel Linear Networks without OADM Nodes Using E-LEAF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	37 dB	37 dB	33 dB	30 dB	32 dB	34 dB	30 dB
2	28 dB	20 dB	20 dB	30 dB	31 dB	27 dB	24 dB	26 dB	27 dB	24 dB
3	25 dB	18 dB	17 dB	27 dB	28 dB	24 dB	22 dB	23 dB	25 dB	22 dB
4	24 dB	15 dB	14 dB	25 dB	26 dB	23 dB	21 dB	22 dB	24 dB	20 dB
5	23 dB	—	—	24 dB	25 dB	22 dB	19 dB	21 dB	22 dB	19 dB
6	21 dB	—	—	22 dB	24 dB	20 dB	17 dB	19 dB	21 dB	17 dB
7	20 dB	—	—	21 dB	23 dB	19 dB	16 dB	18 dB	20 dB	16 dB

Table 5-13 shows the optical performance for 16-channel linear networks using SMF fiber. Span loss values assume the following:

- No OADM nodes are installed and span losses are equal.
- The DCU loss is 9 dB.
- Only OPT-PRE amplifiers are installed.
- The minimum channel power is 4 dBm.
- Wavelengths are picked up without any restriction from Bands 4 and 5 (1542.14 to 1545.51 nm).

Table 5-13 Span Loss for 16-Channel Linear Networks without OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	37 dB	29 dB	28 dB	37 dB	37 dB	36 dB	33 dB	35 dB	37 dB	33 dB
2	32 dB	23 dB	23 dB	33 dB	34 dB	30 dB	27 dB	29 dB	31 dB	27 dB
3	28 dB	21 dB	20 dB	30 dB	30 dB	26 dB	24 dB	26 dB	27 dB	24 dB
4	26 dB	19 dB	18 dB	27 dB	28 dB	24 dB	22 dB	23 dB	25 dB	22 dB
5	24 dB	18 dB	17 dB	26 dB	26 dB	23 dB	21 dB	22 dB	24 dB	21 dB
6	23 dB	17 dB	17 dB	24 dB	25 dB	22 dB	20 dB	21 dB	22 dB	20 dB
7	22 dB	16 dB	15 dB	23 dB	24 dB	21 dB	19 dB	20 dB	21 dB	19 dB

Table 5-14 shows the optical performance for 8-channel linear networks with 8 dBm per channel using SMF fiber. Span loss values assume the following:

- No OADM nodes are installed and span losses are equal.
- The DCU loss is 9 dB.
- Only OPT-PRE amplifiers are installed.

Table 5-14 Span Loss for Eight-Channel Linear Networks without OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	37 dB	31 dB	30 dB	37 dB	37 dB	37 dB	35 dB	37 dB	37 dB	35 dB
2	34 dB	26 dB	25 dB	34 dB	34 dB	32 dB	30 dB	31 dB	33 dB	30 dB
3	31 dB	23 dB	22 dB	33 dB	34 dB	29 dB	26 dB	28 dB	30 dB	26 dB
4	29 dB	—	—	30 dB	31 dB	27 dB	24 dB	26 dB	28 dB	24 dB
5	27 dB	—	—	29 dB	30 dB	26 dB	23 dB	25 dB	26 dB	23 dB
6	—	—	—	27 dB	—	—	—	—	—	—

5.2.3.3 Optical Performance for ROADM Rings and Linear Networks

The following tables list the reference optical performances for ROADM rings and linear networks.

Table 5-15 shows the optical performance for 32-channel linear or ring networks using SMF fiber with only ROADM nodes installed. Span loss values assume the following:

- All nodes in the ring or linear network are ROADM with equal span losses.
- The DCU loss is 9 dB.
- OPT-PRE and OPT-BST/OPT-BST-E amplifiers are installed.

Table 5-15 Span Loss for 32-Channel Linear or Ring Networks with all ROADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	35 dB	25 dB	25 dB	36 dB	37 dB	33 dB	30 dB	32 dB	34 dB	—
2	30 dB	21 dB	20 dB	32 dB	34 dB	28 dB	25 dB	26 dB	29 dB	—
3	28 dB	18 dB	17 dB	30 dB	32 dB	26 dB	23 dB	24 dB	27 dB	—
4	26 dB	—	—	28 dB	30 dB	24 dB	21 dB	22 dB	25 dB	—
5	25 dB	—	—	27 dB	29 dB	23 dB	20 dB	20 dB	23 dB	—
6	24 dB	—	—	26 dB	28 dB	22 dB	18 dB	19 dB	22 dB	—
7	23 dB	—	—	25 dB	27 dB	21 dB	14 dB	17 dB	20 dB	—
8	22 dB	—	—	24 dB	26 dB	20 dB	—	—	18 dB	—
9	21 dB	—	—	23 dB	25 dB	19 dB	—	—	—	—
10	21 dB	—	—	23 dB	25 dB	18 dB	—	—	—	—
11	18[1] dB	—	—	22 dB	24 dB	17 dB	—	—	—	—
12	17[1] dB	—	—	21 dB	24 dB	15 dB	—	—	—	—
13	15[1] dB	—	—	21 dB	23 dB	—	—	—	—	—
14	—	—	—	20 dB	23 dB	—	—	—	—	—
15	—	—	—	20 dB	22 dB	—	—	—	—	—

1. If the number of boosters is greater than 10 and power per channel is = to +1 dBm.

Table 5-16 shows the optical performance for 32-channel linear or ring network with ROADM and OADM nodes using SMF fiber. Span loss values assume the following:

- All nodes in the ring or linear network are ROADM or OADM.
- OPT-PRE and OPT-BST/OPT-BST-E amplifiers are installed.
- Span losses are equal.

Table 5-16 Span Loss for 32-Channel Ring and Linear Networks with ROADM and OADM Nodes Using SMF Fiber

Number of Spans	10 Gbps				2.5 Gbps					
	Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	30 dB	23 dB	24 dB	31 dB	34 dB	31 dB	28 dB	29 dB	30 dB	28 dB
2	26 dB	19 dB	19 dB	27 dB	27 dB	26 dB	23 dB	26 dB	27 dB	23 dB
3	23 dB	—	—	25 dB	26 dB	23 dB	21 dB	23 dB	24 dB	21 dB
4	21 dB	—	—	23 dB	24 dB	22 dB	18 dB	21 dB	22 dB	18 dB
5	20 dB	—	—	22 dB	23 dB	20 dB	13 dB	20 dB	21 dB	13 dB
6	17 dB	—	—	19 dB	22 dB	18 dB	—	17 dB	18 dB	—
7	15[1] dB	—	—	17 dB	21 dB	16 dB	—	15[1]	16 dB	—

1. 0.5 dB of OSNR impairment recovered by FEC margin @ BER>10-6

The following tables show the pass/fail criteria for eight and sixteen ROADM nodes.

Table 5-17 shows the pass/fail criteria for eight ROADM nodes (seven spans) required for any-to-any node circuit reconfigurations:

- All nodes in the ring are ROADM.
- Span losses are equal.

Table 5-17 Pass/Fail Criteria for 32-Channel, Eight-Node ROADM Rings Using SMF Fiber

Span Loss (dB)	Amplifiers Installed	10 Gbps				2.5 Gbps					
		Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
2	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
3	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
4	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
5	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
6	OPT-PRE only	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
7	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
8	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	<7	Yes	Yes	—
9	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
10	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
11	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
12	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
13	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
14	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—
15	OPT-PRE and OPT-BST/ OPT-BST-E	Yes	<7	<7	Yes	Yes	Yes	Yes	Yes	Yes	—

Table 5-18 shows the pass/fail criteria for 16 ROADM nodes (15 spans) required for any-to-any node circuit reconfigurations.

- All nodes in the ring are ROADM.
- Span losses are equal.

Table 5-18 Pass/Fail Criteria for 32-Channel, 16-Node ROADM Rings Using SMF Fiber

Span Loss (dB)	Amplifiers Installed	10 Gbps				2.5 Gbps					
		Class A	Class B	Class C	Class I	Class D	Class E	Class F	Class G	Class H	Class J
1	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
2	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
3	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
4	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
5	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
6	OPT-PRE only	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
7	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
8	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
9	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
10	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
11	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
12	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
13	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
14	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—
15	OPT-PRE and OPT-BST/ OPT-BST-E	<15[1]	<15[1]	<15[1]	Yes	Yes	<15[1]	<15[1]	<15[1]	<15[1]	—

1. Cisco MetroPlanner calculates the maximum ring circumference and number of nodes that can be supported.

5.2.3.4 Optical Performance for Single-Span Networks

Table 5-19 lists the span loss for a single-span link configuration with eight channels. The optical performance for this special configuration is given only for Classes A and C. This configuration assumes a maximum channel capacity of eight channels (8-dBm nominal channel power) used without any restrictions on the 32 available channels.

Table 5-19 Span Loss for Single-Span Link with Eight Channels

Node Configuration	Number of Spans	10 Gbps			2.5 Gbps			
		Class A	Class B	Class C	Class D	Class E	Class F	Class G
With OSCM card	1	37 dB	—	37 dB	—	—	—	—
With OSC-CSM card	1	35 dB	—	35 dB	—	—	—	—

Table 5-20 lists the span loss for a single-span link configuration with 16 channels. The optical performance for this special configuration is given only for Class A and Class C. This configuration assumes a maximum channel capacity of 16 channels (5-dBm nominal channel power) used without any restrictions on the 32 available channels.

Table 5-20 Span Loss for Single-Span Link with 16 Channels

Node Configuration	Number of Spans	10 Gbps			2.5 Gbps			
		Class A	Class B	Class C	Class D	Class E	Class F	Class G
With OSCM or OSC-SCM cards	1	35 dB	—	35 dB	—	—	—	—

Table 5-21 lists the span loss for a single-span link configuration with AD-1C-x.xx cards, OPT-PRE amplifiers, and OPT-BST/OPT-BST-E amplifiers. The single-span link with a flexible channel count is used both for transmitting and receiving. If dispersion compensation is required, a DCU can be used with an OPT-PRE amplifier. The optical performance for this special configuration is given for Classes A through G (8-dBm nominal channel power) used without any restrictions on the 32 available channels.

Table 5-21 Span Loss for Single-Span Link with AD-1C-xx.x Cards, OPT-PRE Amplifiers, and OPT-BST/OPT-BST-E Amplifiers

Node Configuration	Number of Spans	10 Gbps			2.5 Gbps			
		Class A	Class B	Class C	Class D	Class E	Class F	Class G
With OSCM cards[1]	1	37 dB	31 dB	31 dB	37 dB	37 dB	37 dB	37 dB
Hybrid with OSC-CSM cards[2]	1	35 dB	31 dB	31 dB	35 dB	35 dB	35 dB	35 dB

1. OSCM sensitivity limits the performance to 37 dB.
2. OSC-CSM sensitivity limits the performance to 35 dB when it replaces the OSCM.

Table 5-22 lists the span loss for a single-span link configuration with one channel and OPT-BST/OPT-BST-E amplifiers. The optical performance for this special configuration is given for Classes A through G. Classes A, B, and C use 8-dBm nominal channel power. Classes D, E, F, and G use

12-dBm nominal channel power. There are no restriction on the 32 available channels. That is, a line card, transponder, or muxponder wavelength can be extracted from the 32 available wavelengths. Also, the optical service channel is not required.

Table 5-22 Span Loss for Single-Span Link with One Channel and OPT-BST Amplifiers

Number of Spans	10 Gbps			2.5 Gbps			
	Class A	Class B	Class C	Class D	Class E	Class F	Class G
1	20 to 30 dB	17 to 26 dB	17 to 28 dB	Unprotected from 29 to 41 dB Protected from 25 to 41 dB	Unprotected from 28 to 37 dB Protected from 24 to 40 dB	Unprotected from 21 to 34 dB Protected from 18 to 34 dB	From 23 to 36 dB

Table 5-23 lists the span loss for a single-span link configuration with one channel, OPT-BST/OPT-BST-E amplifiers, OPT-PRE amplifiers, and ONS 15216 FlexLayer filters. ONS 15216 FlexLayer filters are used instead of the AD-1C-xx.x cards to reduce equipment costs and increase the span length, since the optical service channel is not necessary. The optical performance for this special configuration is given for Classes A through G. Classes A, B, and C use 8-dBm nominal channel power. Classes D, E, F, and G use 12-dBm nominal channel power. There are no restriction on the first 16 available wavelengths (from 1530.33 to 1544.53 nm).

Table 5-23 Span Loss for Single-Span Link with One Channel, OPT-BST/OPT-BST-E Amplifiers, OPT-PRE Amplifiers, and ONS 15216 FlexLayer Filters

Number of Spans	10 Gbps			2.5 Gbps			
	Class A	Class B	Class C	Class D	Class E	Class F	Class G
1	38 dB	30 dB	30 dB	44 dB	40 dB	38 dB	40 dB

5.2.4 L-Band Optical Performance

Table 5-24 details the target system performance for an ONS 15454 DWDM L-band system.

