
# DWDM Topologies

This chapter explains Cisco ONS 15454 SDH dense wavelength division multiplexing (DWDM) topologies.

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. The DWDM network topologies supported are: hubbed rings, multihubbed rings, meshed rings, linear configurations, and single-span links.

Chapter topics include:

# 12.1 DWDM Rings and TCC2 Cards

Table 12-1 shows the DWDM rings that can be created on each ONS 15454 SDH node using redundant TCC2 cards.

*Table 12-1 ONS 15454 SDH Rings with Redundant TCC2 Cards*

| Ring Type | Maximum Rings per Node |
|---|---|
| Hubbed rings | 1 |
| Multihubbed rings | 1 |
| Meshed rings | 1 |
| Linear configurations | 1 |
| Single-span link | 1 |

# 12.2 DWDM Node Types

The node type in a network configuration is determined by the type of card that is installed in an ONS 15454 SDH DWDM node.

## 12.2.1 Hub Node

A hub node is a single ONS 15454 SDH node equipped with at least two 32 MUX-O cards, two 32 DMX-O cards, and two TCC2 cards. A dispersion compensation unit (DCU) can also be added, if necessary. Installing line cards in Slots 1 to 6 and 12 to 17 is not mandatory for this node type. Figure 12-1 on page 12-3 shows a typical hub node configuration. Only the lower half of the SDH node is shown in this illustration.

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

*Figure 12-1 Hub Node Configuration Example*

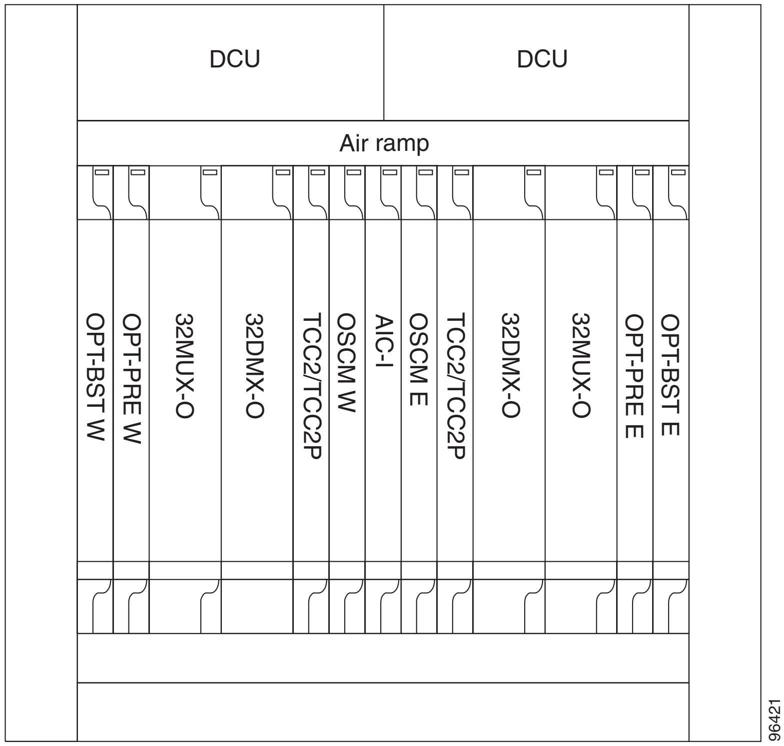
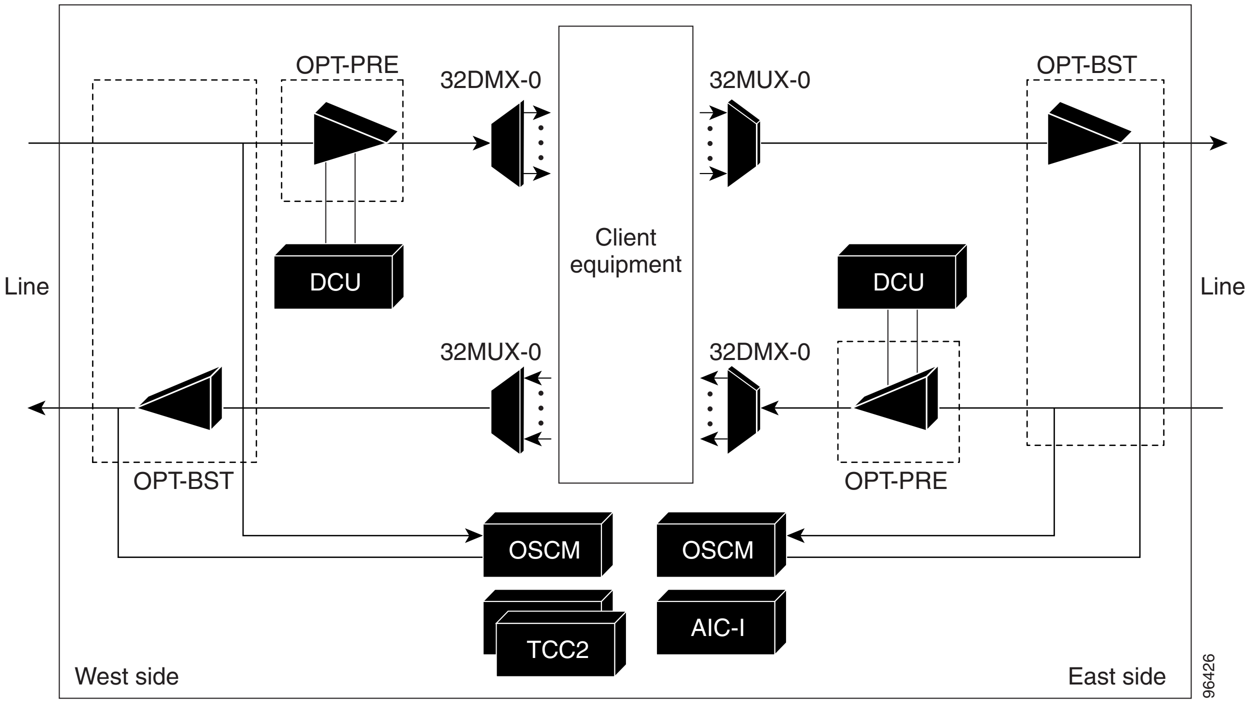



Figure 12-2 on page 12-4 shows the channel flow for a hub node. Up to 32 channels from the client ports are multiplexed and equalized onto one fiber using the 32 MUX-O card. Then, multiplexed channels are transmitted on the line in the eastward direction and fed to the Optical Booster (OPT-BST) amplifier. The output of this amplifier is combined with an output signal from the optical service channel modem (OSCM) card, and transmitted toward the east line.

