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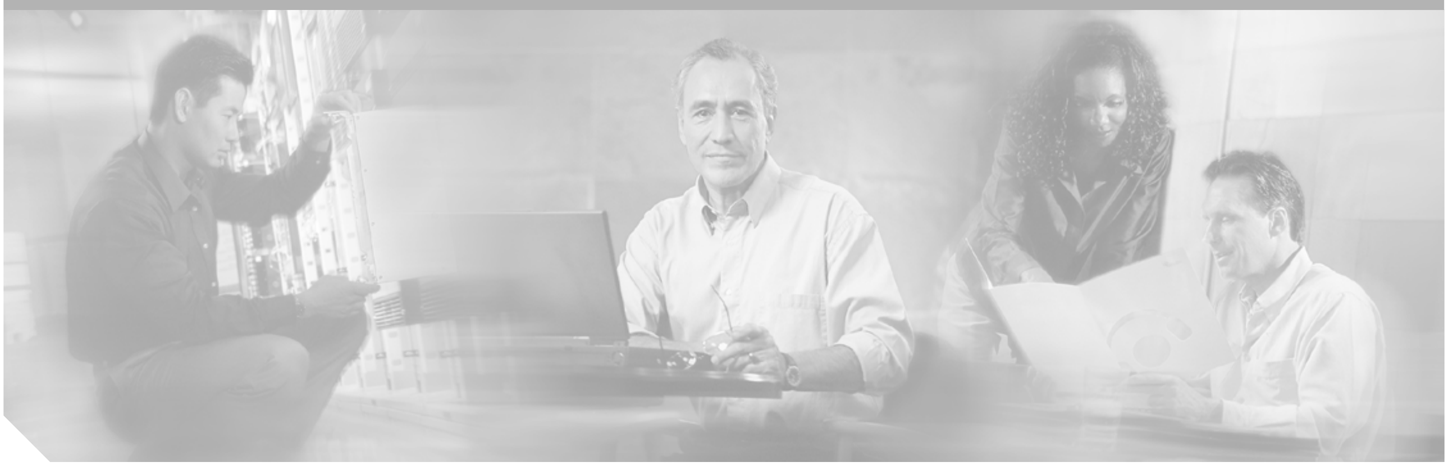

Cisco ONS 15540 ESPx Planning Guide

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Cisco ONS 15540 ESPx Planning Guide

CONTENTS

Preface

This preface describes the purpose, intended audience, organization, and conventions for the *Cisco ONS 15540 ESPx Planning Guide*.

The information contained in this document pertains to the entire range of hardware components and software features supported on the Cisco ONS 15540 ESPx platform. As new hardware and Cisco IOS software releases are made available for the Cisco ONS 15540 ESPx platform, verification of compatibility becomes extremely important. To ensure that your hardware is supported by your release of Cisco IOS software, see the “New and Changed Information” section in the *Cisco ONS 15530 Configuration Guide* for your software release. Also refer to the “Hardware Supported” section and “Feature Set” section of the latest release notes for the Cisco ONS 15540 ESPx.

Purpose

This guide serves as a planning tool for implementing DWDM transport networks using the Cisco ONS 15540 ESPx (Extended Services Platform External). This guide addresses important considerations and provides guidelines for planning an optical network. These include an understanding of the Cisco ONS 15540 ESPx basic system design, supported topologies and protection schemes, engineering rules and restrictions, and optical power budget calculations. Typical example networks are described, along with their associated chassis configurations.

Audience

This guide is intended for system designers, engineers, and others responsible for designing networks based on DWDM transport using the Cisco ONS 15540 ESPx.

Note The design guidelines in this document are based on the best currently available knowledge about the functionality and operation of the Cisco ONS 15540 ESPx. The information in this document is subject to change without notice.

Organization

The chapters of this guide are as follows:

Chapter	Title	Description
Chapter 1	System Overview	Describes the Cisco ONS 15540 ESPx chassis, components, and system architecture.
Chapter 2	Protection Schemes and Network Topologies	Describes the supported network topologies and fault protection schemes.
Chapter 3	Shelf Configuration Rules	Provides the rules for physical configuration of the Cisco ONS 15540 ESPx.
Chapter 4	Optical Loss Budgets	Provides metrics for calculating optical link loss budgets in Cisco ONS 15540 ESPx based networks.
Chapter 5	Example Shelf Configurations and Topologies	Provides examples of common topologies and protection options with configurations.
Appendix A	IBM Storage Protocol Support	Provides design information for applications that use IBM storage protocols.

Related Documentation

This guide is part of a documentation set that supports the Cisco ONS 15540 ESPx. The other documents in the set are as follows:

- *Regulatory Compliance and Safety Information for the Cisco ONS 15500 Series*
- *Cisco ONS 15540 ESPx Hardware Installation Guide*
- *Cisco ONS 15540 ESPx Optical Transport Turn-Up and Test Guide*
- *Cisco ONS 15540 ESPx Cleaning Procedures for Fiber Optic Connections*
- *Cisco ONS 15540 ESPx Configuration Guide*
- *Cisco ONS 15540 ESPx Command Reference*
- *Cisco ONS 15540 ESPx System Alarms and Error Messages*
- *Cisco ONS 15540 ESPx Troubleshooting Guide*
- *Network Management for the Cisco ONS 15540 ESPx*
- *Cisco ONS 15540 ESPx TL1 Command Reference*
- *MIB Quick Reference for the Cisco ONS 15500*
- *Cisco ONS 15540 ESPx Software Upgrade Guide*

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- 1 877 228-7302
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For a complete list of Cisco TAC contacts, go to this URL:

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System Overview

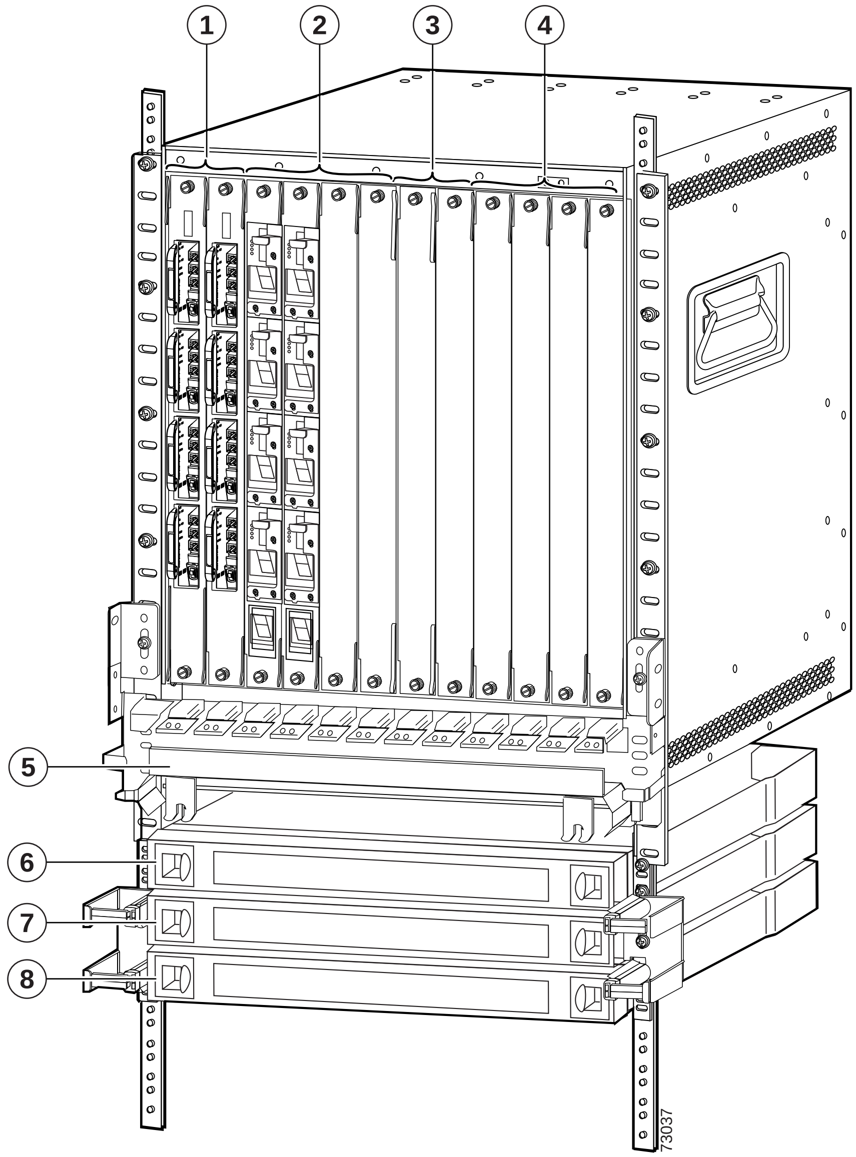
The Cisco ONS 15540 ESPx is an optical transport platform that employs DWDM (dense wavelength division multiplexing) technology. With the Cisco ONS 15540 ESPx, users can take advantage of the availability of dark fiber to build a common infrastructure that supports data networking (Ethernet based as well as SONET/SDH based) and storage networking.

This chapter contains the following major sections:

Chassis Description

The Cisco ONS 15540 ESPx uses a 12-slot modular vertical chassis (see Figure 1-1). The system receives power through redundant –48 VDC inputs. A redundant external AC power supply is available, or DC power can be provided directly. As you face the chassis, the two leftmost slots (slots 0 and 1) hold the mux/demux motherboards. These slots, which are populated with optical mux/demux modules, correspond to the west and east directions, respectively. Slot 0 or 1 can also contain a PSM (protection switch module) to provide trunk fiber protection switch. Slots 2 to 5 and 8 to 11 hold the line card motherboards, which are populated with transponder modules. Slots 6 and 7 hold the processor cards. Air inlet, fan tray, and cable management are located beneath the modular slots. The system has an electrical backplane for system control.

Figure 1-1 Cisco ONS 15540 ESPx Shelf Layout



1	Slots 0 and 1 hold the mux/demux motherboards	**5**	Cable management tray
2	Slots 2 to 5 hold the line card motherboards	**6**	Cable storage drawer
3	Slots 6 and 7 hold the processor cards	**7**	8-channel cross connect drawer
4	Slots 8 to 11 hold the line card motherboards	**8**	8-channel cross connect drawer

System Functional Overview

The Cisco ONS 15540 ESPx connects to client equipment to the DWDM trunk (transport network). Simply described, the Cisco ONS 15540 ESPx takes a client signal and converts it to an ITU-T G.692 compliant wavelength, then optically multiplexes it with the other client signals for transmission over an optical fiber link.

The Cisco ONS 15540 ESPx supports 1+1 path protection using both hardware and software mechanisms. In a single shelf configuration, a Cisco ONS 15540 ESPx node can support up to 32 channels with facility (fiber) protection or 16 channels with line card protection. In a dual shelf configuration a node can support up to 32 channels with line card protection.

The Cisco ONS 15540 ESPx can be deployed in point-to-point, linear add/drop, hubbed ring, and meshed ring topologies. Mulitple trunks connected to a single shelf can support two or more of these topologies.

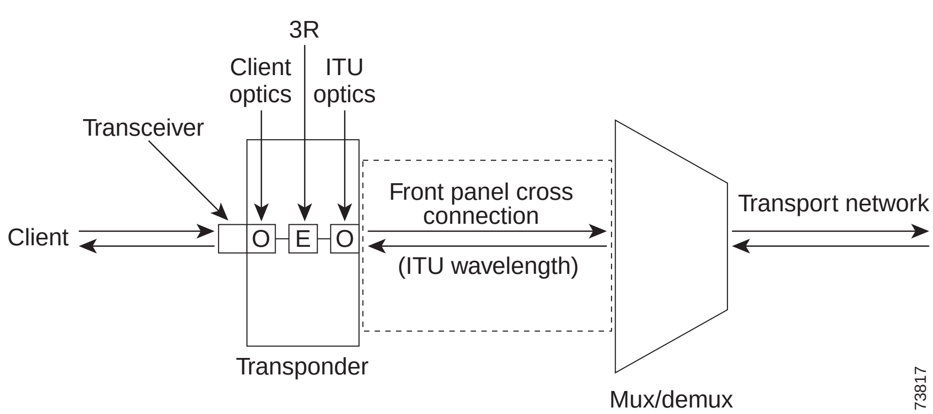
The transponder module receives the client signal through a transceiver attached to the external port. Inside the transponder module the 850-nm or 1310-nm input optical signal is converted to an electrical signal and the 3R (reshape, retime, retransmit) function is performed. A modulated laser diode then converts the electrical signal back to an optical one with a specific wavelength that complies with the ITU laser grid.

Inside the optical mux/demux module the input signals are multiplexed into a single DWDM signal and launched into the fiber on the trunk side. Thus, a one-to-one relationship exists between each client signal and each wavelength on the trunk side.

The Cisco ONS 15540 ESPx is a duplex system with both light emitters for transmission and light detectors for reception. For example, the client side interfaces on the transponder modules both transmit and receive light. The same is true of the transponder's DWDM interface. Also, the optical mux/demux modules both multiplex the transmit signal and demultiplex the receive signal.

Figure 1-2 illustrates the principal functions involved in transmission of the signal between the client and trunk networks within the Cisco ONS 15540 ESPx. The optical signal leaves the transponder module and travels from the backplane side of the transponder module to an optical connector on the front panel of the line card motherboard. Optical cross connections from the front panel of the line card motherboard take the signal to the mux/demux modules.

Figure 1-2 Simplified Data Flow Architecture for the Cisco ONS 15540 ESPx



10-Gigabit Ethernet Functionality

The 10-GE transponder module transports 10-Gigabit Ethernet over the network. The module can be used as a downlink to the Cisco ONS 15530 and for direct connections to 10-GE interfaces on client equipment.

The hardware providing this functionality includes a 10-Gbps line card motherboard and 10-GE transponder modules.

System Components

The Cisco ONS 15540 ESPx has a modular architecture that allows flexibility in configuration and permits incremental upgrades of the system. These components are described in the following sections.

Transponder Modules

The Cisco ONS 15540 ESPx supports four types of transponder modules: Type 1 SM (single-mode), Type 1 MM (multimode), Type 2 extended range with SFP optics, and 10 GE.

The transponder modules populate the line card motherboards and have two interfaces: an external interface that connects to client equipment, and an internal interface that connects to the line card motherboard.

In the transponder module, the client signal is regenerated and retransmitted on an ITU-compliant wavelength.

The laser on each 2.5-Gbps transponder module is capable of generating one of two wavelengths on the trunk side. Thus, 16 different transponder modules exist (for channels 1–2, 3–4,..., 31–32) to support the 32 channels; each module is available in Type 1 SM, Type 1 MM, and Type 2 extended range versions. The wavelength the module generates is configurable from the CLI (command-line interface).

The 10-GE transponder modules each support one wavelength on the trunk side for a total of 32 different transponder modules.

A safety protocol, LSC (laser safety control), shuts the transmit laser down on the trunk side when a fiber break or removed connector is detected. The transponder modules are hot pluggable, permitting in-service upgrades and replacement.

Type 1 SM Transponder Modules and MM Transponder Modules

The SM transponder modules and MM transponder modules are Type 1 transponder modules with fixed, nonpluggable client interface ports. The client interfaces are protocol transparent and bit-rate transparent, and accept either single-mode or multimode client signals on the 1310-nm wavelength through SC connectors. The multimode transponder supports 62.5 µm MM, 50 µm MM, and 9 or 10 µm SM fiber; the single-mode transponder supports 50 µm MM fiber and 9 or 10 µm SM fiber.

The transponder client interfaces support encapsulation of client signals in either 3R enhanced mode, which allows some client protocol monitoring (such as code violations and data errors) or regular 3R mode, where the transponder is transparent to the client data stream. In either case, the content of the client data stream remains unmodified. Configurable failure and degrade thresholds for monitored protocols are also supported.

Table 1-1 shows the common client signal encapsulations supported on the SM transponder modules and MM transponder modules.

Table 1-1 Common Client Signal Encapsulations Supported on SM Transponder Modules and MM Transponder Modules

Client Signal Encapsulation	Fiber Type	Wavelength (nm)		Transponder Type		Protocol Monitoring
		1310	850	SM	MM	
Gigabit Ethernet (1250 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	No	Yes
	MM 50/125 µm	Yes	No	Yes	No	Yes
	MM 62.5/125 µm	Yes	No	No	No	—
Fast Ethernet (100 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	Yes	No
	MM 50/125 µm	Yes	No	Yes	Yes	No
	MM 62.5/125 µm	Yes	No	No	Yes	No
SONET STS-3/ SDH STM-1 (OC-3) (155 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	Yes	Yes
	MM 50/125 µm	Yes	No	Yes	Yes	Yes
	MM 62.5/125 µm	Yes	No	No	Yes	Yes
SONET STS-12/SDH STM-4 (OC-12) (622 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	Yes	Yes
	MM 50/125 µm	Yes	No	Yes	Yes	Yes
	MM 62.5/125 µm	Yes	No	No	Yes	Yes
SONET STS-48/ SDH STM-16 (OC-48) (2488 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	No	Yes
	MM 50/125 µm	Yes	No	Yes	No	Yes
	MM 62.5/125 µm	Yes	No	No	No	—
ATM 155 (OC-3) (155 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	Yes	Yes
	MM 50/125 µm	Yes	No	Yes	Yes	Yes
	MM 62.5/125 µm	Yes	No	No	Yes	Yes
Fiber Channel (1062 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	No	Yes
	MM 50/125 µm	Yes	No	Yes	No	Yes
	MM 62.5/125 µm	Yes	No	No	No	—
Fiber Channel (2125 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	No	Yes
	MM 50/125 µm	Yes	No	Yes	No	Yes
	MM 62.5/125 µm	Yes	No	No	No	—
FDDI (125 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	Yes	No
	MM 50/125 µm	Yes	No	Yes	Yes	No
	MM 62.5/125 µm	Yes	No	No	Yes	No

Table 1-2 shows the IBM storage protocols on the SM transponder modules and MM transponder modules.

Table 1-2 IBM Storage Protocols Supported on Single-Mode and Multimode Transponder Modules

Client Signal Encapsulation	Fiber Type	Wavelength (nm)		Transponder Type		Protocol Monitoring
		1310	850	SM	MM	
ESCON (200 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	Yes	Yes
	MM 50/125 µm	Yes	No	No	Yes	Yes
	MM 62.5/125 µm	Yes	No	No	Yes	Yes
FICON (1062 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	No	Yes
	MM 50/125 µm	Yes	No	Yes[1]	No	Yes
	MM 62.5/125 µm	Yes	No	Yes[1]	No	Yes
FICON (2125 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	No	Yes
	MM 50/125 µm	Yes	No	Yes[2]	No	Yes
	MM 62.5/125 µm	Yes	No	Yes[1]	No	Yes
Coupling Facility, ISC compatibility (1062 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	No	Yes
	MM 50/125 µm	Yes	No	Yes[1]	No	Yes
	MM 62.5/125 µm	No	No	—	—	—
Coupling Facility, ISC peer (2125 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	No	Yes
	MM 50/125 µm	No	No	—	—	—
	MM 62.5/125 µm	No	No	—	—	—
Coupling Facility, ISC peer (1062 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	No	Yes
	MM 50/125 µm	No	No	—	—	—
	MM 62.5/125 µm	No	No	—	—	—
Sysplex Timer (ETR and CLO) (8 Mbps[3])	SM 9 or 10/125 µm	No	No	—	—	—
	MM 50/125 µm	Yes	No	No	Yes	No
	MM 62.5/125 µm	Yes	No	No	Yes	No

1. These protocols require the use of a special mode-conditioning patch cable (available from IBM) at each end of the connection.
2. These protocols require the use of a special mode-conditioning patch cable (available from IBM) at each end of the connection.
3. Sysplex Timer is the only protocol supported at a clock rate less than 16 Mbps.

Table 1-3 shows some other common protocols that are supported on the SM transponder modules and MM transponder modules without protocol monitoring.

Table 1-3 Other Client Signal Encapsulations Supported on Single-Mode and Multimode Transponder Modules

Client Signal Encapsulation	Fiber Type	Wavelength (nm)		Transponder Type		Protocol Monitoring
		1310	850	SM	MM	
DS3 (45 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	Yes	No
	MM 50/125 µm	Yes	No	Yes	Yes	No
	MM 62.5/125 µm	Yes	No	No	Yes	No
OC-1 (51.52 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	Yes	No
	MM 50/125 µm	Yes	No	Yes	Yes	No
	MM 62.5/125 µm	Yes	No	No	Yes	No
OC-24 (933.12 Mbps)	SM 9 or 10/125 µm	Yes	No	Yes	No	No
	MM 50/125 µm	Yes	No	Yes	No	No
	MM 62.5/125 µm	Yes	No	No	No	No

Additional discrete rates are also supported in regular 3R mode. For SM transponder modules, these rates fall between 16 Mbps and 2.5 Gbps; for MM transponder modules, the rates are between 16 Mbps and 622 Mbps.

Note Rates from 851,000 Kbps to 999,999 Kbps and from 1601,000 Kbps to 1,999,999 Kbps are not supported.

The system supports OFC (open fiber control) for Fibre Channel and ISC encapsulations. Alternatively, FLC (forward laser control) can be enabled to shut down the laser on the client or trunk side if a LOL (loss of light) is detected on the other side.

Note The Cisco ONS 15540 ESPx transponder modules do not support autonegotiation for 2-Gbps Fibre Channel. The transponder modules only recognize the configured clock rate or protocol encapsulation.

For detailed information about client interface configuration, refer to the *Cisco ONS 15540 ESPx Configuration Guide*.

Type 2 Extended Range Transponder Modules with SFP Optics

The Type 2 extended range transponder module accepts two types of SFP optics:

- Fixed rate
- Variable rate

Fixed rate SFP optics modules support specific protocols. Table 1-4 lists the features for the fixed rate SFP optics supported by the Type 2 extended range transponder modules.

Table 1-4 Fixed Rate SFP Optics Features

Part Number	Supported Protocols	Fiber Type	Wavelength	Connector Type
15500-XVRA-01A2	ESCON, SONET OC-3 SR, SDH STM-1	MM 50/125 µm MM 62.5/125 µm	1310 nm	MT-RJ
15500-XVRA-02C1	Gigabit Ethernet[1], Fibre Channel (1 Gbps)[2], FICON (1 Gbps), ISC-1 (1-Gbps)	MM 50/125 µm MM 62.5/125 µm	850 nm	LC
15500-SFP-GEFC-SX	Fibre Channel (1 Gbps and 2 Gbps)[3], FICON (1 Gbps and 2 Gbps), ISC-3 (1-Gbps and 2-Gbps), Gigabit Ethernet	MM 50/125 µm MM 62.5/125 µm	850 nm	LC
15500-XVRA-03B1	Gigabit Ethernet[4], Fibre Channel (1 Gbps)[5], FICON (1 Gbps), ISC compatibility mode (1 Gbps), ISC peer mode (1 Gbps)	SM 9/125 µm	1310 nm	LC
15500-XVRA-03B2	Fibre Channel (1 Gbps[6] and 2 Gbps[7]), FICON (1 Gbps and 2 Gbps), ISC compatibility mode (1 Gbps), ISC peer mode (1 Gbps and 2 Gbps)	SM 9/125 µm	1310 nm	LC
15500-XVRA-06B1	SONET OC-12 SR[8], SDH STM-4	SM 9/125 µm	1310 nm	LC
15500-XVRA-07B1	SONET OC-48 SR, SDH STM-16	SM 9/125 µm	1310 nm	LC

1. 1000BASE-SX
2. FC-0-100-M5-SN-S and FC-0-100-M6-SN-S standards
3. FC-0-200-M5-SN-S and FC-0-200-M6-SN-S standards
4. 1000BASE-LX
5. FC-0-100-SM-LC-S standard
6. FC-0-100-SM-LC-S standard
7. FC-0-200-SM-LC-S standard
8. SR = short range

Variable rate SPF optics modules support a range of clock rates. Table 1-5 lists features for the variable rate SFP optics supported by the Type 2 extended range transponder modules.

Table 1-5 Variable Rate SFP Optics Features

Part Number	Clock Rate Range	Protocol Encapsulations Supported	Fiber Type	Wavelength	Connector Type
15500-XVRA-10A1	Low-band 8 Mbps to 200 Mbps	Sysplex (CLO and ETR)[1] (8 Mbps), Fast Ethernet[2] (125 Mbps), SONET OC-3[3] (155.52 Mbps), SDH STM-1 (622 Mbps), ESCON[4] (200 Mbps)	MM 50/125 µm 62.5/125 µm	1310 nm	LC
15500-XVRA-10B1	Low-band 8 Mbps to 200 Mbps	Sysplex (CLO and ETR)[1] (8 Mbps), Fast Ethernet[2] (125 Mbps), SONET OC-3[3] (155.52 Mbps), SDH STM-1 (155.52 Mbps), ESCON[4] (200 Mbps)	SM 9/125 µm	1310 nm	LC
15500-XVRA-11A1	Mid-band 200 Mbps to 622 Mbps	ESCON[4] (200 Mbps), SONET OC-12[3] (622 Mbps), SDH STM-4 (622 Mbps)	MM 50/125 µm 62.5/125 µm	1310 nm	LC
15500-XVRA-11B1	Mid-band 200 Mbps to 1.25 Gbps	ESCON[4] (200 Mbps), SONET OC-12[3] (622 Mbps), SDH STM-4 (622 Mbps), FC[4] (1.062 Gbps), FICON (1.062 Gbps), GE[4] (LX) (1.250 Gbps) ISC compatibility mode (1.062 Gbps), ISC peer mode (1.062 Gbps)	SM 9/125 µm	1310 nm	LC
15500-XVRA-12B1	High-band 1.062 Gbps to 2.488 Gbps	FC[4] (1.062 Gbps and 2.125 Gbps), FICON (1.062 Gbps and 2.125 Gbps), GE[4] (LX) (1.250 Mbps), SONET OC-48 (2.488 Gbps), SDH STM-16 (2.488 Gbps), ISC compatibility mode (1.062 Gbps), ISC peer mode (1.062 Gbps and 2.125 Gbps)	SM 9/125 µm	1310 nm	LC

1. Manchester coded
2. 4B/5B coded
3. Scrambler 2^{23-1}
4. 8B/10B coded

Note The Cisco IOS software only supports Cisco-certified SFP optics on the Type 2 extended range transponder module.