Table 5-24 L-Band Supported Topologies and Node Types

Number of Channels	Fiber Type	Topologies	Node Type
32	SMF-28 DS[1]	Ring Linear Linear without ROADM	Hub Terminal ROADM Line OSC regeneration

1. DS = Dispersion Shifted fiber

5.2.4.1 Optical Performance for Linear Networks Without ROADM Nodes

Table 5-25 shows the optical performance for 32-channel linear networks using SMF fiber. Span loss values assume the following:

- No ROADM nodes are installed
- Only OPT-AMP-L amplifiers are installed
- Span losses are equal

Table 5-25 Span Loss for 32-Channel Ring and Linear Networks Using SMF Fiber (no ROADM Nodes)

Number of Spans	10 Gbps		
	Class A	Class C	Class I
1	37 dB	27 dB	37 dB
2	32 dB	23 dB	34 dB
3	29 dB	20 dB	30 dB
4	27 dB	16 dB	28 dB
5	26 dB	—	27 dB
6	25 dB	—	26 dB
7	24 dB	—	25 dB

Table 5-26 shows the optical performance for 32-channel linear networks using DS fiber. Span loss values assume the following:

- No ROADM nodes are installed
- Only OPT-AMP-L amplifiers are installed
- Span losses are equal

Table 5-26 Span Loss for 32-Channel Ring and Linear Networks Using DS Fiber (no ROADM Nodes)

Number of Spans	10 Gbps		
	Class A	Class C	Class I
1	37 dB	27 dB	37 dB
2	32 dB	23 dB	34 dB
3	29 dB	20 dB	30 dB
4	26 dB	16 dB	28 dB
5	25 dB	—	27 dB
6	24 dB	—	26 dB
7	23 dB	—	24 dB
8	23 dB	—	24 dB
9	23 dB	—	24 dB
10	22 dB	—	23 dB

Table 5-26 Span Loss for 32-Channel Ring and Linear Networks Using DS Fiber (no ROADM Nodes) (continued)

Number of Spans	10 Gbps		
	Class A	**Class C**	**Class I**
11	20 dB	—	23 dB
12	19 dB	—	23 dB
13	18 dB	—	22 dB
14	17 dB	—	22 dB
15	15 dB	—	22 dB

5.2.4.2 Optical Performance for ROADM Rings and Linear Networks

Table 5-27 shows the optical performance for a 32-channel linear or ring network using SMF fiber with only ROADM nodes installed. Span loss values assume the following:

- All nodes in the ring or linear network are ROADM
- OPT-AMP-L and OPT-BST-L amplifiers are installed
- Span losses are equal

Table 5-27 Span Loss for 32-Channel Ring or Linear Networks with all ROADM Nodes Using SMF Fiber

Number of Spans	10 Gbps		
	Class A	**Class C**	**Class I**
1	37 dB	27 dB	37 dB
2	33 dB	21 dB	36 dB
3	32 dB	—	34 dB
4	29 dB	—	32 dB
5	28 dB	—	31 dB
6	27 dB	—	30 dB
7	26 dB	—	29 dB
8	25 dB	—	28 dB
9	24 dB	—	27 dB
10	23 dB	—	27 dB
11	22 dB	—	26 dB
12	20 dB	—	25 dB
13	19 dB	—	25 dB
14	16 dB	—	24 dB
15	—	—	23 dB

Table 5-28 shows the optical performance for a 32-channel linear or ring network with ROADM nodes using DS fiber. Span loss values assume the following:

- All nodes in the ring or linear network are ROADM
- OPT-AMP-L and OPT-BST-L amplifiers are installed
- Span losses are equal

Table 5-28 Span Loss for 32-Channel Ring and Linear Networks with ROADM and OADM Nodes Using DS Fiber

Number of Spans	10 Gbps		
	Class A	Class C	Class I
1	37 dB	27 dB	37 dB
2	33 dB	21 dB	36 dB
3	32 dB	—	34 dB
4	29 dB	—	32 dB
5	28 dB	—	31 dB
6	27 dB	—	30 dB
7	26 dB	—	29 dB
8	25 dB	—	28 dB
9	24 dB	—	27 dB
10	23 dB	—	27 dB
11	22 dB	—	26 dB
12	20 dB	—	25 dB
13	19 dB	—	25 dB
14	16 dB	—	24 dB
15	—	—	23 dB
—	—	—	37 dB

Network Applications

This chapter describes Cisco ONS 15454 DWDM networks and includes the following sections:

- 6.1 Network Topology Discovery
- 6.2 Automatic Power Control
- 6.3 ROADM Power Equalization Monitoring
- 6.4 Span Loss Verification
- 6.5 Network Optical Safety—Automatic Laser Shutdown
- 6.6 Network-Level Gain-Tilt Management of Optical Amplifiers
- 6.7 Automatic Node Setup

6.1 Network Topology Discovery

Each ONS 15454 DWDM node has a network topology discovery function that can:

- Identify other ONS 15454 DWDM nodes in an ONS 15454 DWDM network.
- Identify the different types of DWDM networks.
- Identify when the DWDM network is complete and when it is incomplete.

ONS 15454 DWDM nodes use node services protocol (NSP) to update nodes automatically whenever a change in the network occurs. NSP uses two information exchange mechanisms: hop-by-hop message protocol and broadcast message protocol. Hop-by-hop message protocol elects a master node and exchanges information between nodes in a sequential manner, which instigates a token ring protocol. In a token ring protocol:

- Each node that receives a hop-by-hop message passes it to the next site according to the ring topology and the line direction from which the token was received.
- The message originator always receives the token after it has been sent over the network.
- Only one hop-by-hop message can run on the network at any one time.

NSP broadcast message protocol distributes information that can be shared by all ONS 15454 DWDM nodes on the same network. Broadcast message delivery is managed independently from delivery of the two tokens. Moreover, no synchronization among broadcast messages is required; every node is authorized to send a broadcast message any time it is necessary.

6.2 Automatic Power Control

The ONS 15454 automatic power control (APC) feature performs the following functions:

- Maintains constant per-channel power when changes to the number of channels occur.
- Compensates for optical network degradation (aging effects).
- Simplifies the installation and upgrade of DWDM optical networks by automatically calculating the amplifier setpoints.

Note APC functions are performed by software algorithms on the OPT-BST, OPT-PRE, and TCC2/TCC2P cards.

Amplifier software uses a gain control loop with fast transient suppression to keep the channel power constant regardless of any changes in the number of channels. Amplifiers monitor the changes to the input power and change the output power according to the calculated gain setpoint. The shelf controller software emulates the output power control loop to adjust for fiber degradation. To perform this function, the TCC2 or TCC2P (shelf controller) card needs the channel distribution, which is provided by a signaling protocol, and the expected per-channel power, which you can provision. The TCC2/TCC2P card compares the actual amplifier output power with the expected amplifier output power and modifies the setpoints if any discrepancies occur.

6.2.1 APC at the Amplifier Card Level

In constant gain mode, the amplifier power out control loop performs the following input and output power calculations, where “G” represents gain and “t” represents time.

Pout (t) = G * Pin (t) (mW)

Pout (t) = G + Pin (t) (dB)

In a power-equalized optical system, the total input power is proportional to the number of channels. The amplifier software compensates for any variation of the input power due to changes in the number of channels carried by the incoming signal.

Amplifier software identifies changes in the read input power in two different instances, t1 and t2, as a change in the carried traffic. The letters *m* and *n* in the following formula represent two different channel numbers. Pin/ch represents the per-channel input power:

Pin (t1)= nPin/ch

Pin (t2) = mPin/ch

Amplifier software applies the variation in the input power to the output power with a reaction time that is a fraction of a millisecond. This keeps the power constant on each channel at the output amplifier, even during a channel upgrade or a fiber cut.

Amplifier parameters are configured using east and west conventions for ease of use. Selecting “west” provisions parameters for the preamplifier receiving from the west and the booster amplifier transmitting to the west. Selecting “east” provisions parameters for the preamplifier receiving from the east and the booster amplifier transmitting to the east.

Starting from the expected per-channel power, the amplifiers automatically calculate the gain setpoint after the first channel is provisioned. An amplifier gain setpoint is calculated in order to make it equal to the loss of the span preceding the amplifier. After the gain is calculated, the setpoint is no longer changed by the amplifier. Amplifier gain is recalculated every time the number of provisioned channels returns to zero. If you need to force a recalculation of the gain, move the number of channels back to zero.

6.2.2 APC at the Node and Network Levels

The amplifier adjusts the gain to compensate for span loss. Span loss can change due to aging fiber and components, or to changes in operating conditions. To correct the gain or express variable optical attenuator (VOA) setpoints, APC calculates the difference between the power value read by the photodiodes and the expected power value. The expected power values are calculated using:

- Provisioned per-channel power value
- Channel distribution (the number of express, add, and drop channels in the node)
- Amplified spontaneous emission (ASE) estimation

Channel distribution is determined by the sum of the provisioned and failed channels. Information about provisioned wavelengths is sent to APC on the applicable nodes during circuit creation. Information about failed channels is collected through a signaling protocol that monitors alarms on ports in the applicable nodes and distributes that information to all the other nodes in the network.

ASE calculations purify the noise from the power level reported from the photodiode. Each amplifier can compensate for its own noise, but cascaded amplifiers cannot compensate for ASE generated by preceding nodes. The ASE effect increases when the number of channels decreases; therefore, a correction factor must be calculated in each amplifier of the ring to compensate for ASE build-up.

APC is a network-level feature. The APC algorithm designates a master node that is responsible for starting APC hourly or every time a new circuit is provisioned or removed. Every time the master node signals for APC to start, gain and VOA setpoints are evaluated on all nodes in the network. If corrections are needed in different nodes, they are always performed sequentially following the optical paths starting from the master node.

APC corrects the power level only if the variation exceeds the hysteresis thresholds of +/– 0.5 dB. Any power level fluctuation within the threshold range is skipped because it is considered negligible. Because APC is designed to follow slow time events, it skips corrections greater than 3 dB. This is the typical total aging margin that is provisioned during the network design phase. After you provision the first channel or the amplifiers are turned up for the first time, APC does not apply the 3 dB rule. In this case, APC corrects all the power differences to turn up the node.

Note Software Release 7.x does not report corrections that are not performed and exceed the 3 dB correction factor to Cisco Transport Controller (CTC), Cisco Transport Manager (CTM), and Transaction Language One (TL1) management interfaces.

To avoid large power fluctuations, APC adjusts power levels incrementally. The maximum power correction is +/– 0.5 dB. This is applied to each iteration until the optimal power level is reached. For example, a gain deviation of 2 dB is corrected in four steps. Each of the four steps requires a complete APC check on every node in the network. APC can correct up to a maximum of 3 dB on an hourly basis. If degradation occurs over a longer time period, APC will compensate for it by using all margins that you provision during installation.

When no margin is available, adjustments cannot be made because setpoints exceed ranges. APC communicates the event to CTC, CTM, and TL1 through an APC Fail condition. APC will clear the APC fail condition when the setpoints return to the allowed ranges.

APC automatically disables itself when:

- A HW FAIL alarm is raised by any card in any of the network nodes.
- A Mismatch Equipment Alarm (MEA) is raised by any card in any of the network nodes.
- An Improper Removal (IMPROPRMVL) alarm is raised by any card in any of the network nodes.
- Gain Degrade (GAIN-HDEG), Power Degrade (OPWR-HDEG), and Power Fail (PWR-FAIL) alarms are raised by the output port of any amplifier card in any of the network nodes.
- A VOA degrade or fail alarm is raised by any of the cards in any of the network nodes.

The APC state (Enable/Disable) is located on every node and can be retrieved by the CTC or TL1 interfaces. If an event that disables APC occurs in one of the network nodes, APC is disabled on all the others and the APC state changes to DISABLE - INTERNAL. The disabled state is raised only by the node where the problem occurred to simplify troubleshooting.

APC raises the following standing conditions at the port level in CTC, TL1, and Simple Network Management Protocol (SNMP):

- APC Out of Range—APC cannot assign a new setpoint for a parameter that is allocated to a port because the new setpoint exceeds the parameter range.
- APC Correction Skipped—APC skipped a correction to one parameter allocated to a port because the difference between the expected and current values exceeds the +/– 3 dB security range.

After the error condition is cleared, signaling protocol enables APC on the network and the APC DISABLE - INTERNAL condition is cleared. Because APC is required after channel provisioning to compensate for ASE effects, all optical channel network connection (OCHNC) and optical channel client connection (OCHCC) circuits that you provision during the disabled APC state are kept in the Out-of-Service and Autonomous, Automatic In-Service (OOS-AU,AINS) (ANSI) or Unlocked-disabled,automaticInService (ETSI) service state until APC is enabled. OCHNCs and OCHCCs automatically go into the In-Service and Normal (IS-NR) (ANSI) or Unlocked-enabled (ETSI) service state only after APC is enabled.

6.2.3 Managing APC

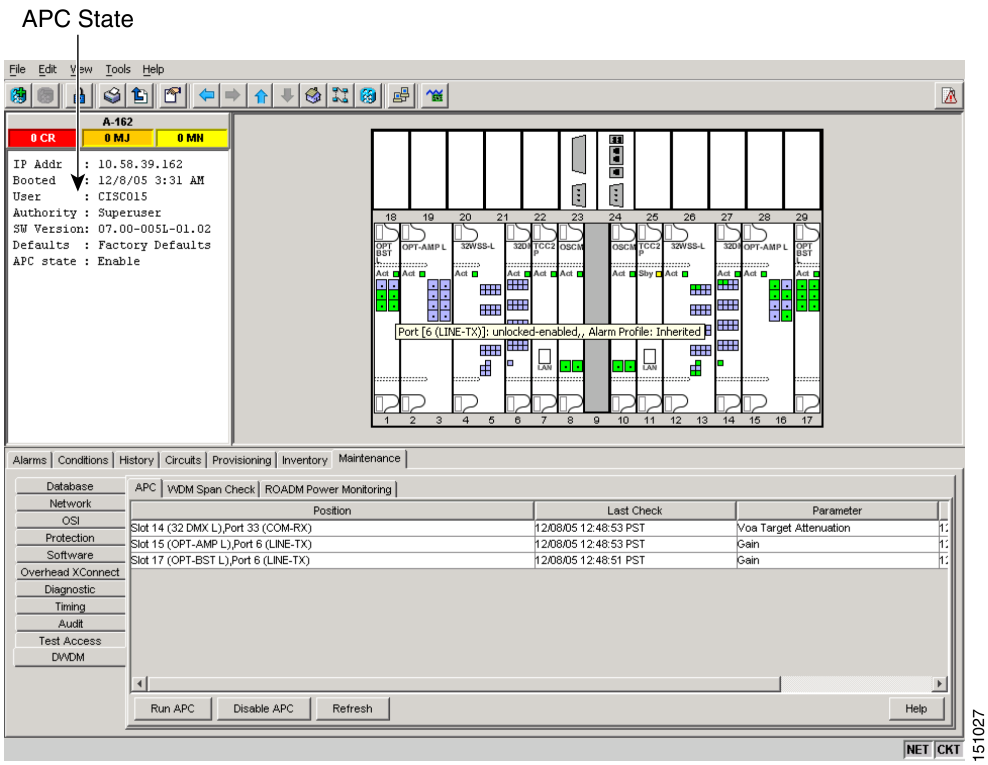
The automatic power control status is indicated by four APC states shown in the node view status area:

- Enable—APC is enabled.
- Disable - Internal—APC has been automatically disabled for an internal cause.
- Disable - User—APC was disabled manually by a user.
- Not Applicable—The node is provisioned to Metro Access or Not DWDM, which do not support APC.