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

*Figure 12-2 Hub Node Channel Flow Example*

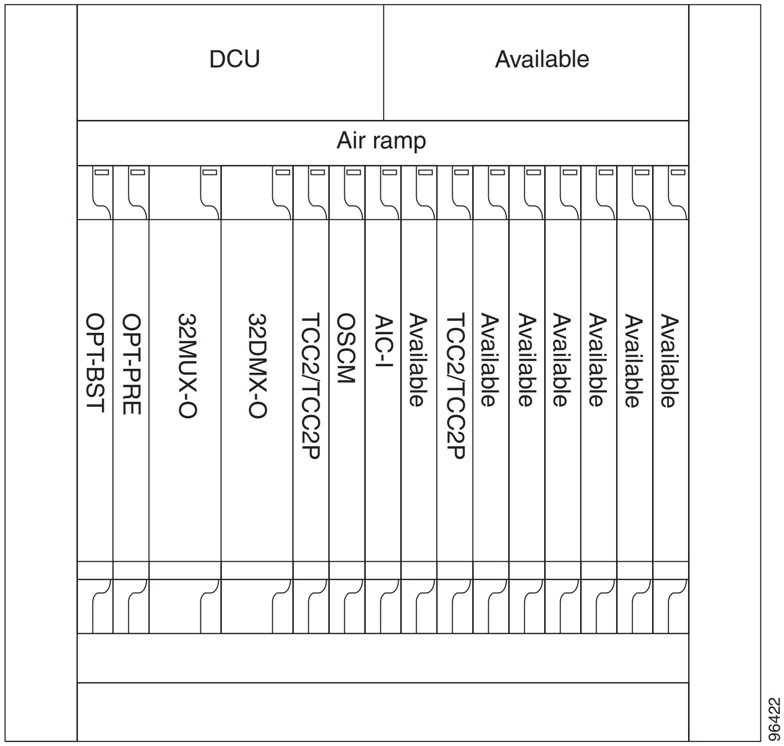



# 12.2.2 Terminal Node

A hub node can be changed into a terminal node by removing either the east or west cards. A terminal node is a single ONS 15454 SDH node equipped with at least one 32 MUX-O card, one 32 DMX-O card, and two TCC2 cards. Figure 12-3 on page 12-5 shows an example of a terminal node with an east side configuration. Only the lower half of the SDH node is shown in this illustration. The channel flow for a terminal node is the same as the hub node (see Figure 12-2).

**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.

*Figure 12-3 Terminal Node Configuration Example*




## 12.2.3 OADM Node

An OADM node is a single ONS 15454 SDH node equipped with at least one AD-xC-xx.x card or one AD-xB-xx.x card and two TCC2 cards. The 32 MUX-O or 32 DMX-O cards should not 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 cross-connect card (called pass through).

Unlike express path, a pass-through channel can be dropped in an altered ring without affecting another channel. OADM amplifier placement and required card placement are determined by the 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 the "Anti-ASE Node" section on page 12-9.

Figure 12-4 on page 12-6 shows an example of an amplified OADM node configuration. Only the lower half of the SDH node is shown in this illustration.

*Figure 12-4 Amplified OADM Node Configuration Example*

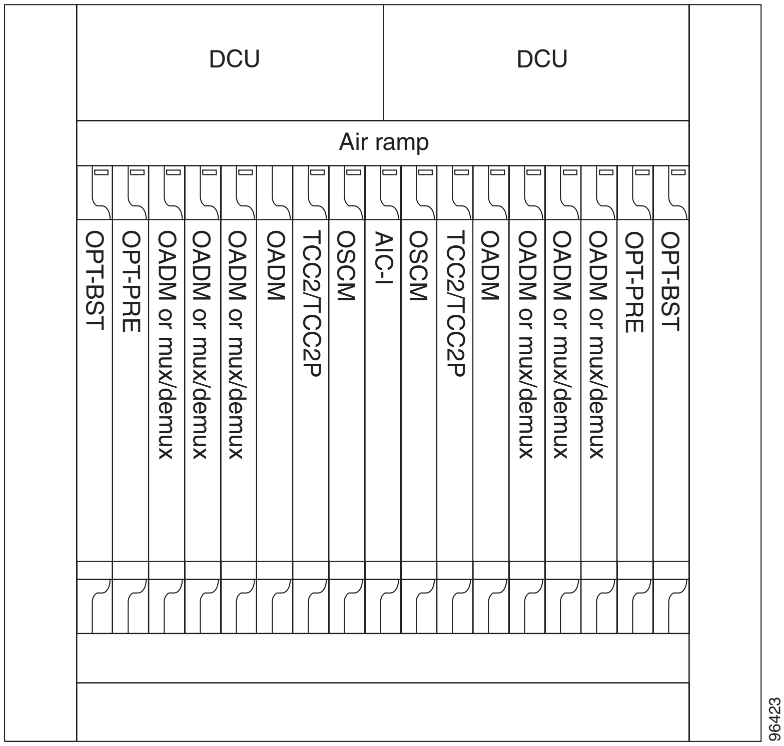



Figure 12-5 on page 12-7 shows an example of a passive OADM node configuration. Only the lower half of the SDH node is shown in this illustration.

