



## Network Reference

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This chapter explains the ONS 15454 dense wavelength division multiplexing (DWDM) network applications and topologies. The chapter also provides network-level optical performance references.



**Note**

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Unless otherwise specified, “ONS 15454” refers to both ANSI and ETSI shelf assemblies.

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**Note**

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In this chapter, “OPT-BST” refers to the OPT-BST, OPT-BST-E, OPT-BST-L cards, and to the OPT-AMP-L and OPT-AMP-17-C cards when they are provisioned in OPT-LINE (optical booster) mode. “OPT-PRE” refers to the OPT-PRE card and to the OPT-AMP-L and OPT-AMP-17-C cards provisioned in OPT-PRE (pre-amplifier) mode.

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**Note**

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OPT-BST-L, 32WSS-L, 32DMX-L, and OPT-AMP-L cards can only be installed in L-band-compatible nodes and networks. OPT-BST, OPT-BST-E, 32WSS, 32DMX, 40-DMX-C, 40-MUX-C, 40-WSS-C, 40-WXC-C, and OPT-AMP-17-C cards can only be installed in C-band-compatible nodes and networks.

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## 10.1 Network Applications

Cisco ONS 15454 nodes can be provisioned for metro core DWDM network applications. Metro core networks often include multiple spans and amplifiers, so the optical signal-to-noise ratio (OSNR) is the limiting factor for channel performance.

Within DWDM networks, the ONS 15454 uses a communications protocol, called Node Services Protocol (NSP), to communicate with other nodes. NSP automatically updates nodes whenever a change in the network occurs. Each ONS 15454 DWDM node can:

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

## 10.2 Network Topologies

The ONS 15454 DWDM network topologies include ring networks, linear networks, and mesh networks.

### 10.2.1 Ring Networks

Ring networks support hubbed, multi-hubbed, any-to-any, and mesh traffic topologies.

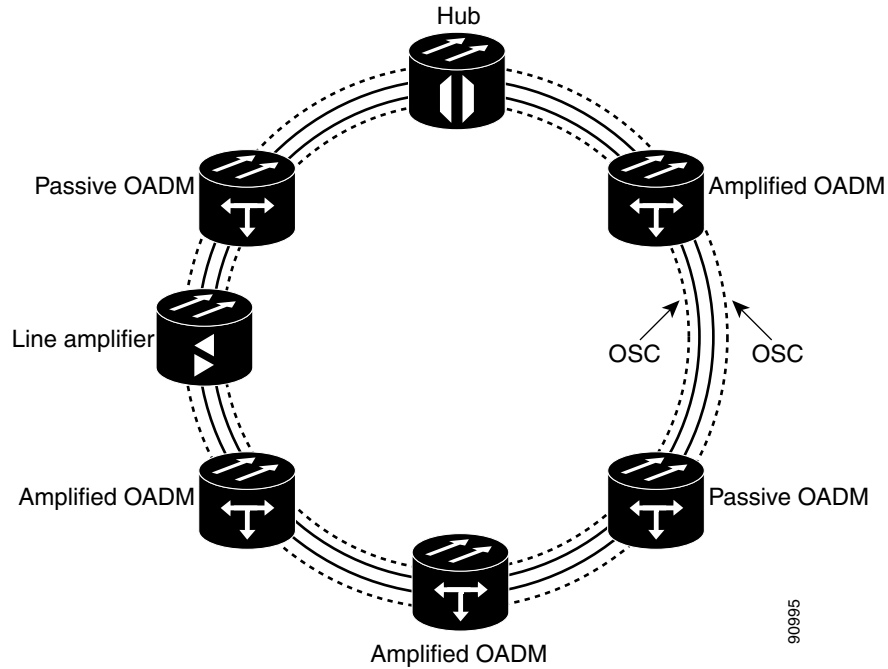
#### 10.2.1.1 Hubbed Traffic Topology

In the hubbed traffic topology ([Figure 10-1](#)), 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 multiplexing (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 topology, that is, no channel reuse is possible. 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.

For more information about hub nodes, see the [“9.1.1 Hub Node” section on page 9-2](#).

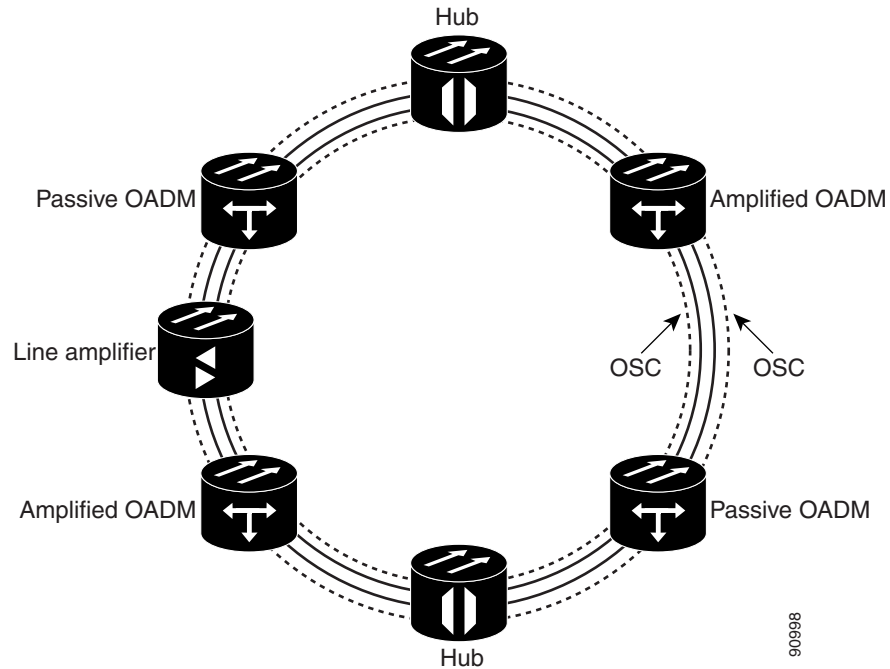
**Figure 10-1 Hubbed Traffic Topology**



### 10.2.1.2 Multihubbed Traffic Topology

A multihubbed traffic topology (Figure 10-2) is based on the hubbed traffic topology, except that two or more hub nodes are added. Protected traffic can only be established between the two hub nodes. Protected traffic can be provisioned between a hub node and any OADM node only 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 10-2** Multihubbed Traffic Topology

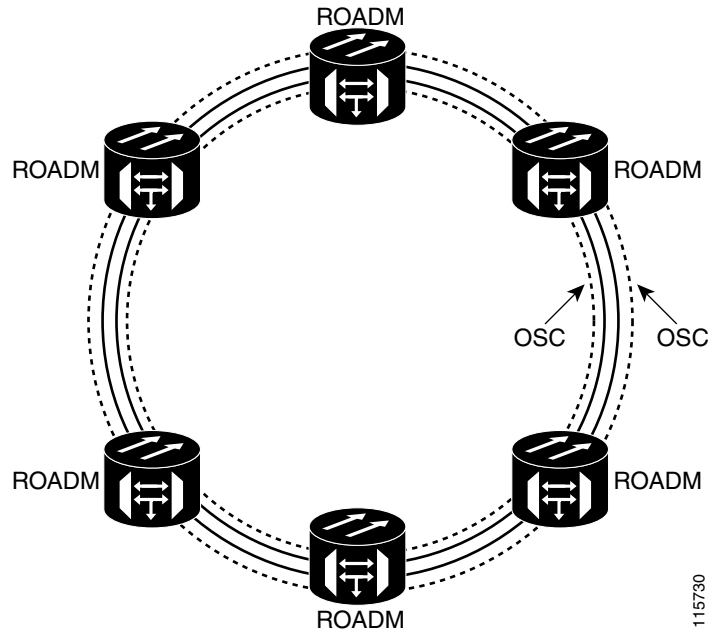


### 10.2.1.3 Any-to-Any Traffic Topology

The any-to-any traffic topology (Figure 10-3) contains only reconfigurable OADM (ROADM) nodes (with or without optical service channel [OSC] regeneration) or optical amplifier nodes. This topology potentially allows you to route every wavelength from any source to any destination node inside the network.

See the “9.1.4 ROADM Node” section on page 9-12 for more information.

Figure 10-3 Any-to-Any Traffic Topology



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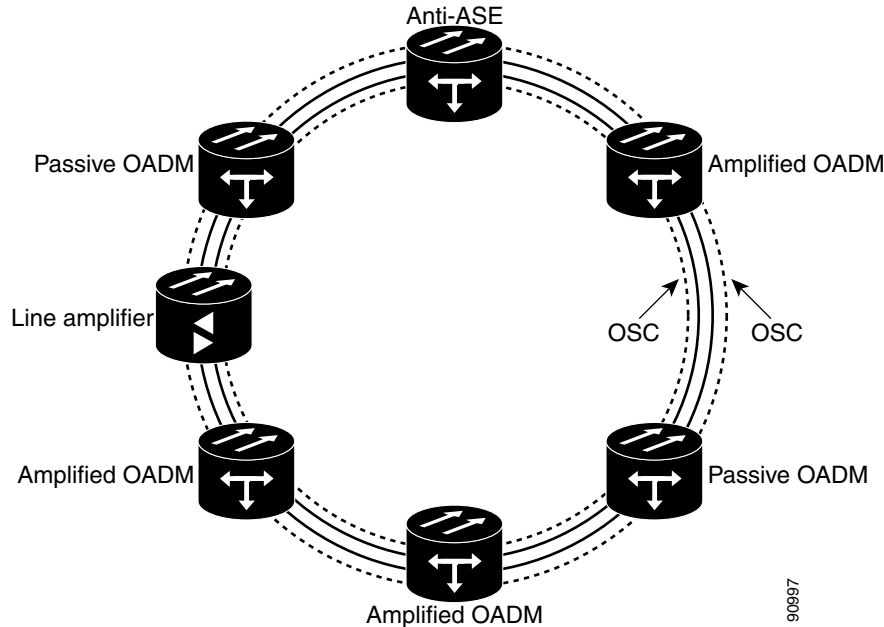
### 10.2.1.4 Meshed Traffic Topology

The meshed traffic topology (Figure 10-4) does not use hubbed nodes; only amplified and passive OADM nodes are present. 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. This is done 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.

For more information about OADM nodes, see the “9.1.3 OADM Node” section on page 9-8. For more information about anti-ASE nodes, see the “9.1.5 Anti-ASE Node” section on page 9-15.

Figure 10-4 Meshed Traffic Topology



## 10.2.2 Linear Networks

Linear configurations are characterized by the use of two terminal nodes, east and west. The 32-channel terminal nodes can be equipped with a 32MUX-O card and a 32DMX-O card, or with a 32WSS card and a 32DMX or 32DMX-O card. The 40-channel terminal nodes can be equipped with a 40-MUX-C card and a 40-DMX-C card or a 40-WSS-C card with a 40-DMX-C 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 10-5 shows five ONS 15454 nodes in a linear configuration with an amplified and a passive OADM node.