You can view the automatic power control information and disable and enable APC manually on the Maintenance > DWDM > APC tab (Figure 6-1).

Caution When APC is disabled, aging compensation is not applied and circuits cannot be activated. Do not disable APC unless it is required for specific maintenance or troubleshooting tasks. Always enable APC as soon as the tasks are completed.

Figure 6-1 Automatic Power Control



The APC subtab provides the following information:

- Slot ID—The ONS 15454 slot number for which APC information is shown is listed in the Position column.
- Port—The port number for which APC information is shown is listed in the Position column.
- Card—The card for which APC information is shown is listed in the Position column.
- Last Modification—Date and time that APC last modified a setpoint for the parameters shown in Table 6-1.
- Last Check—Date and time that APC last verified the setpoints for the parameters shown in Table 6-1.

Table 6-1 APC-Managed Parameters

Card	Port	Parameters
OPT-BST	LINE-3-TX	• Gain • Total Signal Output Power
OPT-PRE	LINE-1-TX	• Gain • Total Signal Output Power
AD-xB-xx.x	LINE-1-TX BAND-n[1]-TX	VOA Target Attenuation

Table 6-1 APC-Managed Parameters (continued)

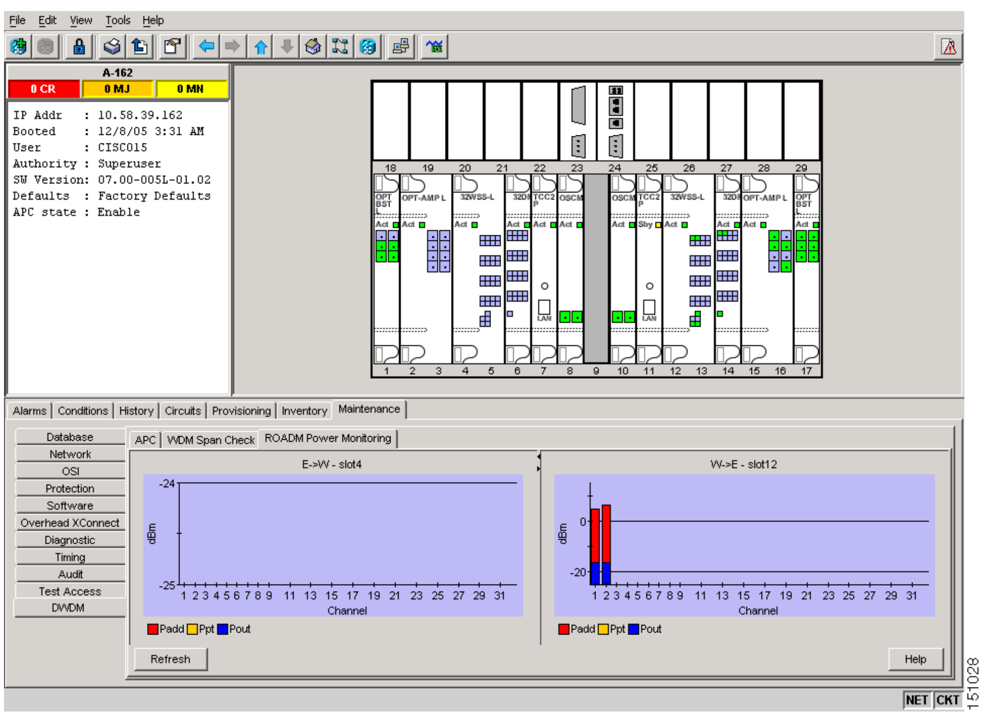
Card	Port	Parameters
AD-1C-xx.x AD-2C-xx.x	LINE-1-TX	VOA Target Attenuation
AD-4C-xx.x	LINE-1-TX CHAN-*n*[2]-TX	VOA Target Attenuation
32DMX	LINE-1-TX	VOA Target Attenuation

1. n = 1–8
2. n = 1–32

6.3 ROADM Power Equalization Monitoring

Reconfigurable optical add/drop multiplexing (ROADM) nodes allow you to monitor the 32WSS card equalization functions on the Maintenance > DWDM > Power Monitoring tab (Figure 6-2). The tab shows the input channel power (Padd), the express or pass-through (Ppt) power, and the power level at output (Pout).

Figure 6-2 Power Monitoring Subtab



6.4 Span Loss Verification

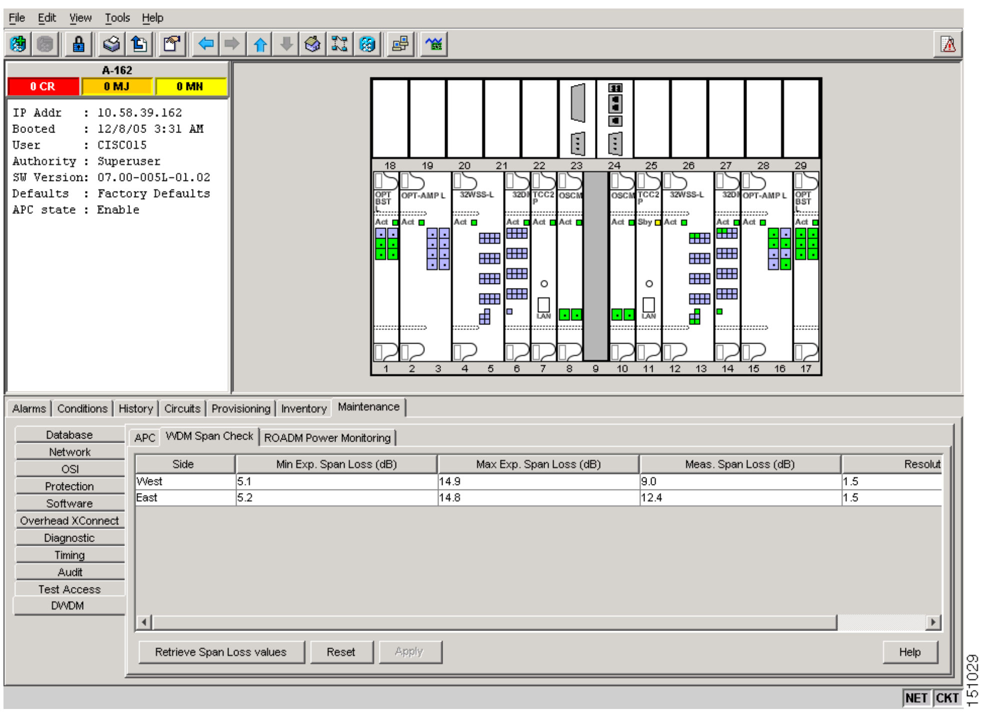
Span loss measurements can be performed from the Maintenance > DWDM > WDM Span Check tab (Figure 6-3). The CTC span check compares the far-end optical service channel (OSC) power with the near-end OSC power. A Span Loss Out of Range condition is raised when the measured span loss is higher than the maximum expected span loss. It is also raised when the measured span loss is lower than the minimum expected span loss and the difference between the minimum and maximum span loss values is greater than 1 dB. The minimum and maximum expected span loss values are calculated by Cisco MetroPlanner for the network and imported into CTC. However, you can manually change the minimum and expected span loss values.

CTC span loss measurements provide a quick span loss check and are useful whenever changes to the network occur, for example after you install equipment or repair a broken fiber. CTC span loss measurement resolutions are:

- +/– 1.5 dB for measured span losses between 0 and 25 dB
- +/– 2.5 dB for measured span losses between 25 and 38 dB

For ONS 15454 span loss measurements with higher resolutions, an optical time domain reflectometer (OTDR) must be used.

Figure 6-3 Span Loss Verification



6.5 Network Optical Safety—Automatic Laser Shutdown

Automatic laser shutdown (ALS) is a key component of the DWDM network optical safety. If a fiber break occurs on the network, ALS automatically shuts down the OSCM and OSC-CSM OSC laser output power and the optical amplifiers contained in the OPT-BST cards. The card-level, Maintenance > ALS subtab provides the following ALS management options for OSCM, OSC-CSM, and OPT-BST cards:

- Disable—ALS is off. The OSC laser transmitter and optical amplifiers are not automatically shut down when a traffic outage loss of signal (LOS) occurs.
- Auto Restart—ALS is on. The OSC laser transmitter and optical amplifiers automatically shut down when traffic outages (LOS) occur. The laser automatically restarts when the conditions that caused the outage are resolved.

Note Auto Restart is the default ALS provisioning for OSCM, OSC-CSM, and OPT-BST cards.

- Manual Restart—ALS is on. The OSC laser transmitter and optical amplifiers automatically shut down when traffic outages (LOS) occur. However, the laser must be manually restarted when conditions that caused the outage are resolved.
- Manual Restart for Test—Manually restarts the OSC laser transmitter and optical amplifiers for testing.

A network optical safety strategy is achieved through the ALS settings on the OPT-BST, OSCM, and OSC-CSM cards. When ALS is enabled on these cards, a network safety mechanism goes into effect in the event of a system failure. However, ALS is also provided on the transponder (TXP) and muxponder (MXP) cards. As long as a network uses OPT-BST, OSCM, and OSC-CSM cards and ALS is enabled on them, ALS does not need to be enabled on the TXPs or MXPs; in fact, ALS is disabled on TXP and MXP by default, and the network optical safety is not impacted.

However, if TXPs and MXPs are connected directly to each other without passing through a DWDM layer, ALS should be enabled on them. The ALS protocol goes into effect when a fiber is cut, enabling some degree of network point-to-point bidirectional traffic management between those cards.

In addition, if ALS is disabled on the DWDM network (ALS is disabled on the OPT-BST, OSCM, and OSC-CSM cards), ALS can be enabled on the TXP and MXP cards to provide some laser management in the event of a fiber break in the network between the cards.

6.5.1 Automatic Power Reduction

Automatic power reduction (APR) is controlled by the software and is not user configurable. During amplifier restart after a system failure, the amplifier (OPT-BST, for example) operates in pulse mode and an automatic power reduction level is activated so that the Hazard Level 1 power limit is not exceeded. This is done to ensure personnel safety.

When a system failure occurs (cut fiber or equipment failure, for example) and ALS Auto Restart is enabled, a sequence of events is placed in motion to shut down the amplifier laser power, then automatically restart the amplifier after the system problem is corrected. As soon as a loss of optical payload and OSC is detected at the far end, the far-end amplifier shuts down. The near-end amplifier then shuts down because in similar fashion, it detects a loss of payload and OSC due to the far-end amplifier shutdown. At this point, the near end attempts to establish communication to the far end using the OSC laser transmitter. To do this, the OSC emits a two-second pulse at very low power (maximum of 0 dB) and waits for a similar two-second pulse in response from the far-end OSC laser transmitter. If no response is received within 100 seconds, the near end tries again. This process continues until the near end receives a two-second response pulse from the far end. This is an indication that the system failure has been corrected and that there is full continuity in the fiber between the two ends.

After the OSC communication has been established, the near-end amplifier is configured by the software to operate in pulse mode at a reduced power level. It emits a nine-second laser pulse with an automatic power reduction to +8 dB. This level assures that Hazard Level 1 is not exceeded, for personnel safety, even though the establishment of successful OCS communication has assured that any broken fiber has been fixed. If the far-end amplifier responds with a nine-second pulse within 100 seconds, both amplifiers are changed from pulse mode at reduced power to normal operating power mode.

For a direct connection between TXP or MXP cards, when ALS Auto Restart is enabled and the connections do not pass through a DWDM layer, a similar process takes place. However, because the connections do not go through any amplifier or OSC cards, the TXP or MXP cards attempt to establish communication directly between themselves after a system failure. This is done using a two-second restart pulse, in a manner similar to that previously described between OSCs at the DWDM layer. The power emitted during the pulse is below Hazard Level 1.

Warning **Invisible laser radiation may be emitted from the end of the unterminated fiber cable or connector. Do not view directly with optical instruments. Viewing the laser output with certain optical instruments (for example, eye loupes, magnifiers, and microscopes) within a distance of 100 mm may pose an eye hazard.** Statement 1056

Note If you must disable ALS, ensure that all fibers are installed in a restricted location. Enable ALS immediately after finishing the maintenance or installation process.