*Figure 12-5 Passive OADM Node Configuration Example*

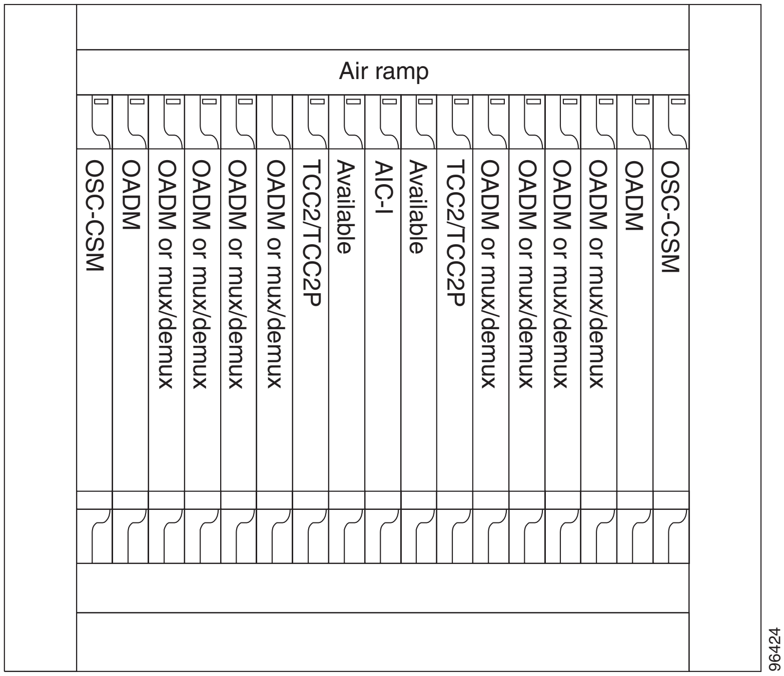



Figure 12-6 on page 12-8 shows an example of the channel flow on the amplified OADM node. Since the 32-wavelength plan is based on eight bands (each band contains four channels), optical adding and dropping can be performed at the band level and/or at the channel level (meaning individual channels can be dropped). An example of an OADM node created using band or channel filters is shown in Figure 12-6. The OPT-PRE and the OPT-BST amplifiers are installed on the east and west sides of the node. Only one-band and one-channel OADMs are installed on the east and west sides of the node.

*Figure 12-6 Amplified OADM Node Channel Flow Example*

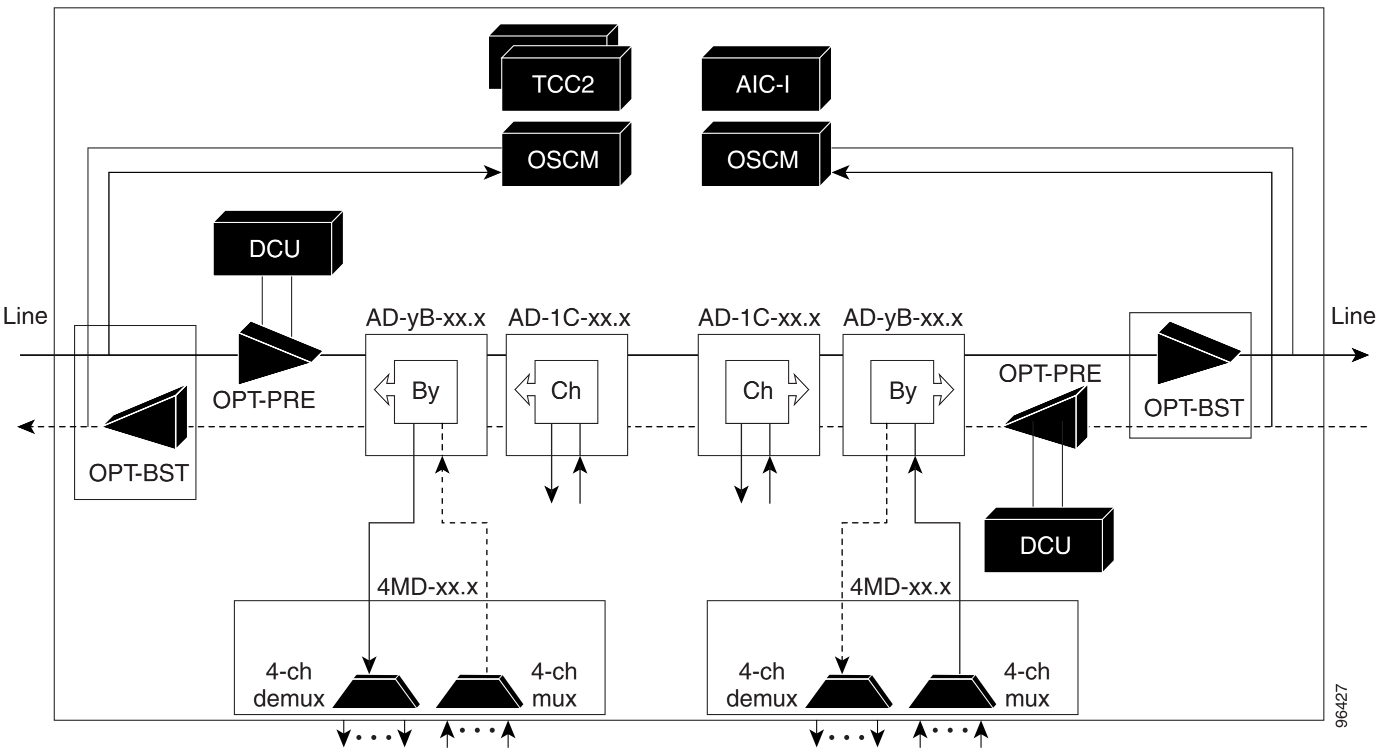
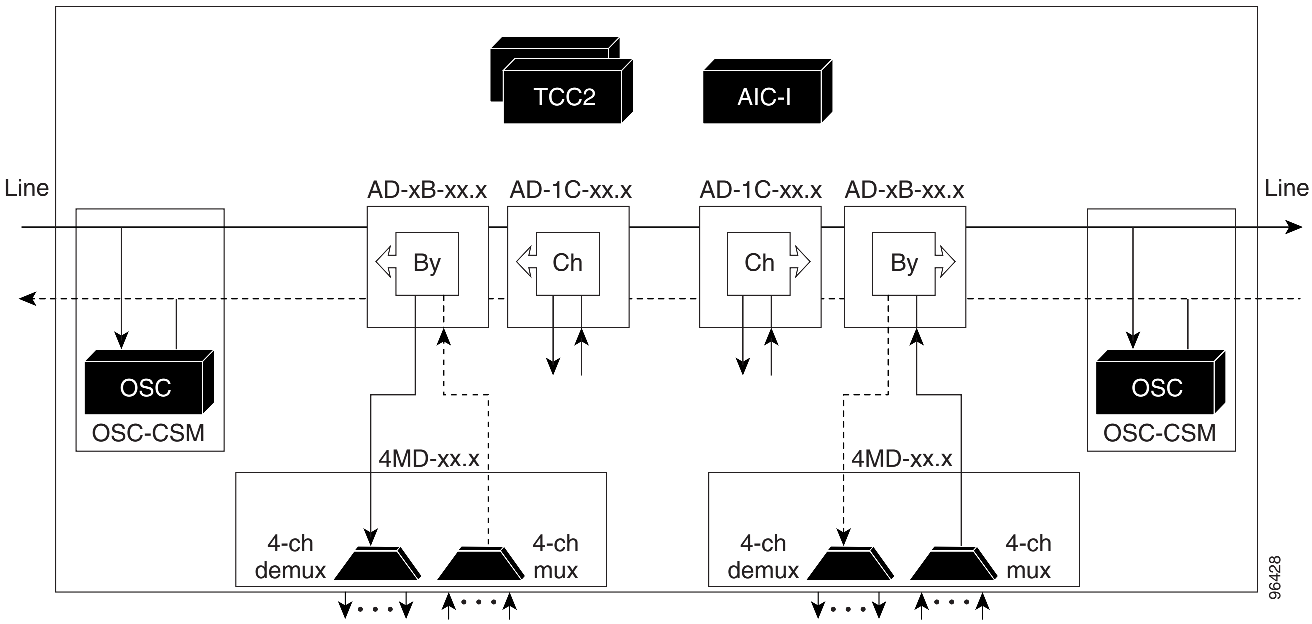