Figure 10-5 Linear Configuration with an OADM Node

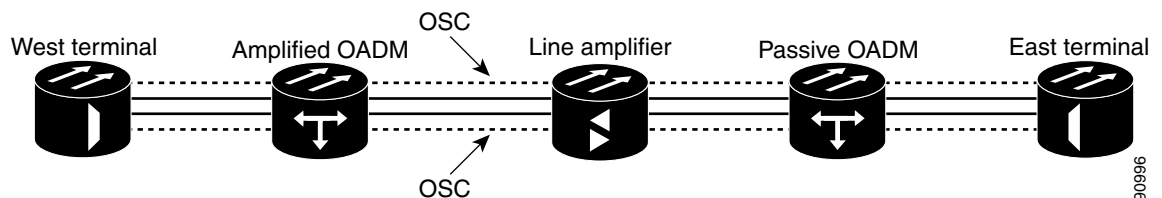
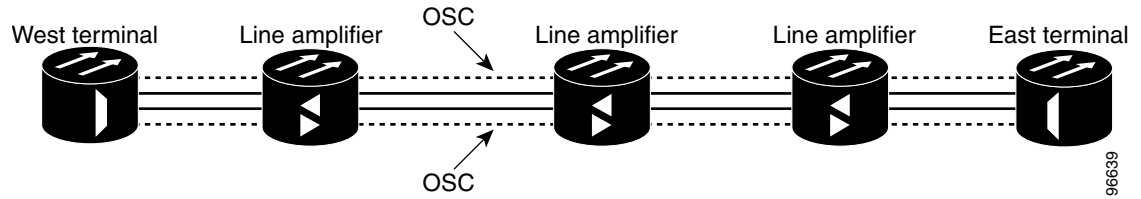
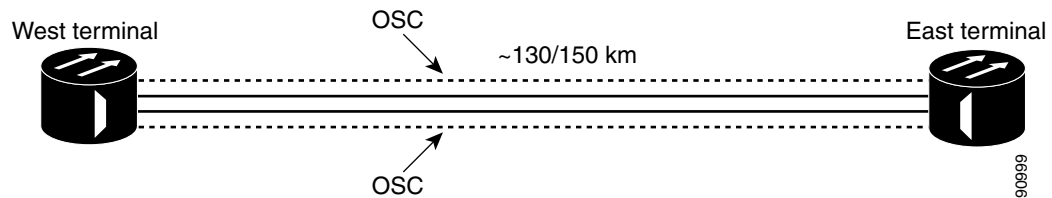


Figure 10-6 shows five ONS 15454 nodes in a linear configuration without an OADM node. See the “9.1.2 Terminal Node” section on page 9-5 for more information.

**Figure 10-6** Linear Configuration without an OADM Node

A single-span link is a type of linear configuration characterized by a single-span link with preamplification and post-amplification. A single-span link is also characterized by the use of two terminal nodes, east and west. Only unprotected traffic can be provisioned on a single-span link.

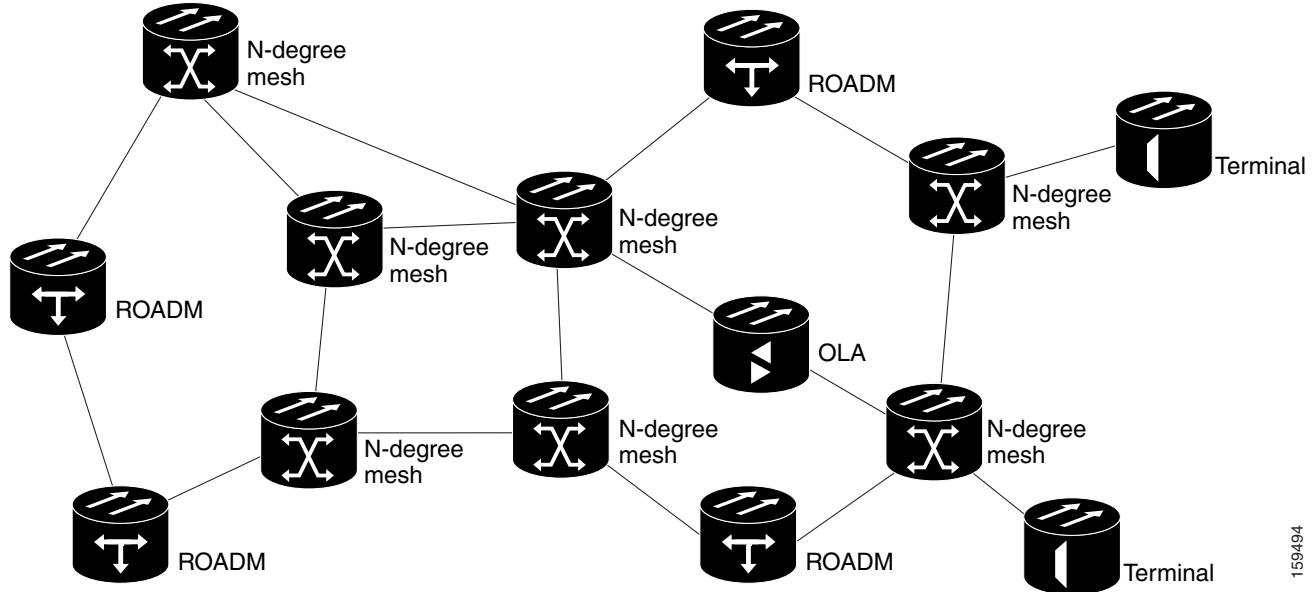
Figure 10-7 shows ONS 15454s in a single-span link. Eight channels are carried on one span. Single-span link losses apply to OC-192/STM-64 LR ITU cards. The optical performance values are valid assuming that the sum of the OADM passive node insertion losses and the span losses does not exceed 35 dB.

**Figure 10-7** Single-Span Link

## 10.2.3 Mesh Networks

A mesh network can be native or multiring. In a native mesh network (Figure 10-8), any combination of four-degree and eight-degree mesh nodes can work together. Four-degree mesh nodes transmit an optical signal in four directions, while an eight-degree mesh node transmits an optical signal in eight directions. For additional information about mesh nodes, see the “9.4 Configuring Mesh DWDM Networks” section on page 9-30. The intermediate nodes are ROADM nodes. In a mesh node, all wavelengths can be routed through four (four-degree mesh node) to eight (eight-degree mesh node) different optical line termination ports using a 40-WXC-C card without any optical-electrical-optical (OEO) regeneration. It is possible to combine 40-WSS-C, 40-WXC-C, and 32WSS cards in the same mesh network without impacting system performance. For nodes equipped with 32WSS cards, the maximum system capacity is 32 channels. Terminal sites are connected to the mesh network as a spur.

Figure 10-8 mesh Network



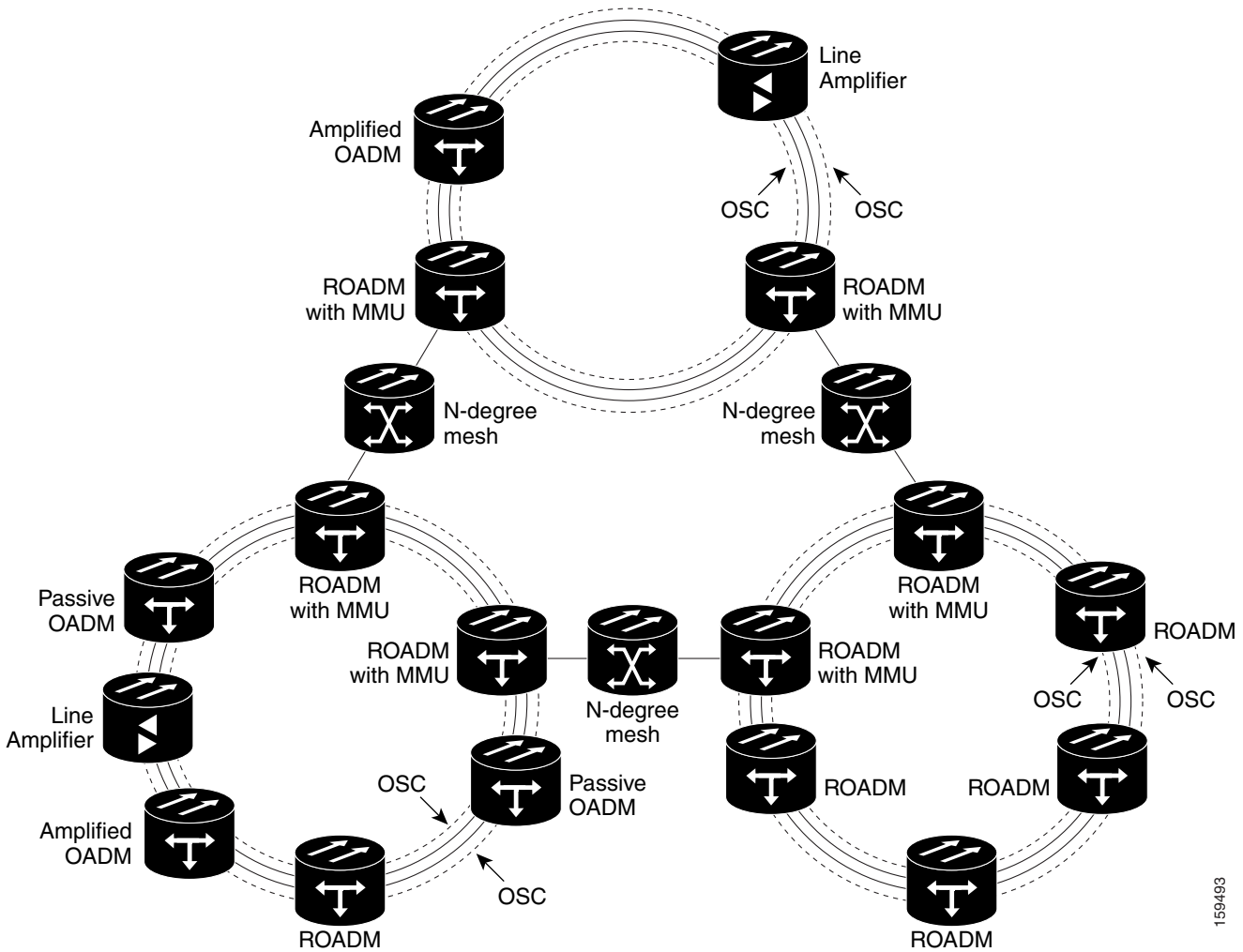
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In a multiring mesh network (Figure 10-9), several rings are connected with four-degree or eight-degree mesh nodes. The intermediate ROADM nodes are equipped with MMU cards. All wavelengths can be routed among two or more rings using a 40-WXC-C card without any O-E-O regeneration. As in a native mesh network, it is possible to combine 40-WSS-C, 40-WXC-C, and 32WSS cards in the same multiring network without impacting system performance. For nodes equipped with 32WSS cards, maximum system capacity is limited to 32 channels. A terminal node is connected to a multiring node as a spur.

For information on node configurations for both native mesh and multiring networks, see the “9.4 Configuring Mesh DWDM Networks” section on page 9-30.