6.5.2 Fiber Cut Scenarios

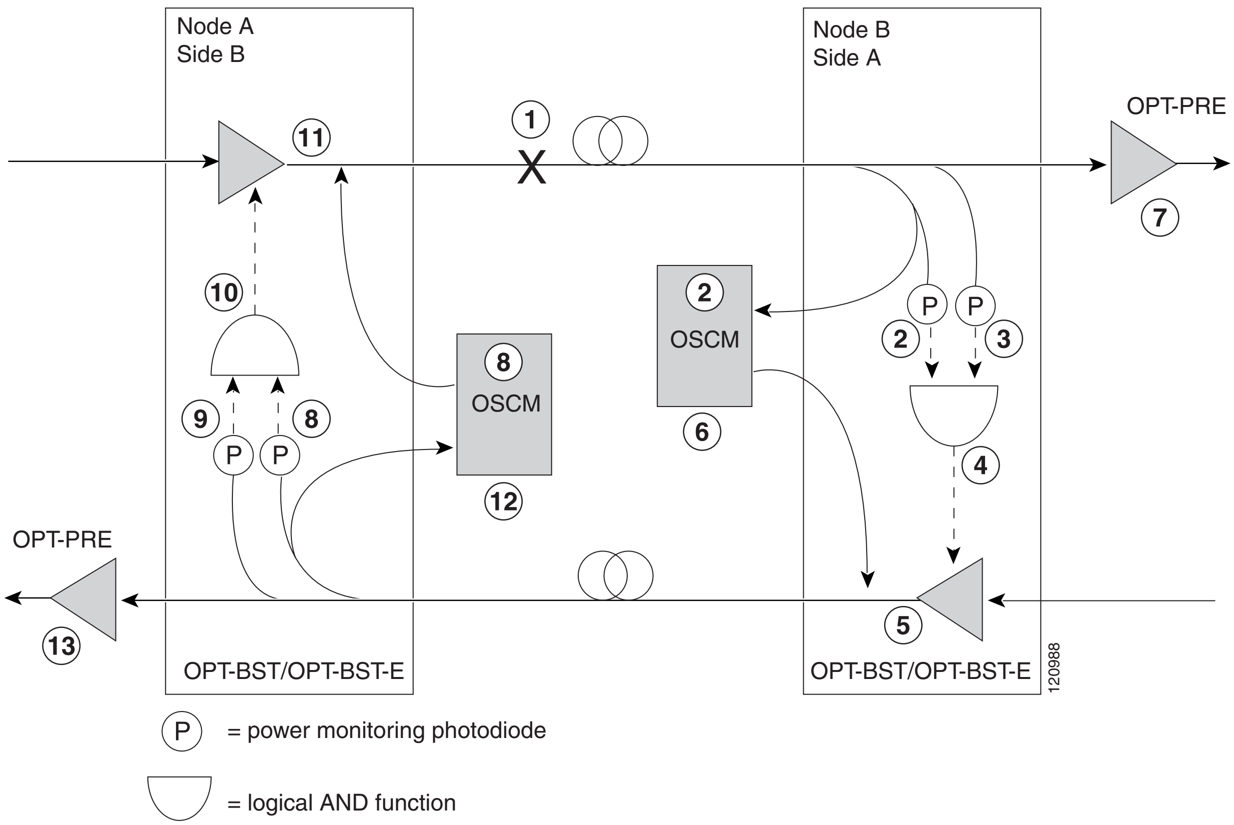
In the following paragraphs, four ALS scenarios are given:

- Nodes using OPT-BST/OPT-BST-E cards (amplified nodes)
- Nodes using OSC-CSM cards (passive nodes)
- Nodes using OPT-BST-L cards (amplified nodes)
- Nodes using OPT-AMP-L cards (amplified nodes)

6.5.2.1 Scenario 1: Fiber Cut in Nodes Using OPT-BST/OPT-BST-E Cards

Figure 6-4 shows nodes using OPT-BST/OPT-BST-E cards with a fiber cut between them.

Figure 6-4 Nodes Using OPT-BST/OPT-BST-E Cards



Two photodiodes at Node B monitor the received signal strength for the optical payload and OSC signals. When the fiber is cut, an LOS is detected at both of the photodiodes. The AND function then indicates an overall LOS condition, which causes the OPT-BST/OPT-BST-E transmitter, OPT-PRE transmitter, and OSCM lasers to shut down. This in turn leads to a LOS for both the optical payload and OSC at Node A, which causes Node A to turn off the OSCM, OPT-PRE transmitter, and OPT-BST/OPT-BST-E transmitter lasers. The sequence of events after a fiber cut is as follows (refer to the numbered circles in Figure 6-4):

1. Fiber is cut.
2. The Node B power monitoring photodiode detects a Loss of Incoming Overhead (LOS-O) on the OPT-BST/OPT-BST-E card and the OSCM card detects a LOS (OC3) at the SONET layer. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
3. The Node B power monitoring photodiode detects a Loss of Incoming Payload (LOS-P) on the OPT-BST/OPT-BST-E card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
4. On the OPT-BST/OPT-BST-E card, the simultaneous LOS-O and LOS-P detection triggers a command to shut down the amplifier. CTC reports an LOS alarm (loss of continuity), while LOS-O and LOS-P are demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
5. The OPT-BST/OPT-BST-E card amplifier is shut down within three seconds.
6. The OSCM laser is shut down.
7. The OPT-PRE card automatically shuts down due to a loss of incoming optical power.

8. The Node A power monitoring photodiode detects a LOS-O on the OPT-BST/OPT-BST-E card and the OSCM card detects a LOS (OC3) at the SONET layer. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
9. The Node A power monitoring photodiode detects a LOS-P on the OPT-BST/OPT-BST-E card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
10. On the OPT-BST/OPT-BST-E, the simultaneous LOS-O and LOS-P detection triggers a command to shut down the amplifier. CTC reports an LOS alarm (loss of continuity), while LOS-O and LOS-P are demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
11. The OPT-BST/OPT-BST-E card amplifier is shut down within three seconds.
12. The OSCM laser is shut down.
13. The Node A OPT-PRE card automatically shuts down due to a loss of incoming optical power.

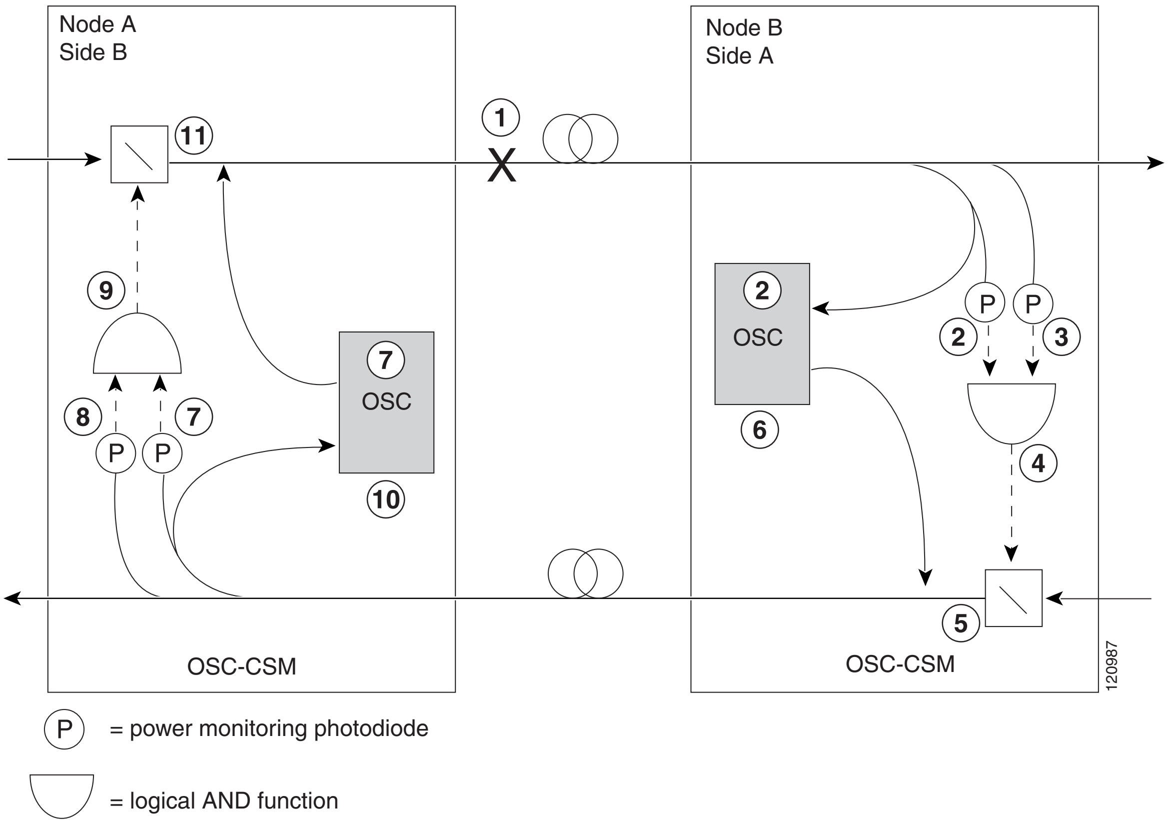
When the fiber is repaired, either an automatic or manual restart at the Node A OPT-BST/OPT-BST-E transmitter or at the Node B OPT-BST/OPT-BST-E transmitter is required. A system that has been shut down is reactivated through the use of a restart pulse. The pulse is used to signal that the optical path has been restored and transmission can begin. For example, when the far end, Node B, receives a pulse, it signals to the Node B OPT-BST/OPT-BST-E transmitter to begin transmitting an optical signal. The OPT-BST/OPT-BST-E receiver at Node A receives that signal and signals the Node A OPT-BST/OPT-BST-E transmitter to resume transmitting.

Note During a laser restart pulse, APR (see the "6.5.1 Automatic Power Reduction" section on page 6-8) ensures that the laser power does not exceed Class 1 limits.

6.5.2.2 Scenario 2: Fiber Cut in Nodes Using OSC-CSM Cards

Figure 6-5 shows nodes using OSC-CSM cards with a fiber cut between them.

Figure 6-5 Nodes Using OSC-CSM Cards



Two photodiodes at the Node B OSC-CSM card monitor the received signal strength for the received optical payload and OSC signals. When the fiber is cut, LOS is detected at both of the photodiodes. The AND function then indicates an overall LOS condition, which causes the Node B OSC laser to shut down and the optical switch to block traffic. This in turn leads to LOS for both the optical payload and OSC signals at Node A, which causes Node A to turn off the OSC laser and the optical switch to block outgoing traffic. The sequence of events after a fiber cut is as follows (refer to the numbered circles in Figure 6-5):

1. Fiber is cut.
2. The Node B power monitoring photodiode detects a LOS-O on the OSC-CSM card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
3. The Node B power monitoring photodiode detects a LOS-P on the OSC-CSM card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
4. On the OSC-CSM, the simultaneous LOS-O and LOS-P detection triggers a change in the position of the optical switch. CTC reports a LOS alarm (loss of continuity), while LOS-O and LOS-P are demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
5. The optical switch blocks outgoing traffic.
6. The OSC laser is shut down.
7. The Node A power monitoring photodiode detects a LOS-O on the OSC-CSM card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
8. The Node A power monitoring photodiode detects a LOS-P on the OSC-CSM card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.

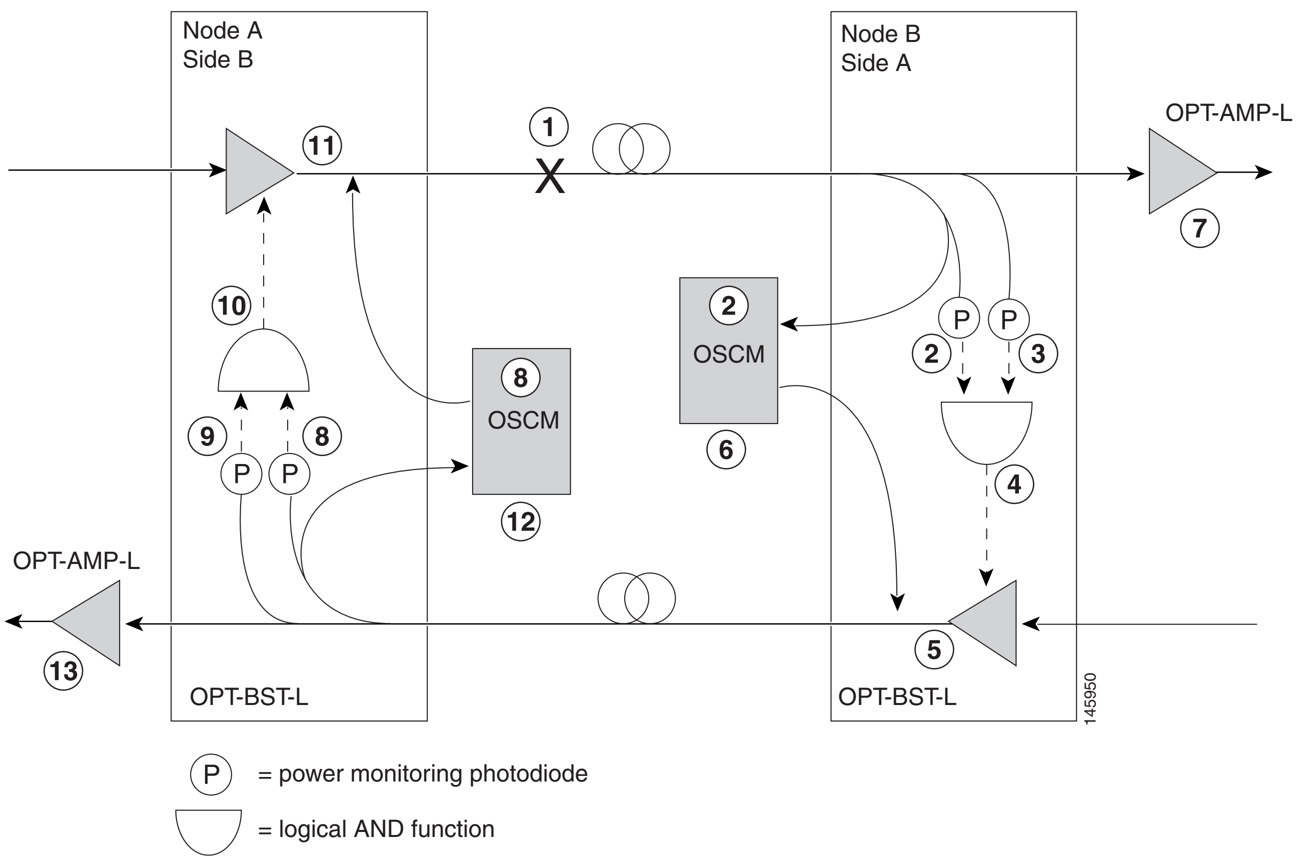
9. On the OSC-CSM, the simultaneous LOS-O and LOS-P detection triggers a change in the position of the optical switch. CTC reports a LOS alarm (loss of continuity), while LOS-O and LOS-P are demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
10. The OSC laser is shut down.
11. The optical switch blocks outgoing traffic.

When the fiber is repaired, either an automatic or manual restart at the Node A OSC-CSM OSC or at the Node B OSC-CSM OSC is required. A system that has been shut down is reactivated through the use of a restart pulse. The pulse is used to signal that the optical path has been restored and transmission can begin. For example, when the far-end Node B receives a pulse, it signals to the Node B OSC to begin transmitting its optical signal and for the optical switch to pass incoming traffic. The OSC-CSM at Node A then receives the signal and tells the Node A OSC to resume transmitting and for the optical switch to pass incoming traffic.

6.5.2.3 Scenario 3: Fiber Cut in Nodes Using OPT-BST-L Cards

Figure 6-6 shows nodes using OPT-BST-L cards with a fiber cut between them.