The following protocols can be monitored with the Type 2 extended range transponder modules:

- ESCON (Enterprise Systems Connection)
- Fibre Channel (1 Gbps and 2 Gbps)

- FICON (Fiber Connection) (1 Gbps and 2 Gbps)
- Gigabit Ethernet
- ISC (InterSystem Channel) links compatibility mode
- ISC links peer mode (1 Gbps and 2 Gbps)
- SDH (Synchronous Digital Hierarchy) (STM-1, STM-4, STM-16)
- SONET (OC-3, OC-12, OC-48)

For detailed information about client interface configuration, refer to the *Cisco ONS 15540 ESPx Configuration Guide*.

Caution The SFP optics supported by the Type 2 extended range transponder modules yield optimal performance at the data rates for which the transceivers are explicitly designed. Configuring a protocol encapsulation or clock rate outside of the clock rate specifications for the transceiver could result in suboptimal performance, depending on the transceiver characteristics (such as receiver sensitivity and output power).

For information on transceiver specifications, refer to the *Cisco ONS 15540 ESPx Hardware Installation Guide*.

The Type 2 extended range transponder modules also support the OFC (open fiber control) safety protocol for Fibre Channel.

Note The Cisco ONS 15540 ESPx transponder modules do not support autonegotiation for 2-Gbps Fibre Channel. The transponder modules only recognize the configured clock rate or protocol encapsulation.

Conditions Monitored on 2.5-Gbps Transponder Modules

For GE, FC, and FICON traffic, the Cisco ONS 15540 ESPx monitors the following conditions:

- CVRD (code violation running disparity) error counts
- Loss of Sync
- Loss of Lock
- Loss of Light

For SONET errors, the Cisco ONS 15540 ESPx monitors the SONET section overhead only, not the SONET line overhead. Specifically, the Cisco ONS 15540 ESPx monitors the B1 byte and the framing bytes. The system can detect the following defect conditions:

- Loss of Light
- Loss of Lock (when the clock cannot be recovered from the received data stream)
- Severely errored frame
- Loss of Frame

For SONET performance, the system monitors the B1 byte, which is used to compute the four SONET section layer performance monitor parameters:

- SEFS-S (second severely errored framing seconds)
- CV-S (section code violations)

- ES-S (section errored seconds)
- SES-S (section severely errored seconds)

For ISC traffic, the system monitors the following conditions:

- CVRD error counts
- Loss of CDR (clock data recovery) Lock
- Loss of Light

10-GE Transparent Transponder Modules

The 10-GE transponder module is double the size of the 2.5-Gbps transponder module and requires a special 10-Gbps line card motherboard. Network configurations that use 10-GE transponder might require Cisco ONS 15216 Dispersion Compensator Units.

Note For a description of the 10-Gbps line card motherboard, see the "10-Gbps Line Card Motherboards" section on page 1-13.

Each 10-GE transponder module supports one client side and one trunk side interface. The client side is a short-reach 1310 nm interface and the trunk side interface is an ITU grid compliant 15xx nm long-reach interface. The transmitter supports a 1260 nm to 1355 nm wavelength range. The 10-GE transponder module is available in 32 versions, one for each of the 32 ITU wavelengths.

The 10-GE transponder module is not protocol independent. It supports the IEEE 802.ae specification for 10GBASE-LR interfaces.

10-GE Transponder Module Performance Monitoring

This section describes the parameters, alarms and statistics that the 10-GE transponder module monitor.

The module monitors the following optical parameters:

- Loss of wavelength optical power (RxLOS)
- Receive optical power (RxPowMon)

The module monitors the following digital or protocol alarms:

- Loss of Sync
- Loss of CDR Lock
- Signal fail threshold
- BERT capabilities

The module collects the following statistics:

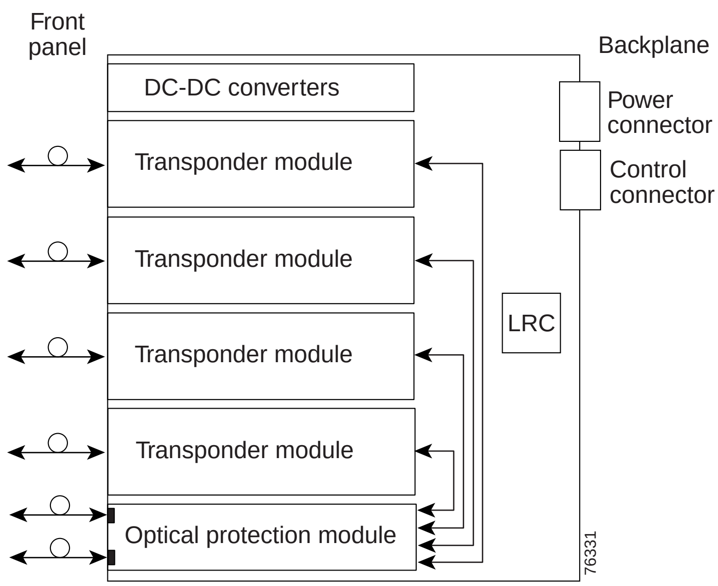
- Code violations
- Running disparities
- 64b/66b CVRD
- CDL HEC errors
- CDL idle packet counter
- Non-CDL packet counter

2.5-Gbps Line Card Motherboards

The 2.5Gbps line card motherboards hold the 2.5-Gbps transponder modules and provide front panel optical connectors for the ITU signal generated by the transponder modules. The 2.5-Gbps line card motherboards are modular and can be populated according to user needs. A single system can hold up to eight line card motherboards, each of which accepts four 2.5-Gbps transponder modules.

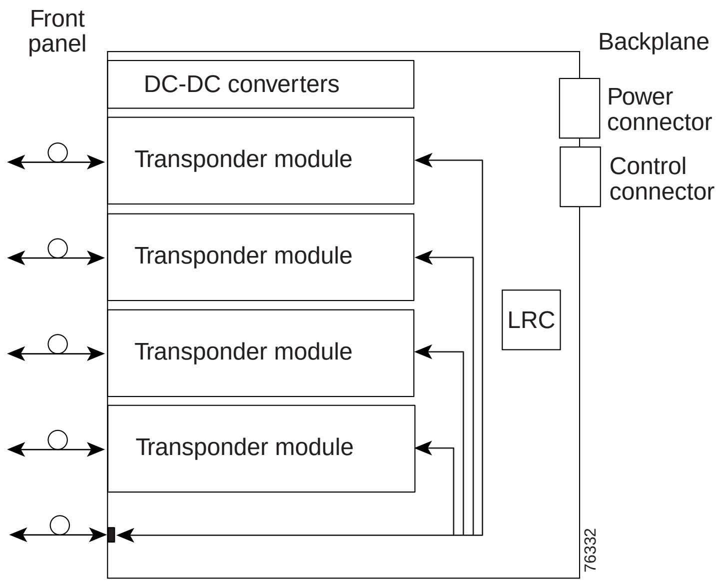
The Cisco ONS 15540 ESPx supports two types of 2.5-Gbps line card motherboards: splitter and nonsplitter. The splitter 2.5-Gbps motherboard provides protection against fiber failure by delivering the ITU wavelengths emitted from their associated 2.5-Gbps transponder modules to two optical connectors on the front panel (see Figure 1-3). Use these optical connectors to connect the line card motherboard to two mux/demux modules, either directly or with the cross connect drawer. The mux/demux modules support the same channels with one sending to the west and one sending to the east.

Figure 1-3 Cisco ONS 15540 ESPx Splitter Line Card Motherboard



The nonsplitter 2.5-Gbps line card motherboard delivers the ITU wavelengths from the associated transponder modules to one optical connector on the front panel (see Figure 1-4). Use this optical connector to connect the line card motherboard to one mux/demux module, either directly or using the cross connect drawer.

Figure 1-4 Cisco ONS 15540 ESPx Nonsplitter Line Card Motherboard



10-Gbps Line Card Motherboards

A single system can hold up to eight dual-subslot 10-Gbps line card motherboards. There are two 10-Gbps line card motherboards available, splitter and nonsplitter.

The splitter protected motherboard provides trunk side protection. The motherboard has two external optical connectors at the bottom of the board, one for the east direction and one for the west direction. Both optical connectors carry the optical signal from a 10-GE transponder to the respective mux/demux motherboard. The two optical connectors are not selectable.

The nonsplitter motherboard is used in configurations where trunk side protection is not required. The motherboard has one external optical connector at the bottom of the board. The optical connector carries a band of wavepatch interfaces and the optical signal from the 10-GE transponder to the respective mux/demux motherboard.

Mux/Demux Motherboards

The mux/demux motherboards hold the optical mux/demux modules. Either slot 0 or slot 1 can be populated with a single mux/demux motherboard for unprotected operation, or both slots can be populated for protected operation.

The Cisco ONS 15540 ESPx chassis supports two types of mux/demux motherboards, with and without OSC support.

The mux/demux motherboards can accept up to four mux/demux modules:

- Up to four 4-channel add/drop mux/demux modules
- Up to four 8-channel add/drop mux/demux modules
- One 32-channel terminal mux/demux module

The mux/demux motherboard can also accept a PSM for trunk fiber based protection along with the mux/demux modules.

OSC Support

The OSC is implemented with a dedicated laser and receiver for a 33rd wavelength (channel 0) on the mux/demux motherboard. The OSC is a per-fiber duplex management channel for communicating between Cisco ONS 15540 ESPx systems. It allows control and management traffic to be carried without the necessity of a separate Ethernet connection to each Cisco ONS 15540 ESPx, Cisco ONS 15540 ESP, and Cisco ONS 15530 in the network.

The OSC is established over a point-to-point connection and is always terminated on a neighboring node. By contrast, data channels may or may not be terminated on a given node, depending on whether the channels are express (pass-through) or add/drop.

The OSC carries the following types of information:

- CDP (Cisco Discovery Protocol) packets—Used to discover neighboring devices
- IP packets—Used for SNMP and Telnet sessions between nodes
- OSCP (OSC Protocol)—Used to determine whether the OSC link is up
- APS protocol packets—Used for controlling signal path switching

Note A Cisco ONS 15540 ESPx system on which the OSC is not present is not known to other systems in the network and cannot be managed by any NMS. Without the OSC, a Cisco ONS 15540 ESPx system must be managed individually by separate Ethernet or serial connections. Thus, it is important when adding a node to an existing network of Cisco ONS 15540 ESPx systems that the added node have OSC support.

Optical Mux/Demux Modules

The optical mux/demux modules are passive devices that optically multiplex and demultiplex a specific band of ITU wavelengths. In the transmit direction, the optical mux/demux modules multiplex signals transmitted by the transponder modules over optical cross connections and provide the interfaces to connect the multiplexed signal to the DWDM trunk side. In the receive direction, the optical mux/demux modules demultiplex the signals from the trunk side before passing them over optical cross connections to the transponder modules.

Optical Mux/Demux Modules and Channel Bands

There are two types of optical mux/demux modules—OADM (optical add/drop multiplexing) and terminal. Each module supports one or more 4-channel *bands*. The OADM modules support one or two bands (four channels or eight channels); the terminal mux/demux modules support eight bands (32 channels).

Table 1-6 lists the optical mux/demux modules that support each channel band. All modules are available with or without OSC support. For correspondence between channel numbers and wavelengths on the ITU grid, refer to the *Cisco ONS 15540 ESPx Hardware Installation Guide*.

Table 1-6 Optical Mux/Demux Modules and Supported Channel Bands

Cisco ONS 15540 ESPx Channels	4-Channel Add/Drop Mux/Demux Module	8-Channel Add/Drop Mux/Demux Module	32-Channel Terminal Mux/Demux Module[1]
1–4	Band A	Band AB	Band AH
5–8	Band B		
9–12	Band C	Band CD	
13–16	Band D		
17–20	Band E	Band EF	
21–24	Band F		
25–28	Band G	Band GH	
29–32	Band H		

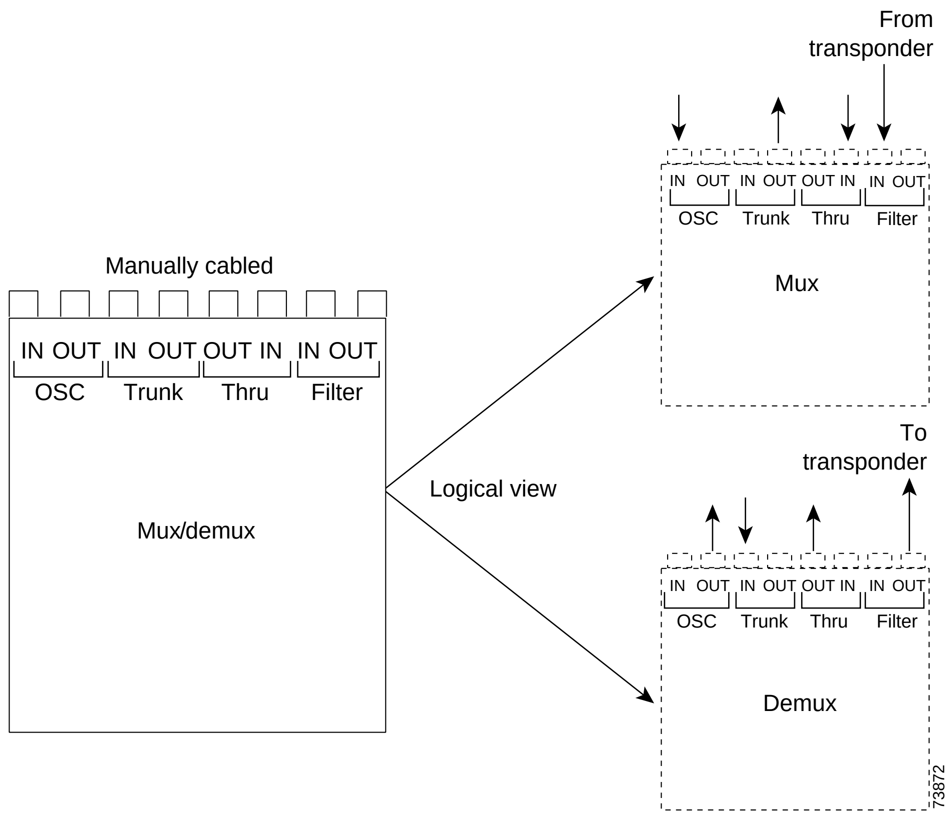
1. A 32-channel terminal mux/demux module occupies all four subslots in a mux/demux motherboard.

OADM Modules

An OADM module adds a specified band of channels at a node and passes the other bands through. To support the 32-channel spectrum, there are eight different 4-channel modules and four different 8-channel modules.

Figure 1-5 shows the physical layout of the Cisco ONS 15540 ESPx OADM module with front panel optical connectors along with a logical view of its multiplexing and demultiplexing functions. Optical signals received from the transponder, the Thru IN connector, and the OSC IN connector are multiplexed and sent through the Trunk OUT connector. The optical signal received from the Trunk IN connector is demultiplexed and the OSC signal is sent to the OSC OUT connector; the dropped channels are sent to the transponder; and the passed channels are sent to the Thru OUT connector.

Figure 1-5 Cisco ONS 15540 ESPx Optical Add/Drop Mux/Demux Module



32-Channel Terminal Mux/Demux Modules

The 32-channel terminal mux/demux module is based on AWG (arrayed waveguide grating) technology and supports the ITU wavelengths within the AH band (channels 1–32) and optionally the OSC. The 32-channel module installs in either slot 0 or slot 1 and supports front panel optical filter connectors, and it occupies all four subslots.

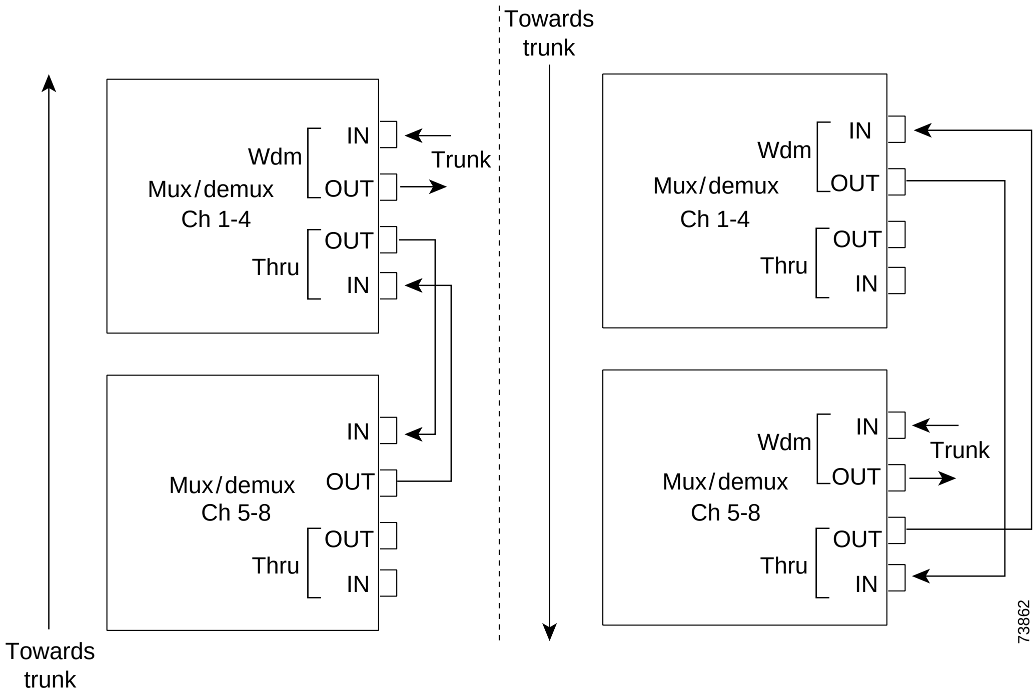
Because of their more favorable optical power loss characteristics, terminal mux/demux modules may be preferred at nodes where selective add/drop is not required, such as in a point-to-point topology or at the hub node in a hubbed ring topology.

Optical Mux/Demux Module Configurations and Cabling

The modular nature of the mux/demux motherboard allows optical mux/demux modules to be added as needed to support the desired number of client signals. In the case of add/drop mux/demux modules, the capacity can be increased with the addition of 4- or 8-channel modules to support increased channel demand or the requirements of a meshed ring topology.

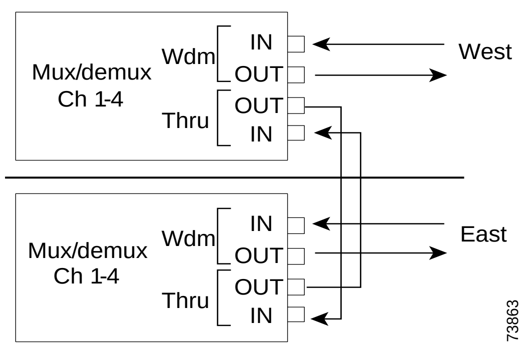
The 4- or 8-channel add/drop modules can be combined in a cascading fashion using optical fiber cables with MU connectors. Figure 1-6, for example, shows how two 4-channel modules are cabled together to upgrade a point-to-point configuration from 4 channels to 8 channels.

Figure 1-6 Cascaded 4-Channel Mux/Demux Modules



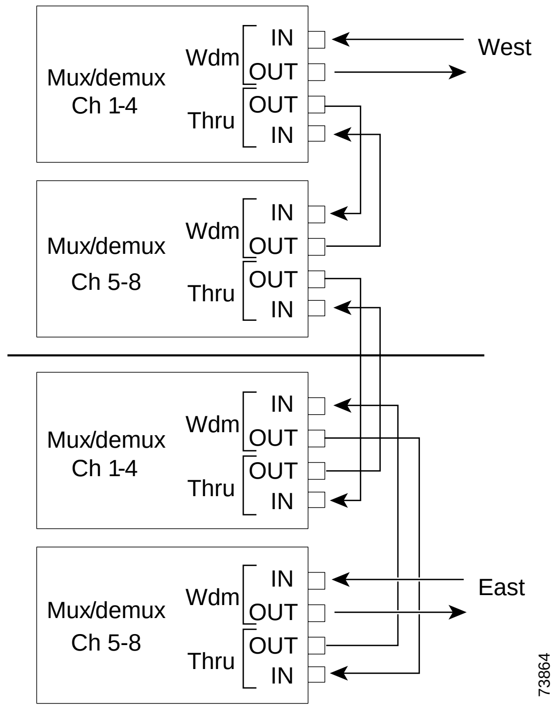
In ring configurations, channels that are not destined for a particular node are passed through that node and sent back on the ring. Figure 1-7 shows an example of how two 4-channel mux/demux modules might be cabled in a protected ring configuration.

Figure 1-7 4-Channel Mux/Demux Modules in a Protected Ring Configuration



In some ring topologies, cascading add/drop mux/demux modules may be required to support the add/drop requirements of the configuration. Figure 1-8 shows one example.

Figure 1-8 Cascaded Add/Drop Mux/Demux Modules in a Protected Ring Configuration

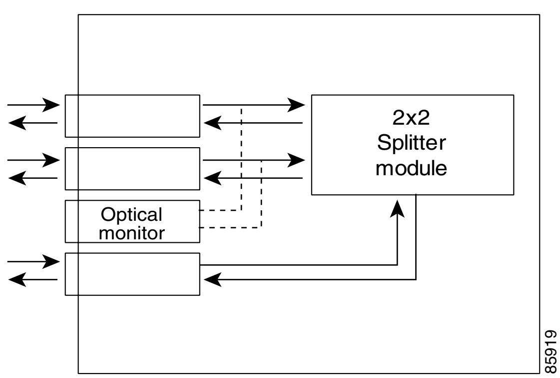


PSMs

The PSM (protection switch module) provides trunk fiber protection for Cisco ONS 15540 ESPx systems configured in point-to-point topologies. The PSM sends the signal from a mux/demux module or a transponder module in both the west and east directions. It receives both the west and east signals and selects one to send to the mux/demux module or the transponder module. Both nodes in the network topology must have the same shelf configuration. When a trunk fiber cut occurs on the active path, the PSM switches the received signal to the standby path. The PSM can protect up to 32 data channels and the OSC (see Figure 1-9).

The PSM also has an optical monitor port for testing the west and east receive signals. This port samples one percent of the receive signal, which can be monitored with an optical power meter.

Figure 1-9 PSM Architecture



Cross Connect Drawer

The Cisco ONS 15540 ESPx design allows access to all optical connectors from the front of the shelf. For futher cabling flexibility, you can also use a cross connect drawer. This is particularly useful for adding and dropping fewer than four channels on a node that contains 4-channel, 8-channel, or 32-channel mux/demux modules. For example, you can cross connect channels 1 and 2 in band A from the west mux/demux module to a transponder module to add and drop at the node and cross connect channels 3 and 4 to pass through to the east mux/demux module unchanged. Each cross connect drawer supports a maximum of 8 protected channels. Protecting more than 8 channels requires additional cross connect drawers.

You can also use the cross connect drawer to receive ITU signals from other DWDM shelves, such as the Cisco ONS 15530, to multiplex and demultiplex the same as signals generated on the Cisco ONS 15540 ESPx shelf.

Processors Cards

The Cisco ONS 15540 ESPx includes two processor cards for redundancy. Each processor consists of a number of subsystems, including a CPU, a system clock, Ethernet switch for communicating between processors and with the LRC (line card redundancy controller) on the mux/demux motherboards and line card motherboards, and a processor redundancy controller. The active processor controls the node, and all cards in the system make use of the system clock and synchronization signals from the active processor.

The processor card is equipped with a console port, a Fast Ethernet interface for Telnet access and network management, and an auxiliary port. There are two slots for Flash PC Cards or Flash disks.

On the processor card front panel are LEDs that display the status of critical, major, and minor signals, as well as the status of alarm cutoff and history conditions. The alarm signals from the processor go to an alarm daughterboard on the backplane, which has a connector for central office alarm facilities.

The processor cards run Cisco IOS software and support the following features:

- Automatic configuration at startup
- Automatic discovery of network neighbors
- Online self-diagnostics and tests
- SSH (Secure Shell)
- Arbitration of processor status (active/standby) and switchover in case of failure without loss of connections
- Automatic synchronization of startup and running configurations
- Autosynchronization of traffic statistics and performance monitoring counters.
- In-service software upgrades
- Per-channel APS (Automatic Protection Switching) in linear and ring topologies using redundant subsystems that monitor link integrity and signal quality
- Trunk fiber based DWDM signal protection using APS in point-to-point topologies
- System configuration and management through the CLI (command-line interface) and SNMP

- Optical power monitoring on the trunk side, digital monitoring on the client side, and per-channel transponder in-service and out-of-service loopback (client and trunk sides)
- Optional out-of-band management of other Cisco ONS 15540 ESPx systems on the network through the OSC (optical supervisory channel).