Figure 12-7 on page 12-9 shows an example of traffic flow on the passive OADM node. The passive OADM node is equipped with a band filter and a channel filter on each side of the node. The signal flow of the channels is the same as described in Figure 12-6 except that the OSC-CSM card is being used instead of the OPT-BST amplifier and the OSCM card.

*Figure 12-7 Passive OADM Node Channel Flow Example*



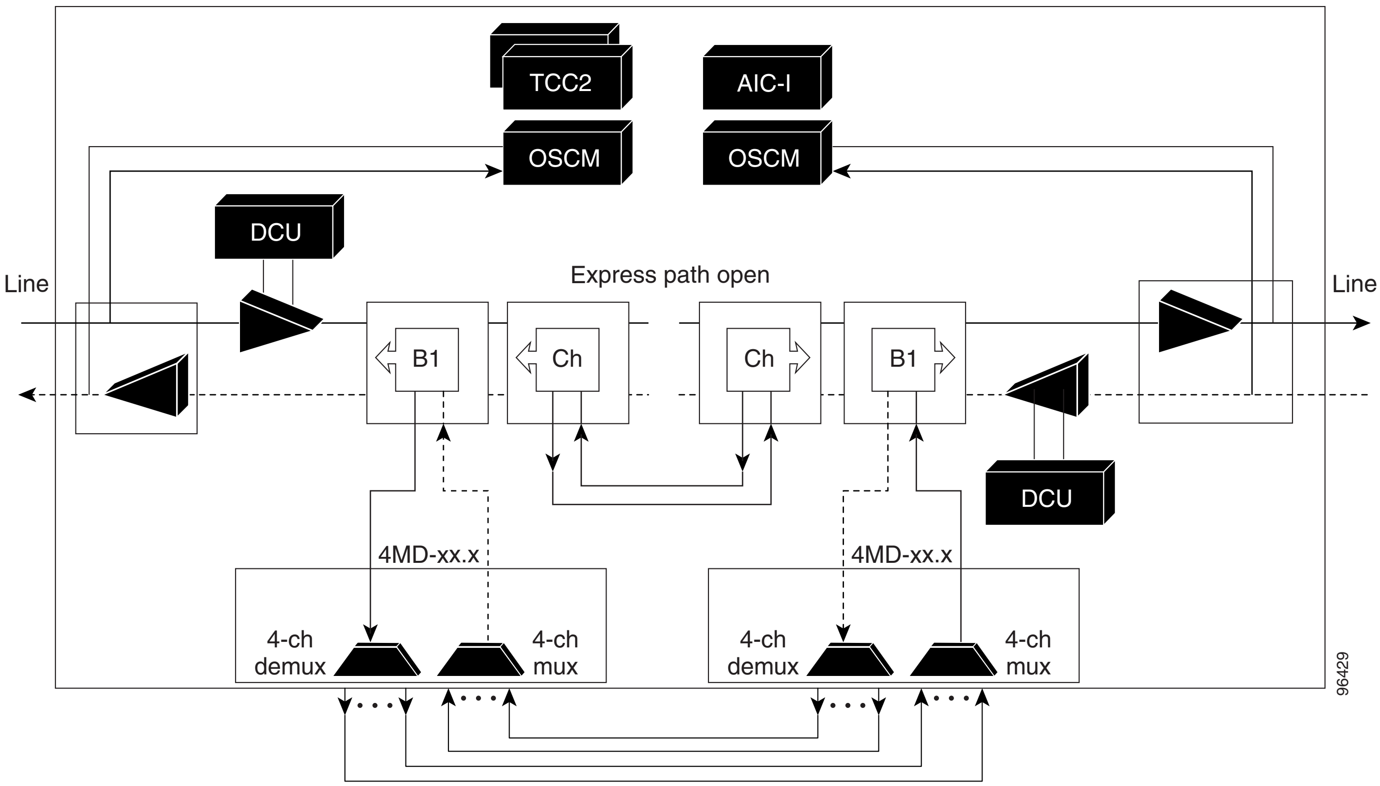

## 12.2.4 Anti-ASE Node

In a meshed ring network, the ONS 15454 SDH 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 dropped and demultiplexed 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. See Figure 12-6 on page 12-8.