Figure 10-9 Multiring Network



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## 10.3 Optical Performance

This section provides optical performance information for ONS 15454 DWDM networks. The performance data is a general guideline based upon the network topology, node type, client cards, fiber type, number of spans, and number of channels. The maximum number of nodes that can be in an ONS 15454 DWDM network is 16. The DWDM topologies and node types that are supported are shown in [Table 10-1](#).

**Table 10-1** Supported Topologies and Node Types

Number of Channels	Fiber	Topologies	Node Types
32 channels	SMF-28 <sup>1</sup>	Ring	Hub
	E-LEAF <sup>2</sup>	Linear	Active OADM
	TW-RS <sup>3</sup>	Linear without OADM	Passive OADM Terminal Line OSC regeneration
16 channels	SMF-28	Ring	Hub
		Linear	Active OADM
		Linear without OADM	Passive OADM Terminal Line OSC regeneration
8 channels	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.

## 10.4 Automatic Power Control

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

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



### Note

APC algorithms manage the optical parameters of the OPT-BST, OPT-PRE, OPT-AMP-17-C, 32DMX, 40-DMX-C, OPT-BST-L, OPT-AMP-L, and 32DMX-L cards.

Amplifier software uses a control gain 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 proportionately according to the calculated gain setpoint. The shelf controller software emulates the control output power loop to adjust for fiber degradation. To perform this function, the TCC2/TCC2P needs to know the channel distribution, which is provided by a signaling protocol, and the expected per-channel power, which you can provision. The TCC2/TCC2P compares the actual amplifier output power with the expected amplifier output power and modifies the setpoints if any discrepancies occur.

## 10.4.1 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 the gain and  $t$  represents time.

$$P_{out}(t) = G * P_{in}(t) \text{ (mW)}$$

$$P_{out}(t) = G + P_{in}(t) \text{ (dB)}$$

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,  $t_1$  and  $t_2$ , as a change in the traffic being carried. The letters  $m$  and  $n$  in the following formula represent two different channel numbers.  $P_{in}/ch$  represents the input power per channel.

$$P_{in}(t_1) = n P_{in}/ch$$

$$P_{in}(t_2) = m P_{in}/ch$$

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.

The per-channel power and working mode (gain or power) are set by automatic node setup (ANS). The provisioning is conducted on a per-side basis. A preamplifier or a booster amplifier facing Side  $i$  are provisioned using the Side  $i$  parameters present in the node database, where  $i$  - A, B, C, D, E, F, G, or H.

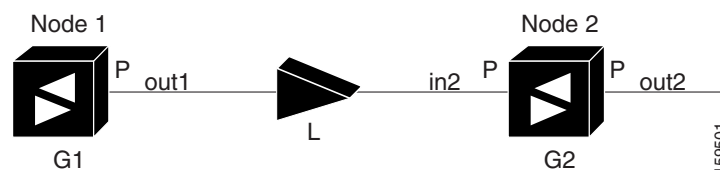
Starting from the expected per-channel power, the amplifiers automatically calculate the gain setpoint after the first channel is provisioned. An amplifier gain setpoint is calculated in order to make it equal to the loss of the span preceding the amplifier itself. After the gain is calculated, the setpoint 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.

## 10.4.2 APC at the Shelf Controller Layer

Amplifiers are managed through software to control changes in the input power caused by changes in the number of channels. The software adjusts the output total power to maintain a constant per-channel power value when the number of input channel changes.

Changes in the network characteristics have an impact on the amplifier input power. Changes in the input power are compensated for only by modifying the original calculated gain, because input power changes imply changes in the span loss. As a consequence, the gain to span loss established at amplifier start-up is no longer satisfied, as shown in [Figure 10-10](#).

**Figure 10-10** Using Amplifier Gain Adjustment to Compensate for System Degradation



In Figure 10-10, Node 1 and Node 2 are equipped with booster amplifiers and preamplifiers. The input power received at the preamplifier on Node 2 (Pin2) depends on the total power launched by the booster amplifier on Node1, Pout1(n) (where n is the number of channels), and the effect of the span attenuation (L) between the two nodes. Span loss changes due to aging fiber and components or changes in operating conditions. The power into Node 2 is given by the following formula:

$$\text{Pin2} = L \text{Pout1}(n)$$

The phase gain of the preamplifier on Node 2 (GPre-2) is set during provisioning in order to compensate for the span loss so that the Node 2 preamplifier output power (Pout-Pre-2) is equal to the original transmitted power, as represented in the following formula:

$$\text{Pout-Pre-2} = L \times \text{GPre-2} \times \text{Pout1}(n)$$

In cases of system degradation, the power received at Node 2 decreases due to the change of span insertion loss (from L to L'). As a consequence of the preamplifier gain control working mode, the Node 2 preamplifier output power (Pout-Pre-2) also decreases. The goal of APC at the shelf controller layer is simply to detect if an amplifier output change is needed because of changes in the number of channels or to other factors. If factors other than changes in the number of channels occur, APC provisions a new gain at the Node 2 preamplifier (GPre-2') to compensate for the new span loss, as shown in the formula:

$$\text{GPre-2}' = \text{GPre-2} (L / L') = \text{GPre-2} + [\text{Pout-Pre-2} - \text{Exp}(\text{Pout-Pre-2})]$$

Generalizing on the above relationship, APC is able to compensate for system degradation by adjusting working amplifier gain or variable optical attenuation (VOA) and to eliminate 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)
- 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 that is distributed among different nodes. An APC domain is a set of nodes that is controlled by the same instance of APC at the network level. An APC domain optically identifies a portion of the network that can be independently regulated. An optical network can be divided into several different domains, with the following characteristics:

- Every domain is terminated by two node sides. The node sides terminating domains are:
  - Terminal node (any type)
  - ROADM node
  - Hub node
  - Cross-connect (XC) termination mesh node
  - Line termination mesh node
- APC domains are shown in both Cisco Transport Controller (CTC) and Transaction Language One (TL1).

- In CTC, domains are shown in the network view and reported as a list of spans. Each span is identified by a node/side pair, for example:

```
APC Domain Node_1 Side A, Node_4 Side B
+ Span 1: Node_1 Side A, Node_2 Side B
+ Span 2: Node_2 Side A, Node_3 Side B
+ Span 3: Node_3 Side A, Node_4 Side B
```

- APC domains are not refreshed automatically; instead, they are refreshed using a Refresh button.

Inside a domain, 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 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  $\pm 0.5$  dB. Any power level fluctuation within the threshold range is skipped since 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.

To avoid large power fluctuations, APC adjusts power levels incrementally. The maximum power correction is  $\pm 0.5$  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 compensates for it by using all margins that you provision during installation.

If no margin is available, adjustments cannot be made because setpoints exceed the ranges. APC communicates the event to CTC, Cisco Transport Manager (CTM), and TL1 through an APC Fail condition. APC clears the APC fail condition when the setpoints return to the allowed ranges.

APC can be manually disabled. In addition, APC automatically disables itself when:

- An HF (Hardware Fail) alarm is raised by any card in any of the domain nodes.
- A Mismatch Equipment Alarm (MEA) is raised by any card in any of the domain nodes.
- An Improper Removal (IMPROPRMVL) alarm is raised by any card in any of the domain 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 domain nodes.
- A VOA degrade or fail alarm is raised by any of the cards in any of the domain nodes.
- The signaling protocol detects that one of the APC instances in any of the domain nodes is no longer reachable.

The APC state (Enable/Disable) is located on every node and can be retrieved by the CTC or TL1 interface. If an event that disables APC occurs in one of the network nodes, APC is disabled on all the other nodes 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 minor, non-service affecting alarms 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  $\pm 3$  dB security range.

- APC Disabled—APC is disabled, either by a user or internal action.

After the error condition is cleared, the 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.

## 10.4.3 Managing APC

The APC status is indicated by four APC states shown in the node view status area:

- Enabled—APC is enabled.
- Disabled—APC was disabled manually by a user.
- Disable - Internal—APC has been automatically disabled for an internal cause.
- Not Applicable—The node is provisioned to Not DWDM, which does not support APC.

You can view the APC information and disable and enable APC manually on the Maintenance > DWDM > APC tab. See [Figure 10-11](#) for an example of how the information is displayed.



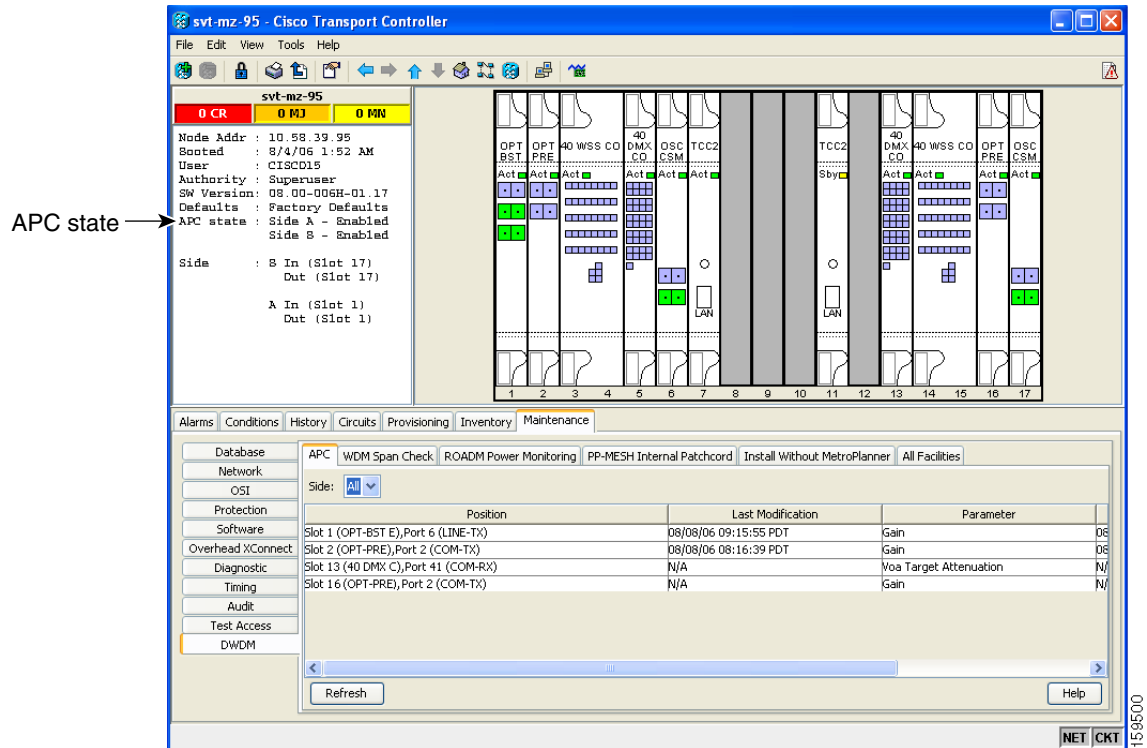
### Caution

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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.