Figure 6-6 Nodes Using OPT-BST-L Cards



Two photodiodes at Node B monitor the received signal strength for the optical payload and OSC signals. When the fiber is cut, an LOS is detected at both of the photodiodes. The AND function then indicates an overall LOS condition, which causes the OPT-BST-L transmitter and OSCM lasers to shut down. This in turn leads to a LOS for both the optical payload and OSC at Node A, which causes Node A to turn off the OSCM OSC transmitter and OPT-BST-L amplifier lasers. The sequence of events after a fiber cut is as follows (refer to the numbered circles in Figure 6-6):

1. Fiber is cut.
2. The Node B power monitoring photodiode detects an LOS-O on the OPT-BST-L card and the OSCM card detects a LOS (OC3) at the SONET layer. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
3. The Node B power monitoring photodiode detects a LOS-P on the OPT-BST-L card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
4. On the OPT-BST-L card, the simultaneous LOS-O and LOS-P detection triggers a command to shut down the amplifier. CTC reports an LOS alarm (loss of continuity), while LOS-O and LOS-P are demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
5. The OPT-BST-L card amplifier is shut down within three seconds.
6. The OSCM laser is shut down.
7. The OPT-AMP-L card automatically shuts down due to a loss of incoming optical power.
8. The Node A power monitoring photodiode detects a LOS-O on the OPT-BST-L card and the OSCM card detects a LOS (OC3) at the SONET layer. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
9. The Node A power monitoring photodiode detects a LOS-P on the OPT-BST-L card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
10. On the OPT-BST-L, the simultaneous LOS-O and LOS-P detection triggers a command to shut down the amplifier. CTC reports an LOS alarm (loss of continuity), while LOS-O and LOS-P are demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
11. The OPT-BST-L card amplifier is shut down within three seconds.
12. The OSCM laser is shut down.
13. The Node A OPT-AMP-L card automatically shuts down due to a loss of incoming optical power.

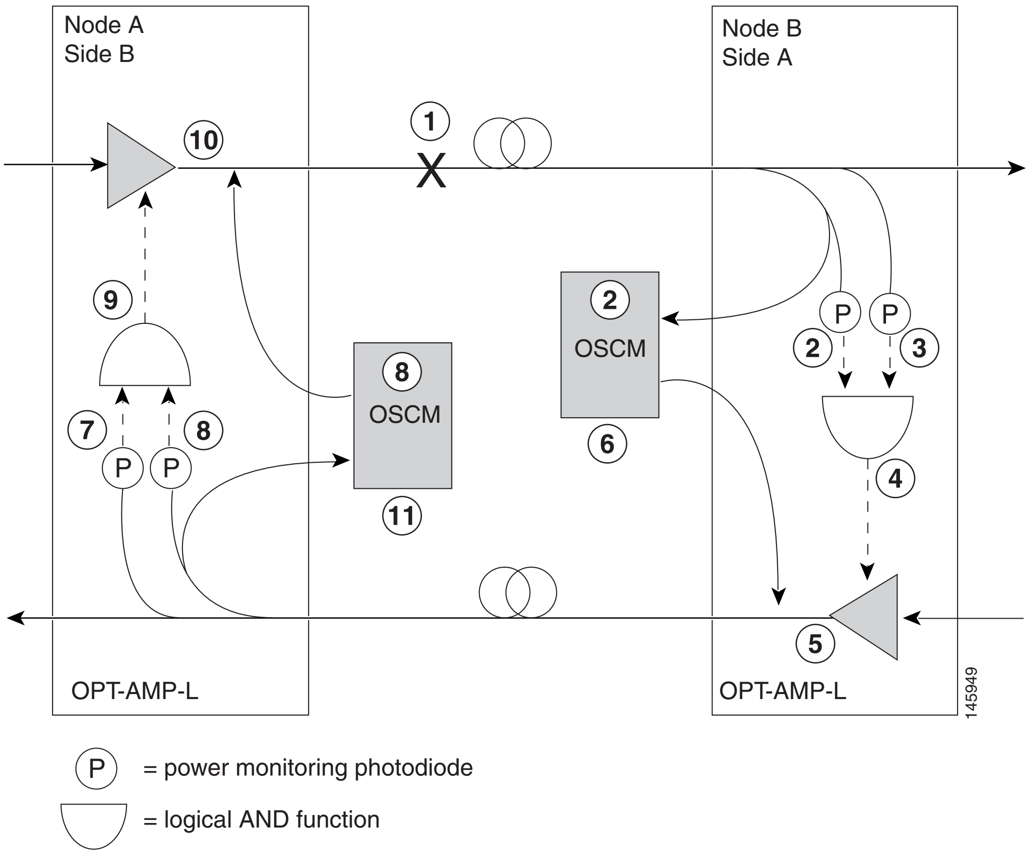
When the fiber is repaired, either an automatic or manual restart at the Node A OPT-BST-L transmitter or at the Node B OPT-BST-L transmitter is required. A system that has been shut down is reactivated through the use of a restart pulse. The pulse is used to signal that the optical path has been restored and transmission can begin. For example, when the far end, Node B, receives a pulse, it signals to the Node B OPT-BST-L transmitter to begin transmitting an optical signal. The OPT-BST-L receiver at Node A receives that signal and signals the Node A OPT-BST-L transmitter to resume transmitting.

Note During a laser restart pulse, APR (see the "6.5.1 Automatic Power Reduction" section on page 6-8) ensures that the laser power does not exceed Class 1 limits.

6.5.2.4 Scenario 4: Fiber Cut in Nodes Using OPT-AMP-L (OPT-BST Mode) Cards

Figure 6-7 shows nodes using OPT-AMP-L (in OPT-BST mode) cards with a fiber cut between them.

Figure 6-7 Nodes Using OPT-AMP-L Cards



Two photodiodes at Node B monitor the received signal strength for the optical payload and OSC signals. When the fiber is cut, an LOS is detected at both of the photodiodes. The AND function then indicates an overall LOS condition, which causes the OPT-AMP-L amplifier transmitter and OSCM OSC lasers to shut down. This in turn leads to a LOS for both the optical payload and OSC at Node A, which causes Node A to turn off the OSCM OSC and OPT-AMP-L amplifier lasers. The sequence of events after a fiber cut is as follows (refer to the numbered circles in Figure 6-7):

1. Fiber is cut.
2. The Node B power monitoring photodiode detects an LOS-O on the OPT-AMP-L card and the OSCM card detects a LOS (OC3) at the SONET layer. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
3. The Node B power monitoring photodiode detects an LOS-P on the OPT-AMP-L card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
4. On the OPT-AMP-L card, the simultaneous LOS-O and LOS-P detection triggers a command to shut down the amplifier. CTC reports an LOS alarm (loss of continuity), while LOS-O and LOS-P are demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
5. The OPT-AMP-L card amplifier is shut down within three seconds.
6. The OSCM laser is shut down.
7. The Node A power monitoring photodiode detects a LOS-O on the OPT-AMP-L card and the OSCM card detects a LOS (OC3) at the SONET layer. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.

8. The Node A power monitoring photodiode detects a LOS-P on the OPT-AMP-L card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
9. On the OPT-AMP-L, the simultaneous LOS-O and LOS-P detection triggers a command to shut down the amplifier. CTC reports an LOS alarm (loss of continuity), while LOS-O and LOS-P are demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
10. The OPT-AMP-L card amplifier is shut down within three seconds.
11. The OSCM laser is shut down.

When the fiber is repaired, either an automatic or manual restart at the Node A OPT-AMP-L transmitter or at the Node B OPT-AMP-L transmitter is required. A system that has been shut down is reactivated through the use of a restart pulse. The pulse is used to signal that the optical path has been restored and transmission can begin. For example, when the far end, Node B, receives a pulse, it signals to the Node B OPT-AMP-L transmitter to begin transmitting an optical signal. The OPT-AMP-L receiver at Node A receives that signal and signals the Node A OPT-AMP-L transmitter to resume transmitting.

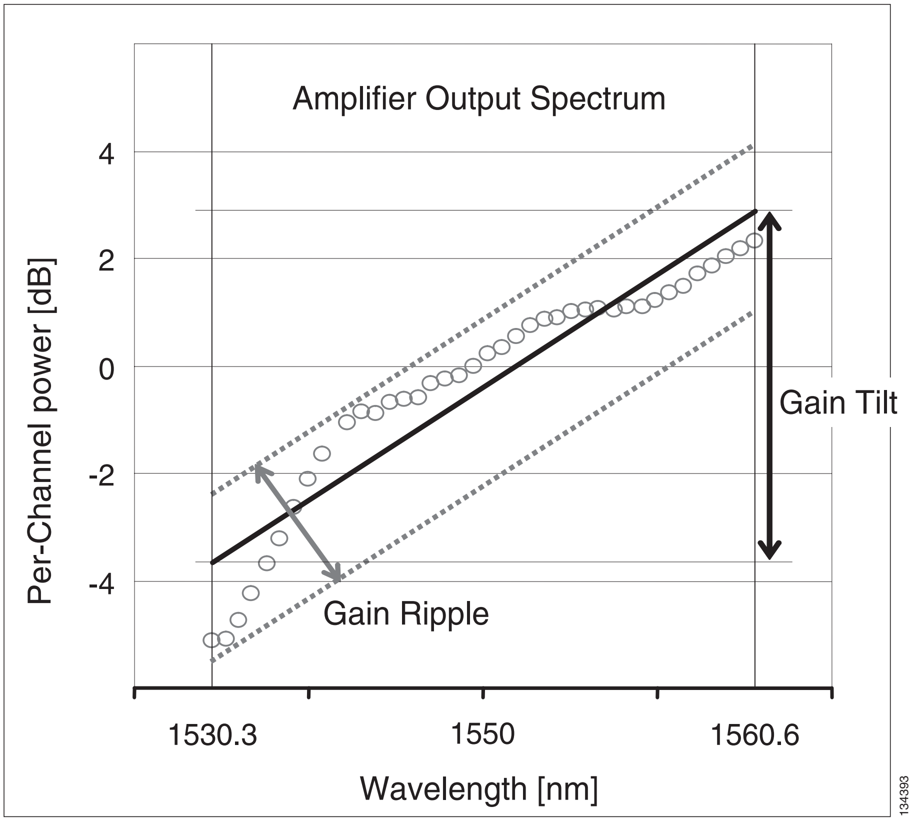
Note During a laser restart pulse, APR (see the "6.5.1 Automatic Power Reduction" section on page 6-8) ensures that the laser power does not exceed Class 1 limits.

6.6 Network-Level Gain-Tilt Management of Optical Amplifiers

The ability to control and adjust per-channel optical power equalization is a principal feature of ONS 15454 DWDM metro core network applications. A critical parameter to assure optical spectrum equalization throughout the DWDM system is the gain flatness of erbium-doped fiber amplifiers (EDFAs).

Two items, gain tilt and gain ripple, are factors in the power equalization of optical amplifier cards such as the OPT-BST and OPT-PRE. Figure 6-8 shows a graph of the amplifier output power spectrum and how it is affected by gain tilt and gain ripple.

Figure 6-8 Effect of Gain Ripple and Gain Tilt on Amplifier Output Power



Gain ripple and gain tilt are defined as follows:

- Gain ripple is random and depends on the spectral shape of the amplifier optical components.
- Gain tilt is systematic and depends on the gain setpoint (Gstp) of the optical amplifier, which is a mathematical function F(Gstp) that relates to the internal amplifier design.

Gain tilt is the only contribution to the power spectrum disequalization that can be compensated at the card level. A VOA internal to the amplifier can be used to compensate for gain tilt.

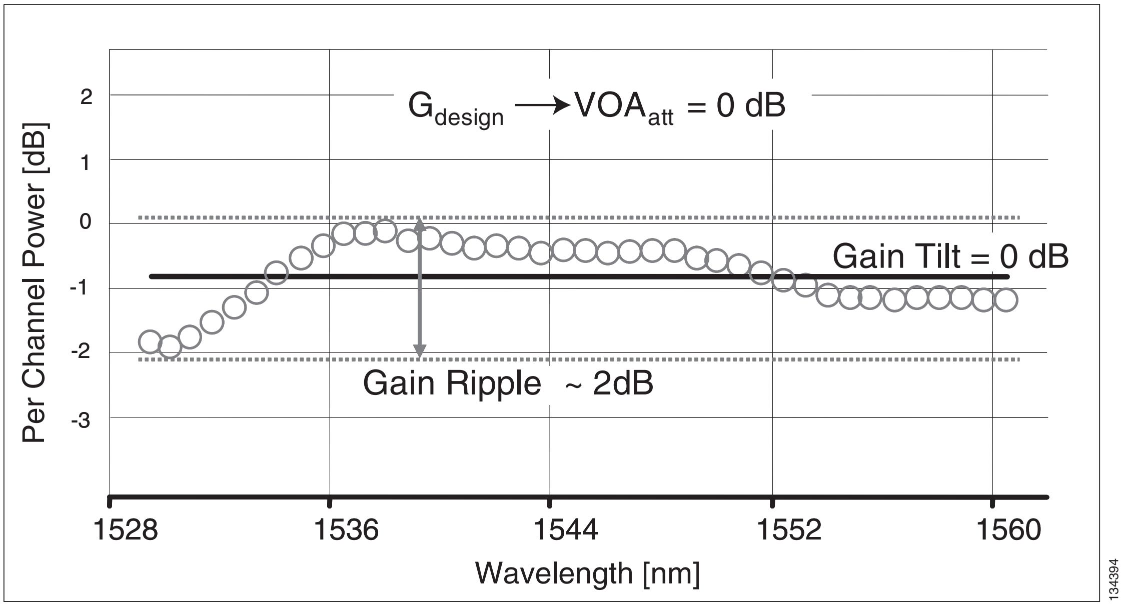
An optical spectrum analyzer (OSA) is used to acquire the output power spectrum of an amplifier. The OSA shows the peak-to-peak difference between the maximum and minimum power levels, and takes into account the contributions of both gain tilt and gain ripple.

Note Peak-to-peak power acquisition using an OSA cannot be used to measure the gain tilt, because gain ripple itself is a component of the actual measurement.