Figure 12-8 shows an anti-ASE node that uses five wavelengths, two of which are terminated in the anti-ASE node. Use MetroPlanner or another network planning tool to determine the best configuration for anti-ASE nodes.

*Figure 12-8 Anti-ASE Node Channel Flow Example*

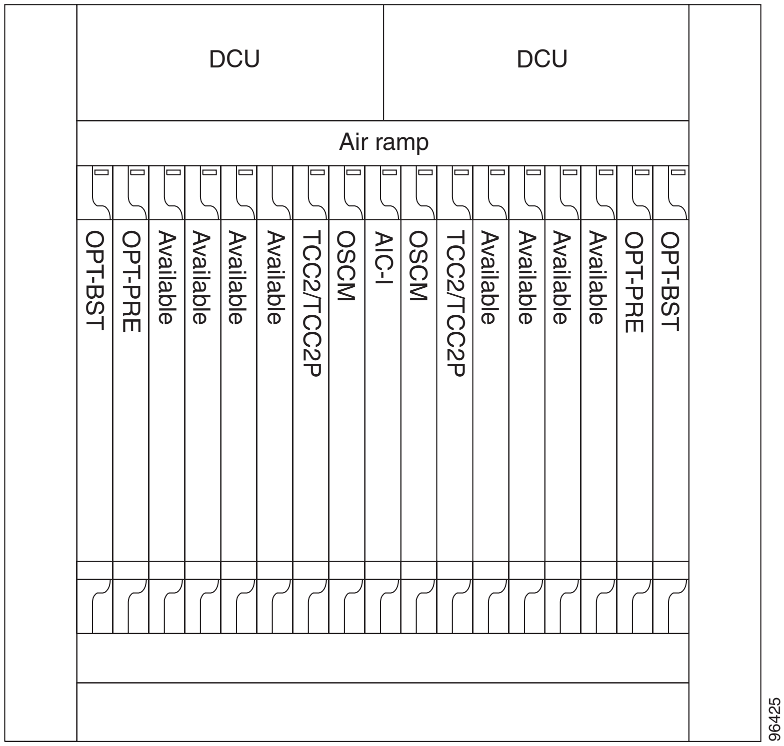



## 12.2.5 Line Amplifier Node

A line node is a single ONS 15454 SDH node equipped with OPT-PRE amplifiers or OPT-BST amplifiers and TCC2 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 cards are connected to the east or west ports of the booster amplifiers to multiplex the optical service channel (OSC) signal with the pass-though channels. If the node does not contain OPT-BST amplifiers, you must use OSC-CSM cards rather than OSCM cards in your configuration. Figure 12-9 on page 12-11 shows an example of a line node configuration. Only the lower half of the SDH node is shown in this illustration.

*Figure 12-9 Line Node Configuration Example*




# 12.3 Hubbed Rings

In the hubbed ring topology (Figure 12-10 on page 12-12) 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, that is, no channel reuse is possible. However, the same channel can be reused in difference 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 12-10 Hubbed Ring*

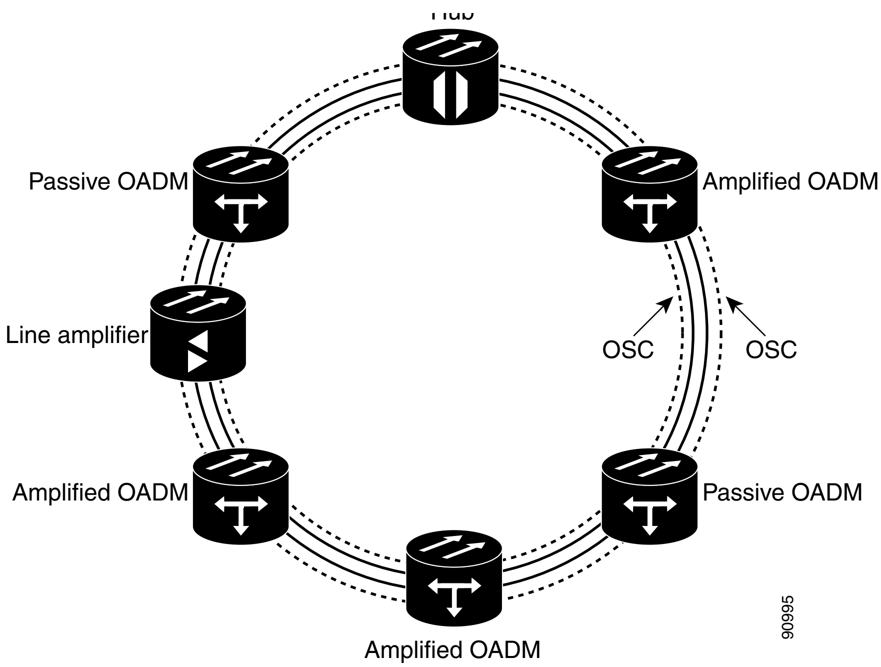



Table 12-2 lists the span loss for a hubbed ring. This applies to metro core networks only.