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Figure 10-11 Automatic Power Control



The APC subtab provides the following information:

- Position—The slot number, card, and port for which APC information is shown.
- Last Modification—Date and time APC parameter setpoints were last modified.
- Parameter—The parameter that APC last modified.
- Last Check—Date and time APC parameter setpoints were last verified.
- Side—The side where the APC information for the card and port is shown.
- State—The APC state.

A wrong use of maintenance procedures (for example, the procedures to be applied in case of fiber cut repair) can lead the system to raise the APC Correction Skipped alarm. The APC Correction Skipped alarm strongly limits network management (for example, a new circuit cannot be turned into IS). The Force APC Correction button helps to restore normal conditions by clearing the APC Correction Skipped alarm.

The Force APC Correction button must be used under the Cisco TAC surveillance since its misuse can lead to traffic loss.

The Force APC Correction button is available in the **Card View > Maintenance > APC** tab pane in CTC for the following cards:

- OPT-PRE
- OPT-BST-E
- OPT-BST
- OPT-AMP-C
- OPT-AMP-17C

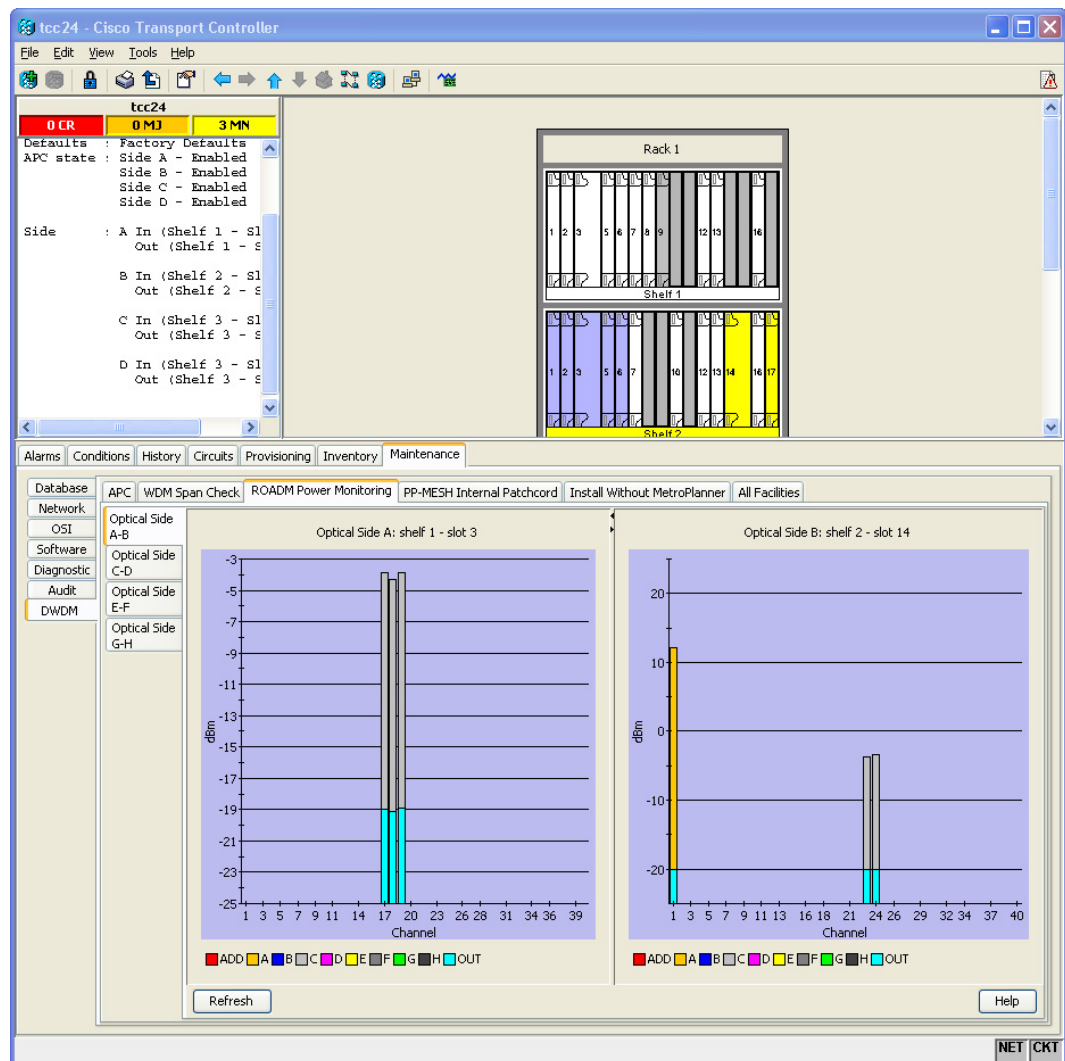
- AD-xB
- AD-xC

This feature is not available for the TL1 interface.

## 10.5 ROADM Power Equalization Monitoring

ROADM nodes allow you to monitor the 32WSS, 40-WSS-C, and 40-WXC-C card equalization functions on the Maintenance > DWDM > ROADM Power Monitoring > Optical Side *n-n* tab, where *n-n* is A-B, C-D, E-F, or G-H (Figure 10-12). The tab shows the input channel power (Padd), the express or pass-through power (Ppt) and the power level at output (Pout).

Figure 10-12 ROADM Power Monitoring Subtab





## 10.6 Span Loss Verification

Span loss measurements can be performed from the Maintenance > DWDM > WDM Span Check tab (Figure 10-13). The CTC span check compares the far-end 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 10-13 Span Loss Verification

The screenshot shows the Cisco Transport Controller (tcc24) interface. The top left pane displays system information for tcc24, including APC state (Side A-D Enabled) and Side A-D In/Out configurations. The top right pane shows a rack diagram with two shelves, Shelf 1 and Shelf 2, each containing 16 slots. The bottom pane displays the 'WDM Span Check' table.

Side	Min Exp. Span Loss (dB)	Max Exp. Span Loss (dB)	Meas. Span Loss (dB)	Resolution (dB)
B	0.0	60.0	9.4	1.5
A	0.0	60.0	9.8	1.5

Buttons at the bottom of the table include 'Retrieve Span Loss values', 'Reset', 'Apply', and 'Help'.

## 10.7 Network Optical Safety

If a fiber break occurs on the network, automatic laser shutdown (ALS) automatically shuts down the OSCM and OSC-CSM OSC laser output power and the optical amplifiers contained in the OPT-BST, OPT-BST-E, OPT-BST-L, OPT-AMP-L, and OPT-AMP-17-C cards. The Maintenance > ALS tabs in CTC card view provide the following ALS management options for OSCM, OSC-CSM, OPT-BST, OPT-BST-E, OPT-BST-L, OPT-AMP-L, and OPT-AMP-17-C 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. It automatically restarts when the conditions that caused the outage are resolved. Auto Restart is the default ALS provisioning for OSCM, OSC-CSM, OPT-BST, OPT-BST-E, OPT-BST-L, OPT-AMP-L, and OPT-AMP-17-C 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.

**Warning**

**All ONS 15454 users must be properly trained on laser safety hazards in accordance with IEC 60825-2, or ANSI Z136.1.**

## 10.7.1 Automatic Laser Shutdown

When ALS is enabled on OPT-BST, OPT-BST-E, OPT-BST-L, OPT-AMP-L, OPT-AMP-17-C, OSCM, and OSC-CSM cards, a network safety mechanism will occur in the event of a system failure. ALS provisioning is also provided on the transponder (TXP) and muxponder (MXP) cards. However, if a network uses ALS-enabled OPT-BST, OPT-BST-E, OPT-BST-L, OPT-AMP-L, OPT-AMP-17-C, OSCM, and OSC-CSM cards, ALS does not need to be enabled on the TXP cards or MXP cards. ALS is disabled on TXP and MXP cards by default and the network optical safety is not impacted.

If TXP and MXP cards 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 the cards.

If ALS is disabled on the OPT-BST, OPT-BST-E, OPT-BST-L, OPT-AMP-L, OPT-AMP-17-C, OSCM, and OSC-CSM cards (the DWDM network), ALS can be enabled on the TXP and MXP cards to provide laser management in the event of a fiber break in the network between the cards.

## 10.7.2 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 APR 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 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 dBm) 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, indicating the system failure is corrected and full continuity in the fiber between the two ends exists.

After the OSC communication is 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 dBm. This level assures that Hazard Level 1 is not exceeded, for personnel safety, even though the establishment of successful OSC communication is assurance that any broken fiber is 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**

**In the event that ALS is disabled, a larger amount of invisible laser radiation might be emitted from the end of the unterminated fiber cable or connector. Do not view the end of the fiber 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.**

**Note**

If you must disable ALS, verify that all fibers are installed in a restricted location. Enable ALS immediately after finishing the maintenance or installation process.

**Note**

For the line amplifier to start up automatically, disable the ALS on the terminal node that is unidirectional.

## 10.7.3 Fiber Cut Scenarios

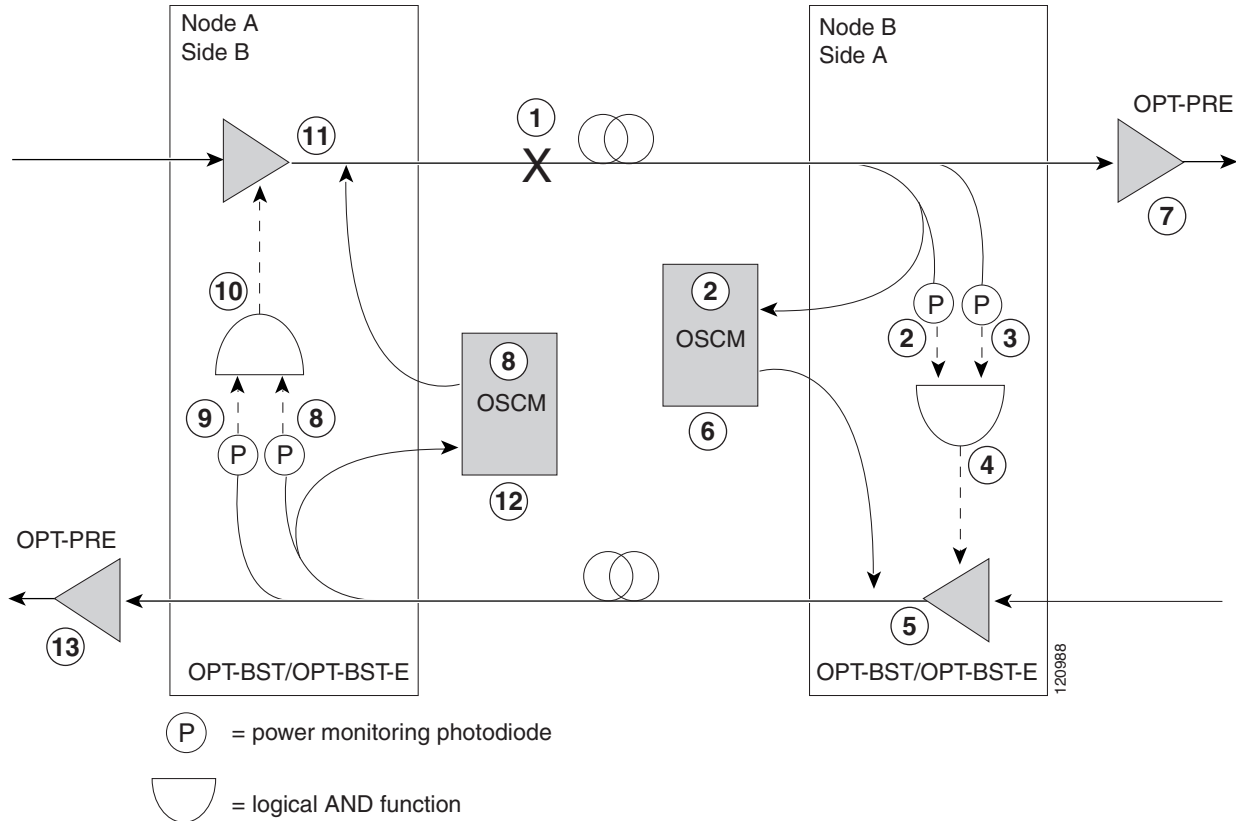
In the following paragraphs, four ALS scenarios are given:

- 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 or OPT-AMP-17-C cards (amplified nodes)
- Nodes using DCN extension

### 10.7.3.1 Scenario 1: Fiber Cut in Nodes Using OPT-BST/OPT-BST-E Cards

Figure 10-14 shows nodes using OPT-BST/OPT-BST-E cards with a fiber cut between them.