Processor Redundancy and Online Insertion and Removal

When the Cisco ONS 15540 ESPx is powered up, the two processors engage in an arbitration process to determine which will be the active and which will be the standby. Previous power state information is stored in the processor non-volatile random access memory (NVRAM). The processor that was previously active reassumes the active role. During operation, the two processors remain synchronized (application states, running and startup configurations, system images), and the two clocks are maintained in phase alignment. The operational status of each processor is monitored by the processor redundancy controller of the other processor through the backplane Ethernet. In the event of a failure or removal of an active processor, the standby processor immediately takes over and assumes the active role. Once the problem on the faulty card has been resolved, it can be manually restored to the active function.

In addition to providing protection against hardware or software failure, the redundant processor arrangement also permits installing a new Cisco IOS system image without system downtime. For more information about processor redundancy operation, as well as other software features, refer to the *Cisco ONS 15540 ESPx Configuration Guide*.

System and Network Management

The Cisco ONS 15540 ESPx is fully manageable through the following three mechanisms: the in-band message channel, the OSC, and a direct Ethernet connection to the NME (network management Ethernet) on the processor card. While all shelves will be equipped with at least one processor card, provisioning the OSC is optional, and the in-band message channel is only available on the 10-GE transponder modules.

All three mechanisms can be deployed within a single network. Each mechanism is associated with an interface that can be assigned an IP address. Management information will be routed between these interfaces.

Different levels of availability exist for each of these management mechanisms. High availability for the direct NME connection can be achieved with redundant processor cards. The OSC becomes highly available when it is provisioned on both the working and protection trunk fibers. The availability of a particular in-band message channel will mirror the availability of the ITU wavelength with which it is associated.

In-Band Message Channel

The in-band message channel establishes a method for providing in-band, per-wavelength OAM&P (operations, administration, management, and provisioning) functions.

The in-band OAM&P messages carry the following types of information:

- Internodal management traffic.
- APS (Automatic Protection Switching) protocol messages.

- Subport identifiers for signal aggregation.
- Signal defect indications used by the system to identify line, segment, or path failures in the network topology and to take appropriate recovery responses to such failures. These indications include the following:
  - BDI-E (end-to-end backward defect indication)
  - FDI-E (end-to-end forward defect indication)
  - BDI-H (hop-to-hop backward defect indication)
  - FDI-H (hop-to-hop forward defect indication)
- CRC (cyclic redundancy check) computations.

In-Band Message Channel Consideration

The following considerations apply for the in-band message channel:

- The in-band message channel is carried along with 10-GE transponder module signals and does not required extra equipment or a slot in the shelf.
- The in-band message channel is only supported on the 10-GE transponder modules. If a shelf only has 2.5-Gbps transponder modules, the in-band message channel is not available.
- The in-band message channel must be enabled on both nodes that support the wavelength.

OSC

The OSC is an out-of-band method for providing OAM&P functions on a 33rd wavelength. The OSC supports a message channel that functions like the SONET DCC for management and provisioning. Messages transit the network hop-by-hop, and can be forwarded or routed according to established routing protocols. The OSC can be used to carry traffic to a network management system, or to carry other internodal management traffic such as link management, fiber failure isolation, performance monitoring, alarms, and APS protocol messages.

OSC Considerations

The following considerations apply for the OSC:

- OSC must be support on the mux/demux motherboards.
- When a node supports OSC, the neighboring nodes in the topology must also support OSC.
- To manage the network topology, every node must support OSC.

NME

The NME is a 10/100 Ethernet port on the processor card. You can connect this port to a router and configure the interface to route messages using established routing protocols. The NME can be used to carry traffic to a network management system.

Note The NME provides little in the way of topology management or fault isolation. We recommend using the in-band message channel, OSC, or both to manage and troubleshoot your network topology.

NME Considerations

The following considerations apply to the NME:

- To remotely manage nodes in the network topology using the NME, each system must be accessible through an IP network.
- The NME port is present on every processor card and does not require extra equipment or a slot in the shelf.

Comparison of In-Band Message Channel, SONET, and OSC

Table 1-7 compares the features provided by the in-band message channel, SONET, and OSC.

Table 1-7 Comparison of the In-Band Message Channel, SONET, and OSC

Feature	OSC	In-Band Message Channel	SONET[1]
Management reach	Per fiber section	Per wavelength	Per wavelength
Fault isolation and topology discovery	Hop-by-hop fiber (physical topology)	End-to-end wavelength (logical topology)	End-to-end wavelength (logical topology)
Payload	Separate out-of-band channel	10-GE, GE, ESCON, Fibre Channel, FICON[2]	SONET (OC-n)
Management channel	Per fibre via a 33rd wavelength (channel 0)	Per wavelength via a message byte	Per wavelength via section DCC
Performance monitoring	OSC protocol	8B/10B(GE), 64/66B (10-GE), HEC[3], frame FCS	Section BIP[4]

1. SONET based management is not supported on the Cisco ONS 15540 ESPx and is included for comparison with the in-band message channel only.
2. ESCON, Fibre Channel, and FICON traffic carrying in-band message channel messages originate in a Cisco ONS 15530 system connected to the Cisco ONS 15540 ESPx by way of a 10-Gbps uplink card to the 10-GE transponder module.
3. HEC = Header Error Control
4. BIP = bit interleaved parity

For the most comprehensive set of monitoring and management capabilities, use both the in-band message channel and OSC on your network. The in-band message channel provides fault isolation and monitoring at the wavelength level, and OSC provides that functionality for the fiber.

CHAPTER 2

Protection Schemes and Network Topologies

This chapter describes how protection is implemented on the Cisco ONS 15540 ESPx. It also describes the supported network topologies and how protection works in these topologies. This chapter contains the following major sections:

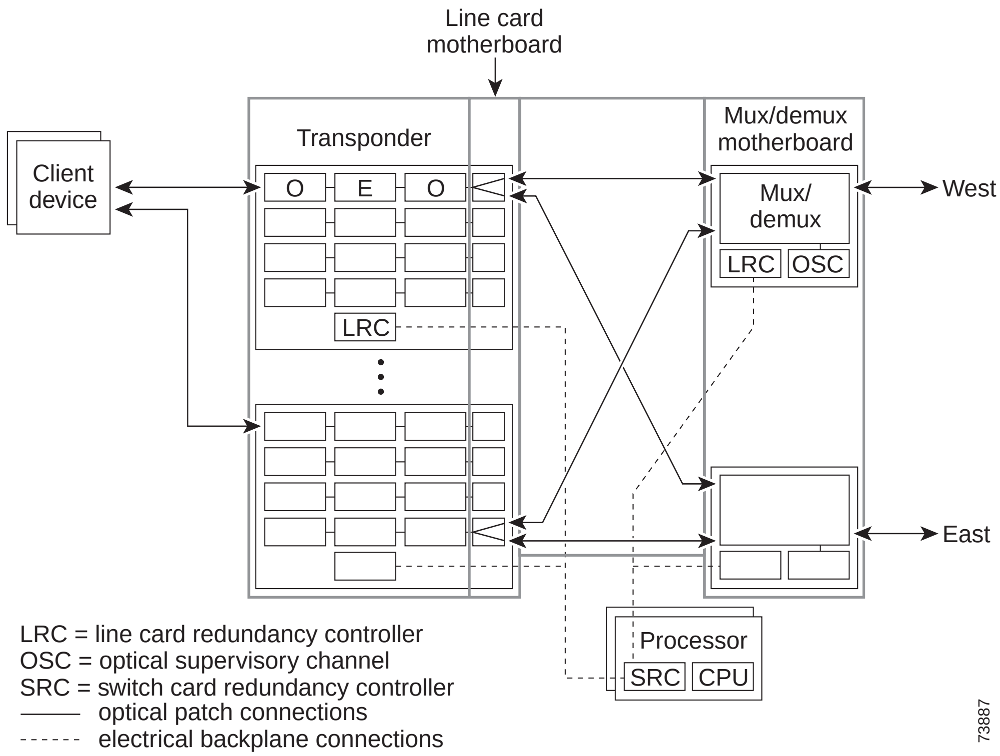
About Protection Against Fiber and System Failures

The design of the Cisco ONS 15540 ESPx provides for two levels of network protection, facility protection and line card protection. Facility protection provides protection against failures due to fiber cuts or unacceptable signal degradation on the trunk side. Line card protection provides protection against failures both on the fiber and in the transponders, which contain the light emitting and light detecting devices as well as the 3R (reshape, retime, retransmit) electronics. Line card protection can also be implemented using redundant client signals. This provides protection against the failure of the client, the transponder, or the fiber.

Splitter Based Facility Protection

To survive a fiber failure, fiber optic networks are designed with both active and standby fibers. In the event of a fiber cut or other facility failure, working traffic is switched to the protection fiber. The Cisco ONS 15540 ESPx supports such facility protection using a *splitter* scheme (see Figure 2-1) to send the output of the DWDM transmitter on two trunk side interfaces.

Figure 2-1 Splitter Protection Scheme



With splitter protection, a splitter module on the line card motherboard duplicates the DWDM signal from each transponder module. The front panel of the splitter line card motherboard has two MTP connectors for cross connections to the mux/demux modules. The transponder modules signals are transmitted out of both MTP connectors, but in the receive direction, an optical switch selects one signal per transponder module to be the active one. If a failure is detected on an active signal, a switch to the standby signal is made under control of the LRC (line card redundancy controller). Assuming, for example, that the active signal in Figure 2-1 is on the east interface, a failure of the signal on that fiber would result in a switchover, and the signal on the west interface would be selected for the receive signal.

APS switchovers are triggered in hardware by loss of light on the receive signal.

Splitter Protection Considerations

The following considerations apply when using splitter protection:

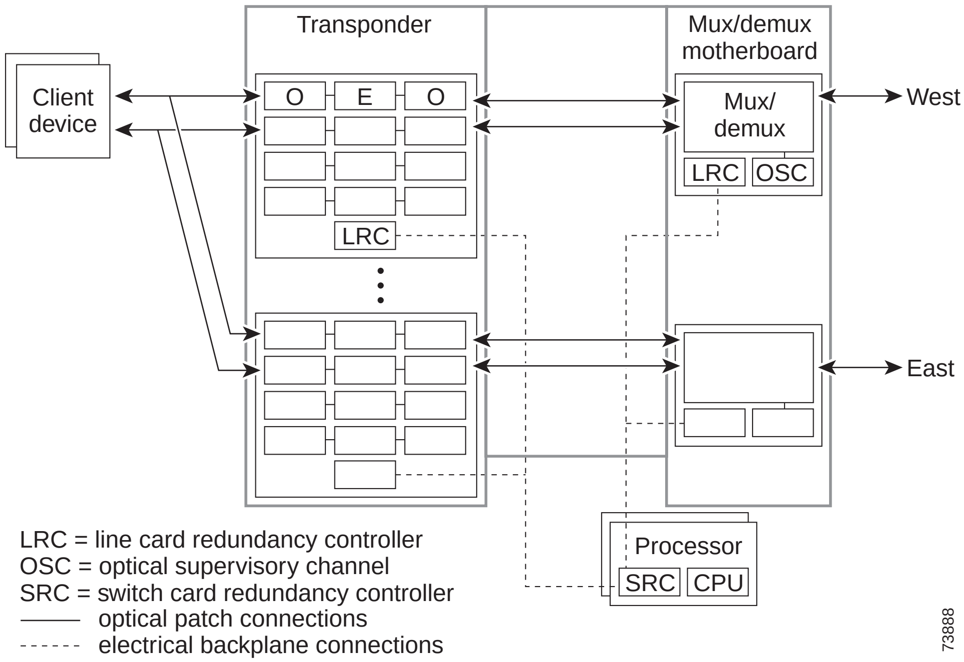
- The splitter protected line card motherboard supports splitter protection. Because the signal splitter introduces 4.6 dB of loss in the transmit direction, we recommend using the unprotected line card motherboards for configurations where splitter protection is not required.
- Switchover after a failure under splitter protection is nonrevertive. After a switchover, manual intervention is required to revert to using the previously failed fiber for the working traffic once the fault has been remedied.

For rules on how to configure the shelf for splitter protection, see Chapter 3, "Shelf Configuration Rules." For instructions on configuring the software for splitter protection, refer to the *Cisco ONS 15540 ESPx Configuration Guide*.

Y-Cable Based Line Card Protection

The Cisco ONS 15540 ESPx supports line card protection using a *y-cable* scheme. Y-cable protection protects against both facility failures and failure of the transponder module. Using an external 2:1 combiner cable (the y-cable) between the client equipment and the transponder interfaces, the client signal is duplicated and send to two transponder interfaces. Figure 2-2 illustrates this arrangement.

Figure 2-2 Y-Cable Protection Scheme



In y-cable protected configurations, one of the transponder modules functions as the active and the other as the standby. On the active transponder, all the lasers and receivers are sending and receiving the client signal. On the standby transponder, however, the client side laser is turned off to avoid corrupting the signal transmitted back to the client equipment. The performance monitor on the active transponder module optically monitors the signal received from the trunk side. If loss of light, signal failure, or signal degrade is detected, and an acceptable standby signal is available, the system switches over to the standby signal. The precise conditions that trigger a switchover based on signal failure or signal degrade are configurable in the alarm threshold software.

Y-Cable Protection Considerations

The following considerations apply when using y-cable protection:

- Y-cable protection does not protect against failures of the client equipment. To protect against client failures, protection should be implemented on the client equipment itself in addition to the line card protection configuration on the Cisco ONS 15540 ESPx shelf.
- Due to their lower optical power loss, we recommend using the unprotected line card motherboards for configurations with y-cable protection.

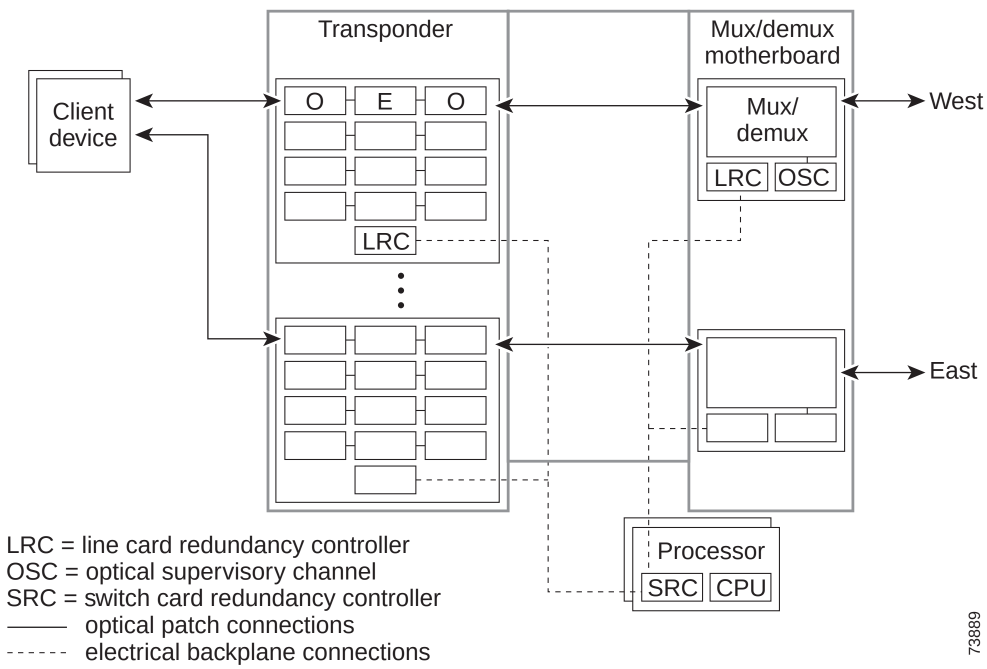
- The APS software that supports y-cable protection can be configured as revertive or nonrevertive. After a switchover, the working traffic can be put back on the previously failed fiber, once the fault has been remedied, either automatically (revertive) or through manual intervention (nonrevertive).
- Y-cable protected configurations allow monitoring of the protection fiber without the OSC.

For rules on how to configure the shelf for y-cable protection, see Chapter 3, "Shelf Configuration Rules." For instructions on configuring the software for y-cable protection, refer to the *Cisco ONS 15540 ESPx Configuration Guide*.

Client Based Line Card Protection

While y-cable protection protects against failures in the transponders or on the fiber, the client still remains vulnerable. For some applications additional protection of the client equipment may be desirable. As Figure 2-3 shows, the same architecture that supports y-cable protection also supports client protection. Rather than using a y-cable to split a single client signal, the client equipment transmits and receives two separate signals. Operationally, client protection is also different in that signal monitoring and switchover are under control of the client rather than the protection mechanisms on the Cisco ONS 15540 ESPx.

Figure 2-3 Client Based Line Card Protection Scheme



Client Protection Considerations

The following considerations apply when using client protection:

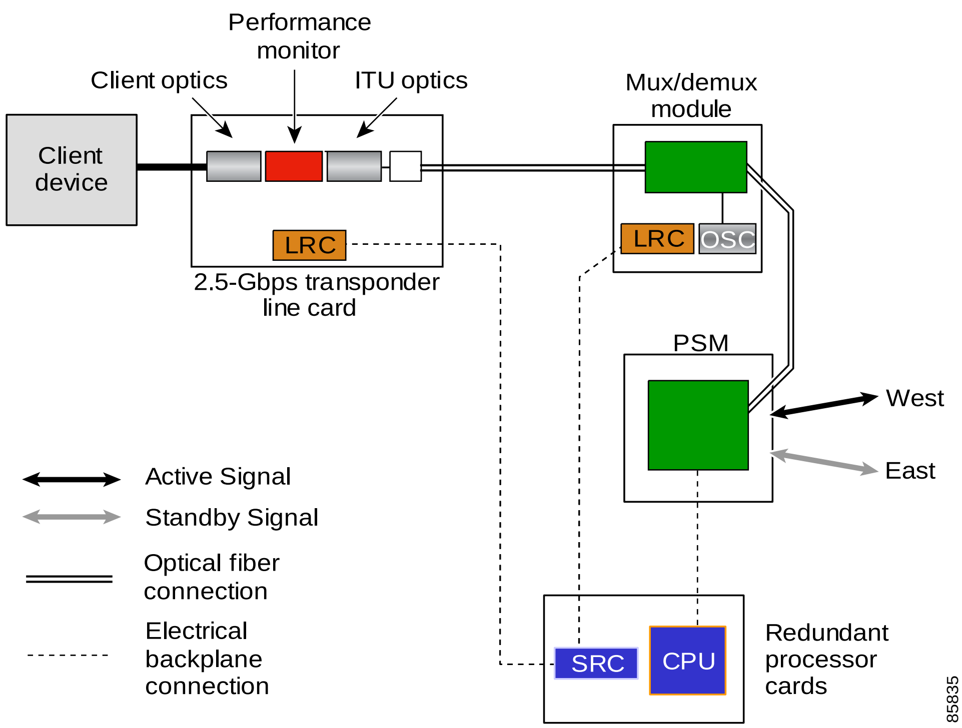
- Client protection uses the same shelf configuration as y-cable based line card protection.
- Due to their lower optical loss, we recommend using the unprotected line card motherboards for configurations with client protection.
- Client protected configurations allow monitoring of the protection fiber without the OSC.

Trunk Fiber Based Protection

The PSM (protection switch module) provides trunk fiber based protection for Cisco ONS 15540 ESPx systems configured in point-to-point topologies. This type of protection only guards against trunk fiber cuts, not specific channel failure as provided by splitter and line card based schemes. However, this protection scheme allows for much simpler shelf configurations in topologies where per-channel protection is not required.

Figure 2-4 shows trunk fiber based protection configured with a transponder line card.

Figure 2-4 Trunk Fiber Based Protection Scheme



Trunk Fiber Based Protection Considerations

The following considerations apply when using trunk fiber based protection:

- Trunk fiber based protection does not protect against failures on the shelf itself or the client equipment. To protect against these failures, line card protection should be implemented on the client equipment itself.
- The APS software that supports trunk fiber based protection can be configured as revertive or nonrevertive. After a switchover, the active traffic can be put back on the previously failed working fiber, once the fault has been remedied, either automatically (revertive) or through manual intervention (nonrevertive).
- Use PSMs only in point-to-point topologies.
- In a dual shelf node, install the PSM on the shelf connected to the trunk fiber.

- The point-to-point topology can have no more than two EDFAs. The cumulative noise of three or more EDFAs interferes with detecting the data channel loss on the PSM.
- When EDFAs are present in the topology, the power of the data channels at the PSM receiver must be greater than the cumulative noise of the EDFAs.

Supported Topologies

The Cisco ONS 15540 ESPx can be used in linear and ring topologies with Cisco ONS 15540 ESP, Cisco ONS 15530, and Cisco ONS 15540 ESPx systems. Linear topologies include protected and unprotected point-to-point and bus. Ring topologies support add/drop nodes and can be hubbed or meshed. The following sections give a brief overview of these topologies.

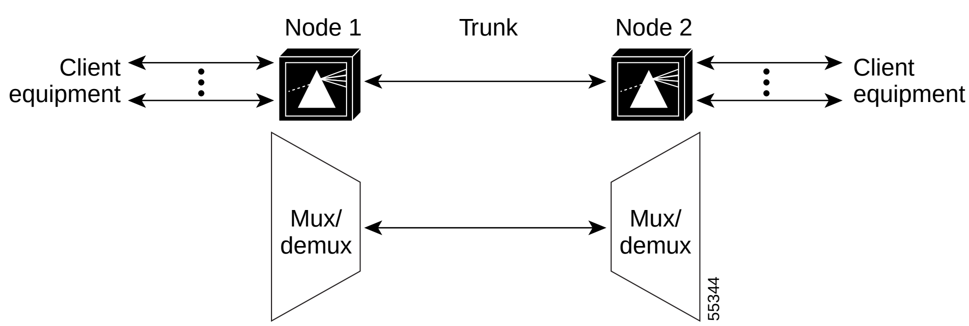
Linear Topologies

In a pure point-to-point topology all channels terminate on the nodes at each end of the trunk. Point-to-point topologies have many common applications, including extending the reach of GE or SONET, and can be configured for unprotected or for protected operation.

Unprotected Point-to-Point Topology

Figure 2-5 shows a point-to-point topology without protection. In this configuration only one optical mux/demux slot is used in each of the nodes. The west or east trunk side interface (mux/demux slot 0 or 1) of node 1 connects to the corresponding interface on node 2.

Figure 2-5 Unprotected Point-to-Point Topology



For an example configuration of an unprotected point-to-point topology, see the "Unprotected 32-Channel Point-to-Point Configuration" section on page 5-13.

Protected Point-to-Point Topology

Figure 2-6 shows a protected point-to-point topology configured for splitter or line card per-channel protection. In either case, there are two trunk side interfaces, west and east, connected by two fiber pairs.

Figure 2-6 ***Splitter and Line Card Protected Point-to-Point Topology***

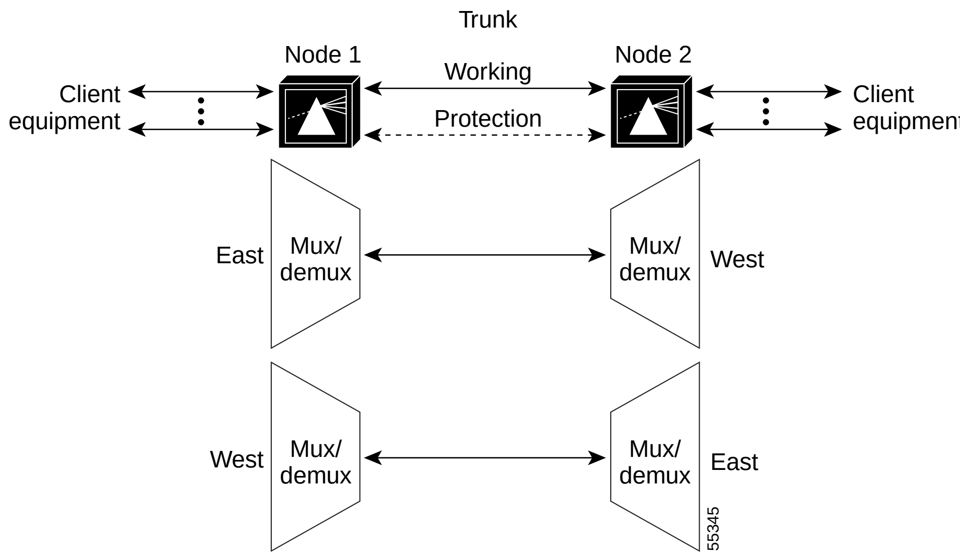
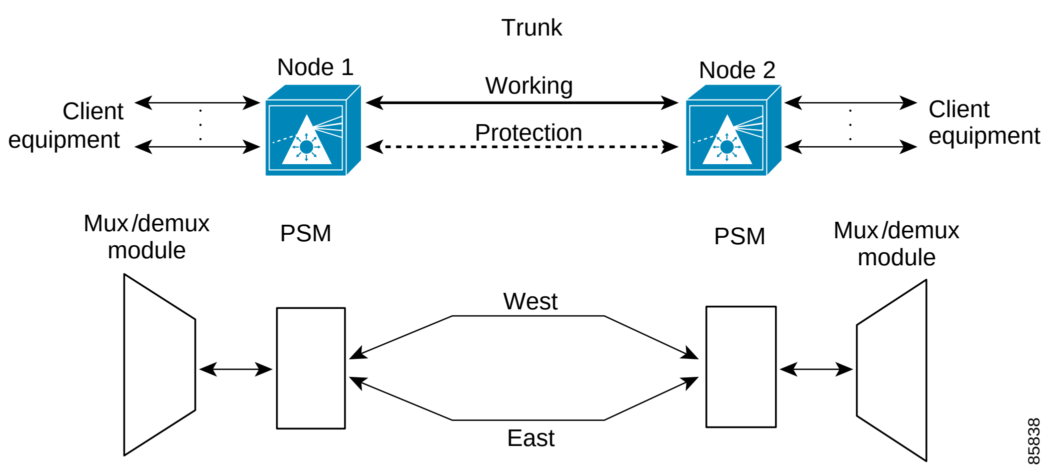


Figure 2-7 shows a protected point-to-point topology configured for trunk fiber protection. There are two trunk side interfaces, west and east, connected by two fiber pairs.