6.6.1 Gain Tilt Control at the Card Level

The OPT-BST and OPT-PRE amplifier cards have a flat output (gain tilt = 0 dB) for only a specific gain value (Gdesign), based on the internal optical design (see Figure 6-9).

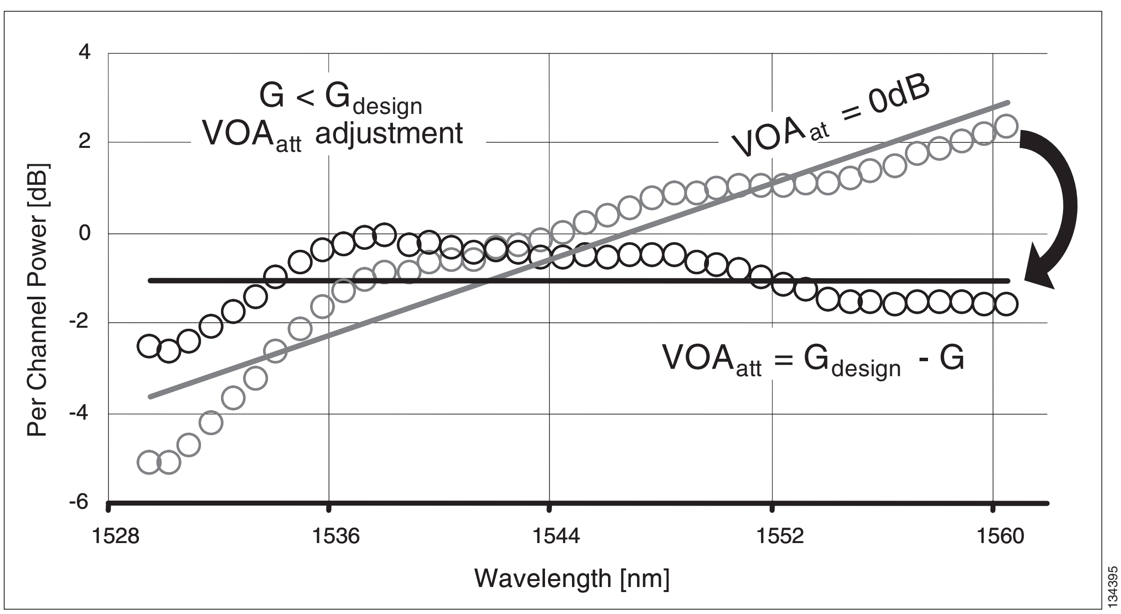
Figure 6-9 Flat Gain (Gain Tilt = 0 dB)



If the working gain setpoint of the amplifier is different from Gdesign, the output spectrum begins to suffer a gain tilt variation.

In order to compensate for the absolute value of the increase of the spectrum tilt, the OPT-BST and OPT-PRE cards automatically adjust the attenuation of the VOA to maintain a flat power profile at the output, as shown in Figure 6-10.

Figure 6-10 Effect of VOA Attenuation on Gain Tilt



The VOA attenuator automatic regulation guarantees (within limits) a zero tilt condition in the EDFA for a wide range of possible gain setpoint values.

Table 6-2 shows the flat output gain range limits for the OPT-BST and OPT-PRE cards, as well as the maximum (worst case) values of gain tilt and gain ripple expected in the specific gain range. OPT-AMP-L card can also function as an OPT-BST or OPT-PRE.

Table 6-2 Flat Output Gain Range Limits

Amplifier Card Type	Flat Output Gain Range	Gain Tilt (Maximum)	Gain Ripple (Maximum)
OPT-BST	G < 20 dB	0.5 dB	1.5 dB
OPT-PRE	G < 21 dB	0.5 dB	1.5 dB

If the operating gain value is outside of the range shown in Table 6-2, the EDFA introduces a tilt contribution for which the card itself cannot directly compensate. This condition is managed in different ways, depending the amplifier card type:

- OPT-BST—The OPT-BST amplifier is, by card design, not allowed to work outside the zero tilt range. Cisco MetroPlanner validates network designs using the OPT-BST amplifier card only when the gain is less than or equal to 20 dB.
- OPT-PRE—Cisco MetroPlanner allows network designs even if the operating gain value is equal to or greater than 21 dB. In this case, a system-level tilt compensation strategy is adopted by the DWDM system. A more detailed explanation is given in the "6.6.2 System Level Gain Tilt Control" section on page 6-19.

6.6.2 System Level Gain Tilt Control

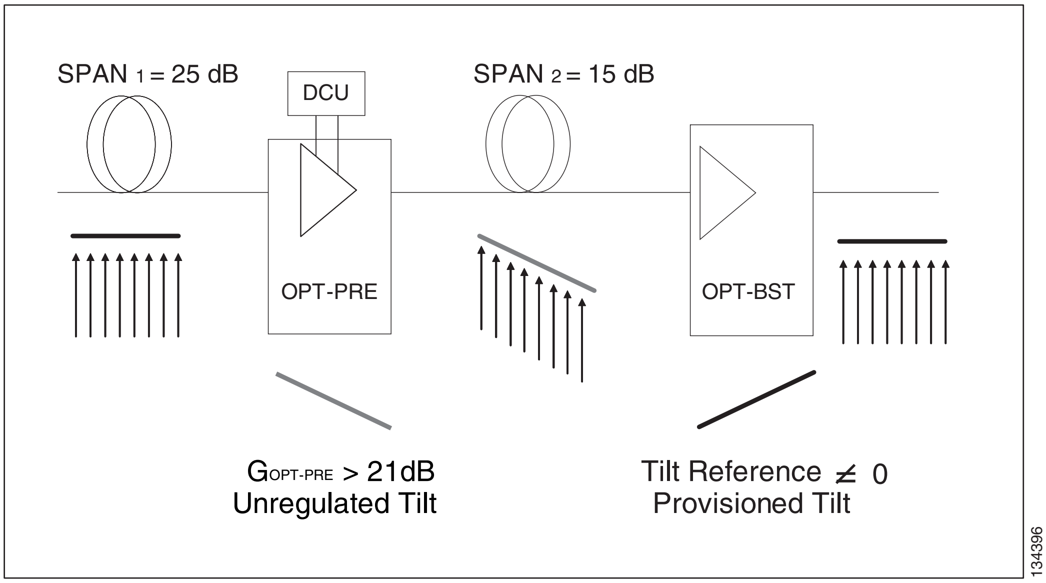
System level gain tilt control for OPT-PRE cards is achievable with two main scenarios:

- Without an ROADM node
- With an ROADM node

6.6.2.1 System Gain Tilt Compensation Without ROADM Nodes

When an OPT-PRE card along a specific line direction (west-to-east or east-to-west) is working outside the flat output gain range (G > 21 dB), the unregulated tilt is compensated for in spans not connected to ROADM nodes by configuring an equal but opposite tilt on one or more of the amplifiers in the downstream direction. The number of downstream amplifiers involved depends on the amount of tilt compensation needed and the gain setpoint of the amplifiers that are involved. See Figure 6-11.

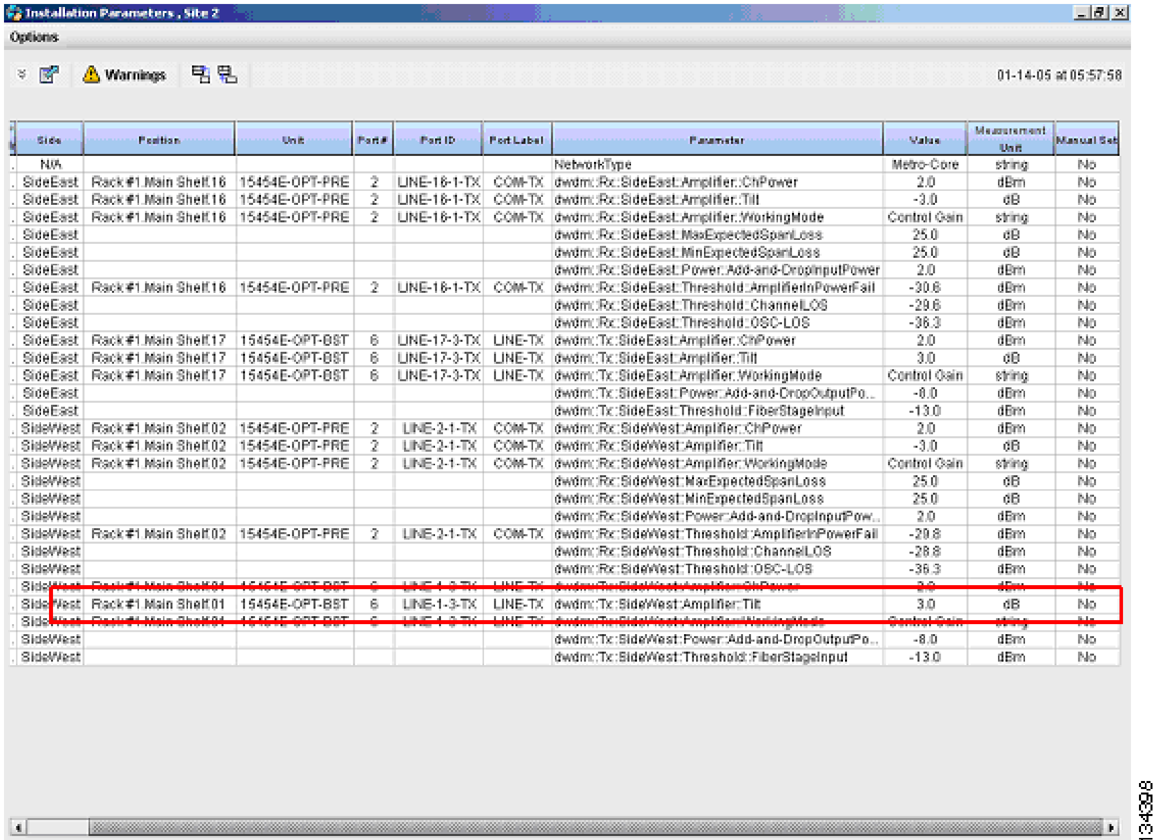
Figure 6-11 System Tilt Compensation Without an ROADM Node



The proper tilt reference value is calculated by Cisco MetroPlanner and inserted in the Installation Parameter List imported during the node turn-up process (see the "Turn Up a Node" chapter in the *Cisco ONS 15454 DWDM Procedure Guide*). For both OPT-PRE and OPT-BST cards, the provisionable gain tilt reference range is between –3 dB and +3 dB.

During the automatic node setup (ANS) procedure, the tilt value for the OPT-BST or OPT-PRE card is provisioned by the TCC2/TCC2P card (see Figure 6-12). The provisioned tilt reference value is reported in the CTC OPT-PRE or OPT-BST card view (in the Provisioning > Opt. Ampli. Line > Parameters > Tilt Reference tab).

Figure 6-12 Cisco MetroPlanner Installation Parameters



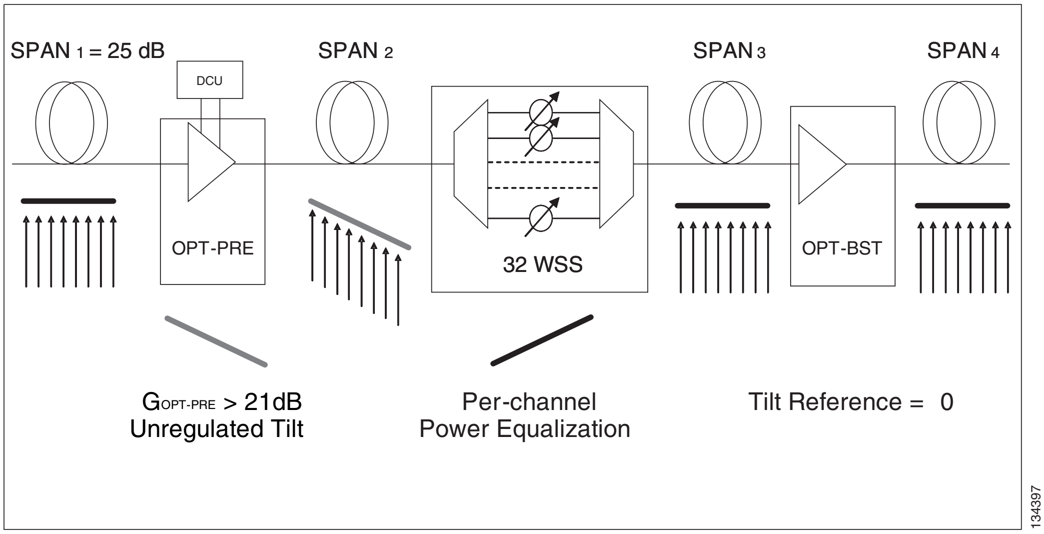
Side	Position	Unit	Port#	Port ID	Port Label	Parameter	Value	Measurement Unit	Manual Set
N/A						NetworkType	Metro-Core	string	No
SideEast	Rack#1.Main Shelf.16	15454E-OPT-PRE	2	LINE-16-1-TX	COM-TX	dwdm::Rx::SideEast::Amplifier::ChPower	2.0	dBm	No
SideEast	Rack#1.Main Shelf.16	15454E-OPT-PRE	2	LINE-16-1-TX	COM-TX	dwdm::Rx::SideEast::Amplifier::Tilt	-3.0	dB	No
SideEast	Rack#1.Main Shelf.16	15454E-OPT-PRE	2	LINE-16-1-TX	COM-TX	dwdm::Rx::SideEast::Amplifier::WorkingMode	Control Gain	string	No
SideEast						dwdm::Rx::SideEast::MaxExpectedSpanLoss	25.0	dB	No
SideEast						dwdm::Rx::SideEast::MinExpectedSpanLoss	25.0	dB	No
SideEast						dwdm::Rx::SideEast::Power::Add-and-DropInputPower	2.0	dBm	No
SideEast	Rack#1.Main Shelf.16	15454E-OPT-PRE	2	LINE-16-1-TX	COM-TX	dwdm::Rx::SideEast::Threshold::AmplifierInPowerFail	-30.6	dBm	No
SideEast						dwdm::Rx::SideEast::Threshold::ChannelLOS	-29.6	dBm	No
SideEast						dwdm::Rx::SideEast::Threshold::OSC-LOS	-36.3	dBm	No
SideEast	Rack#1.Main Shelf.17	15454E-OPT-BST	6	LINE-17-3-TX	LINE-TX	dwdm::Tx::SideEast::Amplifier::ChPower	2.0	dBm	No
SideEast	Rack#1.Main Shelf.17	15454E-OPT-BST	6	LINE-17-3-TX	LINE-TX	dwdm::Tx::SideEast::Amplifier::Tilt	3.0	dB	No
SideEast	Rack#1.Main Shelf.17	15454E-OPT-BST	6	LINE-17-3-TX	LINE-TX	dwdm::Tx::SideEast::Amplifier::WorkingMode	Control Gain	string	No
SideEast						dwdm::Tx::SideEast::Power::Add-and-DropOutputPo...	-8.0	dBm	No
SideEast						dwdm::Tx::SideEast::Threshold::FiberStageInput	-13.0	dBm	No
SideWest	Rack#1.Main Shelf.02	15454E-OPT-PRE	2	LINE-2-1-TX	COM-TX	dwdm::Rx::SideWest::Amplifier::ChPower	2.0	dBm	No
SideWest	Rack#1.Main Shelf.02	15454E-OPT-PRE	2	LINE-2-1-TX	COM-TX	dwdm::Rx::SideWest::Amplifier::Tilt	-3.0	dB	No
SideWest	Rack#1.Main Shelf.02	15454E-OPT-PRE	2	LINE-2-1-TX	COM-TX	dwdm::Rx::SideWest::Amplifier::WorkingMode	Control Gain	string	No
SideWest						dwdm::Rx::SideWest::MaxExpectedSpanLoss	25.0	dB	No
SideWest						dwdm::Rx::SideWest::MinExpectedSpanLoss	25.0	dB	No
SideWest						dwdm::Rx::SideWest::Power::Add-and-DropInputPow...	2.0	dBm	No
SideWest	Rack#1.Main Shelf.02	15454E-OPT-PRE	2	LINE-2-1-TX	COM-TX	dwdm::Rx::SideWest::Threshold::AmplifierInPowerFail	-29.8	dBm	No
SideWest						dwdm::Rx::SideWest::Threshold::ChannelLOS	-28.8	dBm	No
SideWest						dwdm::Rx::SideWest::Threshold::OSC-LOS	-36.3	dBm	No
SideWest	Rack#1.Main Shelf.01	15454E-OPT-BST	6	LINE-1-3-TX	LINE-TX	dwdm::Tx::SideWest::Amplifier::ChPower	2.0	dBm	No
SideWest	Rack#1.Main Shelf.01	15454E-OPT-BST	6	LINE-1-3-TX	LINE-TX	dwdm::Tx::SideWest::Amplifier::Tilt	3.0	dB	No
SideWest	Rack#1.Main Shelf.01	15454E-OPT-BST	6	LINE-1-3-TX	LINE-TX	dwdm::Tx::SideWest::Amplifier::WorkingMode	Control Gain	string	No
SideWest						dwdm::Tx::SideWest::Power::Add-and-DropOutputPo...	-8.0	dBm	No
SideWest						dwdm::Tx::SideWest::Threshold::FiberStageInput	-13.0	dBm	No