Figure 10-14 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 an 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 10-14):

1. Fiber is cut.
2. 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*.
3. 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*.
4. The OPT-BST/OPT-BST-E card amplifier is shut down within one second.
5. The OSCM laser is shut down.
6. The OPT-PRE card automatically shuts down due to a loss of incoming optical power.
7. 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*.
8. 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*.

9. 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*.
10. The OPT-BST/OPT-BST-E card amplifier is shut down within one second.
11. The OSCM laser is shut down.
12. 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**

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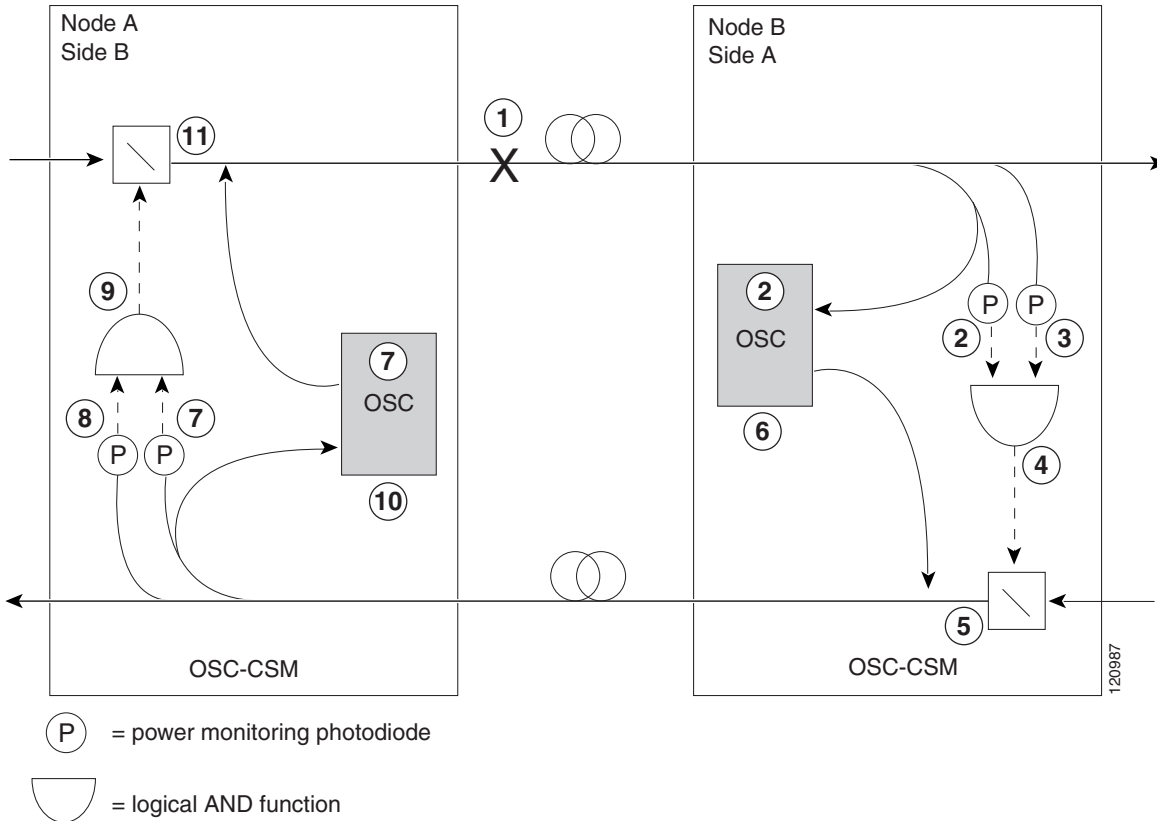
During a laser restart pulse, APR ensures that the laser power does not exceed Class 1 limits. See the [“10.7.2 Automatic Power Reduction”](#) section on page 10-19 for more information about APR.

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### 10.7.3.2 Scenario 2: Fiber Cut in Nodes Using OSC-CSM Cards

[Figure 10-15](#) shows nodes using OSC-CSM cards with a fiber cut between them.

Figure 10-15 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 10-15):

1. Fiber is cut.
2. The Node B power monitoring photodiode detects a LOS-P on the OSC-CSM card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
3. 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*.
4. The optical switch blocks outgoing traffic.
5. The OSC laser is shut down.
6. The Node A power monitoring photodiode detects a LOS-O on the OSC-CSM card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
7. The Node A power monitoring photodiode detects a LOS-P on the OSC-CSM card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.

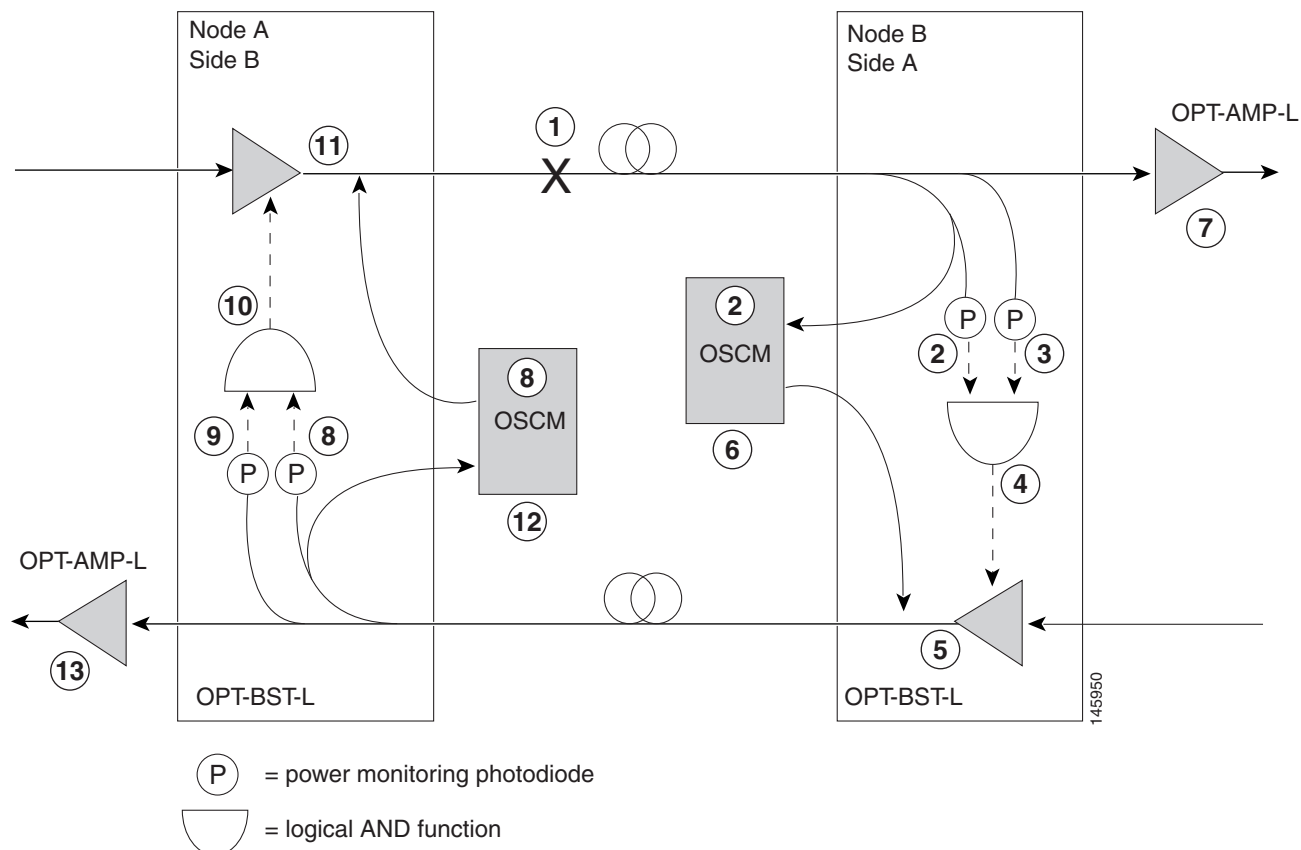
8. On the OSC-CSM, the simultaneous LOS-O and LOS-P detection triggers a change in the position of the optical switch. CTC reports a LOS alarm (loss of continuity), while LOS-O and LOS-P are demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
9. The OSC laser is shut down.
10. The optical switch blocks outgoing traffic.

When the fiber is repaired, either an automatic or manual restart at the Node A OSC-CSM card OSC or at the Node B OSC-CSM card OSC is required. A system that has been shut down is reactivated through the use of a restart pulse. The pulse indicates the optical path is 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.

### 10.7.3.3 Scenario 3: Fiber Cut in Nodes Using OPT-BST-L Cards

Figure 10-16 shows nodes using OPT-BST-L cards with a fiber cut between them.

Figure 10-16 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 an LOS for both the optical payload and the 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 10-16](#)):

1. Fiber is cut.
2. The Node B power monitoring photodiode detects an LOS-P on the OPT-BST-L card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
3. 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*.
4. The OPT-BST-L card amplifier is shut down within one second.
5. The OSCM laser is shut down.
6. The OPT-AMP-L or OPT-AMP-17-C card automatically shuts down due to a loss of incoming optical power.
7. The Node A power monitoring photodiode detects an LOS-O on the OPT-BST-L card and the OSCM card detects an LOS (OC3) at the SONET layer. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
8. The Node A power monitoring photodiode detects an LOS-P on the OPT-BST-L card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
9. 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 the LOS-O and LOS-P are demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
10. The OPT-BST-L card amplifier is shut down within one second.
11. The OSCM laser is shut down.
12. The Node A OPT-AMP-L or OPT-AMP-17-C card automatically shuts down due to an LOS for the 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 indicates the optical path is 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 ensures that the laser power does not exceed Class 1 limits. See the [“10.7.2 Automatic Power Reduction”](#) section on page 10-19 for more information about APR.