Figure 2-7 ***Trunk Fiber Protected Point-to-Point Topology***

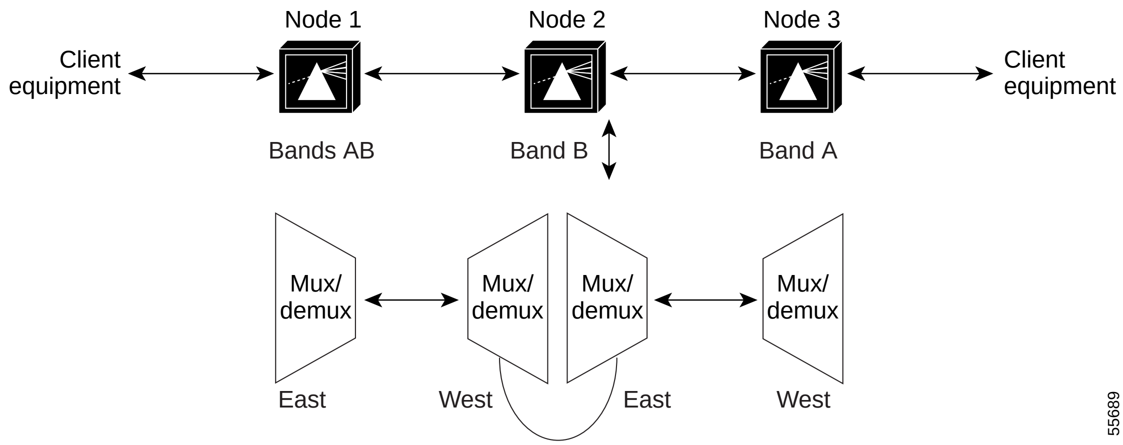


For an example configuration of a protected point-to-point topology, see the "Line Card Protected 16-Channel Point-to-Point Configuration" section on page 5-17.

Bus Topology

In a bus topology, sometimes called *linear add/drop*, there is an intermediate add/drop node between the two terminal nodes. Figure 2-8 shows an example of this type of topology. Bands A and B (channels 1-4 and 5-8) terminate at node 1. Band B is dropped at node 2, which passes band A through. To support this configuration, the add/drop node must have add/drop mux/demux modules in both slots 0 and 1 for west and east directions.

Figure 2-8 Bus Topology Example



This type of topology offers limited protection. In this example a failure on the link between node 2 and node 3 would result in the loss of band A, but band B would remain operational between nodes 1 and 2. A failure on the link between node 1 and node 2 would result in a loss of both bands.

Note If protection for all bands is required in a topology such as this, where there is a single add/drop node between two terminal nodes, a ring can be used.

Ring Topologies

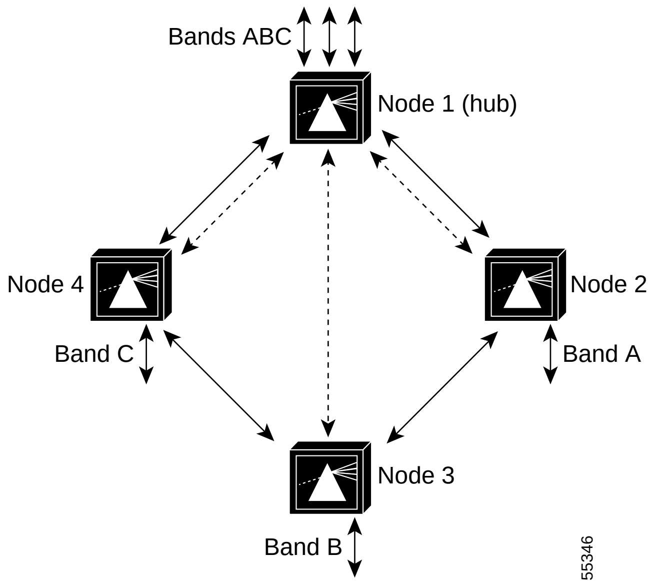
In a ring topology, client equipment is attached to three or more Cisco ONS 15540 ESPx, Cisco ONS 15540 ESP, and Cisco ONS 15530 systems, which are interconnected in a closed loop. Channels can be dropped and added at one or more nodes on a ring. Rings have many common applications, including providing extended access to SANs (storage area networks) and upgrading existing SONET rings. In the cases where SONET rings are at capacity, the SONET equipment can be moved off the ring and connected to the Cisco ONS 15540 ESPx, Cisco ONS 15540 ESP, or Cisco ONS 15530 systems. Then the SONET client signals are multiplexed and transported over the DWDM link, thus increasing the capacity of existing fiber.

Hubbed Ring

A hubbed ring is composed of a hub node and two or more add/drop or satellite nodes. All channels on the ring originate and terminate on the hub node. At the add/drop node, some channels are terminated and regenerated (dropped and added back) while other channels (express channels) are passed through optically, without being electrically regenerated.

Channels are dropped and added in bands. Figure 2-9 shows a four-node hubbed ring in which bands ABC terminate on node 1. Nodes 1 and 2 communicate using band A, nodes 1 and 3 communicate using band B, and nodes 1 and 4 communicate using band C.

Figure 2-9 Hubbed Ring Topology Example

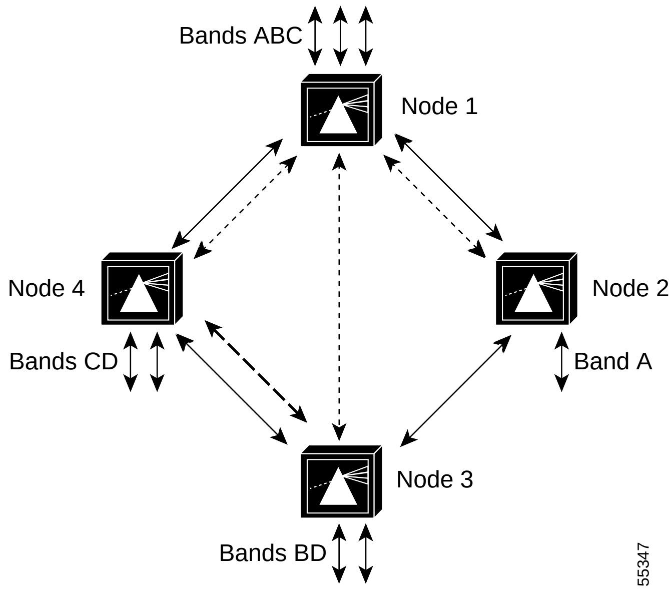


For example configurations of hubbed ring topologies, see the "Hubbed Ring Topologies" section on page 5-21.

Meshed Ring

A meshed ring is a physical ring that has the logical characteristics of a mesh topology. While traffic travels on a physical ring, the logical connections between individual nodes are meshed. An example of this type of configuration, which is sometimes called a *logical mesh*, is shown in Figure 2-10. Nodes 1 and 2 communicate using band A, nodes 1 and 3 communicate using band B, and nodes 1 and 4 communicate using band C, as in the previous example (Figure 2-9). In this example, however, the fact that nodes 3 and 4 communicate independently using band D makes it a meshed ring.

Figure 2-10 Meshed Ring Topology Example



For example configurations of meshed ring topologies, see the "Meshed Ring Topologies" section on page 5-44.

Protection in Ring Topologies

Protection in the Cisco ONS 15540 ESPx is supported using per-channel unidirectional path switching or bidirectional path switching. Protection mechanisms are implemented in both the hardware and the APS software.

Unidirectional Path Switching

Unidirectional path switching is based on a variant of the SONET UPSR (Unidirectional Path Switched Ring). For each channel on a ring, traffic is transmitted in both directions from each node, using one of the fiber pair for each direction; on each node, traffic is received from one direction. In the event of a failure of the receive signal at a node, the node switches over to receive the signal from the other direction. Switching decisions are made on a node-by-node basis, and some channels can be received from one direction while others are received from the other direction. Protection in rings can be implemented on the Cisco ONS 15540 ESPx using either a splitter or y-cable configuration.

Figure 2-11 shows a three-node hubbed ring. In the example, node 1 is sending traffic from both east and west mux/demux interfaces, but is actively receiving only on the west side.

Figure 2-11 Per-Channel Unidirectional Path Switching in Normal State

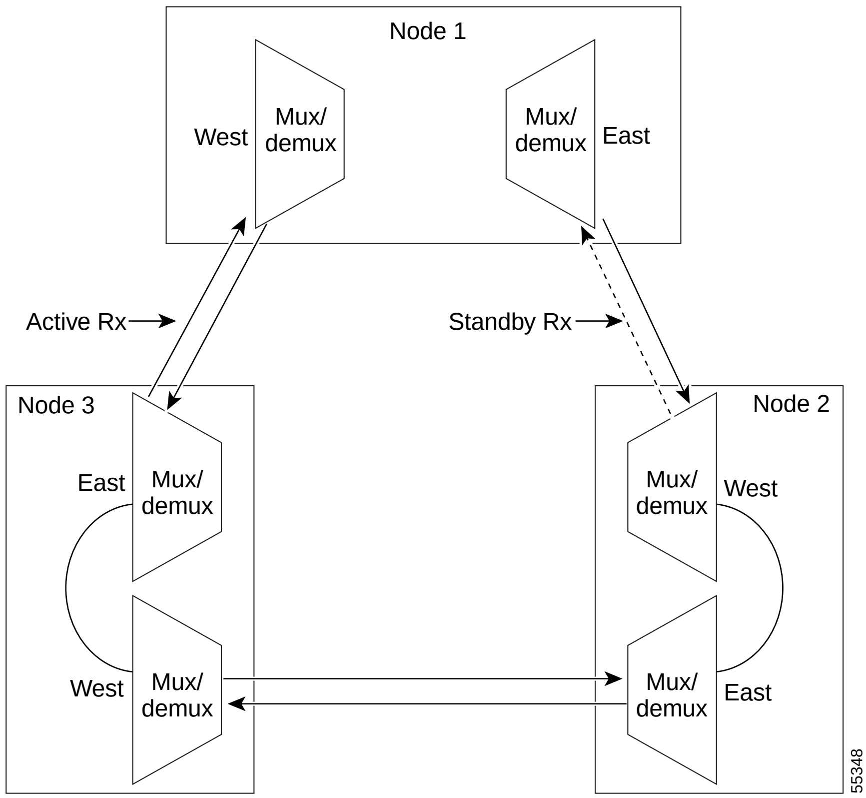
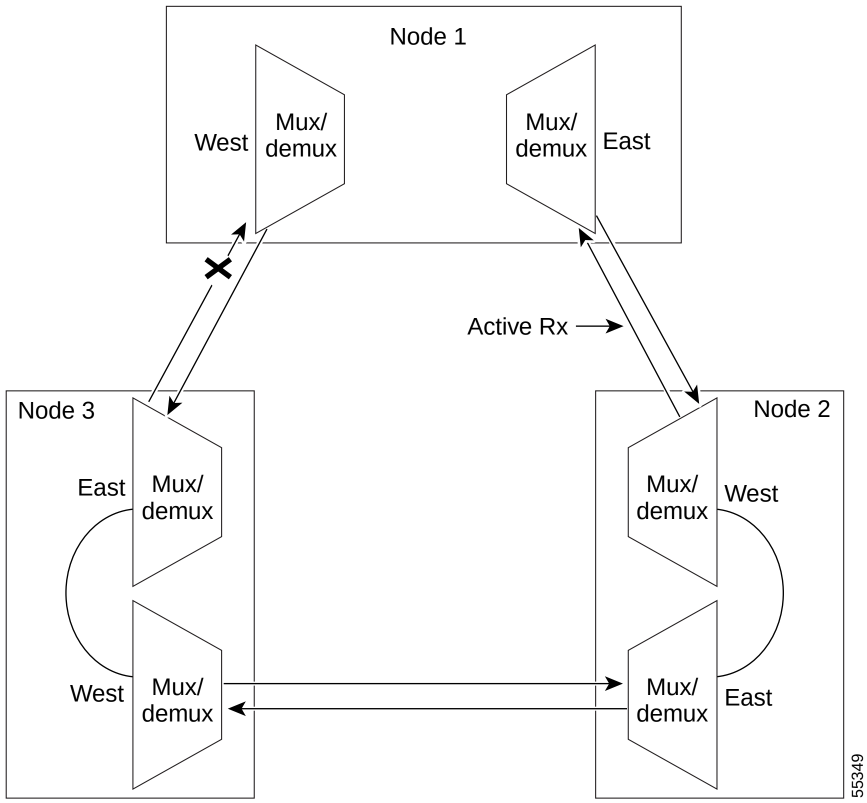


Figure 2-12 shows a channel failure on the receive signal from node 3 to node 1. In this event, node 1 switches to the receive signal on its east mux/demux interface for the failed channel(s). Assuming that the failure is only in one direction between node 1 and node 3, node 3 would not be required to switch receive directions. If, however, both directions were affected (for example, a fiber cut) and node 3 had been receiving on its east side, it would switch to the west side for its active receive signal.

Figure 2-12 Per-Channel Unidirectional Path Switching after Protection Switch



Bidirectional Path Switching

The Cisco ONS 15540 ESPx also supports bidirectional path switching through the APS software. When configured for bidirectional switching, a node that detects a fault sends a signal over the APS message channel to the source node to also switch its receive direction. Assume, for example, that the channels configured between node 1 and node 3 in Figure 2-12 were communicating over the link that fails. When node 1 switches to receive those channels from the east side (over node 2), node 3 would also switch to receive those channels from its west side. This ensures that the distance between the two nodes remains the same for those channels for the active signal. This option is supports protocols that are distance sensitive.

Multiple Trunk Support

The Cisco ONS 15540 ESPx allows two or more trunks to connect to a single shelf. Both point-to-point topologies and ring topologies are allowed in a multiple trunk configuration. All of the trunks can support optical protection but the OSC will only be available as the APS message channel and network management for one trunk. The other trunk must use either the in-band message channel or an IP connection for the APS message channel and network management.

CHAPTER 3

Shelf Configuration Rules

The design of the Cisco ONS 15540 ESPx requires that a set of rules be followed during physical configuration of the shelf. These rules, along with examples, are provided in this chapter. This chapter contains the following major sections:

Note Applying the shelf configuration rules requires an understanding of the Cisco ONS 15540 ESPx system components and protection schemes. See especially the "System Components" section on page 1-4 and the "About Protection Against Fiber and System Failures" section on page 2-1.

Shelf Rules for Mux/Demux Motherboards

This section describes the shelf rules for mux/demux motherboards.

OSC Support

In configurations where the OSC is not used, only one mux/demux motherboard is required on the shelf. When the OSC is used, two mux/demux motherboards with OSC support are required on the shelf.

Shelf Rules for 4-Channel and 8-Channel Add/Drop Mux/Demux Modules

This section describes the shelf rules for 4-channel and 8-channel add/drop mux/demux modules for different types of protection.

Add/Drop Mux/Demux Modules Without Protection

In an unprotected configuration, a shelf can have only one 4-channel or 8-channel add/drop mux/demux module with a given channel band transmitting and receiving in a given direction (either west or east). Table 3-1 lists the conflicting bands 4-channel and 8-channel add/drop mux/demux modules. If an add/drop mux/demux module that supports a band in a particular row of column 1 in Table 3-1 is installed on a shelf in an unprotected configuration, that shelf cannot also have a module that supports any of the conflicting bands in column 2 transmitting and receiving in the same direction. For example, modules for band A and band AB both cannot transmit to and receive from the west.

Table 3-1 Conflicting Bands for Add/Drop Mux/Demux Module

Band	Conflicting Bands
A	A with OSC, AB, AB with OSC
B	B with OSC, AB, AB with OSC
C	C with OSC, CD, CD with OSC
D	D with OSC, CD, CD with OSC
E	E with OSC, EF, EF with OSC
F	F with OSC, EF, EF with OSC
G	G with OSC, GH, GH with OSC
H	H with OSC, GH, GH with OSC
A with OSC	A, AB, any band with OSC
B with OSC	B, AB, any band with OSC
C with OSC	C, CD, any band with OSC
D with OSC	D, CD, any band with OSC
E with OSC	E, EF, any band with OSC
F with OSC	F, EF, any band with OSC
G with OSC	G, GH, any band with OSC
H with OSC	H, GH, any band with OSC
AB	A, A with OSC, B, B with OSC, AB, AB with OSC
CD	C, C with OSC, D, D with OSC, CD, CD with OSC
EF	E, E with OSC, F, F with OSC, EF, EF with OSC
GH	G, G with OSC, H, H with OSC, GH, GH with OSC
AB with OSC	A, B, AB, any band with OSC
CD with OSC	C, D, CD, any band with OSC

Table 3-1 Conflicting Bands for Add/Drop Mux/Demux Module (continued)

Band	Conflicting Bands
EF with OSC	E, F, EF, any band with OSC
GH with OSC	G, H, GH, any band with OSC

Add/Drop Mux/Demux Modules with Protection

When configuring channels to use splitter protection or line card protection, two 4-channel or 8-channel add/drop mux/demux modules with the same channels must be present on the shelf. Table 3-1 lists the conflicting bands when using the 4-channel or 8-channel add/drop mux/demux modules. If two add/drop mux/demux modules that support a band in a particular row of column 1 in Table 3-1 are installed on a shelf in an unprotected configuration, that shelf cannot also have other mux/demux modules that support any of the conflicting bands in column 2. For example, if the two mux/demux modules support band A, then there can be no mux/demux modules supporting band AB on the same shelf.

Note During migration, one of the modules might not be present, or one of the modules might contain only a subset of the channels present on the other module.

Figure 3-1 shows an example shelf configuration for splitter protection with add/drop mux/demux modules for band AB in positions 0/0 and 1/0.

Figure 3-1 Example Installation of Add/Drop Mux/Demux Modules with Splitter Protection

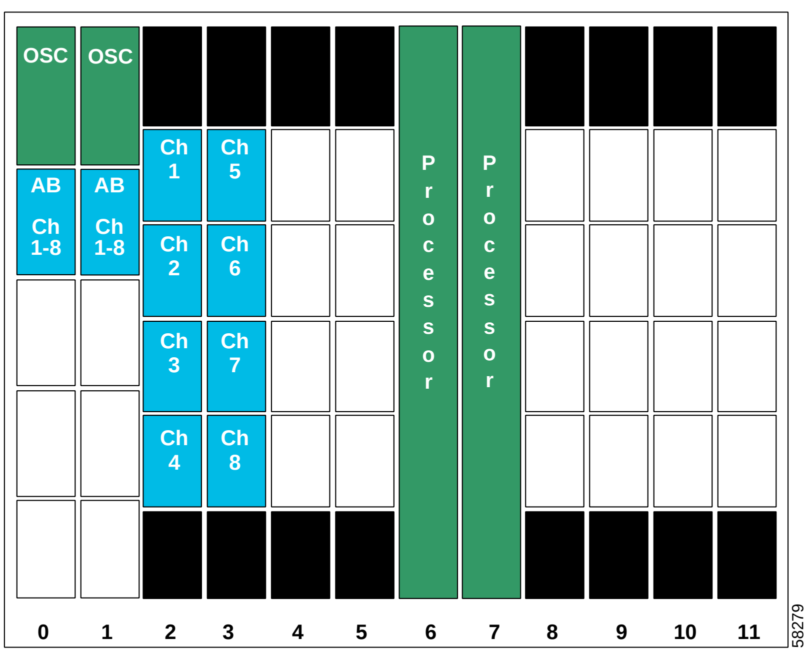
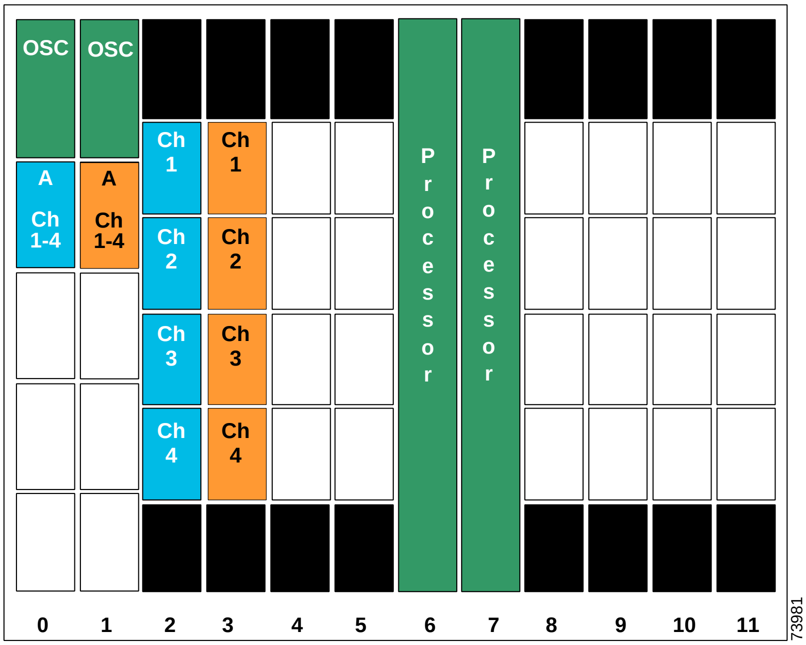


Figure 3-2 shows an example shelf configuration for line card protection with add/drop mux/demux modules for band A in positions 0/0 and 1/0.

Figure 3-2 Example Installation of Add/Drop Mux/Demux Modules with Line Card Protection



Cabling Add/Drop Mux/Demux Modules

The following rules apply when cabling the trunk and thru interfaces on the 4-channel and 8-channel add/drop mux/demux modules:

- Use optical fiber cables with MU connectors for cabling the mux/demux modules to each other and to the OSC.
- Cable the OSC from the mux/demux motherboard only to the add/drop mux/demux module that connects to the trunk (east and west sides). Connect the OSC IN on the mux/demux module to OSC OUT on the mux/demux motherboard; connect the OSC OUT on the mux/demux module to OSC IN on the mux/demux motherboard.
- Connect west to east, never west to west or east to east, between nodes in a ring.
- Connect the trunk receive direction to TI (trunk interface) IN, and trunk transmit direction to TI OUT (east and west sides).
- Connect Thru OUT to TI IN, and OUT to TI IN between add/drop mux/demux modules on the same side.
- Connect Thru OUT to Thru IN between add/drop mux/demux modules on west and east sides.

For examples of cabling add/drop mux/demux module in a protected ring configuration, see Figure 1-7 on page 1-17 and Figure 1-8 on page 1-18.

Shelf Rules for 32-Channel Terminal Mux/Demux Modules

The following rules apply when cabling the 32-channel terminal mux/demux modules:

- No cabling is necessary between 32-channel terminal mux/demux modules.
- Cable the OSC from the mux/demux motherboard to the OA and OD connectors on the terminal mux/demux module. Connect OSC OUT to OA and OSC IN to OD.

Shelf Rules for Transponder Modules

The following rules apply to transponder modules:

- When using y-cable protection, ensure that both transponder modules are the same type (single-mode, multimode, extended range, or 10-GE) for a given client signal. For example, if client signal A connects by a y-cable to transponders in positions 2/0 and 8/0, then both of those transponder modules must either be single-mode, multimode, or extended range. Also, if using extended range transponder modules, the transceivers must be the same type.
- It is possible for some transponder modules to be missing. This might happen in cases where channels are not needed, or during migration.
- When the line card motherboard directly is directly cabled to the mux/demux module or mux/demux motherboard, the transponder modules in the line card motherboard must support channels in the same 4-channel band. Table 3-2 shows the required positions for the transponder modules in the line card motherboard.