6.6.2.2 System Gain Tilt Compensation With ROADM Nodes

When an ROADM node is present in the network, as shown in Figure 6-13, a per-channel dynamic gain equalization can be performed. Both gain tilt and gain ripple are completely compensated using the following techniques:

- Implementing the per-channel VOAs present inside the 32WSS
- Operating in Power Control Mode with the specific power setpoint designed by Cisco MetroPlanner

Figure 6-13 System Tilt Compensation With an ROADM Node



6.7 Automatic Node Setup

ANS is a TCC2/TCC2P function that adjusts values of the variable optical attenuators (VOAs) on the DWDM channel paths to equalize the per-channel power at the amplifier input. This power equalization means that at launch, all the channels have the same amplifier power level, independent from the input signal on the client interface and independent from the path crossed by the signal inside the node. This equalization is needed for two reasons:

- Every path introduces a different penalty on the signal that crosses it.
- Client interfaces add their signal to the ONS 15454 DWDM ring with different power levels.

To support ANS, the integrated VOAs and photodiodes are provided in the following ONS 15454 DWDM cards:

- AD-xB-xx.x card express and drop paths
- AD-xC-xx.x card express and add paths
- 4MD-xx.x card input ports
- 32MUX-O card input ports
- 32WSS card input ports
- 32DMX-O and 32DMX card output ports

Optical power is equalized by regulating the VOAs. Based on the expected per-channel power, ANS automatically calculates the VOA values by:

- Reconstructing the different channel paths
- Retrieving the path insertion loss (stored in each DWDM transmission element)

VOAs operate in one of three working modes:

- Automatic VOA Shutdown—In this mode, the VOA is set at maximum attenuation value. Automatic VOA shutdown mode is set when the channel is not provisioned to ensure system reliability in the event that power is accidentally inserted.

- Constant Attenuation Value—In this mode, the VOA is regulated to a constant attenuation independent from the value of the input signal. Constant attenuation value mode is set on the following VOAs:
  - OADM band card VOAs on express and drop paths (as operating mode)
  - OADM channel card VOAs during power insertion startup
  - Multiplexer/Demultiplexer card VOAs during power insertion startup
- Constant Power Value—In this mode, the VOA values are automatically regulated to keep a constant output power when changes occur to the input power signal. This working condition is set on OADM channel card VOAs as "operating" and on 32MUX-O, 32WSS, 32DMX-O, and 32DMX card VOAs as "operating mode."

In the normal operating mode, OADM band card VOAs are set to a constant attenuation, while OADM channel card VOAs are set to a constant power. ANS requires the following VOA provisioning parameters to be specified:

- Target attenuation (OADM band card VOA and OADM channel card startup)
- Target power (channel VOA)

To allow you to modify ANS values based on your DWDM deployment, provisioning parameters are divided into two contributions:

- Reference Contribution— (Display only) Set by ANS.
- Calibration Contribution—Set by user.

The ANS equalization algorithm requires the following knowledge of the DWDM transmission element layout:

- The order in which the DWDM elements are connected together on the express paths
- Channels that are dropped and added
- Channels or bands that have been configured as pass-through

ANS assumes that every DWDM port has a line direction parameter that is either west to east (W-E) or east to west (E-W). ANS automatically configures the mandatory optical connections according to following main rules:

- Cards equipped in Slots 1 to 6 have a drop section facing west.
- Cards equipped in Slots 12 to 17 have a drop section facing east.
- Contiguous cards are cascaded on the express path.
- 4MD-xx.x and AD-xB-xx.x are always optically coupled.
- A 4MD-xx.x absence forces an optical pass-through connection.
- Transmit (Tx) ports are always connected to receive (Rx) ports.

Optical patchcords are passive devices that are not autodiscovered by ANS. However, optical patchcords are used to build the alarm correlation graph. From CTC or TL1 you can:

- Calculate the default connections on the NE.
- Retrieve the list of existing connections.
- Retrieve the list of free ports.
- Create new connections or modify existing ones.
- Launch ANS.

After you launch ANS, one of the following statuses is provided for each ANS parameter:

- Success - Changed—The parameter setpoint was recalculated successfully.
- Success - Unchanged—The parameter setpoint did not need recalculation.
- Not Applicable—The parameter setpoint does not apply to this node type.
- Fail - Out of Range—The calculated setpoint is outside the expected range.
- Fail - Port in IS State—The parameter could not be calculated because the port is in service.

Optical connections are identified by the two termination points, each with an assigned slot and port. ANS checks that a new connection is feasible (according to embedded connection rules) and returns a denied message in the case of a violation.

ANS requires provisioning of the expected wavelength. When provisioning the expected wavelength, the following rules apply:

- The card name is generically characterized by the card family, and not the particular wavelengths supported (for example, AD-2C for all 2-channel OADMs).
- At the provisioning layer, you can provision a generic card for a specific slot using CTC or TL1.
- Wavelength assignment is done at the port level.
- An equipment mismatch alarm is raised when a mismatch between the identified and provisioned value occurs. The default value for the provisioned attribute is AUTO.

6.7.1 Automatic Node Setup Parameters

All ONS 15454 ANS parameters are calculated by Cisco MetroPlanner for nodes configured for metro core networks. (Parameters must be configured manually for metro access nodes.) Cisco MetroPlanner exports the calculated parameters to an ASCII file called NE Update. In CTC, you can import the NE Update file to automatically provision the node. Table 6-3 shows ANS parameters arranged in east and west, transmit and receive groups.

Table 6-3 ANS Parameters

Direction	ANS Parameters
West Side - Receive	• West Side Rx Max Expected Span Loss • West Side Rx Min Expected Span Loss • West Side Rx Amplifier Working Mode • West Side Rx Amplifier Ch Power • West Side Rx Amplifier Gain • West Side Rx Amplifier Tilt • West Side OSC LOS Threshold • West Side Channel LOS Threshold • West Side Rx Amplifier Input Power Fail Th • West Side Add and Drop Stage Input Power • West Side Add and Drop Stage Drop Power • West Side Add and Drop Stage Band (*n*) Drop Power (*n* = 1 to 8) • West Side Add and Drop Stage Channel (*n*) Drop Power (*n* = 1 to 32)
East Side - Receive	• East Side Rx Max Expected Span Loss • East Side Rx Min Expected Span Loss • East Side Rx Amplifier Working Mode • East Side Rx Amplifier Ch Power • East Side Rx Amplifier Gain • East Side Rx Amplifier Tilt • East Side OSC LOS Threshold • East Side Channel LOS Threshold • East Side Rx Amplifier Input Power Fail Th • East Side Add and Drop Stage Input Power • East Side Add and Drop Stage Drop Power • East Side Add and Drop Stage Band (*n*) Drop Power (*n* = 1 to 8) • East Side Add and Drop Stage Channel (*n*) Drop Power (*n* = 1 to 32)

Table 6-3 ANS Parameters (continued)

Direction	ANS Parameters
West Side - Transmit	• West Side Tx Amplifier Working Mode • West Side Tx Amplifier Ch Power • West Side Tx Amplifier Gain • West Side Tx Amplifier Tilt • West Side Fiber Stage Input Threshold • West Side Add and Drop Stage Output Power • West Side Add and Drop Stage By-Pass Power
East Side - Transmit	• East Side Tx Amplifier Working Mode • East Side Tx Amplifier Ch Power • East Side Tx Amplifier Gain • East Side Tx Amplifier Tilt • East Side Fiber Stage Input Threshold • East Side Add and Drop Stage Output Power • East Side Add and Drop Stage By-Pass Power

6.7.2 View and Provision ANS Parameters

All ANS parameters can be viewed and provisioned from the node view Provisioning > WDM-ANS > Provisioning tab, shown in Figure 6-14. The WDM-ANS > Provisioning > Provisioning tab presents the parameters in the following tree view:

root

+/– East

    +/– Receiving

        +/– Amplifier

        +/– Power

        +/– Threshold

    +/– Transmitting

        +/– Amplifier

        +/– Power

        +/– Threshold

+/– West

    +/– Receiving

        +/– Amplifier

        +/– Power

        +/– Threshold

    +/– Transmitting

+/– Amplifier

+/– Power

+/– Threshold

Figure 6-14 WDM-ANS Provisioning

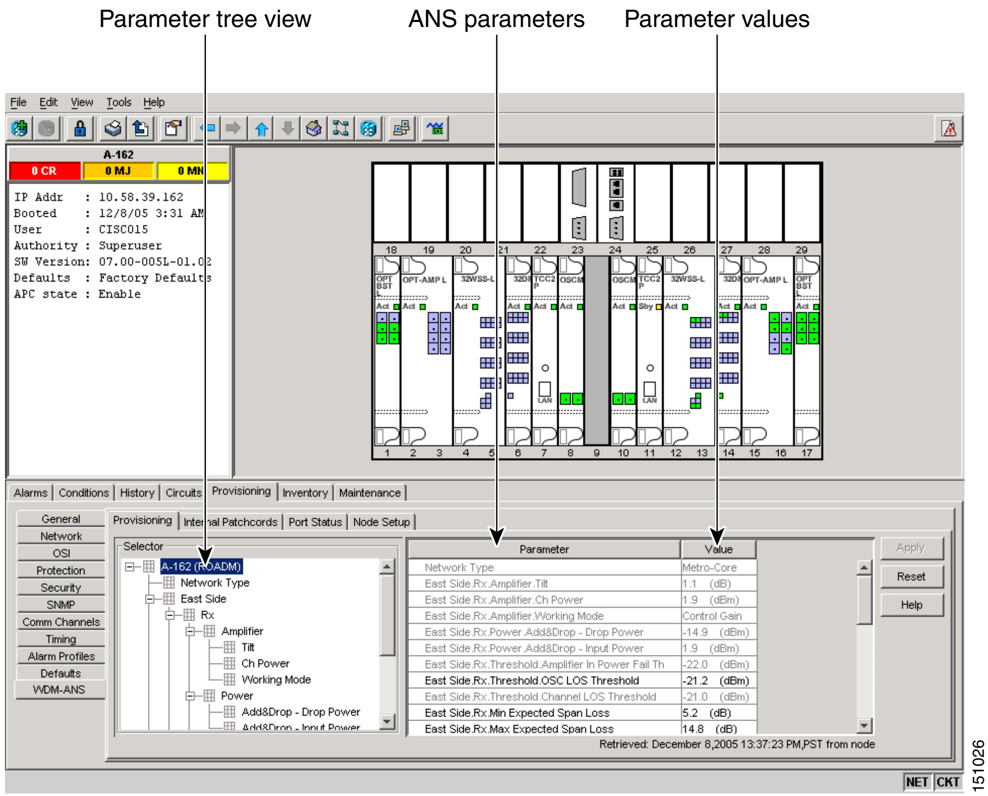


Table 6-4 shows the available parameters based on platform, line direction, and functional group.