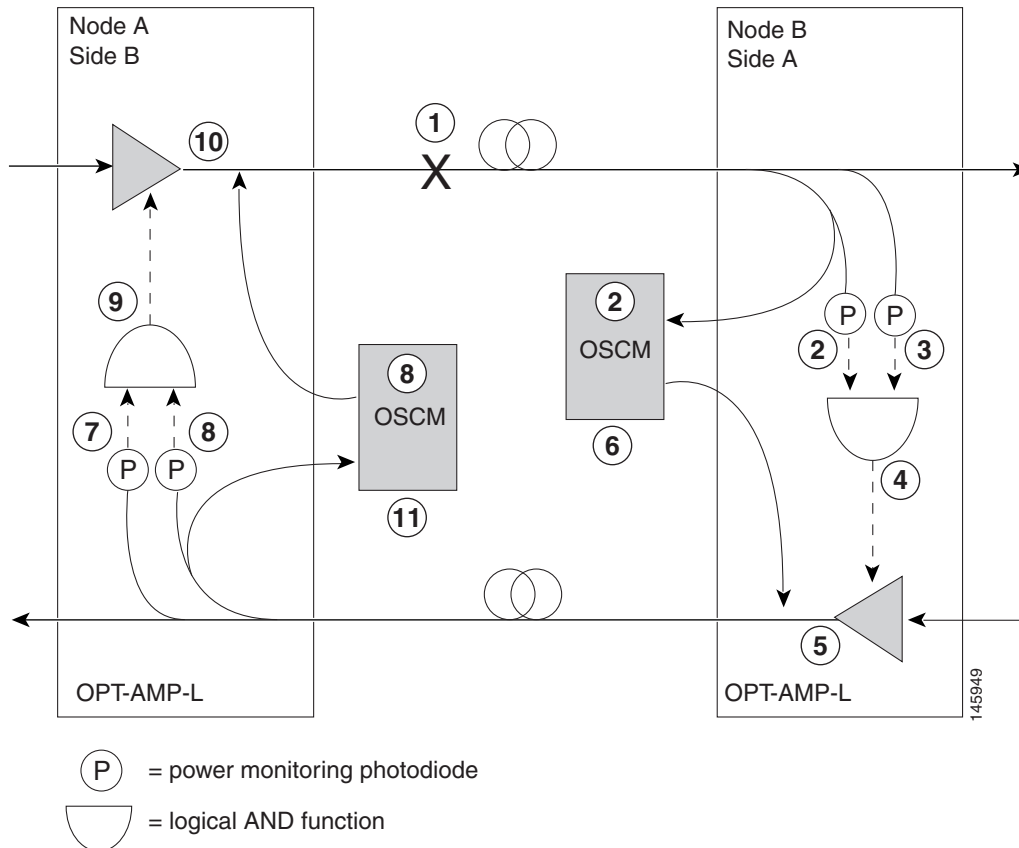
### 10.7.3.4 Scenario 4: Fiber Cut in Nodes Using OPT-AMP-L or OPT-AMP-17-C (OPT-LINE mode) Cards

[Figure 10-17](#) shows nodes using OPT-AMP-L or OPT-AMP-17-C (in OPT-LINE mode) cards with a fiber cut between them.

**Note**

A reference to the OPT-AMP-L card also refers to the OPT-AMP-17-C card.

Figure 10-17 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 an 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 10-17](#)):

1. Fiber is cut.
2. 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*.
3. 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*.
4. The OPT-AMP-L card amplifier is shut down within one second.
5. The OSCM laser is shut down.
6. The Node A power monitoring photodiode detects an LOS-O on the OPT-AMP-L card and the OSCM card detects an LOS (OC3) at the SONET layer. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
7. The Node A power monitoring photodiode detects an LOS-P on the OPT-AMP-L card. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.

8. 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*.
9. The OPT-AMP-L card amplifier is shut down within one second.
10. 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 indicates the optical path is 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.

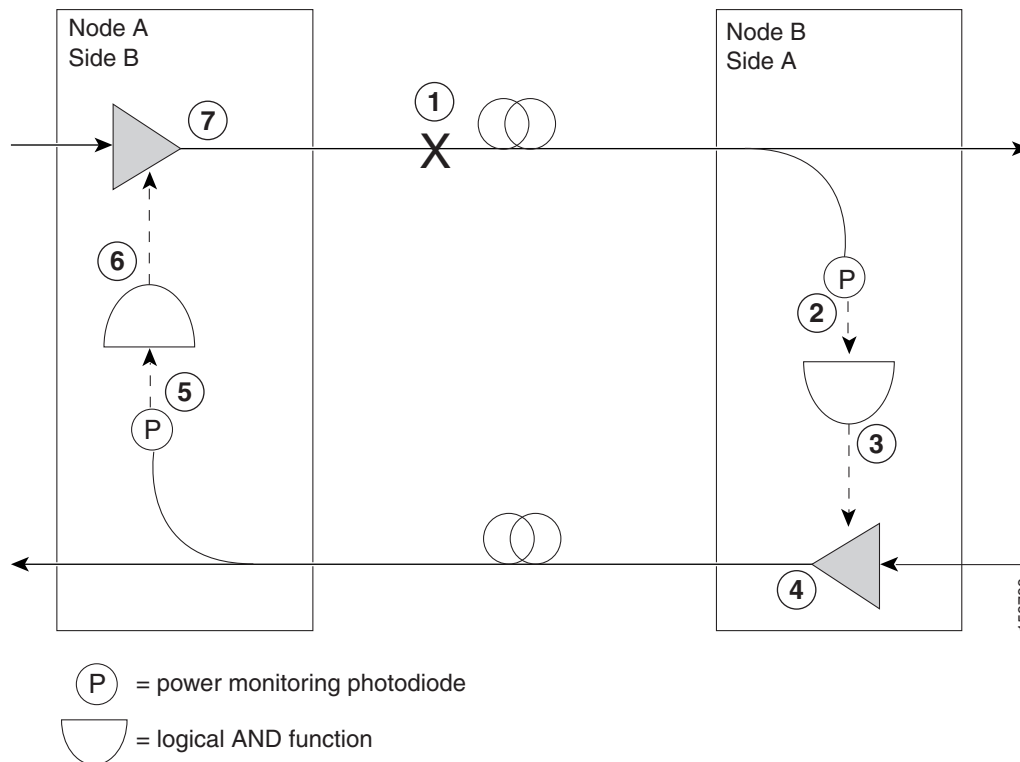
**Note**

During a laser restart pulse, APR ensures that the laser power does not exceed Class 1 limits. See the “10.7.2 Automatic Power Reduction” section on page 10-19 for more information about APR.

### 10.7.3.5 Scenario 5: Fiber Cut in Nodes Using DCN Extension

Figure 10-18 shows a fiber cut scenario for nodes that do not have OSC connectivity. In the scenario, references to the OPT-BST cards refers to the OPT-BST, OPT-BST-L, OPT-BST-E, and the OPT-AMP-L and OPT-AMP-17-C cards when provisioned in OPT-LINE mode.

**Figure 10-18** Fiber Cut With DCN Extension



Two photodiodes at Node B monitor the received signal strength for the optical payload. When the fiber is cut, an LOS is detected on the channel photodiode while the other one never gets a signal because the OSC is not present. The AND function then indicates an overall LOS condition, which causes the OPT-BST amplifier transmitter to shut down. This in turn leads to a LOS for the optical payload at Node A, which causes Node A to turn off the OPT-BST amplifier lasers.

The sequence of events after a fiber cut is as follows (refer to the numbered circles in [Figure 10-18](#)):

1. Fiber is cut.
2. The Node B power monitoring photodiode detects an LOS-P on the OPT-BST card. Refer to the Cisco ONS 15454 DWDM Troubleshooting Guide for LOS-P troubleshooting procedures.
3. On the OPT-BST card, the LOS-P detection triggers a command to shut down the amplifier. CTC reports an LOS alarm (loss of continuity), while LOS-P is demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide* for alarm troubleshooting procedures.
4. The OPT-BST-E card amplifier is shut down within one second.
5. The Node A power monitoring photodiode detects a LOS-P on the OPT-BST-E card. Refer to the Cisco ONS 15454 DWDM Troubleshooting Guide for alarm troubleshooting procedures.
6. On the OPT-BST-E, the LOS-P detection triggers a command to shut down the amplifier. CTC reports an LOS alarm (loss of continuity), while LOS-P is demoted. Refer to the *Cisco ONS 15454 DWDM Troubleshooting Guide*.
7. The OPT-BST-E card amplifier is shut down within one second.

When the fiber is repaired, a manual restart with 90 sec restart pulse time (MANUAL RESTART FOR TEST) at the Node A OPT-BST-E transmitter and at the Node B OPT-BST-E transmitter is required. A system that has been shut down is reactivated through the use of a 90 sec restart pulse. The pulse indicates that the optical path is restored and transmission can begin.

For example, when the far end, Node B, receives a pulse, it signals to the Node B OPT-BST-E transmitter to begin transmitting an optical signal. The OPT-BST-E receiver at Node A receives that signal and signals the Node A OPT-BST-E transmitter to resume transmitting.


**Note**

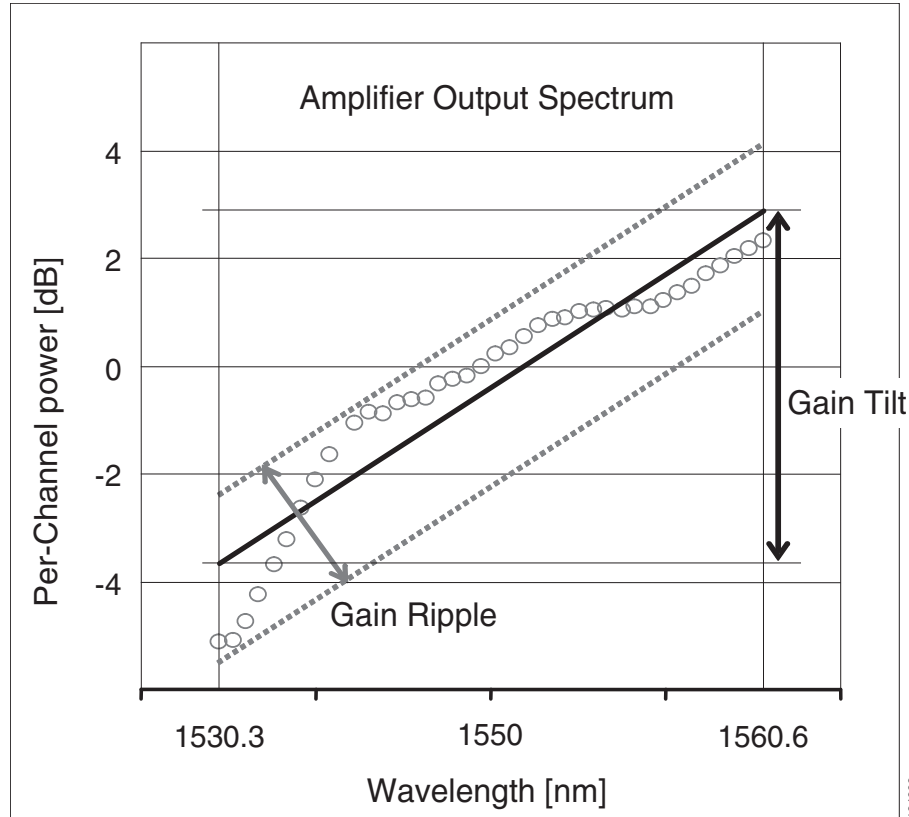
During a laser restart pulse, APR ensures that the laser power does not exceed Class 1 limits. See the [“10.7.2 Automatic Power Reduction”](#) section on page 10-19 for more information about APR.