Table 3-2 Transponder Module Placement When Using Direct Cross Connects

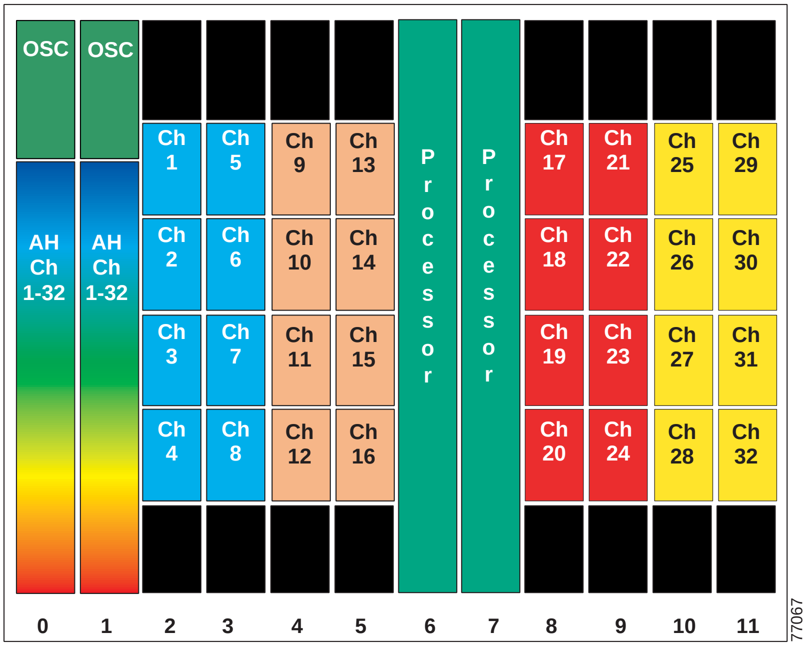
Channel[1]	Transponder Slot/Subslot[2]
w+0	*y*/0
w+1	*y*/1
w+2	*y*/2
w+3	*y*/3

1. w = first channel number in a 4-channel band
2. y = transponder slot number in the shelf

See Figure 3-3 for an example configuration.

Note When using a cross connect panel rather than direct cross connections, the transponder modules can be installed in any order in a line card motherboard. However, for easier shelf management, we recommend using the same ordering as described in Table 3-2.

Figure 3-3 Example Shelf Configuration Using 32-Channel Terminal Mux/Demux Modules



Shelf Rules for Line Card Motherboards

The line card motherboards have MTP connectors located on their front panels: one connector on unprotected motherboards and two connectors for splitter protected motherboards.

In 2.5-Gbps line card motherboards, each MTP connector supports one 4-channel band. In 10-Gbps line card motherboards, each MTP connector supports one 1-channel band.

Line card motherboards can only install into slots 2 through 5 and slots 8 through 11.

Rules for Configurations with 10-Gbps Line Card Motherboards

An unprotected configuration of 10-Gbps line card motherboards with 10-GE transponder modules supports 16 channels. A protected configuration supports 8 channels.

Rules for Protected Configurations

The rules for line card motherboards in protected configurations are as follows:

- If splitter protection is used, the transponder slots must use the splitter protected line card motherboards.
- If line card protection is used, the transponder slots should use the unprotected line card motherboards, which do not have the 2x2 optical splitter.
- You can use splitter protected line card motherboards for line card protected configurations. When using splitter protected line card motherboards for line card protections, configure all wavepatch *y*/*z*/1 interfaces in the slot as "shutdown." The upper MTP connector on the line card motherboard is wavepatch *x/y/0;* the lower MTP connector on the line card motherboard is wavepatch *x/y/1*

Note When configuring a system for line card protection, the unprotected line card motherboards offer the additional advantage of having lower optical power loss.

Cabling Line Card Motherboards to the Mux/Demux Modules

The Cisco ONS 15540 ESPx supports mux/demux modules with front panel optical filter connectors. If all channels in the line card motherboard are added and dropped at the node, cross connect the line card motherboard MTP connector directly to the mux/demux module. Each mux/demux module supports a specific band of channels. Every 4-channel band on the mux/demux module has its own MTP connector. A 4-channel mux/demux module has one MTP connector, an 8-channels has two, and a 32-channel mux/demux module has eight. Always connect the line card motherboard to the MTP connector for the channels supported by the transponders in the line card motherboard.

Shelf Rules for PSMs

For trunk fiber protection to function when the PSM (protection switch module) connects to a mux/demux module, the OSC or the in-band message channel (or both) must be available on the shelf. If the OSC is present, the PSM must connect to the mux/demux module that supports the OSC. If the PSM connects to a 10-GE transponder module, use the in-band message channel as the APS message channel to support trunk fiber protection. If the PSM connects to a 2.5-Gbps transponder module, use IP for the APS message channel.

Cabling Rules for Cross Connect Drawers

The optical cross connect drawer provides a much greater degree of flexibility for provisioning channels on the Cisco ONS 15540 ESPx. It allows you access to individual channels within a band. You can, for example, pass through some channels within a band while adding and dropping others. The cross connect drawer also allows the Cisco ONS 15540 ESPx to accept ITU grid signals from other platforms, such as the Cisco ONS 15530.

For protected configurations, a cross connect drawer supports up to 16 channels. To support more than 8 protected channels, use two cross connect drawers.

Note We recommend using direct cross connections between the line card motherboard and mux/demux module in configurations where no individual channels in the band are passed through and none come from other platforms. Using a cross connect drawer increases the optical power loss.

General Rules for Ring Topologies

The following network rules apply to ring topologies:

- A channel must be present on only two nodes in the ring when using splitter protection.
- All channels added by a node on an east add/drop mux/demux modules must be dropped on a west add/drop mux/demux module of one or more other nodes on the ring. All channels added by a node on a west add/drop mux/demux module must be dropped by an east add/drop mux/demux module of one or more other nodes on the ring. This rule may be violated during migration.
- A node cannot add a channel that is already present in the same direction until it has dropped that channel.

Optical Loss Budgets

The optical loss budget is an important aspect in designing networks with the Cisco ONS 15540 ESPx. The optical loss budget is the ultimate limiting factor in distances between nodes in a topology. This chapter contains the following major sections:

Note The optical specifications described in this chapter are only for the individual components and should not be used to characterize the entire network performance.

Note The information in this chapter applies only to nonamplified network design.

About dB and dBm

Signal power loss or gain is never a fixed amount of power, but a portion of power, such as one-half or one-quarter. To calculate lost power along a signal path using fractional values you cannot add 1/2 and 1/4 to arrive at a total loss. Instead, you must multiply 1/2 by 1/4. This makes calculations for large networks time-consuming and difficult.

For this reason, the amount of signal loss or gain within a system, or the amount of loss or gain caused by some component in a system, is expressed using the *decibel* (dB). Decibels are logarithmic and can easily be used to calculate total loss or gain just by doing addition. Decibels also scale logarithmically. For example, a signal gain of 3 dB means that the signal doubles in power; a signal loss of 3 dB means that the signal halves in power.

Keep in mind that the decibel expresses a ratio of signal powers. This requires a reference point when expressing loss or gain in dB. For example, the statement "there is a 5 dB drop in power over the connection" is meaningful, but the statement "the signal is 5 dB at the connection" is not meaningful. When you use dB you are not expressing a measure of signal strength, but a measure of signal power loss or gain.

It is important not to confuse decibel and *decibel milliwatt* (dBm). The latter is a measure of signal power in relation to 1 mW. Thus a signal power of 0 dBm is 1 mW, a signal power of 3 dBm is 2 mW, 6 dBm is 4 mW, and so on. Conversely, –3 dBm is 0.5 mW, –6 dBm is 0.25 mW, and so on. Thus the more negative the dBm value, the closer the power level approaches zero.

Overall Optical Loss Budget

An optical signal degrades as it propagates through a network. Components such as optical mux/demux modules, fiber, fiber connectors, splitters, and switches introduce attenuation. Ultimately, the maximum allowable distance between the transmitting laser and the receiver is based upon the optical link budget that remains after subtracting the power losses experienced by the channels with the worst path as they traverse the components at each node.

Table 4-1 lists the laser transmitter power and receiver sensitivity range for the data channels, the OSC (Optical Supervisory Channel), and the PSM (protection switch module).

Table 4-1 Trunk Side Transmitter Power and Receiver Ranges

	Transmit Power (dBm)		Receiver Sensitivity (dBm)	
Channel	**Minimum**	**Maximum**	**Minimum**	**Overload**
SM transponder module and MM transponder module data channel	4	8	–28	–8
Extended range transponder module data channel	5	10	–28	–8
10-GE transponder module data channel	1	6	–22	–8
OSC	4	8	–19	–1.5
PSM			–31	17[1]

1. The receiver detector only reports up to 0 dBm in the CLI (command-line interface). To measure the actual input power to the receiver, use an optical power meter on the optical monitoring port.

Note Add the proper system-level penalty to the receive power based on your actual network topology characteristics, such as dispersion.

The goal in calculating optical loss is to ensure that the total loss does not exceed the overall optical link (or span) budget. For example, the OSC has an optical link budget of 26 dB, which is equal to the OSC receiver sensitivity (–22 dBm) subtracted from the OSC laser minimum launch power (4 dBm) on the mux/demux motherboard. Typically, in point-to-point topologies, the OSC optical power budget is the distance limiting factor, while in ring topologies, the data channel optical power budget is the distance limiting factor.

Calculating Optical Loss Budgets

Using the optical loss characteristics for the Cisco ONS 15540 ESPx components, you can calculate the optical loss between the transmitting laser on one node and the receiver on another node. The general rules for calculating the optical loss budget are as follows:

- The maximum power loss between the nodes cannot exceed the minimum transmit power of the laser minus the minimum sensitivity of the receiver and network-level penalty.

Note Determine the proper network-level penalty to the receive power based on your actual network topology characteristics, such as dispersion.

- The minimum attenuation between the nodes must be greater than the maximum transmitter power of the laser minus the receiver overload value.

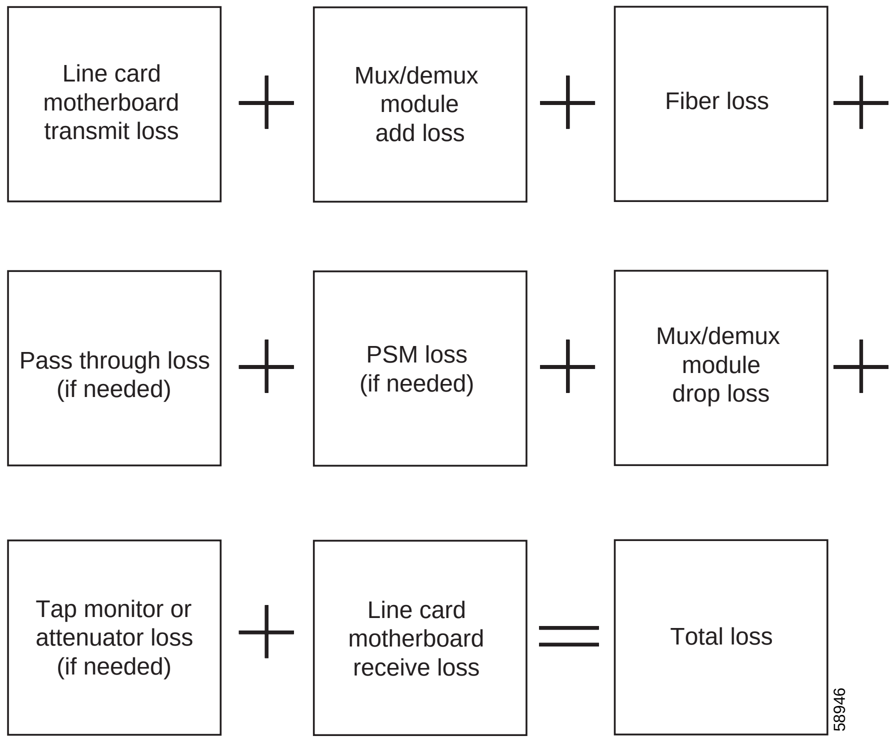
The following example shows how to calculate the optical loss budget for 2.5-Gbps data channels from an extended range transponder module using the values in Table 4-1:

- The power loss between the transmitter laser and receiver must not exceed 33 (5 – (–28)) dB or the signal will not be detected accurately.
- At least 18 (10 – (–8)) dB of attenuation between neighboring nodes prevents receiver saturation.

To validate a network design, the optical loss must be calculated for each band of channels. This calculation must be done for both directions if protection is implemented, and for the OSC between each pair of nodes. The optical loss is calculated by summing the losses introduced by each component in the signal path.

At a minimum, any data channel path calculation must include line card transmit loss, channel add loss, fiber loss, channel drop loss, and line card receive loss (see Figure 4-1). In ring topologies, pass through losses must be considered. Losses due to external devices such as fixed attenuators and monitoring taps must also be included.

Figure 4-1 Elements of Optical Loss in a Minimal Configuration



For examples of optical loss budget calculations, see the topologies described in Chapter 5, "Example Shelf Configurations and Topologies."

Optical Loss for the 2.5-Gbps Line Card Motherboards

In the transmit direction, the splitter line card motherboard attenuates the ITU signal emitted from its associated transponders significantly more than does the east or west motherboard. In the receive direction, the splitter line card motherboard attenuates the signal destined for its associated transponder significantly more than does the east or west motherboard.

Table 4-2 shows the optical loss for the splitter and unprotected motherboards supported by the Cisco ONS 15540 ESPx in the transmit and receive directions.

Table 4-2 Optical Loss for Cisco ONS 15540 ESPx 2.5-Gbps Line Card Motherboards

Line Card Motherboard Type and Direction	Loss (dB)
Splitter motherboard Tx	4.5
Splitter motherboard Rx	1.8
Unprotected motherboard Tx	1.0
Unprotected motherboard Rx	1.0

Optical Loss for 10-Gbps Line Card Motherboards

Table 4-3 shows the optical loss for the splitter and nonsplitter 10-Gbps line card motherboards for the Cisco ONS 15540 ESPx

Table 4-3 Optical Loss for the Splitter and Nonsplitter 10-Gbps Line Card Motherboards

Protection Type and Direction	Loss (dB)
Splitter Tx	3.5
Splitter Rx	0.8
Nonsplitter Tx	0.5
Nonsplitter Rx	0.5

Optical Loss for Mux/Demux Modules

Optical mux/demux modules attenuate the signals as they are multiplexed, demultiplexed, and passed through. The amount of attenuation depends upon the type of optical mux/demux module and the path the optical signal takes through the modules.

Loss for Data Channels

Table 4-4 shows the optical loss for the data channels between the 4-channel or 8-channel add/drop mux/demux modules and the transponders, and between the pass through add and drop connectors on the modules.

Table 4-4 Optical Loss for Data Channels Through the Add/Drop Mux/Demux Modules

Optical Mux/Demux Module Type	Trunk IN to Line Card Motherboard (Data Drop) in dB	Line Card Motherboard to Trunk OUT (Data Add) in dB	Trunk IN to Thru OUT (Pass Through Drop) in dB	Thru IN to Trunk OUT (Pass Through Add) in dB
4-channel with OSC	4.1	4.1	1.5	1.5
8-channel with OSC	4.8	4.8	2.0	2.0
4-channel without OSC	4.1	4.1	1.0	1.0
8-channel without OSC	4.8	4.8	1.5	1.5

Table 4-5 list the optical loss for the 32-channel terminal mux/demux modules.

Table 4-5 Optical Loss for Data Channels Through the 32-Channel Terminal Mux/Demux Modules

Optical Mux/Demux Module Type	IN to Line Card Motherboard (Data Drop) in dB	Line Card Motherboard to OUT (Data Add) in dB
32-channel (channels 1–32)	5.4	5.4

Note The insertion losses listed in Table 4-4 and Table 4-5 are worst case values. Take this into consideration when calculating the minimum loss budget.

Loss for the OSC

Table 4-6 shows the optical loss for the OSC between the mux/demux motherboard and the optical mux/demux modules.

Table 4-6 Optical Loss for the OSC Through the Optical Mux/Demux Modules

Optical Mux/Demux Module Type	Trunk IN to OSC Transceiver (dB)	OSC Transceiver to Trunk OUT (dB)
4-channel with OSC	2.8	2.8
8-channel with OSC	3.3	3.3
32-channel with OSC	7.1	7.1

Optical Loss for Cross Connect Drawers

The cross connect drawer supported by the Cisco ONS 15540 ESPx allows individual channels within a band to be added and dropped while other channels in the band are passed through. The maximum optical loss per channel is 0.6 dB.

Optical Loss for PSMs

The PSM attenuates the trunk signal as it passes between the trunk fiber and the mux/demux module or the transponder module. Table 4-7 shows the optical loss for the channels passing through a PSM.

Table 4-7 Optical Loss for Channels Passing Through PSMs

Direction	Minimum Loss (dB)	Maximum Loss (dB)
Transmit	2.7	3.7
Receive		1.7

Fiber Plant Testing

Verifying fiber characteristics to qualify the fiber in the network requires proper testing. This section describes the test requirements but not the actual procedures. After finishing the test measurements, compare the measurements with the specifications from the manufacturer, and determine whether the fiber supports your system requirements or whether changes to the network are necessary.

This test measurement data can also be used to determine whether your network can support higher bandwidth services such as 10 Gigabit Ethernet, and can help determine network requirements for dispersion compensator modules or amplifiers.

The test measurement results must be documented and will be referred to during acceptance testing of a network, as described in the *Cisco ONS 15540 ESPx Optical Transport Turn-Up and Test Guide*.

Fiber optic testing procedures must be performed to measure the following parameters:

- Link loss (attenuation)
- ORL (optical return loss)
- PMD (polarization mode dispersion)
- chromatic dispersion

Link Loss (Attenuation)

Testing for link loss, or attenuation, verifies whether fiber spans meet loss budget requirements.

Attenuation includes intrinsic fiber loss, losses associated with connectors and splices, and bending losses due to cabling and installation. An OTDR (optical time domain reflector/reflectometer) is used when a comprehensive accounting of these losses is required. The OTDR sends a laser pulse through each fiber; both directions of the fiber are tested at 1310 nm and 1550 nm wavelengths.

OTDRs also provide information about fiber uniformity, splice characteristics, and total link distance. For the most accurate loss test measurements, an LTS (loss test set) that consists of a calibrated optical source and detector is used. However, the LTS does not provide information about the various contributions (including contributions related to splice and fiber) to the total link loss calculation.

A combination of OTDR and LTS tests is needed for accurate documentation of the fiber facilities being tested. In cases where the fiber is very old, testing loss as a function of wavelength (also called spectral attenuation) might be necessary. This is particularly important for qualifying the fiber for multiwavelength operation. Portable chromatic dispersion measurement systems often include an optional spectral attenuation measurement.

ORL

ORL is a measure of the total fraction of light reflected by the system. Splices, reflections created at optical connectors, and components can adversely affect the behavior of laser transmitters, and they all must be kept to a minimum of 24 dB or less. You can use either an OTDR or an LTS equipped with an ORL meter for ORL measurements. However, an ORL meter yields more accurate results.

PMD

PMD has essentially the same effect on the system performance as chromatic dispersion, which causes errors due to the "smearing" of the optical signal. However, PMD has a different origin from chromatic dispersion. PMD occurs when different polarization states propagate through the fiber at slightly different velocities.

PMD is defined as the time-averaged DGD (differential group delay) at the optical signal wavelength. The causes are fiber core eccentricity, ellipticity, and stresses introduced during the manufacturing process. PMD is a problem for higher bit rates (10 GE and above) and can become a limiting factor when designing optical links.

The time-variant nature of dispersion makes it more difficult to compensate for PMD effects than for chromatic dispersion. "Older" (deployed) fiber may have significant PMD—many times higher than the 0.5 ps/Ð km specification seen on most new fiber. Accurate measurements of PMD are very important to guarantee operation at 10 Gbps. Portable PMD measuring instruments have recently become an essential part of a comprehensive suite of tests for new and installed fiber. Because many fibers in a cable are typically measured for PMD, instruments with fast measurement times are highly desirable.

Chromatic Dispersion

Chromatic dispersion testing is performed to verify that measurements meet your dispersion budget.

Chromatic dispersion is the most common form of dispersion found in single-mode fiber. Temporal in nature, chromatic dispersion is related only to the wavelength of the optical signal. For a given fiber type and wavelength, the spectral line width of the transmitter and its bit rate determine the chromatic dispersion tolerance of a system. Dispersion management is of particular concern for high bit rates (10 Gbps) using conventional single-mode fiber. Depending on the design of the 10-Gbps transceiver module, dispersion compensation might be needed to accommodate an upgrade from GE to 10 GE in order to keep the same targeted distances.

Portable chromatic dispersion measurement instruments are essential for testing the chromatic dispersion characteristics of installed fiber.

Fiber Requirements for 10-Gbps Transmission

Do not deploy 10-Gbps wavelengths, or even 2.5-Gbps wavelengths, over G.653 fiber. This type of fiber causes enormous amounts of nonlinear effects.

CHAPTER 5

Example Shelf Configurations and Topologies

The requirements of a particular topology determine what components must be used and how they are interconnected. This chapter provides examples of shelf configurations, optical power budget calculations, and optical mux/demux module cabling specific to each of the main types of topologies supported by the Cisco ONS 15540 ESPx. This chapter contains the following major sections:

Note For information on topology configurations consisting of Cisco ONS 15540 ESPx, Cisco ONS 15540 ESP, and Cisco ONS 15530 shelves, refer to the *Cisco ONS 15530 Planning Guide*.

Shelf Configurations

The Cisco ONS 15540 ESPx provides two ways to cable transponder motherboards to the mux/demux modules: directly or using the cross connect drawer. This section shows how to cable a single shelf for the different types of protection configuration.

Note The cabling schemes illustrated in the figures in this section emphasize the relationships between the shelf components and do not include the cable management system. For detailed information on cabling the shelf components, refer to the *Cisco ONS 15540 ESPx Hardware Installation Guide*.

Unprotected Configurations

This section describes the configuration of and cabling between the mux/demux modules and line card motherboard for unprotected configurations.

Note You can use splitter protected line card motherboards but they have a higher optical loss.

Direct Cabling

Figure 5-1 shows an example of how to directly cable an unprotected configuration.

Figure 5-1 Direct Cabling Between Line Card Motherboards and 4-Channel Mux/Demux Modules for Unprotected Configurations

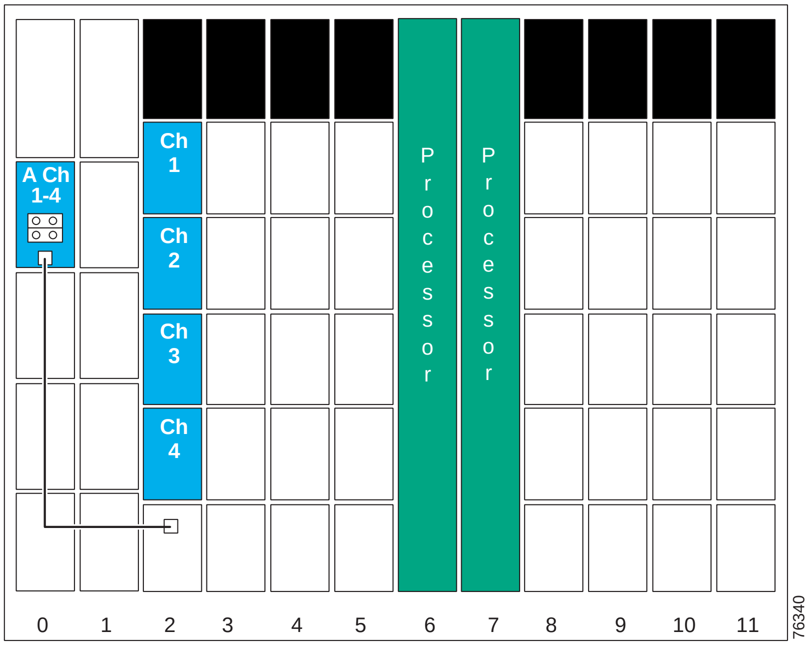
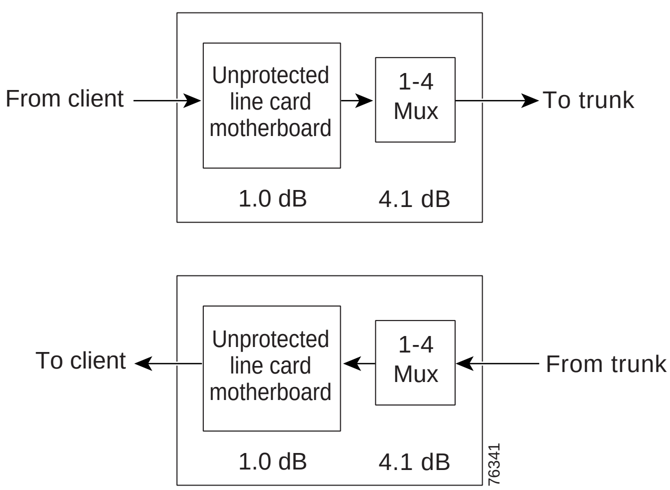


Figure 5-2 shows the optical power budget for a directly connected unprotected configuration.

Figure 5-2 Optical Power Budget for Directly Cabled Unprotected Configurations



Cross Connect Drawer Cabling

Figure 5-3 shows an example of how to cable an unprotected configuration with the cross connect drawer.