***Table 12-2 Span Loss for a Hubbed Ring***

| Number of Spans[1] | Class A[2] | Class B[2] | Class C[2] | Class D[2] | Class E[2] | Class F[2] | Class G[2] |
|---|---|---|---|---|---|---|---|
| Classes A through C are 10-Gbps interfaces | | | | Classes D through G are 2.5-Gbps interfaces | | | |
| 1 | 30 dB | 23 dB | 23 dB | 32 dB | 29 dB | 27 dB | 28 dB |
| 2 | 26 dB | 13 dB | 13 dB | 27 dB | 23 dB | 21 dB | 22 dB |
| 3 | 23 dB | — | — | 25 dB | 21 dB | 17 dB | 19 dB |
| 4 | 21 dB | — | — | 24 dB | 18 dB | — | 15 dB |
| 5 | 20 dB | — | — | 23 dB | 14 dB | — | — |
| 6 | 17 dB | — | — | 21 dB | — | — | — |
| 7 | 15 dB | — | — | 20 dB | — | — | — |

1. The optical performance values are valid assuming that all OADM nodes have a loss of 16 dB and equal span losses.
2. The following class definitions refer to the ONS 15454 SDH card being used:

Class A—10-Gbps multirate transponder with forward error correction (FEC) or 10-Gbps muxponder with FEC

Class B—10-Gbps multirate transponder without FEC

Class C—OC-192 LR ITU

Class D—2.5-Gbps multirate transponder both protected and unprotected with FEC enabled

Class E—2.5-Gbps multirate transponder both protected and unprotected without FEC enabled

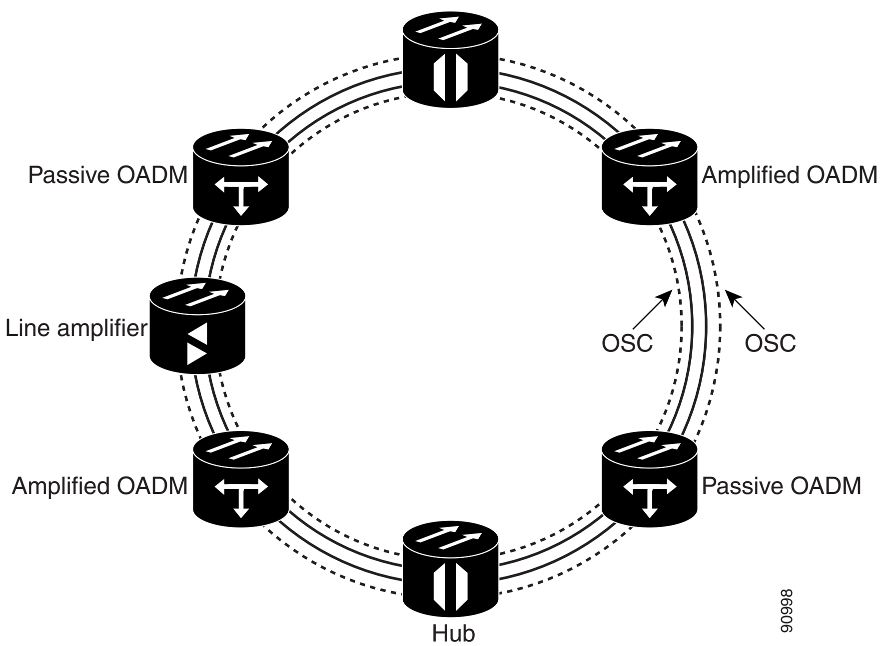
Class F—2.5-Gbps multirate transponder both protected and unprotected in regenerate and reshape (2R) mode

Class G—OC-48 ELR 100 GHz

# 12.4 Multihubbed Rings

A multihubbed ring (Figure 12-11) is based on the hubbed ring 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 12-11 Multihubbed Ring***




For information on span losses in a ring configuration, see Table 12-2 on page 12-12. This applies to metro core networks only.

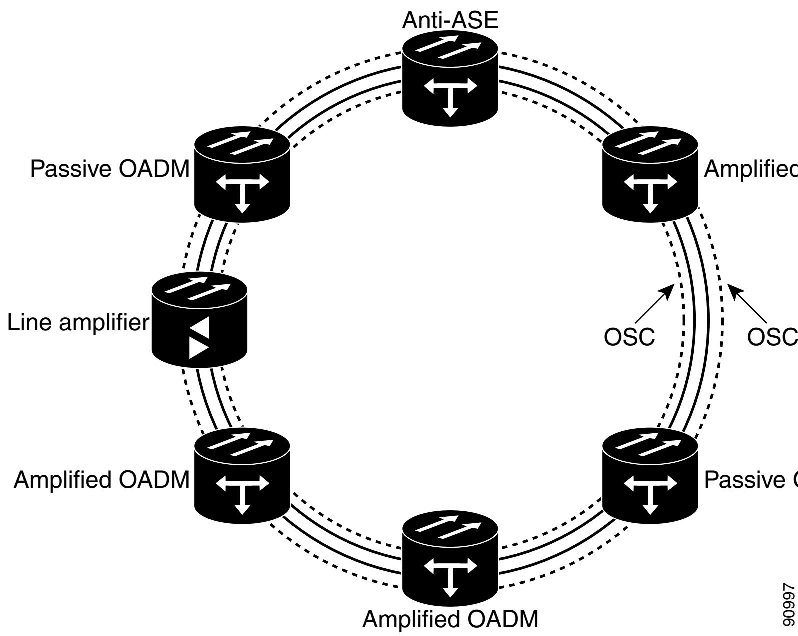
# 12.5 Meshed Rings

The meshed ring topology (Figure 12-12 on page 12-14) 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 32 MUX-O cards and 32 DMX-O cards. This solution is adopted when the total number of wavelengths deployed in the ring is higher than ten.
- 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 "hitless." In other words, no channels in the anti-ASE node can travel through the express path of the OADM node.