## 10.8 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 10-19](#) shows a graph of the amplifier output power spectrum and how it is affected by gain tilt and gain ripple.

Figure 10-19 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 ( $G_{stp}$ ) of the optical amplifier, which is a mathematical function  $F(G_{stp})$  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.



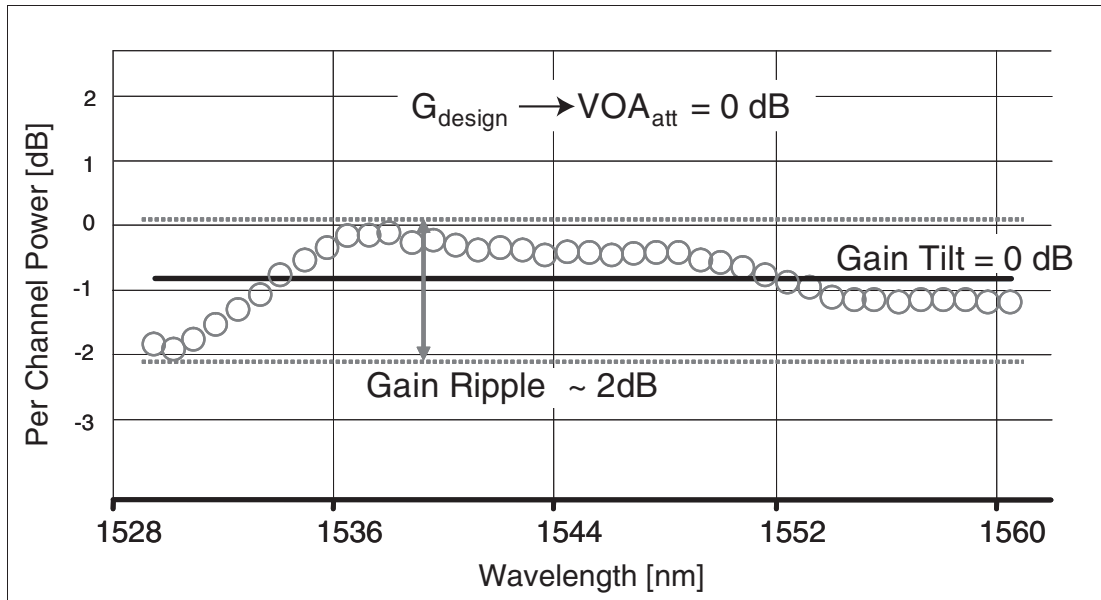
**Note**

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.

## 10.8.1 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 ( $G_{design}$ ), based on the internal optical design (see Figure 10-20).

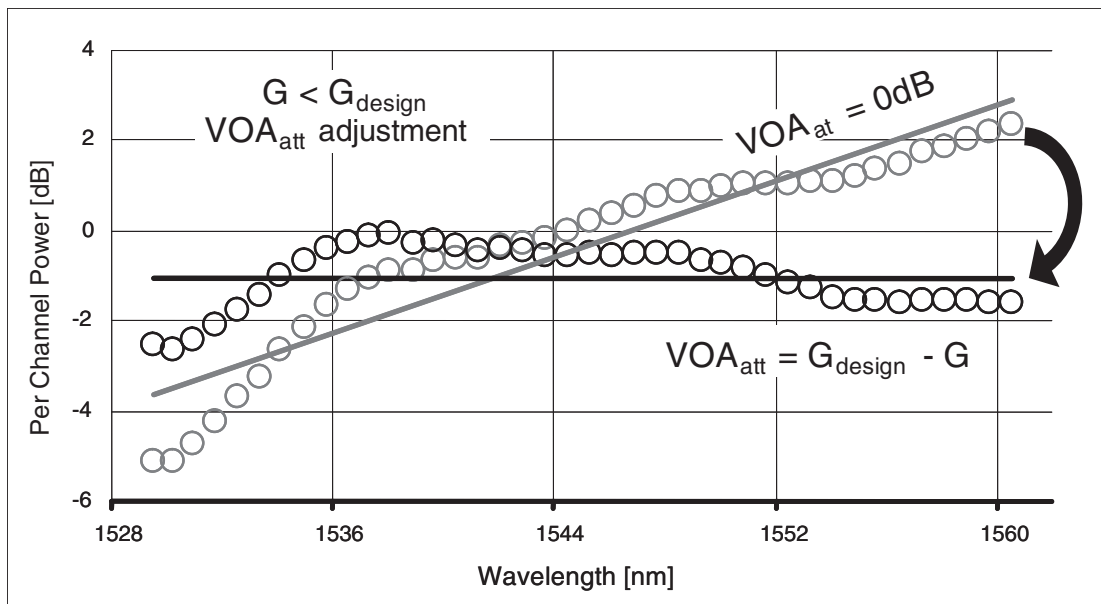
Figure 10-20 Flat Gain (Gain Tilt = 0 dB)



If the working gain setpoint of the amplifier is different from  $G_{\text{design}}$ , 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 10-21.

Figure 10-21 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 10-2 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.

**Table 10-2 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 10-2, the EDFA introduces a tilt contribution for which the card itself cannot directly compensate. This condition is managed in different ways, depending on the amplifier card type:

- OPT-BST—The OPT-BST amplifier is, by design, not allowed to work outside the zero tilt range. Cisco MetroPlanner network designs use 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 Section 10.8.2 System Level Gain Tilt Control.

## 10.8.2 System Level Gain Tilt Control

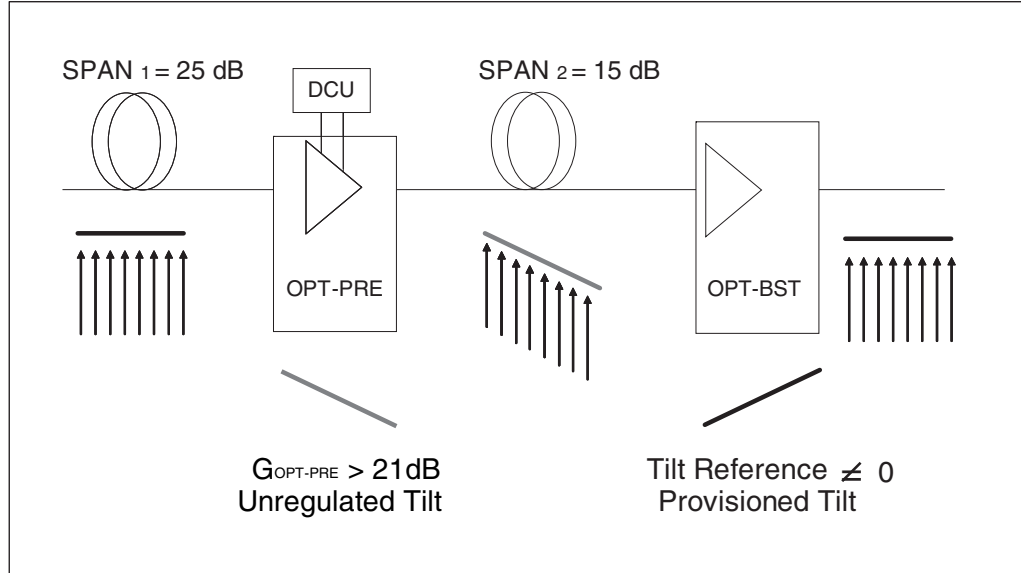
System level gain tilt control for OPT-PRE cards is achievable with two main scenarios:

- Without an ROADM node
- With an ROADM node

### 10.8.2.1 System Gain Tilt Compensation Without ROADM Nodes

When an OPT-PRE card along a specific line direction (Side A-to-Side B or Side B-to-Side A) 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 10-22.

Figure 10-22 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 ANS procedure, the Tilt value for the OPT-BST or OPT-PRE card is provisioned by the TCC2/TCC2P card (see [Figure 10-23](#)). 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 10-23 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:Rc:SideEast:Amplifier:ChPower	2.0	dBm	No
SideEast	Rack #1 Main Shelf 16	15454E-OPT-PRE	2	LINE-16-1-TX	COM-TX	dwdm:Rc:SideEast:Amplifier:Tilt	-3.0	dB	No
SideEast	Rack #1 Main Shelf 16	15454E-OPT-PRE	2	LINE-16-1-TX	COM-TX	dwdm:Rc:SideEast:Amplifier:WorkingMode	Control Gain	string	No
SideEast						dwdm:Rc:SideEast:MaxExpectedSpanLoss	25.0	dB	No
SideEast						dwdm:Rc:SideEast:MinExpectedSpanLoss	25.0	dB	No
SideEast						dwdm:Rc: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:Rc:SideEast:Threshold:AmplifierPowerFail	-30.6	dBm	No
SideEast						dwdm:Rc:SideEast:Threshold:ChannelLOS	-29.6	dBm	No
SideEast						dwdm:Rc: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:Rc:SideWest:Amplifier:ChPower	2.0	dBm	No
SideWest	Rack #1 Main Shelf 02	15454E-OPT-PRE	2	LINE-2-1-TX	COM-TX	dwdm:Rc:SideWest:Amplifier:Tilt	-3.0	dB	No
SideWest	Rack #1 Main Shelf 02	15454E-OPT-PRE	2	LINE-2-1-TX	COM-TX	dwdm:Rc:SideWest:Amplifier:WorkingMode	Control Gain	string	No
SideWest						dwdm:Rc:SideWest:MaxExpectedSpanLoss	25.0	dB	No
SideWest						dwdm:Rc:SideWest:MinExpectedSpanLoss	25.0	dB	No
SideWest						dwdm:Rc: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:Rc:SideWest:Threshold:AmplifierPowerFail	-29.8	dBm	No
SideWest						dwdm:Rc:SideWest:Threshold:ChannelLOS	-28.8	dBm	No
SideWest						dwdm:Rc:SideWest:Threshold:OSC-LOS	-36.3	dBm	No
SideWest	Rack #1 Main Shelf 04	15454E-OPT-BST	6	LINE-1-3-TX	LINE-TX	dwdm:Tx:SideWest:Amplifier:ChPower	3.0	dBm	No
SideWest	Rack #1 Main Shelf 04	15454E-OPT-BST	6	LINE-1-3-TX	LINE-TX	dwdm:Tx:SideWest:Amplifier:Tilt	3.0	dB	No
SideWest	Rack #1 Main Shelf 04	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