Figure 5-3 Cabling With the Cross Connect Drawer Between Line Card Motherboards and 4-Channel Mux/Demux Modules for Unprotected Configurations

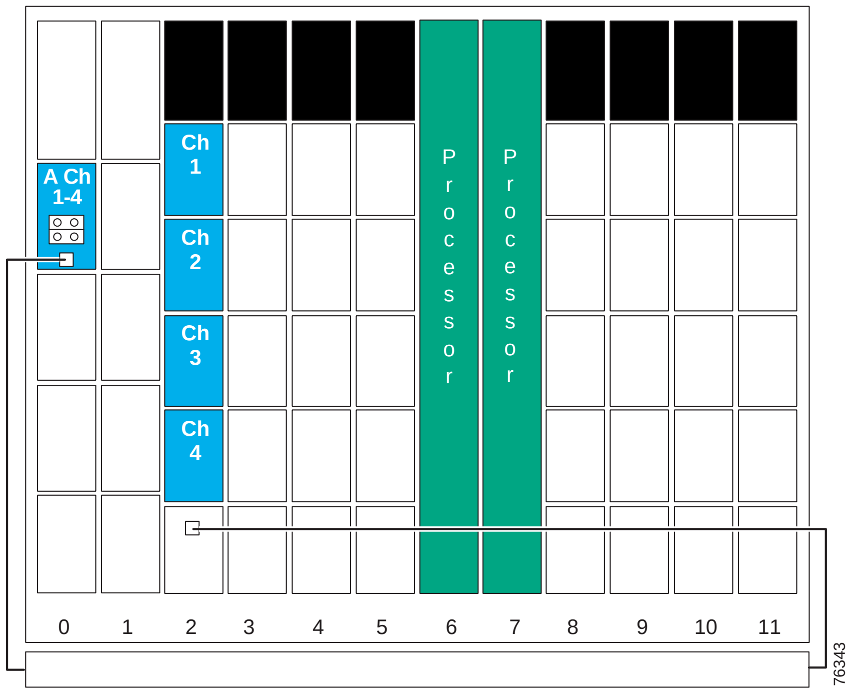
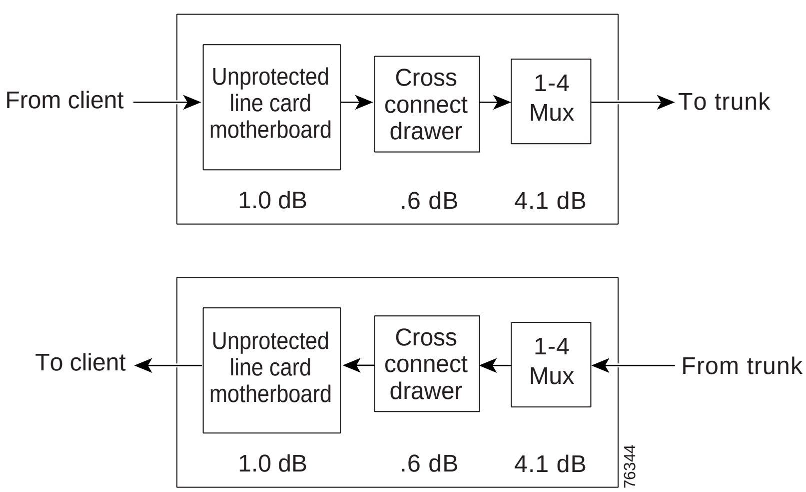


Figure 5-4 shows the optical power budget for a cross connect drawer connected in an unprotected configuration.

Figure 5-4 Optical Power Budget for Cross Connect Drawer Cabled Unprotected Configurations



Splitter Protected Configurations

This section describes the configuration of and cabling between the mux/demux modules and line card motherboards for splitter protected configurations.

Direct Cabling

Figure 5-5 shows an example of how to directly cable a splitter protected configuration.

Figure 5-5 Direct Cabling Between Line Card Motherboards and 4-Channel Mux/Demux Modules for Splitter Protected Configurations

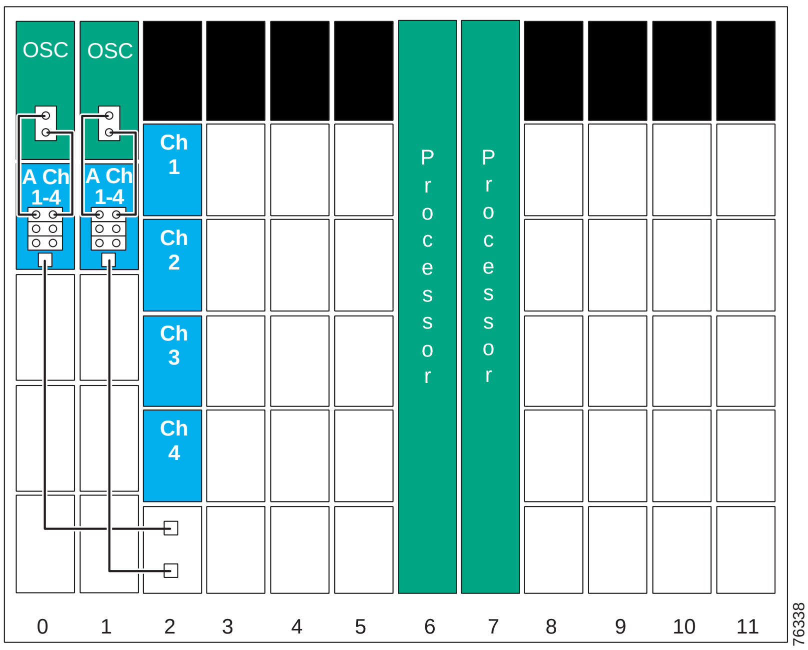
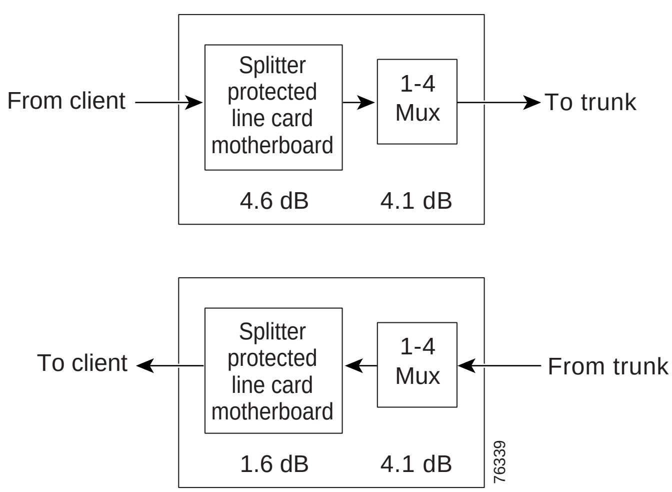


Figure 5-6 shows the optical power budget for a directly connected splitter protected configuration.

Figure 5-6 Optical Power Budget for Directly Cabled Splitter Protected Configurations



Cross Connect Drawer Cabling

Figure 5-7 shows an example of how to cable a splitter protected configuration with the cross connect drawer.

Figure 5-7 Cabling With the Cross Connect Drawer Between Line Card Motherboards and 4-Channel Mux/Demux Modules for Splitter Protected Configurations

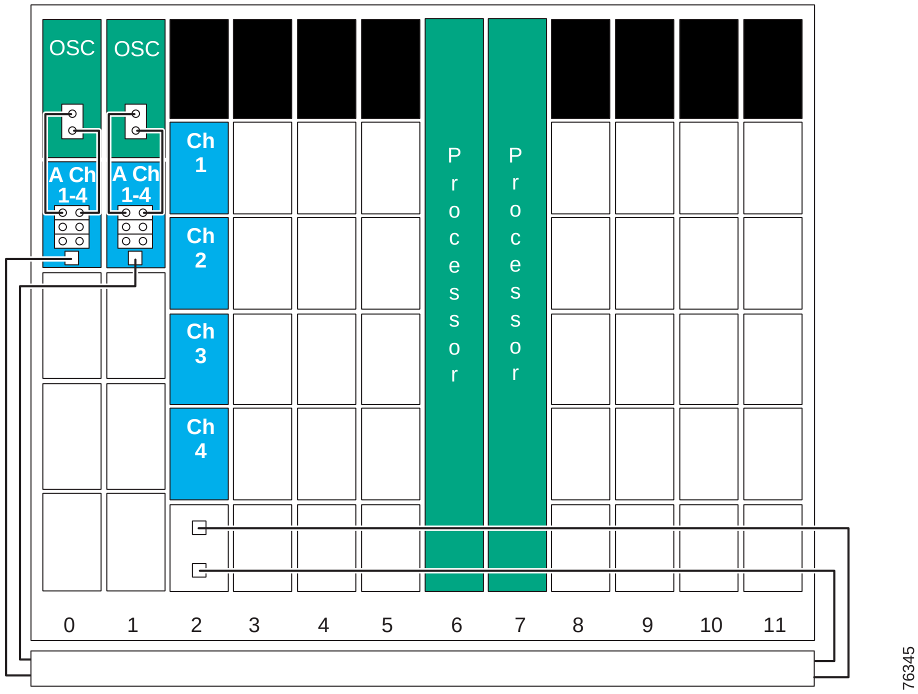
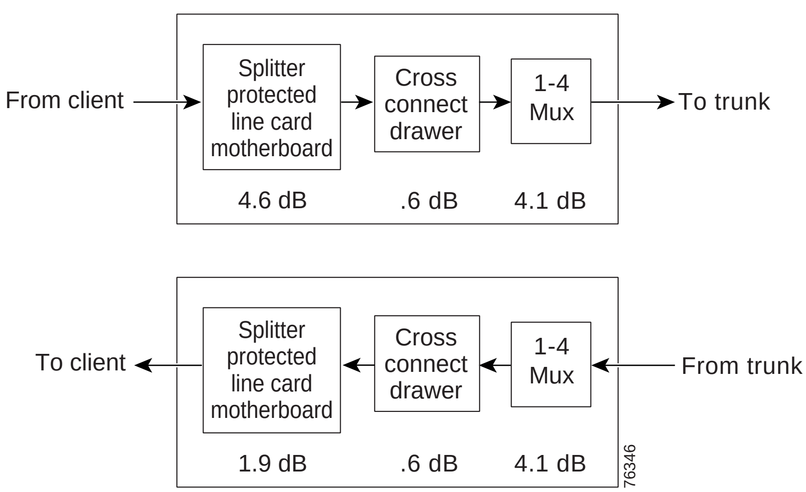


Figure 5-8 shows the optical power budget for a cross connect drawer connected in a splitter protected configuration.

Figure 5-8 Optical Power Budget for Cross Connect Drawer Cabled Splitter Protected Configurations



Line Card Protected Configurations

This section describes the configuration of and cabling between the mux/demux modules and line card motherboards for line card protected configurations.

Direct Cabling

Figure 5-9 shows an example of how to directly cable a line card protected configuration.

Figure 5-9 Direct Cabling Between Line Card Motherboards and 4-Channel Mux/Demux Modules for Line Card Protected Configurations

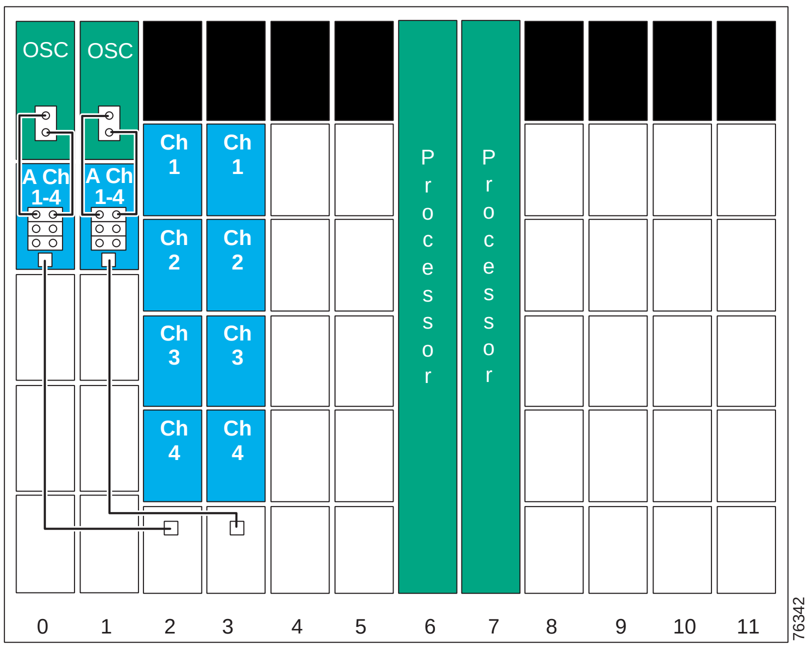
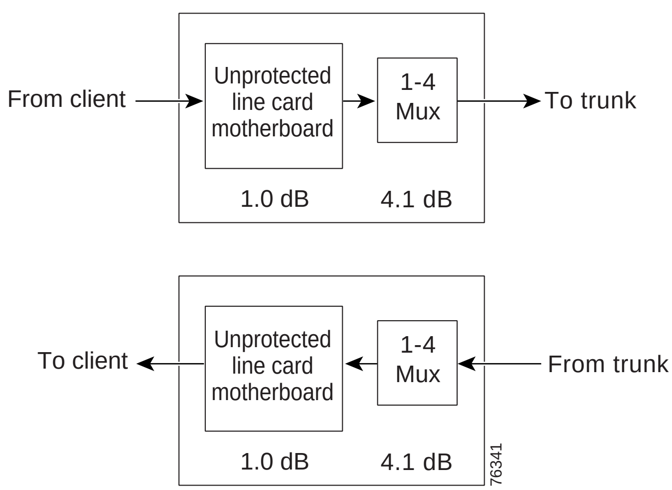


Figure 5-10 shows the optical power budget for a directly connected line card protected configuration.

Figure 5-10 Optical Power Budget for Directly Cabled Line Card Protected Configurations



Cross Connect Drawer Cabling

Figure 5-11 shows an example of how to cable a line card protected configuration with the cross connect drawer.

Figure 5-11 Cabling With the Cross Connect Drawer Between Line Card Motherboards and 4-Channel Mux/Demux Modules for Line Card Protected Configurations

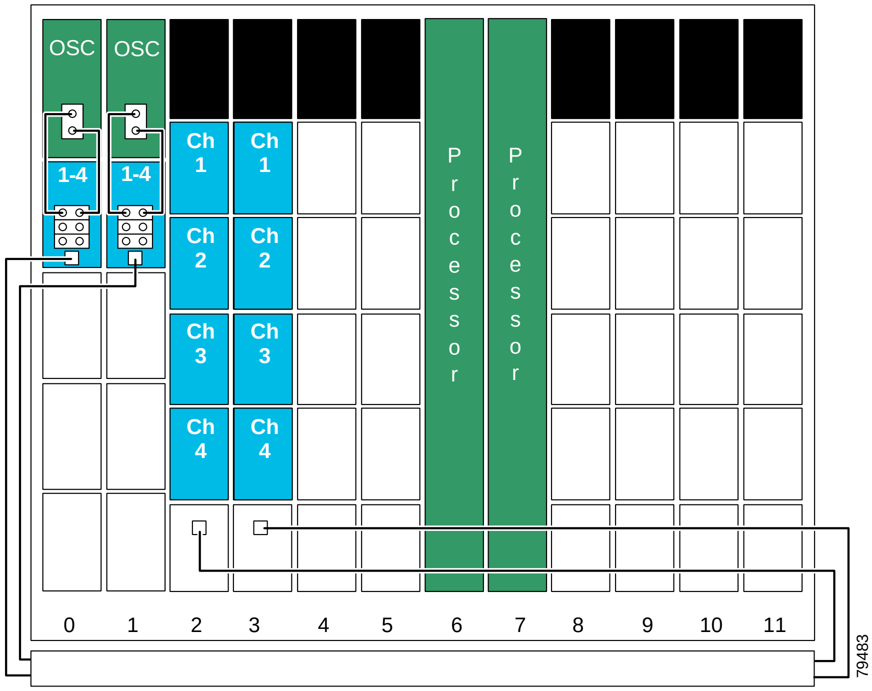
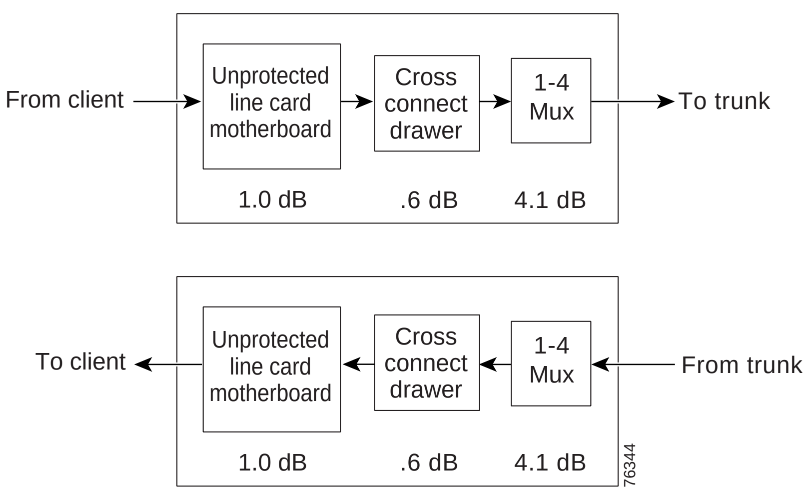


Figure 5-12 shows the optical power budget for a cross connect drawer connected in a line card protected configuration.

Figure 5-12 Optical Power Budget for Cross Connect Drawer Cabled Line Card Protected Configurations



Trunk Fiber Protected Configurations

This section describes the configuration of and cabling between the mux/demux modules and the PSM (protection switch module) for trunk fiber protected configurations.

Figure 5-13 shows an example of how to cable a trunk fiber protected configuration.

Figure 5-13 Cabling Between 4-Channel Mux/Demux Modules and PSM for Line Card Protected Configurations

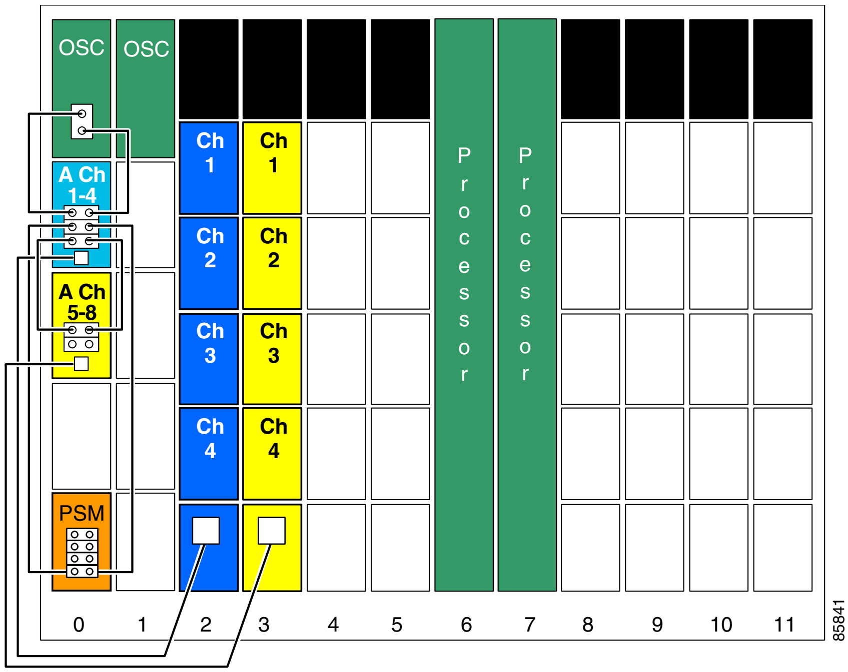
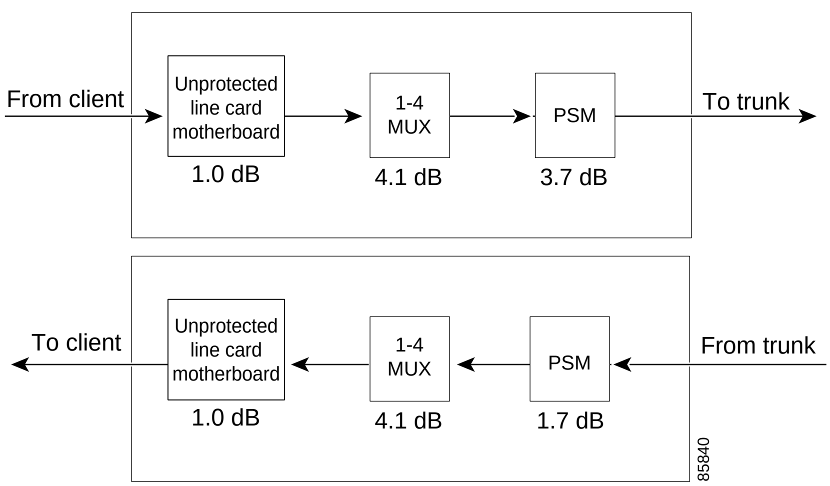


Figure 5-14 shows the optical power budget for a directly connected line card protected configuration.

Figure 5-14 Optical Power Budget for Trunk Fiber Protected Configurations



The PSM can also connect directly to a line card motherboard. That configuration would not include the loss for the mux/demux modules.

Point-to-Point Topologies

Use the following criteria in determining the equipment needed for a point-to-point topology:

- Number of channels at deployment and in the future
- Distance between nodes
- Potential topology changes in the future (such as migration to ring)
- Presence of OSC

There are many optical mux/demux module combinations that can satisfy the requirements of a network design. For example, a shelf can support 32 channels using eight 4-channel mux/demux modules, four 8-channel mux/demux modules, or one 32-channel mux/demux module. However, certain configurations can prove costly as network requirements change.

The terminal mux/demux modules are ideally suited for a point-to-point topology. They impose less optical link loss than cascading the 4-channel and 8-channel modules, thereby maximizing the distance between nodes. Price per channel is also less if the current or future channel requirement is near 32. However, if future plans include migrating to a ring environment, a terminal mux/demux module is not ideal. If, for example, a point-to-point topology using 32-channel mux/demux modules at each end were migrated to a hubbed ring, the node that became an add/drop node could not use the 32-channel module (though the hub node could use that module). If the migration were to a meshed ring, neither node could use the 32-channel module.

Note For information on point-to-point topology configurations consisting of Cisco ONS 15540 ESPx, Cisco ONS 15540 ESP, and Cisco ONS 15530 shelves, refer to the *Cisco ONS 15530 Planning Guide*.

Unprotected 16 Channel Point-to-Point Configuration with 10-Gbps Line Card Motherboards

Figure 5-15 shows the optical power loss for each of the components traversed by data channels 1 to 16 and for the OSC. This configuration uses an unprotected 10-Gbps line card motherboard. A fully populated shelf supports 16 channels in an unprotected configuration.

Figure 5-15 Optical Power Budget for Unprotected Point-to-Point Topology with 10-Gbps Line Card Motherboard

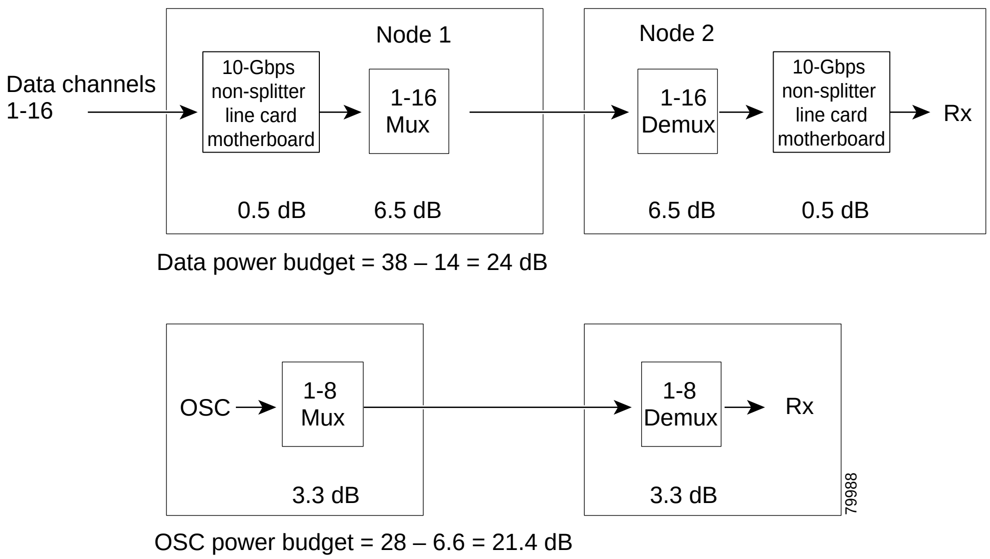
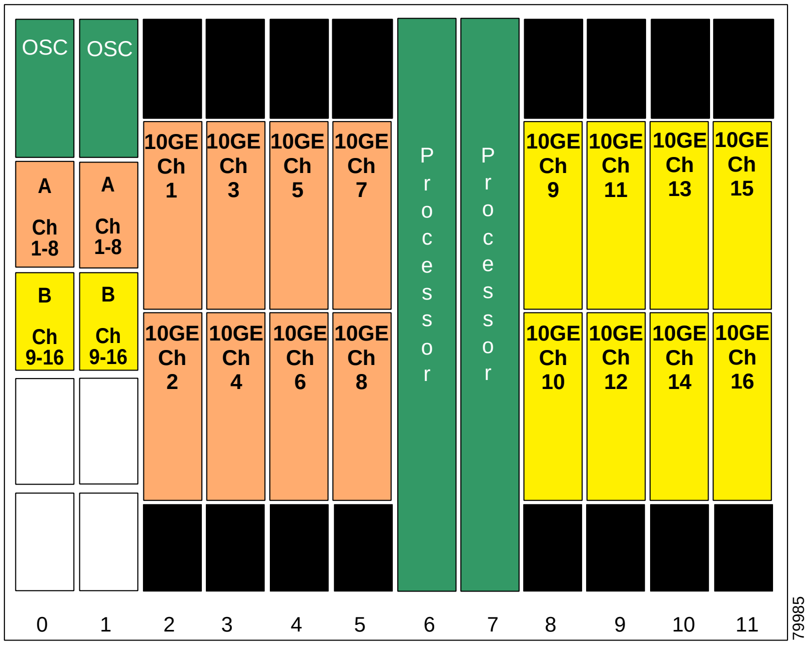


Figure 5-16 shows how the shelf for each node is populated to support a 16-channel unprotected configuration using 10-Gbps line card motherboards.