For more information about anti-ASE nodes, see the "Anti-ASE Node" section on page 12-9.

***Figure 12-12 Meshed Ring***




For information on span losses in a ring configuration, see Table 12-2 on page 12-12. For information on span losses in a ring without OADMs, see Table 12-4 on page 12-16. The tables apply to metro core networks only.

# 12.6 Linear Configurations

Linear configurations are characterized by the use of two terminal nodes (west and east). The terminal nodes must be equipped with a 32 MUX-O card and a 32 DMX-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 12-13 shows five ONS 15454 SDH nodes in a linear configuration with an OADM node.

***Figure 12-13 Linear Configuration with an OADM Node***

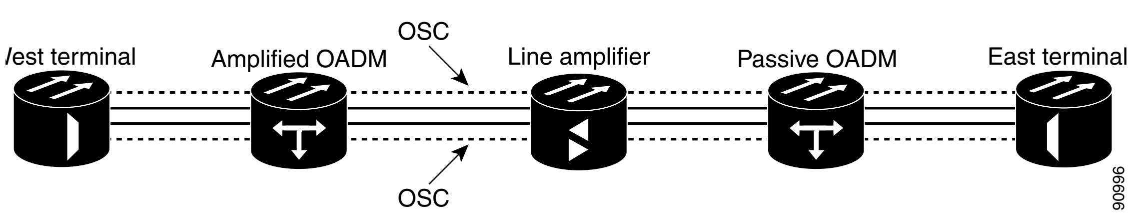



Table 12-3 lists the span loss for a linear configuration with OADM nodes for metro core networks only.

*Table 12-3 Span Loss for Linear Configuration with OADM Nodes*

| Number of Spans[1] | Class A[2] | Class B[2] | Class C[2] | Class D[2] | Class E[2] | Class F[2] | Class G[2] |
|---|---|---|---|---|---|---|---|
| Classes A through C are 10-Gbps interfaces | | | | Classes D through G are 2.5-Gbps interfaces | | | |
| 1 | 30 dB | 23 dB | 23 dB | 32 dB | 29 dB | 27 dB | 28 dB |
| 2 | 26 dB | 13 dB | 13 dB | 27 dB | 23 dB | 21 dB | 22 dB |
| 3 | 23 dB | — | — | 25 dB | 21 dB | 17 dB | 19 dB |
| 4 | 21 dB | — | — | 24 dB | 18 dB | — | 15 dB |
| 5 | 20 dB | — | — | 23 dB | 14 dB | — | — |
| 6 | 17 dB | — | — | 21 dB | — | — | — |
| 7 | 15 dB | — | — | 20 dB | — | — | — |

1. The optical performance values are valid assuming that all OADM nodes have a loss of 16 dB and equal span losses.
2. The following class definitions refer to the ONS 15454 SDH card being used:

Class A—10-Gbps multirate transponder with FEC or 10-Gbps muxponder with FEC
Class B—10-Gbps multirate transponder without FEC
Class C—OC-192 LR ITU
Class D—2.5-Gbps multirate transponder both protected and unprotected with FEC enabled
Class E—2.5-Gbps multirate transponder both protected and unprotected without FEC enabled
Class F—2.5-Gbps multirate transponder both protected and unprotected in 2R mode
Class G—OC-48 ELR 100 GHz

Figure 12-14 shows five ONS 15454 SDH nodes in a linear configuration without an OADM node.

*Figure 12-14 Linear Configuration Without an OADM Node*

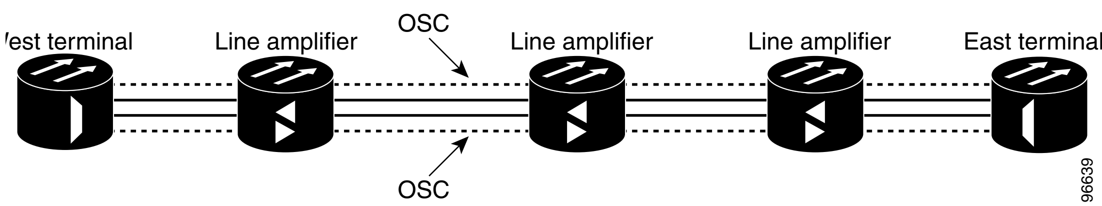


Table 12-4 lists the span loss for a linear configuration without OADMs.

*Table 12-4 Span Loss for a Linear Configuration Without OADM Nodes*

| Number of Spans | Class A[1] | Class B[1] | Class C[1] | Class D[1] | Class E[1] | Class F[1] | Class G[1] |
|---|---|---|---|---|---|---|---|
| Classes A through C are 10-Gbps interfaces | | | | Classes D through G are 2.5-Gbps interfaces | | | |
| 1 | 30 dB | 23 dB | 23 dB | 32 dB | 29 dB | 27 dB | 28 dB |
| 2 | 26 dB | 18 dB | 18 dB | 28 dB | 25 dB | 22 dB | 23 dB |
| 3 | 25 dB | 14 dB | 14dB | 26 dB | 23 dB | 20 dB | 21 dB |
| 4 | 23dB | — | — | 25 dB | 21 dB | 19 dB | 20 dB |
| 5 | 22 dB | — | — | 24 dB | 20 dB | 18 dB | 19 dB |
| 6 | 21 dB | — | — | 22 dB | 19 dB | 14 dB | 15 dB |
| 7 | 20 dB | — | — | 21 dB | 18 dB | 13 dB | 14 dB |

1. The following class definitions refer to the ONS 15454 SDH card being used:

Class A—10-Gbps multirate transponder with FEC or 10-Gbps muxponder with FEC

Class B—10-Gbps multirate transponder without FEC

Class C—OC-192 LR ITU

Class D—2.5-Gbps multirate transponder both protected and unprotected with FEC enabled

Class E—2.5-Gbps multirate transponder both protected and unprotected without FEC enabled

Class F—2.5-Gbps multirate transponder both protected and unprotected in 2R mode

Class G—OC-48 ELR 100 GHz

# 12.7 Single-Span Link

Single-span link is a type of linear configuration characterized by a single-span link with pre-amplification and post-amplification. A span link is also characterized by the use of two terminal nodes (west and east). The terminal nodes must be equipped with a 32 MUX-O card and a 32 DMX-O card. OADM passive nodes can be inserted between the two terminal nodes. Only unprotected traffic can be provisioned on a single-span link.