Table 6-4 ANS-WDM > Provisioning Subtab Parameters

Tree Element	Parameters
root	Network Type (dwdm)
root +/– East +/– Receiving	East Side Rx Max Expected Span Loss
	East Side Rx Min Expected Span Loss
root +/– East +/– Receiving +/– Amplifier	East Side Rx Amplifier Working Mode
	East Side Rx Amplifier Ch Power
	East Side Rx Amplifier Gain
	East Side Rx Amplifier Tilt

Table 6-4 ANS-WDM > Provisioning Subtab Parameters (continued)

Tree Element	Parameters
root +/– East +/– Receiving +/– Power	East Side Add&Drop - Input Power East Side Add&Drop - Drop Power East Side Band *n* Drop Power (*n* = 1–8) East Side Channel *n* Drop Power East (*n* = 1–32)
root +/– East +/– Receiving +/– Threshold	East Side OSC LOS Threshold East Side Channel LOS Threshold East Side Rx Amplifier In Power Fail Th
root +/– East +/– Transmitting +/– Amplifier	East Side Tx Amplifier Working Mode East Side Tx Amplifier Ch Power East Side Tx Amplifier Gain East Side Tx Amplifier Tilt
root +/– East +/– Transmitting +/– Power	East Side Add&Drop - Output Power East Side Add&Drop - By-Pass Power
root +/– East +/– Transmitting +/– Threshold	East Side Fiber Stage Input Threshold
root +/– West +/– Receiving	West Side Rx Max Expected Span Loss West Side Rx Min Expected Span Loss
root +/– West +/– Receiving +/– Amplifier	West Side Rx Amplifier Working Mode West Side Rx Amplifier Ch Power West Side Rx Amplifier Gain West Side Rx Amplifier Tilt
root +/– West +/– Receiving +/– Power	West Side Add&Drop - Input Power West Side Add&Drop - Drop Power West Side Band *n* Drop Power (*n* = 1–8) West Side Channel *n* Drop Power (*n* = 1–32)
root +/– West +/– Receiving +/– Threshold	West Side OSC LOS Threshold West Side Channel LOS Threshold West Side Rx Amplifier In Power Fail Th
root +/– West +/– Transmitting +/– Amplifier	West Side Tx Amplifier Working Mode West Side Tx Amplifier Ch Power West Side Tx Amplifier Gain West Side Tx Amplifier Tilt
root +/– East +/– Transmitting +/– Power	West Side Add&Drop - Output Power West Side Add&Drop - By-Pass Power
root +/– West +/– Transmitting +/– Threshold	West Side Fiber Stage Input Threshold

The ANS parameters that appear in the WDM-ANS > Provisioning tab depend on the node type. Table 6-5 shows the DWDN node types and their ANS parameters.

Table 6-5 ANS Parameters By Node Type

Node Type	Parameter Group	Parameters
Hub	Network	Network Type
	Span Loss	East and West Expected Span Loss
	Amplifier Tx	East and West Side Transmit Amplifier Working Mode East and West Side Transmit Amplifier Channel Power East and West Side Transmit Amplifier Gain East and West Side Transmit Amplifier Tilt
	Amplifier Rx	East and West Side Receive Amplifier Working Mode East and West Side Receive Amplifier Channel Power East and West Side Receive Amplifier Gain East and West Side Receive Amplifier Tilt
	Thresholds Tx	East and West Side Fiber Stage Input Threshold
	Thresholds Rx	East and West Side Osc Los Threshold East and West Side Channel Los Threshold East and West Side Receive Amplifier Input Power Fail
	Power	East and West Side Add&Drop - Input Power East and West Side Add&Drop - Output Power East and West Side Add&Drop - By-Pass Power East and West Side Channel (*n*) Drop Power where n = 1-32

Table 6-5 ANS Parameters By Node Type (continued)

Node Type	Parameter Group	Parameters
Terminal	Network	Network Type
	Span Loss	East or West Expected Span Loss
	Amplifier Tx	East or West Side Transmit Amplifier Working Mode East or West Side Transmit Amplifier Channel Power East or West Side Transmit Amplifier Gain East or West Side Transmit Amplifier Tilt
	Amplifier Rx	East or West Side Receive Amplifier Working Mode East or West Side Receive Amplifier Channel Power East or West Side Receive Amplifier Gain East or West Side Receive Amplifier Tilt
	Thresholds Tx	East or West Side Fiber Stage Input Threshold
	Thresholds Rx	East or West Side Osc Los Threshold East or West Side Channel Los Threshold East or West Side Receive Amplifier Input Power Fail
	Power	East or West Side Add&Drop - Input Power East or West Side Add&Drop - Output Power East or West Side Channel (*n*) Drop Power (*n* = 1–32)
Flexible Channel Count Terminal	Network	Network Type
	Span Loss	East and West Expected Span Loss
	Amplifier Tx	East and West Side Transmit Amplifier Working Mode East and West Side Transmit Amplifier Channel Power East and West Side Transmit Amplifier Gain East and West Side Transmit Amplifier Tilt
	Amplifier Rx	East and West Side Receive Amplifier Working Mode East and West Side Receive Amplifier Channel Power East and West Side Receive Amplifier Gain East and West Side Receive Amplifier Tilt
	Thresholds Tx	East and West Side Fiber Stage Input Threshold
	Thresholds Rx	East and West Side Osc Los Threshold East and West Side Channel Los Threshold East and West Side Receive Amplifier Input Power Fail
	Power	East and West Side Add&Drop - Input Power East and West Side Add&Drop - Output Power East and West Side Band (*n*) Drop Power (*n* = 1–8)

Table 6-5 ANS Parameters By Node Type (continued)

Node Type	Parameter Group	Parameters
OADM	Network	Network Type
	Span Loss	East and West Expected Span Loss
	Amplifier Tx	East and West Side Transmit Amplifier Working Mode East and West Side Transmit Amplifier Channel Power East and West Side Transmit Amplifier Gain East and West Side Transmit Amplifier Tilt
	Amplifier Rx	East and West Side Receive Amplifier Working Mode East and West Side Receive Amplifier Channel Power East and West Side Receive Amplifier Gain East and West Side Receive Amplifier Tilt
	Thresholds Tx	East and West Side Fiber Stage Input Threshold
	Thresholds Rx	East and West Side Osc Los Threshold East and West Side Channel Los Threshold East and West Side Receive Amplifier Input Power Fail
	Power	East and West Side Add&Drop - Input Power East and West Side Add&Drop - Output Power East and West Side Band (*n*) Drop Power (*n* = 1–8)
Line Amplifier	Network	Network Type
	Span Loss	East and West Expected Span Loss
	Amplifier Tx	East and West Side Transmit Amplifier Working Mode East and West Side Transmit Amplifier Channel Power East and West Side Transmit Amplifier Gain East and West Side Transmit Amplifier Tilt
	Amplifier Rx	East and West Side Receive Amplifier Working Mode East and West Side Receive Amplifier Channel Power East and West Side Receive Amplifier Gain East and West Side Receive Amplifier Tilt
	Thresholds Tx	East and West Side Fiber Stage Input Threshold
	Thresholds Rx	East and West Side Osc Los Threshold East and West Side Channel Los Threshold East and West Side Receive Amplifier Input Power Fail

Table 6-5 ANS Parameters By Node Type (continued)

Node Type	Parameter Group	Parameters
ROADM	Network	Network Type
	Span Loss	East and West Expected Span Loss
	Amplifier Tx	East and West Side Transmit Amplifier Working Mode East and West Side Transmit Amplifier Channel Power East and West Side Transmit Amplifier Gain East and West Side Transmit Amplifier Tilt
	Amplifier Rx	East and West Side Receive Amplifier Working Mode East and West Side Receive Amplifier Channel Power East and West Side Receive Amplifier Gain East and West Side Receive Amplifier Tilt
	Thresholds Tx	East and West Side Fiber Stage Input Threshold
	Thresholds Rx	East and West Side Osc Los Threshold East and West Side Channel Los Threshold East and West Side Receive Amplifier Input Power Fail
	Power	East and West Side Add&Drop - Input Power (if a 32DMX east/west card is installed) East and West Side Add&Drop - Output Power East and West Side Add&Drop - Drop Power (if a 32DMX east/west card is installed) East and West Side Channel (n) Drop Power (if a 32DMX-O east/west card is installed) (*n* = 1–32)

Table 6-6 shows the following information for each ONS 15454 ANS parameter:

- Min—Minimum value in decibels.
- Max—Maximum value in decibels.
- Def—Default value in decibels. Other defaults include MC (metro core), CG (control gain), U (unknown).
- Group—Group(s) to which the parameter belongs: ES (east side), WS (west side), Rx (receive), Tx (transmit), Amp (amplifier), P (power), DB (drop band), DC (drop channel), A (attenuation), Th (threshold).
- Network Type—Parameter network type: MC (metro core), MA (metro access), ND (not DWDM)
- Optical Type—Parameter optical type: TS (32 channel terminal), FC (flexible channel count terminal), O (OADM), H (hub), LS (line amplifier), R (ROADM), U (unknown)

Table 6-6 ANS Parameters Summary

Parameter Name	Min	Max	Def	Group	Network Type	Optical Type
Network Type	—	—	MC	Root	MC, MA, ND	U, TS, FC, O, H, LS, R
West Side Rx Max Expected Span Loss	0	60	60	WS, Rx	MC, MA	TS, FC, O, H, LS, R

Table 6-6 ANS Parameters Summary (continued)

Parameter Name	Min	Max	Def	Group	Network Type	Optical Type
East Side Rx Max Expected Span Loss	0	60	60	ES, Rx	MC, MA	TS, FC, O, H, LS, R
West Side Rx Min Expected Span Loss	0	60	60	WS, Rx	MC, MA	TS, FC, O, H, LS, R
East Side Rx Min Expected Span Loss	0	60	60	ES, Rx	MC, MA	TS, FC, O, H, LS, R
West Side Tx Amplifier Working Mode	—	—	CG	WS, Tx, Amp	MC, MA, ND	TS, FC, O, H, LS, R
East Side Tx Amplifier Working Mode	—	—	CG	ES, Rx	MC, MA	TS, FC, O, H, LS, R
West Side Rx Amplifier Working Mode	—	—	CG	WS, Tx, Amp	MC, MA, ND	TS, FC, O, H, LS, R
East Side Rx Amplifier Working Mode	—	—	CG	ES, Rx	MC, MA	TS, FC, O, H, LS, R
West Side Tx Amplifier Ch Power	–10	17	2	WS, Tx, Amp	MC, MA, ND	TS, FC, O, H, LS, R
East Side Tx Amplifier Ch Power	–10	17	2	WS, Tx, Amp	MC, MA, ND	TS, FC, O, H, LS, R
West Side Rx Amplifier Ch Power	–10	17	2	WS, Tx, Amp	MC, MA, ND	TS, FC, O, H, LS, R
East Side Rx Amplifier Ch Power	–10	17	2	WS, Tx, Amp	MC, MA, ND	TS, FC, O, H, LS, R
West Side Tx Amplifier Gain	0	30	0	WS, Tx, Amp	MA	TS, FC, O, H, LS, R
East Side Tx Amplifier Gain	0	30	0	WS, Tx, Amp	MA	TS, FC, O, H, LS. R
West Side Rx Amplifier Gain	0	30	0	WS, Tx, Amp	MA	TS, FC, O, H, LS, R
East Side Rx Amplifier Gain	0	30	0	WS, Tx, Amp	MA	TS, FC, O, H, LS, R
West Side Tx Amplifier Tilt	0	30	0	WS, Tx, Amp	MC, MA	TS, FC, O, H, LS, R
East Side Tx Amplifier Tilt	0	30	0	WS, Tx, Amp	MC, MA	TS, FC, O, H, LS, R
West Side Rx Amplifier Tilt	0	30	0	WS, Rx, Amp	MC, MA	TS, FC, O, H, LS, R
East Side Rx Amplifier Tilt	0	30	0	WS, Rx, Amp	MC, MA	TS, FC, O, H, LS, R
West Side OSC LOS Threshold	–50	30	U	WS, Rx, Th	MC, MA	TS, FC, O, H, LS, R
East Side OSC LOS Threshold	–50	30	U	WS, Rx, Th	MC, MA	TS, FC, O, H, LS, R
West Side Channel LOS Threshold	–50	30	U	WS, Rx, Th	MC, MA	TS, FC, O, H, LS, R
East Side Channel LOS Threshold	–50	30	U	ES, Rx, Th	MC, MA, ND	TS, FC, O, H, LS, R
West Side Fiber State Input Threshold	–50	30	U	WS, Tx, Th	MC, MA, ND	TS, FC, O, H, LS, R
East Side Fiber State Input Threshold	–50	30	U	ES, Tx, Th	MC, MA, ND	TS, FC, O, H, LS, R
West Side Add&Drop - Output Power	–50	30	–14	WS, Tx, P	MC	TS, FC, O, H, R
East Side Add&Drop - Output Power	–50	30	–14	ES, Tx, P	MC	TS, FC, O, H, R
West Side Add&Drop - Input Power	–50	30	–14	WS, Rx, P	MC	TS, FC, O, H, R
East Side Add&Drop - Input Power	–50	30	–14	ES, Rx, P	MC	TS, FC, O, H, R
West Side Add&Drop - By-Pass Power	–50	30	–14	WS, Tx, P	MC	H
East Side Add&Drop - By-Pass Power	–50	30	–14	ES, Tx, P	MC	H
West Side Add&Drop - Drop Power	–50	30	–14	WS, Tx, P	MC	R
East Side Add&Drop - Drop Power	–50	30	–14	ES, Tx, P	MC	R
West Side Band 1...8 Drop Power	–50	30	–14	WS, Rx, P, DB	MC	FC, O
East Side Band 1...8 Drop Power	–50	30	–14	ES, Rx, P, DB	MC	FC, O

Table 6-6 ANS Parameters Summary (continued)

Parameter Name	Min	Max	Def	Group	Network Type	Optical Type
West Side Channel 1...32 Drop Power	–50	30	–14	WS, Rx, P, DC, B1	MC, MA	TS, H, R
East Side Channel 1...32 Drop Power	–50	30	–14	ES, Rx, P, DC, B1	MC, MA	TS, H, R

INDEX

Numerics

A

B

C

D

E

F

G

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L

M

N

O

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T

V

W

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