Figure 5-16 Shelf Configuration for Unprotected 16-Channel Point-to-Point Topology with 10-Gbps Line Card Motherboard



Protected 8-Channel Point-to-Point Configuration with 10-Gbps Line Card Motherboards

Figure 5-17 shows the optical power loss for each of the components traversed by data channels 1 to 8 and for the OSC. This configuration uses a protected 10-Gbps line card motherboard. A fully populated shelf supports 8 channels in a protected configuration.

Figure 5-17 Optical Power Budget for Protected Point-to-Point Topology with 10-Gbps Line Card Motherboard

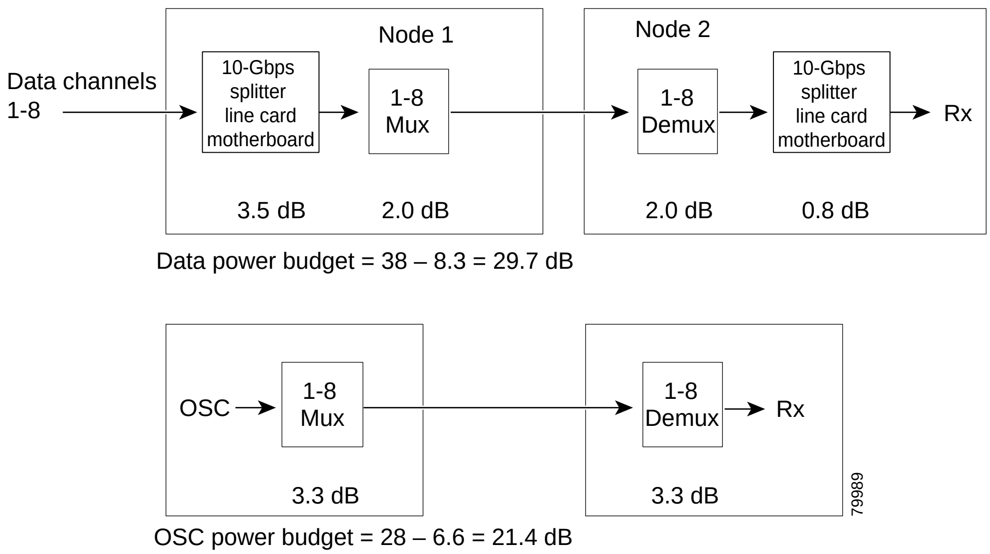
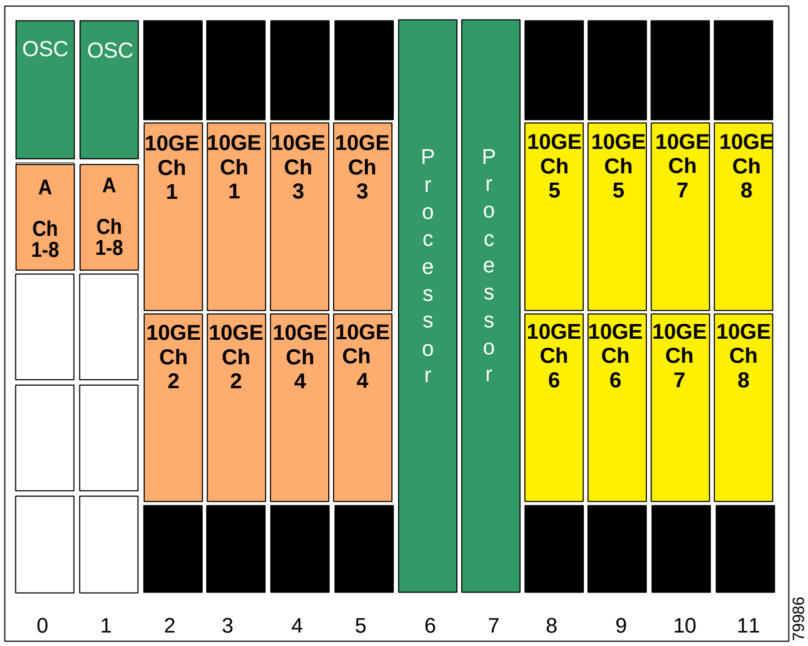


Figure 5-18 shows how the shelf for each node is populated to support a 8-channel protected configuration using 10-Gbps line card motherboards.

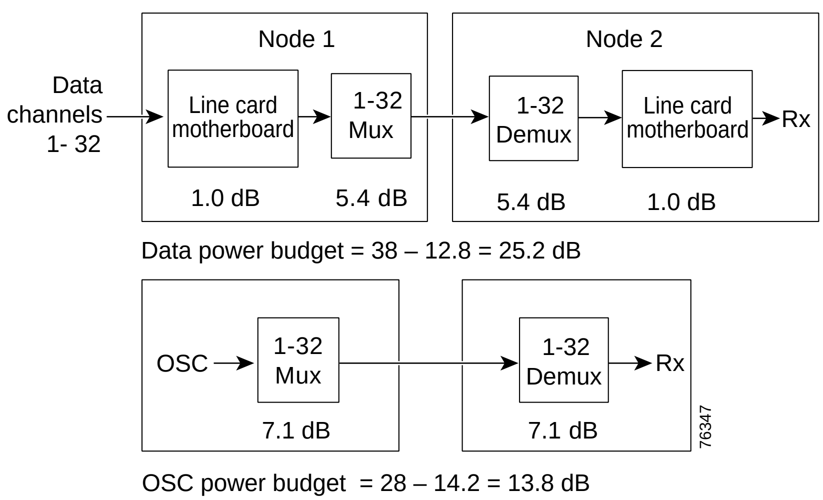
Figure 5-18 Shelf Configuration for Protected 8-Channel Point-to-Point Topology with 10-Gbps Line Card Motherboard



Unprotected 32-Channel Point-to-Point Configuration

Figure 5-19 shows the optical power loss for each of the components traversed by data channels 1 to 8 and for the OSC. This configuration uses an unprotected line card motherboard.

Figure 5-19 Optical Power Budget for Unprotected Point-to-Point Topology



In an unprotected point-to-point topology, the Cisco ONS 15540 ESPx can support up to 32 unprotected channels on a single fiber pair.

Figure 5-20 shows how the shelf for each node is populated to support a 32-channel unprotected configuration using one 32-channel mux/demux module. The line card motherboards are all unprotected. The line card motherboards in slots 2 to 5 cross connect to the mux/demux module in slot 0/0 and the line card motherboards in slots 8 to 11 cross connect to the mux/demux module in slot 0/2.

Figure 5-20 Shelf Configuration for Unprotected 32-Channel Point-to-Point Topology

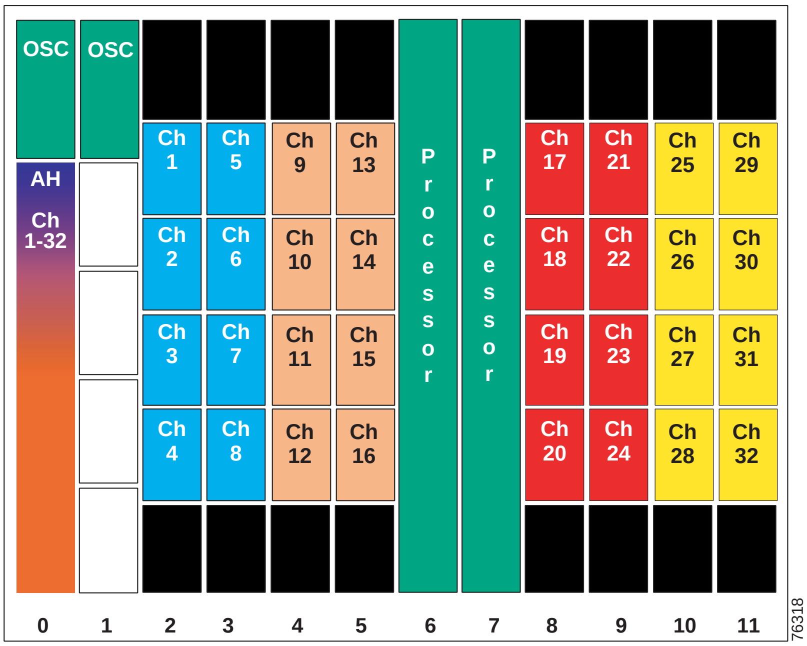
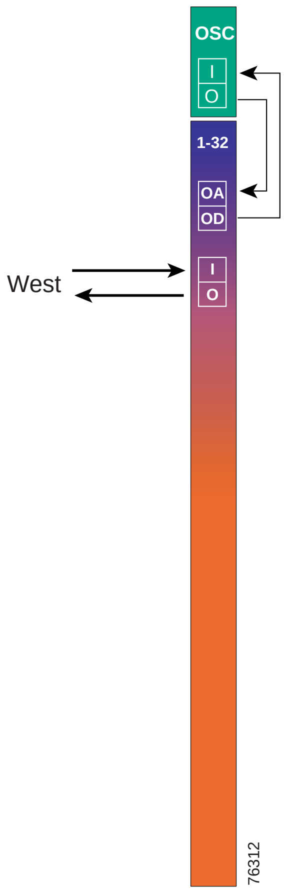


Figure 5-21 shows how the terminal mux/demux modules are cabled for the 32-channel unprotected point-to-point configuration.

Figure 5-21 Terminal Mux/Demux Module Cabling with OSC for Unprotected 32-Channel Point-to-Point Topology



Splitter Protected 32-Channel Point-to-Point Configuration

In a splitter protected point-to-point topology, the Cisco ONS 15540 ESPx can support up to 32 protected channels on two fiber pairs.

Figure 5-22 shows the optical power loss for each of the components traversed by data channels 17 to 32, which have the greatest amount of loss, and for the OSC. This configuration uses the splitter protected line card motherboards.

Figure 5-22 Optical Power Budget for Splitter Protected Point-to-Point Topology

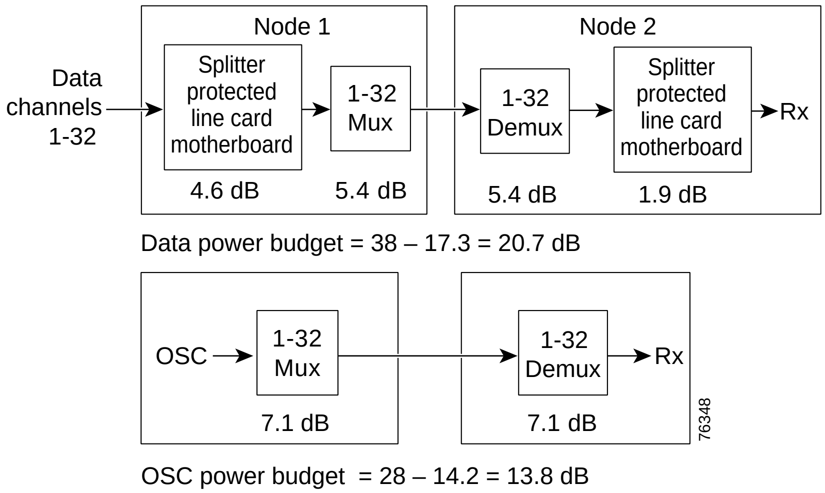


Figure 5-23 shows the shelf configuration for both nodes in a 32-channel splitter protected point-to-point topology. For splitter protection, the splitter protected line card motherboards are used, along with terminal mux/demux modules in both west and east mux/demux slots 0 and 1.

Figure 5-23 Shelf Configuration for Splitter Protected 32-Channel Point-to-Point Topology

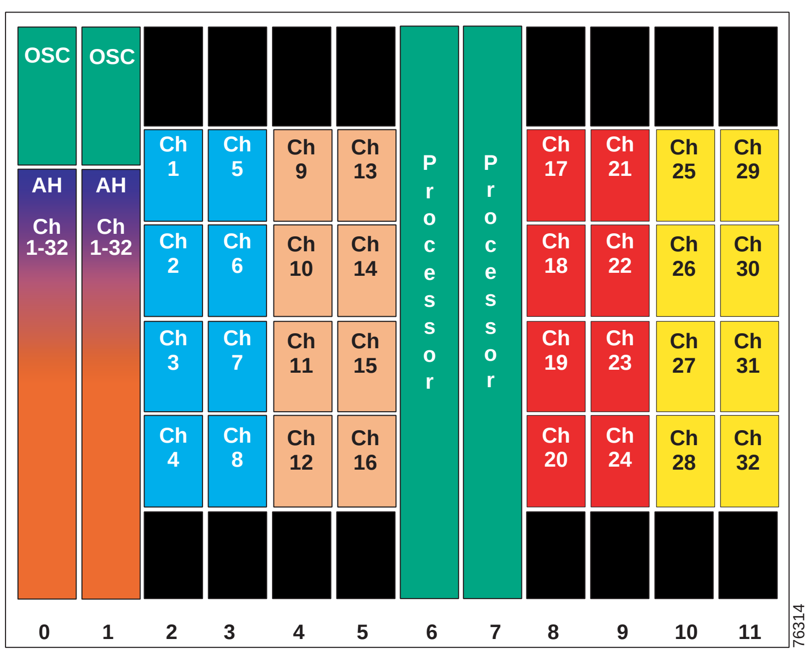
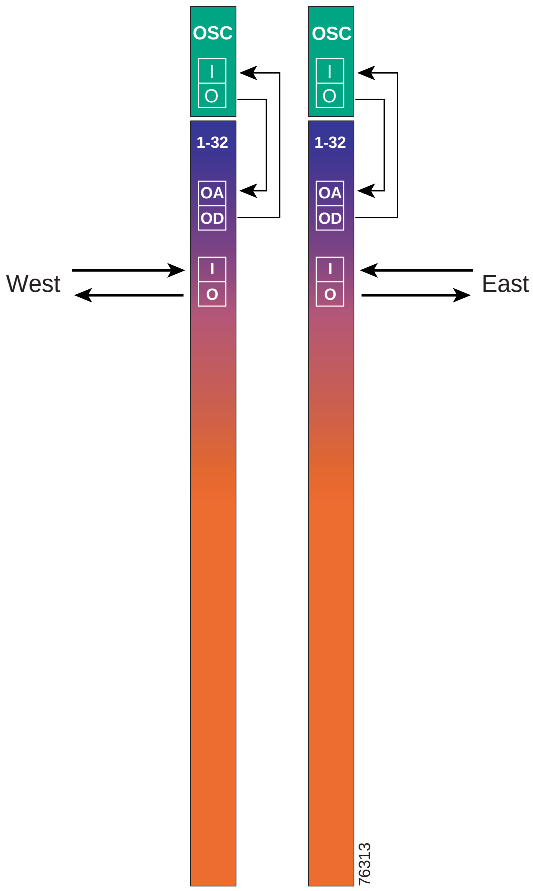


Figure 5-24 shows how the terminal mux/demux modules are cabled for the 32-channel splitter protected point-to-point configuration.

Figure 5-24 Terminal Mux/Demux Module Cabling with OSC for Splitter Protected 32-Channel Point-to-Point Topology



Line Card Protected 16-Channel Point-to-Point Configuration

In a line card protected point-to-point topology, a single Cisco ONS 15540 ESPx shelf can support up to 16 protected channels on two fiber pairs.

Figure 5-25 shows the optical power loss for each of the components traversed by the 16 data channels and the OSC, along with the resulting power budget. This configuration uses the east and unprotected line card motherboards.

Figure 5-25 Optical Power Budget for Line Card Protected 16-Channel Point-to-Point Topology

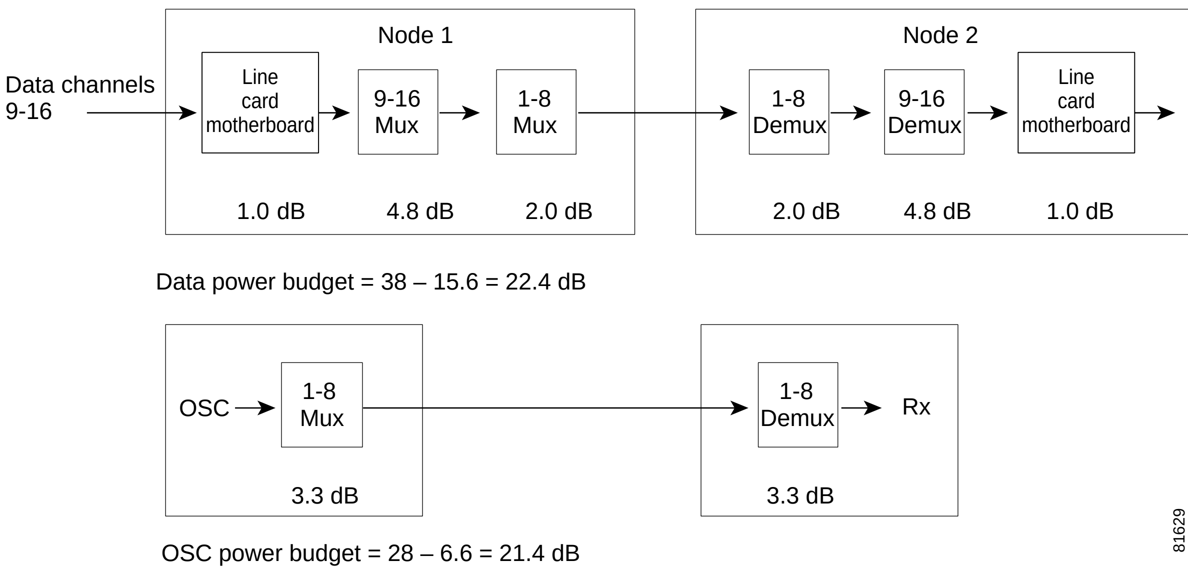


Figure 5-26 shows the shelf configuration for both nodes in a 16-channel line card protected point-to-point topology. For line card protection, the line card motherboards in slots 2 to 5 cross connect to the mux/demux modules in slots 0 and the line card motherboards in slots 8 to 11 cross connect to the mux/demux modules in slot 1.

Figure 5-26 Shelf Configuration for Line Card Protected 16-Channel Point-to-Point Topology

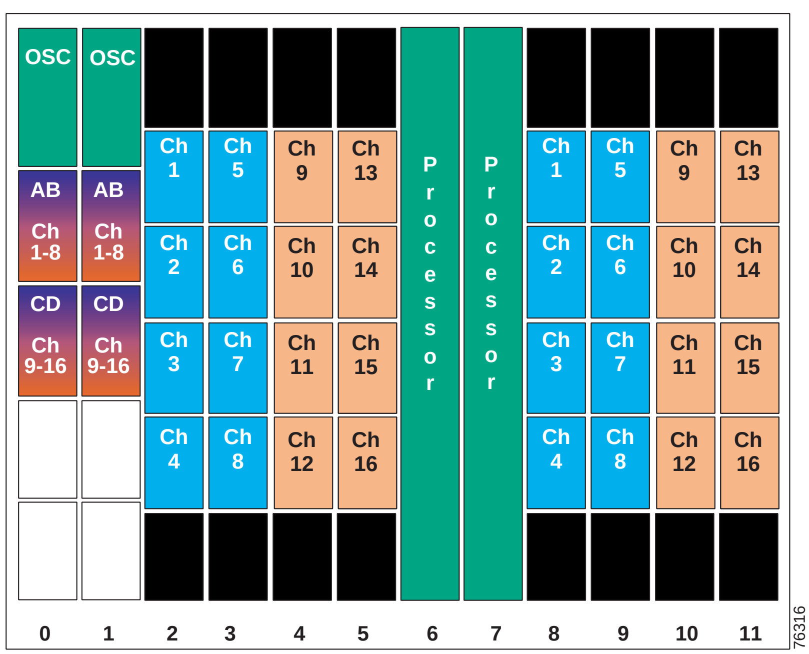
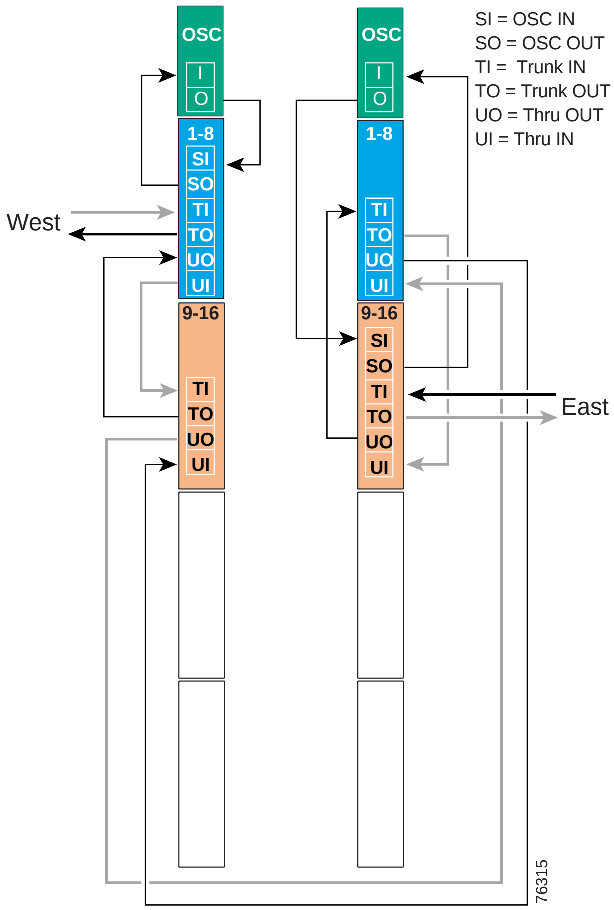


Figure 5-27 shows how the terminal mux/demux modules are cabled for the 16-channel line card protected point-to-point configuration.

Figure 5-27 Terminal Mux/Demux Module Cabling with OSC for Line Card Protected 16-Channel Point-to-Point Topology



Line Card Protected 32-Channel Point-to-Point Configuration

By cascading two Cisco ONS 15540 ESPx shelves, 32 channels can be supported in a line card protected point-to-point configuration. Shelf 1 is configured for channels 1 to 16 with OSC, while shelf 2 is configured for channels 17 to 32 without OSC. The terminal mux/demux modules are patched between the two shelves as if they were in the same shelf. In this configuration, shelf 2 cannot support the OSC, which means that a separate Ethernet connection to that shelf is required for management purposes.

The optical power budget for this configuration is the same as for a 32-channel unprotected configuration, shown in Figure 5-19 on page 5-13.

Note It is possible to use the 8-channel add/drop mux/demux modules in two shelves for a 32-channel line card protected configuration. However, we do not recommend this configuration because of the high optical power loss.

The configuration and terminal mux/demux cabling for shelf 1 in the line card protected 32-channel configuration are the same as for the line card protected 16-channel configuration, shown in Figure 5-26 on page 5-18 and Figure 5-27 on page 5-19. The configuration for shelf 2 is shown in Figure 5-28. As in shelf 1, the line card motherboards in slots 2 to 5 cross connect to the mux/demux modules in slot 0 and the line card motherboards in slots 8 to 11 cross connect to the mux/demux modules in slot 1.

Figure 5-28 Shelf 2 Configuration for Line Card Protected 32-Channel Point-to-Point Topology

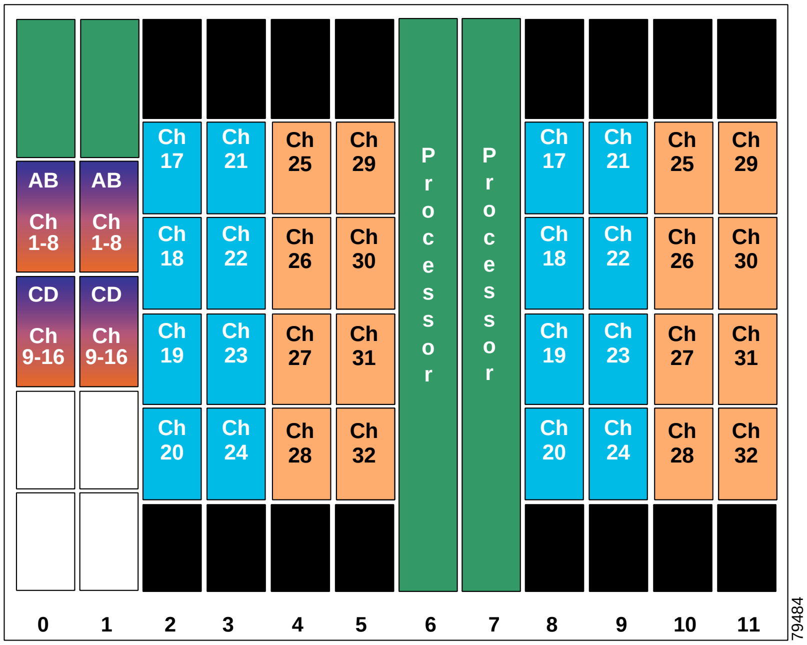
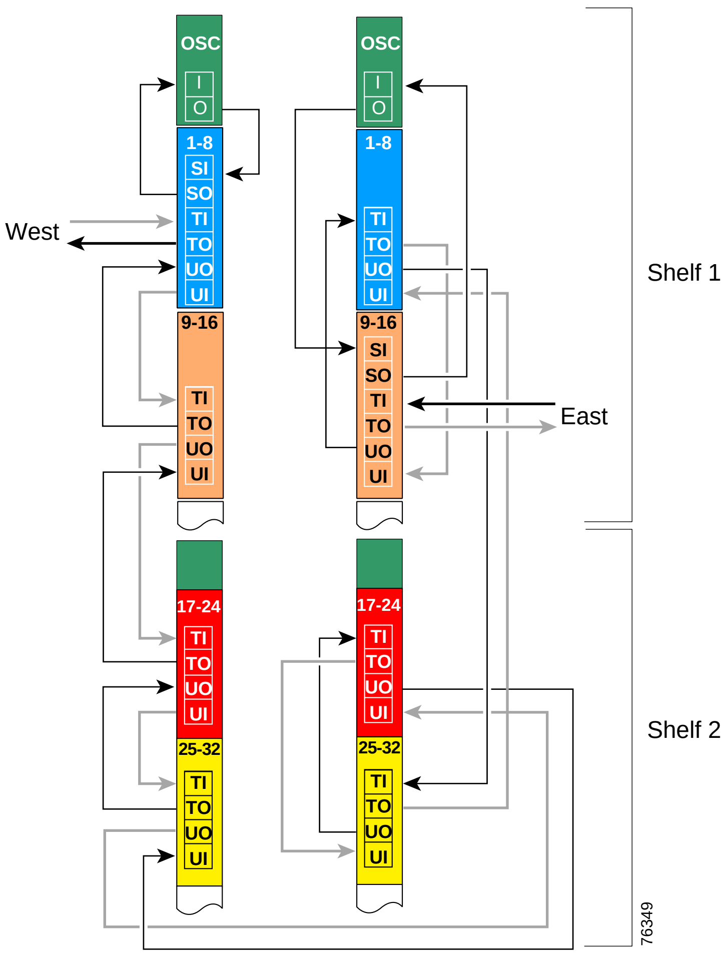


Figure 5-29 shows how the terminal mux/demux modules are cabled between the two shelves to support all 32 channels on both the east and west sides.