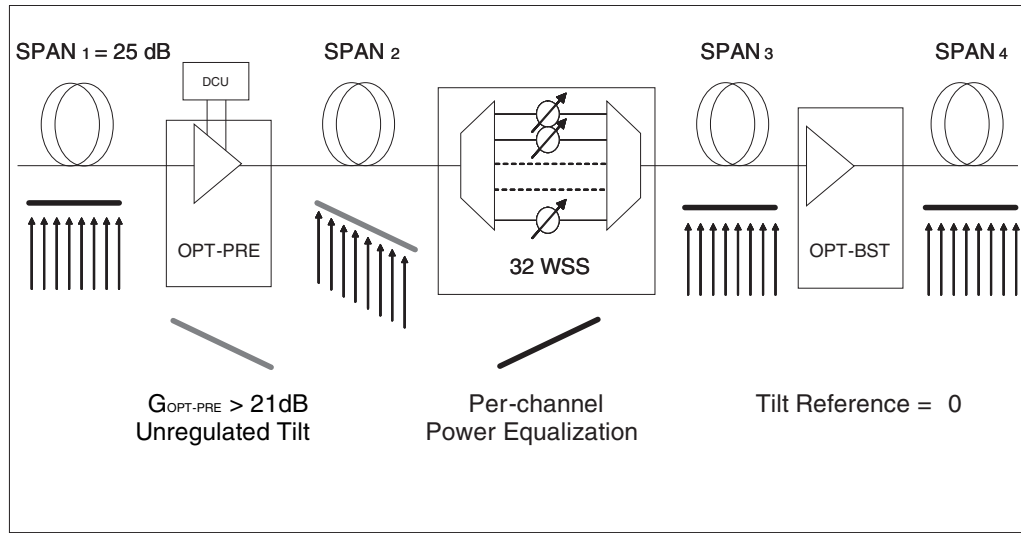
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### 10.8.2.2 System Gain Tilt Compensation With ROADM Nodes

When a ROADM node is present in the network, as shown in Figure 10-24, 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 10-24 System Tilt Compensation With an ROADM Node



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## 10.9 Optical Data Rate Derivations

This section discusses the derivation of several data rates commonly used in optical networking.

### 10.9.1 OC-192/STM-64 Data Rate (9.95328 Gbps)

The SONET OC-1 rate is 51.84 Mbps. This rate results from a standard SONET frame, which consists of 9 rows of 90 columns of 8-bit bytes (810 bytes total). The transmission rate is 8000 frames per second (125 microseconds per frame). This works out to 51.84 Mbps, as follows:

$$(9) \times (90 \text{ bytes/frame}) \times (8 \text{ bits/byte}) \times (8000 \text{ frames/sec}) = 51.84 \text{ Mbps}$$

$$\text{OC-192 is } 192 \times 51.84 \text{ Mbps} = 9953.28 \text{ Mbps} = 9.95328 \text{ Gbps}$$

STM-64 is an SDH rate that is equivalent to the SONET OC-192 data rate.

### 10.9.2 10GE Data Rate (10.3125 Gbps)

10.3125 Gbps is the standard 10 Gbps Ethernet LAN rate. The reason the rate is higher than 10.000 Gbps is due to the 64-bit to 66-bit data encoding. The result is  $10 \text{ Gbps} \times 66/64 = 10.3125 \text{ Gbps}$ . The reason for 64-bit to 66-bit encoding is to ensure that there are adequate data transitions to ensure proper operation of a clock and data recovery circuit at the far end. Additionally, the encoding assures a data stream that is DC balanced.

### 10.9.3 10G FC Data Rate (10.51875 Gbps)

The Fibre Channel rate is based on the OC-192 rate of 9.95328 Gbps, with the addition of 64-bit to 66-bit encoding and WAN Interconnect Sublayer (WIS) overhead bytes.

The rate is derived from the basic 9.95328 Gbps OC-192 rate. First, it has the 64-bit to 66-bit encoding added, which brings it to the 10.3125 Gbps rate (10 Gbps x 66/64 = 10.3125 Gbps). Beyond that, the WIS overhead is added, which is an additional two percent on top of the 10.3125 Gbps. This yields:

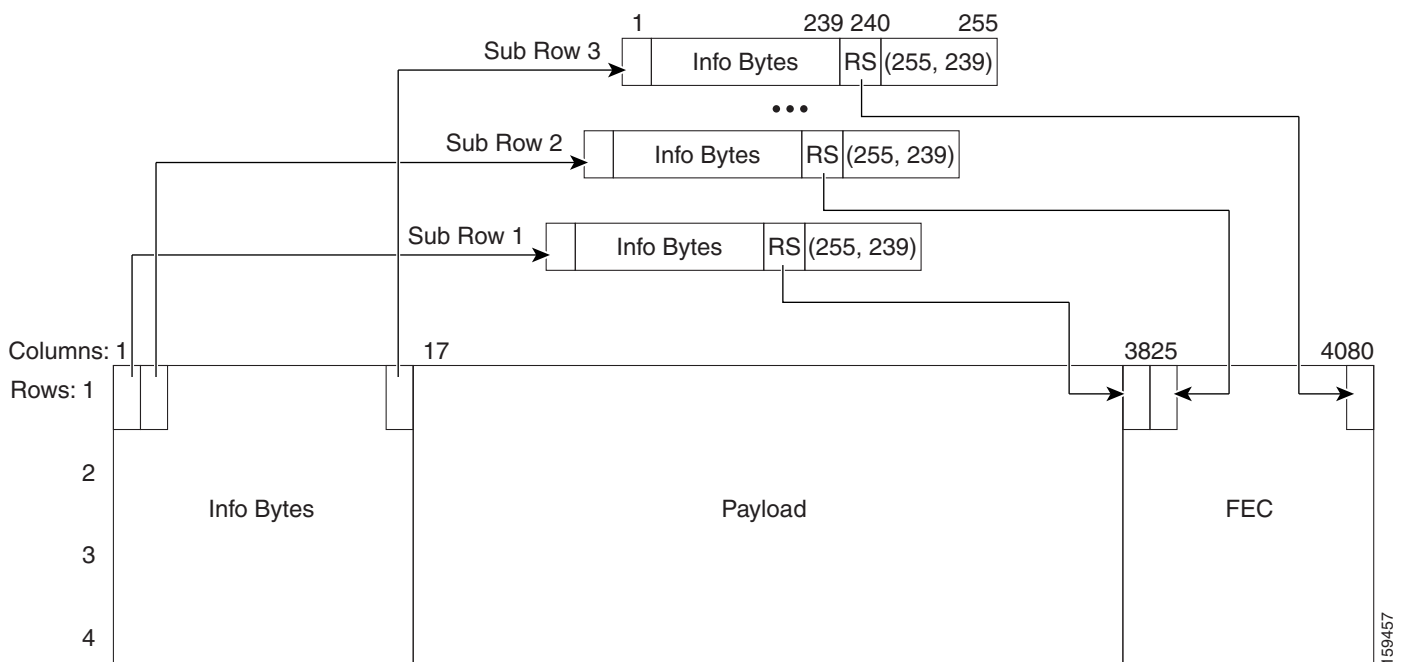
$$10.3125 \text{ Gbps} \times .02 = 0.20625 \text{ Gbps}$$

$$10.3125 \text{ Gbps} + 0.20625 \text{ Gbps} = 10.51875 \text{ Gbps}$$

## 10.9.4 ITU-T G.709 Optical Data Rates

To understand optical networking data rates, an understanding of the ITU-T G.709 frame structure, shown in [Figure 10-25](#), is needed.

**Figure 10-25** ITU-T G.709 Frame Structure



Each of the sub-rows in [Figure 10-25](#) contains 255 bytes. Sixteen are interleaved horizontally (16 x 255 = 4080). This is repeated four times to make up the complete ITU-T G.709 frame.

The Reed Solomon (RS) (255,239) designation indicates the forward error correction (FEC) bytes. There are 16 FEC, or parity, bytes. The ITU-T G.709 protocol uses one overhead byte and 238 data bytes to compute 16 parity bytes to form 255 byte blocks—the RS (255,239) algorithm. Interleaving the information provides two key advantages. First, the encoding rate of each stream is reduced relative to the line transmission rate and, second, it reduces the sensitivity to bursts of error. The interleaving combined with the inherent correction strength of the RS (255,239) algorithm enables the correction of transmission bursts of up to 128 consecutive errored bytes. As a result, the ITU-T G.709 contiguous burst error correcting capability is enhanced 16 times above the capacity of the RS(255,239) algorithm by itself.

ITU-T G.709 defines the Optical Transport Unit 2 (OTU2) rate as 10.70923 Gbps. ITU-T G.709 defines three line rates:

1. 2,666,057.143 kbps—Optical Transport Unit 1 (OTU1)

2. 10,709,225.316 kbps—Optical Transport Unit 2 (OTU2)
3. 43,018,413.559 kbps—Optical Transport Unit 3 (OTU3)

The OTU2 rate is higher than OC-192 because the OTU2 has to carry overhead and FEC bytes in its frame; the bits must be sent faster to carry the payload information at the OC-192 rate.

The ITU-T G.709 frame has two parts. Two are similar to a SDH/SONET frame:

1. Overhead area for operation, administration, and maintenance functions
2. Payload area for customer data

In addition, the ITU-T G.709 frame also includes FEC bytes.

### 10.9.4.1 OC-192 Packaged Into OTU2 G.709 Frame Data Rate (10.70923 Gbps)

In this case, an OC-192 frame is being transported over a OTU2 G.709 frame, which adds the benefit of FEC. The OC-192 data rate (9.95328 Gbps) must increase in order to transport more bytes (OC-192 plus ITU-T G.709 overhead plus ITU-T G.709 FEC bytes) in the same amount of time. In an OTU2 transmission, 237 of the 255 bytes are OC-192 payload. This means the resultant data rate is:

$$9.95328 \times 255/237 = 10.70923 \text{ Gbps}$$

### 10.9.4.2 10GE Packaged Into OTU2 G.709 Frame Data Rate (Nonstandard 11.0957 Gbps)

Encapsulating Ethernet data into an OTU2 G.709 frame is considered non-standard. The goal is to add the benefit of ITU-T G.709 encapsulation to achieve better burst error performance. However, this means adding overhead and FEC bytes, so more bytes must be transmitted in the same amount of time, so the data rate must increase. The new data rate is:

$$10.3215 \times 255/237 = 11.0957 \text{ Gbps}$$

### 10.9.4.3 10G FC Packaged Into OTU2 G.709 Frame Data Rate (Nonstandard 11.31764 Gbps)

Encapsulating Fibre Channel in an OTU2 frame is considered non-standard. The rate is higher than the 10.51875 rate because OTU2 includes FEC bytes. The bits must run at a faster rate so that the payload is provided at the standard Fibre Channel rate. The rate is:

$$10.51875 \times 255/237 = 11.31764 \text{ Gbps}$$