Figure 12-15 shows ONS 15454 SDH nodes in a single-span link. Eight channels are carried on one span. The losses in a single-span link only apply to OC-192 LR ITU cards. The optical performance values are valid assuming that the sum of the OADM passive nodes insertion losses and the span losses does not exceed 37 dB.

*Figure 12-15 Single-Span Link*

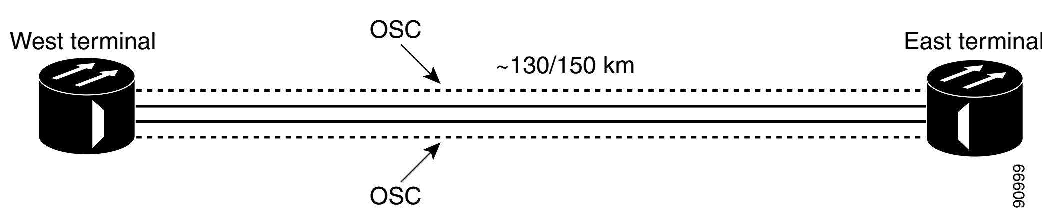



Table 12-5 lists the span loss for a single-span link configuration for metro core networks only.

*Table 12-5 Span Loss for Linear Configuration*

| Number of Spans[1] | Class A[2] | Class D[2] |
|---|---|---|
| 1 | 37 dB | 37 dB |
| 2 | 37 dB | 37 dB |
| 3 | 37 dB | 37 dB |
| 4 | 37 dB | 37 dB |
| 5 | 37 dB | 37 dB |
| 6 | 37 dB | 37 dB |
| 7 | 37 dB | 37 dB |

1. The optical performance values are valid assuming a maximum channel capacity of eight channels.
2. The following class definitions refer to the ONS 15454 SDH card being used:

Class A—10-Gbps multirate transponder with FEC or 10-Gbps muxponder with FEC

Class D—2.5-Gbps multirate transponder unprotected with FEC enabled

# 12.8 Automatic Power Control

Each ONS 15454 SDH DWDM node has an automatic power control (APC) feature that performs the following functions:

- Maintains constant channel power when channels are added and dropped or maintains the channel power constant when span loss degradation occurs.
- Provides automatic provisioning of amplifier parameters (such as gain) during network installation.

To perform these functions, all input and output ports are equipped with a variable optical attenuator (VOA) and a real or virtual photodiode. A virtual photodiode is a firmware calculation of the power at that port calculated by adding the measured values of all single-channel ports and applying the proper path insertion loss. VOAs and photodiodes have the following properties:

- VOAs are always present on input channels and drop bands.
- On output channels, a VOA is present only for the 32 DMX-O card.
- No VOAs exist on the add bands.
- For channels with VOAs, a photodiode is always present after the VOA.
- VOAs that are Optical Transport Section (OTS) or Optical Multiplex Section (OMS) paths are set in constant attenuation.
- VOAs that are Optical Channel (OCH) paths are set in constant power.

Management of channel number variation (including variations caused by fiber cuts) requires fast, real-time processing. This processing is performed by the firmware and processor in the amplifiers. Less time-sensitive processing for management of fiber span or passive optical component degradation is performed by the TCC2.

ONS 15454 SDH DWDM optical amplifiers work in two different modes when an input power change occurs:

- Constant Gain—The amplifiers change the output power. Gain is kept constant. This mode is used when channels are added or dropped.
- Constant Output Power—The amplifiers change the gain and keep the output power constant.

Constant gain mode is implemented in the DWDM amplifier cards to follow changes in the number of channels. These changes occur rapidly and require quick responses. Constant output power mode is implemented at the TCC2 to follow system degradations that are typically slow.

# 12.9 Automatic Node Setup

Automatic node setup (ANS) is a TCC2 function that adjusts values of the 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 SDH DWDM ring with different power levels.

To support ANS, the integrated VOAs and photodiodes are provided in the following DWDM cards:

- OADM band cards (AD-xB-xx.x), express and drop path
- OADM channel cards (AD-xC-xx.x), express and add path
- 4-Channel Terminal Multiplexer/Demultiplexer (4MD-xx.x) input port
- 32-Channel Terminal Multiplexer (32 MUX-O) input port
- 32-Channel Terminal Demultiplexer (32 DMX-O) output port

Optical power is equaled by regulating the VOAs. Knowing the expected per-channel power, ANS automatically calculates the VOA values by:

- Reconstructing the different channels 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
  - The 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 multiplexer/demultiplexer 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 (read only)—Set by ANS.
- Calibration Contribution (read and write)—Set by user.

The ANS equalization algorithm requires 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 a hitless connection.
- Transmit (Tx) ports are always connected to receive (Rx) ports.

Optical patch cords are passive devices that are not autodiscovered by ANS. However, optical patch cords are used to build the alarm correlation graph. ANS uses CTC and TL1 as the user interface to:

- 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.

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 value and the provisioned value occurs. The default value for the provisioned attribute is AUTO.

# 12.10 DWDM Network Topology Discovery

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

- Identify other ONS 15454 SDH DWDM nodes in an ONS 15454 SDH DWDM network.

- Identify the different types of DWDM networks.
- Identify when the DWDM network is complete and when it is incomplete.

ONS 15454 SDH DWDM nodes use node services protocol (NSP) to automatically update nodes 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 simulating 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 is to be shared by all ONS 15454 SDH DWDM nodes on the same network. Broadcast message delivery is managed in an independent way 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.