Figure 5-29 Terminal Mux/Demux Module Cabling with Two Shelves for Line Card Protected 32-Channel Point-to-Point Topology



Hubbed Ring Topologies

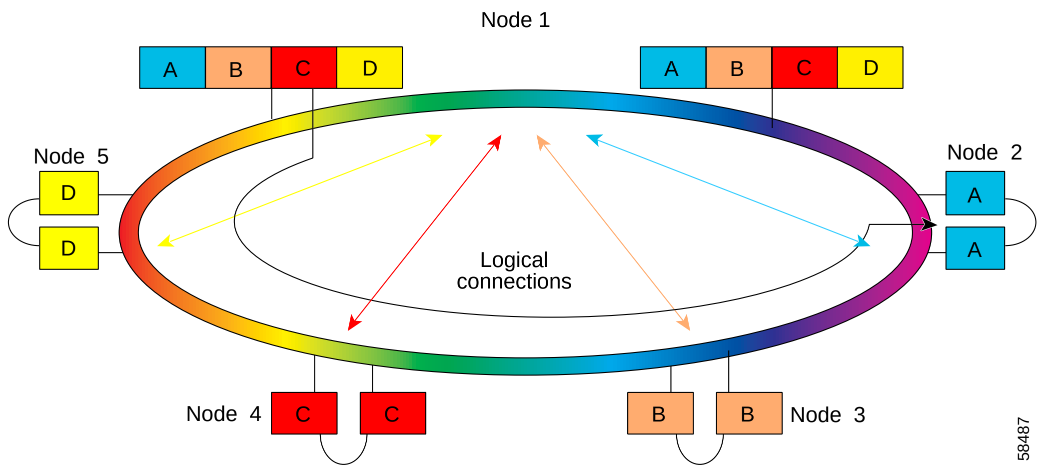
In a hubbed ring architecture, one node serves as the hub (or terminal) node, while all other nodes perform add/drop functions. This type of topology is also sometimes called *hub and spoke*, because each of the spoke nodes is logically connected to only the hub node. In a hubbed ring, the hub can use terminal mux/demux modules, while each of the spoke nodes must be equipped with add/drop mux/demux modules.

Note For information on hubbed ring topology configurations consisting of Cisco ONS 15540 ESPx, Cisco ONS 15540 ESP, and Cisco ONS 15530 shelves, refer to the *Cisco ONS 15530 Planning Guide*.

Figure 5-30 shows the channel plan for a 16-channel hubbed ring where a band of four channels is dropped at each spoke node. The hub node in this example uses two 8-channel add/drop mux/demux modules. The nodes communicate as follows:

- Nodes 1-2 over band A
- Nodes 1-3 over band B
- Nodes 1-4 over band C
- Nodes 1-5 over band D

Figure 5-30 Hubbed Ring Channel Plan



Splitter Protected Hubbed Ring Configuration

Assuming that all nodes were equidistant in the ring, the path with the greatest optical link loss (the "worst path") would be the path for band A between node 1 and node 2. This path is shown in Figure 5-30 by the black line connecting node 1 to node 2 by way of nodes 5, 4, and 3.

Figure 5-31 shows the optical power loss through each of the components from node 1 to node 2 for band A, and for the OSC. This configuration uses the splitter protected line card motherboards.

Figure 5-31 Optical Power Budget for Splitter Protected Hubbed Ring

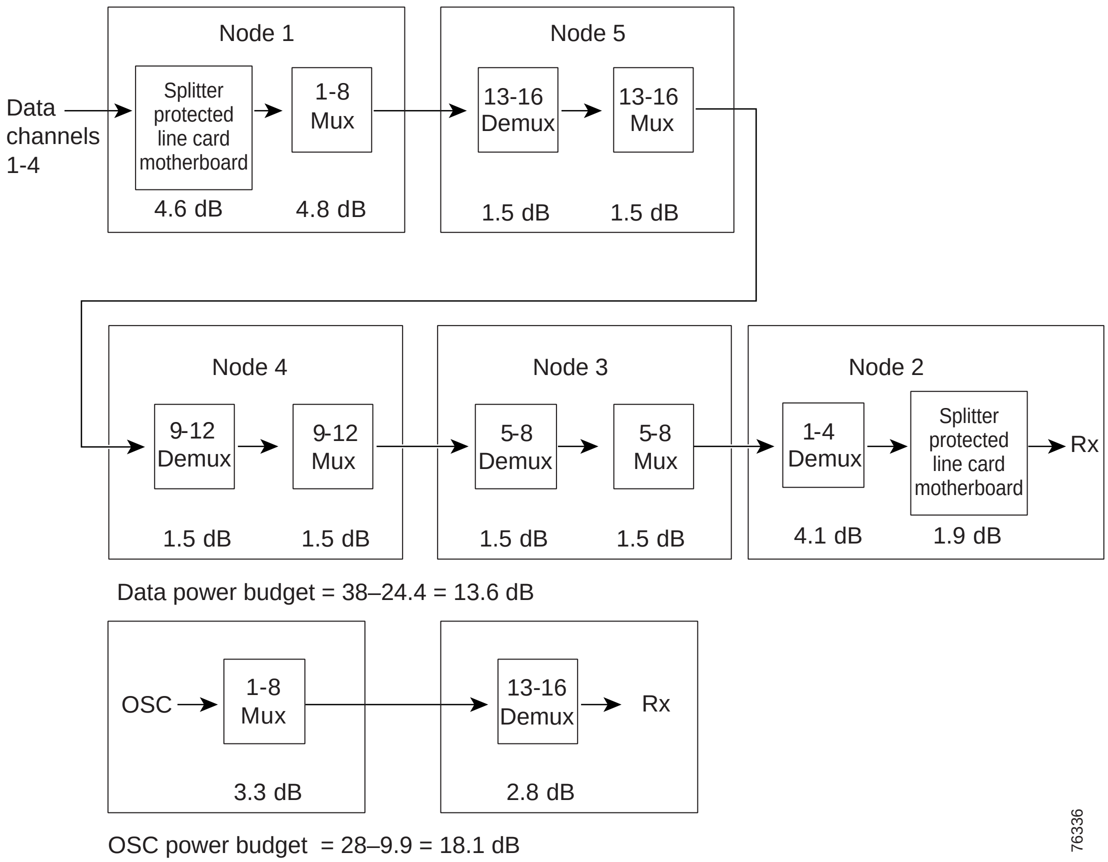


Figure 5-32 shows how the hub node shelf is populated in the 16-channel splitter protected hubbed ring topology. Splitter protected line card motherboards are installed in slots 2 to 5, and two 8-channel add/drop mux/demux modules are used in the west and east mux/demux slots 0 and 1. Each line card motherboard cross connects to both mux/demux modules.

Figure 5-32 Shelf Configuration for 16-Channel Hub Node in Splitter Protected Hubbed Ring

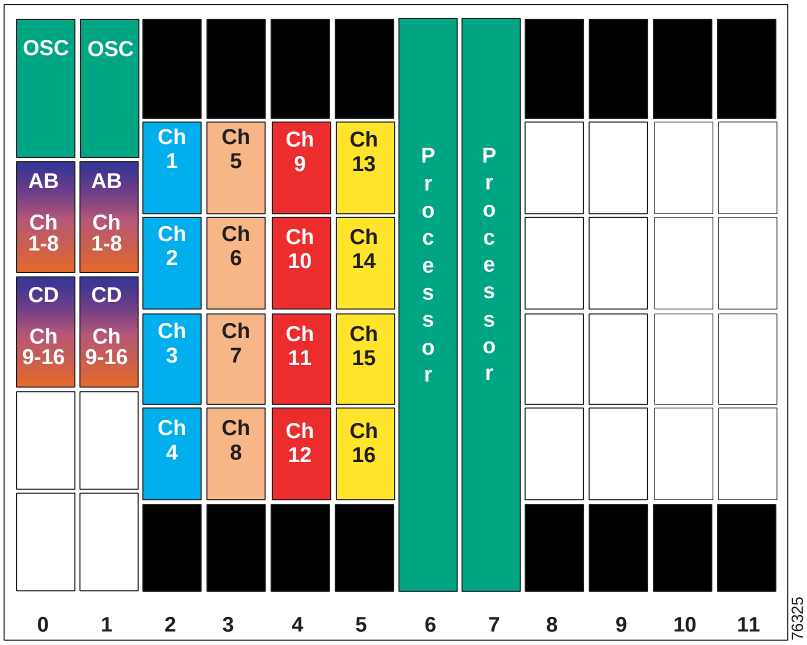


Figure 5-33 shows how the 8-channel add/drop mux/demux modules are cabled for the hub node in the splitter protected hubbed ring.

Figure 5-33 Add/Drop Mux/Demux Module Cabling with OSC for 16-Channel Hub Node in Splitter Protected Hubbed Ring

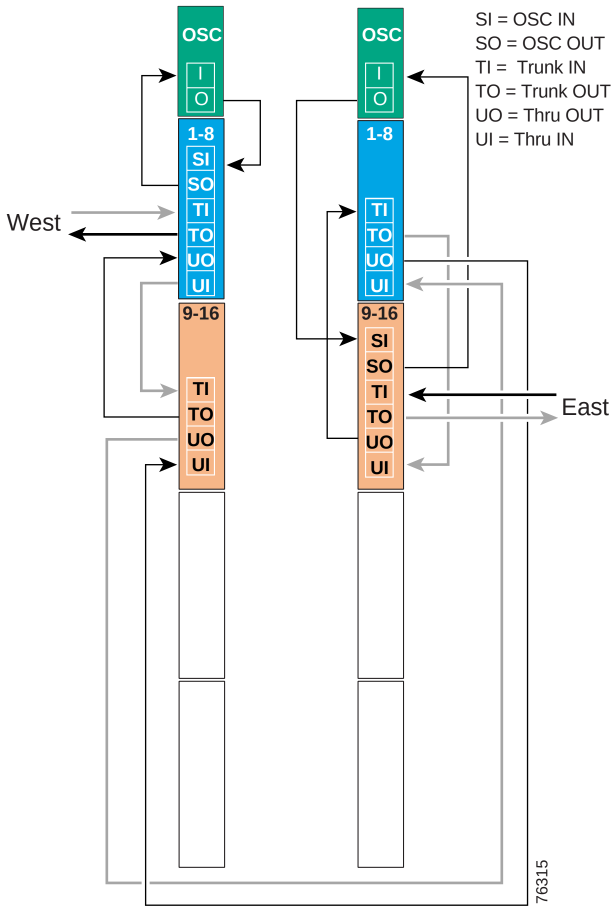


Figure 5-34 shows the shelf configuration for node 2 in the hubbed ring. A splitter protected line card motherboard is used in slot 2, and 4-channel mux/demux modules are used in subslot 0 of the west and east mux/demux slots 0 and 1. The line card motherboard cross connects to both mux/demux modules.

Figure 5-34 Shelf Configuration for Node 2 in Splitter Protected Hubbed Ring

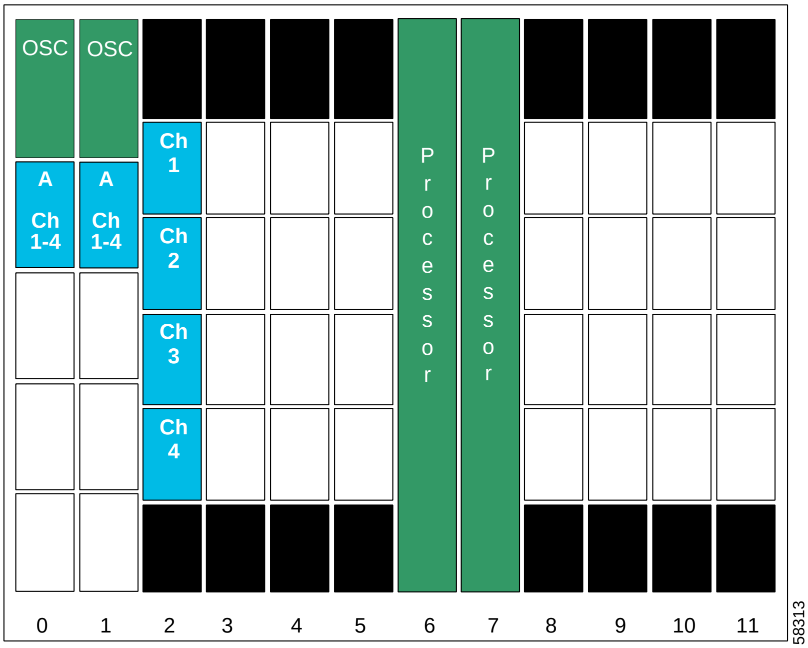


Figure 5-35 shows how the 4-channel mux/demux modules are cabled for node 2 in the splitter protected hubbed ring.

Figure 5-35 Add/Drop Mux/Demux Module Cabling with OSC for Node 2 in Splitter Protected Hubbed Ring

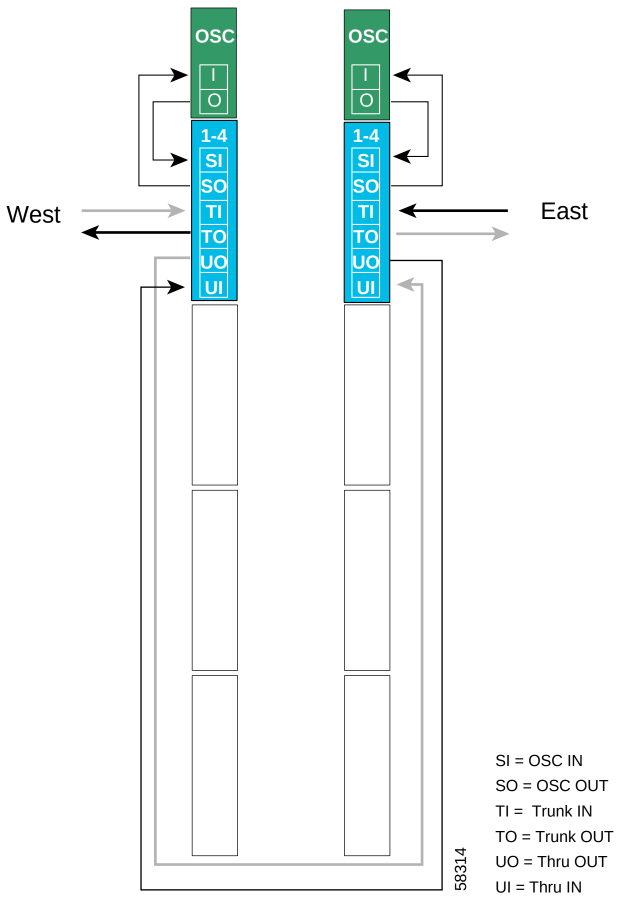


Figure 5-36 shows the shelf configuration for node 3 in the hubbed ring. A splitter protected line card motherboard is used in slot 5, and 4-channel mux/demux modules are used in subslot 1 of the west and east mux/demux slots 0 and 1. The line card motherboard cross connects to both mux/demux modules.

Figure 5-36 Shelf Configuration for Node 3 in Splitter Protected Hubbed Ring

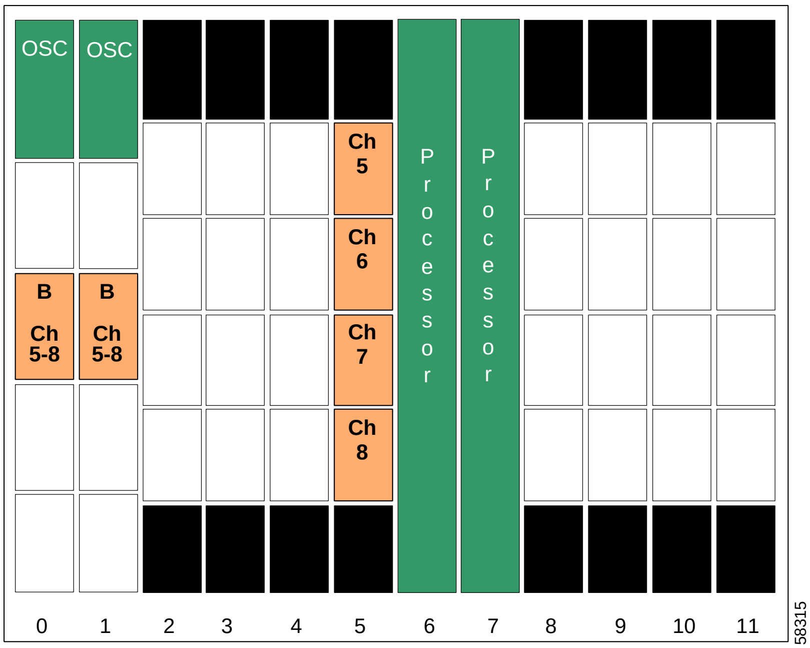


Figure 5-37 shows how the 4-channel mux/demux modules are cabled for node 3 in the splitter protected hubbed ring.

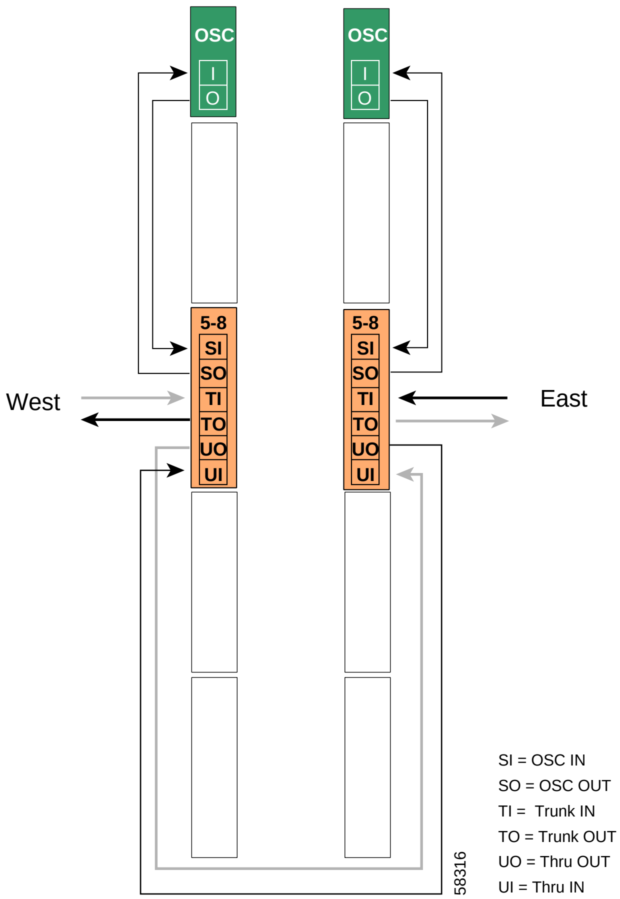


Figure 5-37 Add/Drop Mux/Demux Module Cabling with OSC for Node 3 in Splitter Protected Hubbed Ring

Figure 5-38 shows the shelf configuration for node 4 in the hubbed ring. A splitter protected line card motherboard is used in slot 8, and 4-channel mux/demux modules are used in subslot 2 of the west and east mux/demux slots 0 and 1. The line card motherboard cross connects to both mux/demux modules.

Figure 5-38 Shelf Configuration for Node 4 in Splitter Protected Hubbed Ring

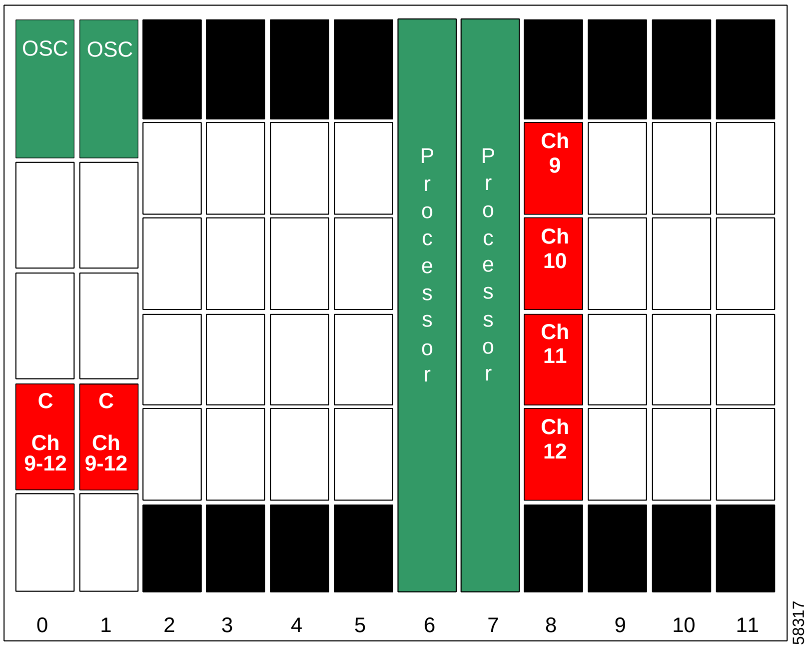


Figure 5-39 shows how the 4-channel mux/demux modules are cabled for node 4 in the splitter protected hubbed ring.

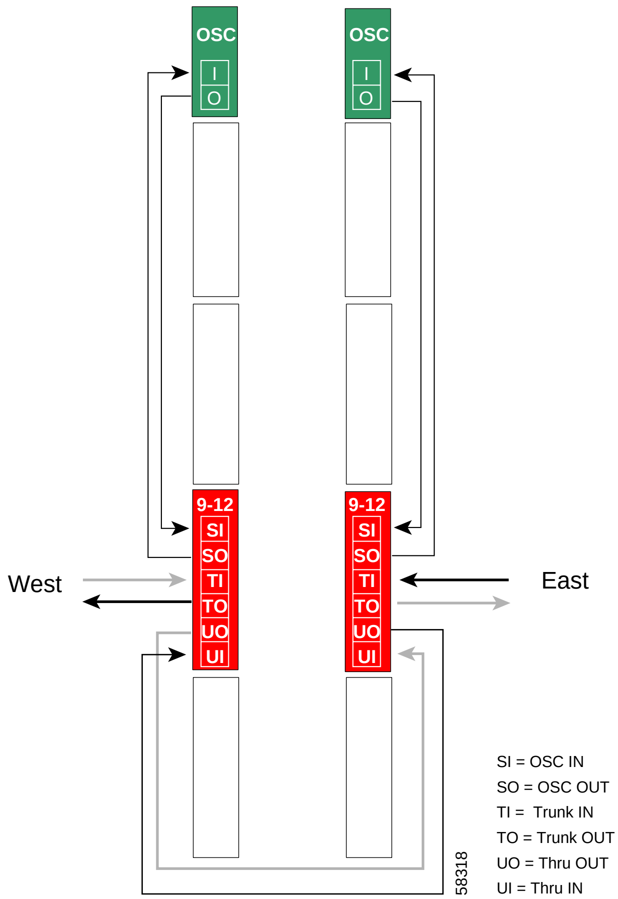


Figure 5-39 Add/Drop Mux/Demux Module Cabling with OSC for Node 4 in Splitter Protected Hubbed Ring

Figure 5-40 shows the shelf configuration for node 5 in the hubbed ring. A splitter protected line card motherboard is used in slot 11, and 4-channel mux/demux modules are used in subslot 3 of the west and east mux/demux slots 0 and 1. The line card motherboard cross connects to both mux/demux modules.

Figure 5-40 Shelf Configuration for Node 5 in Splitter Protected Hubbed Ring

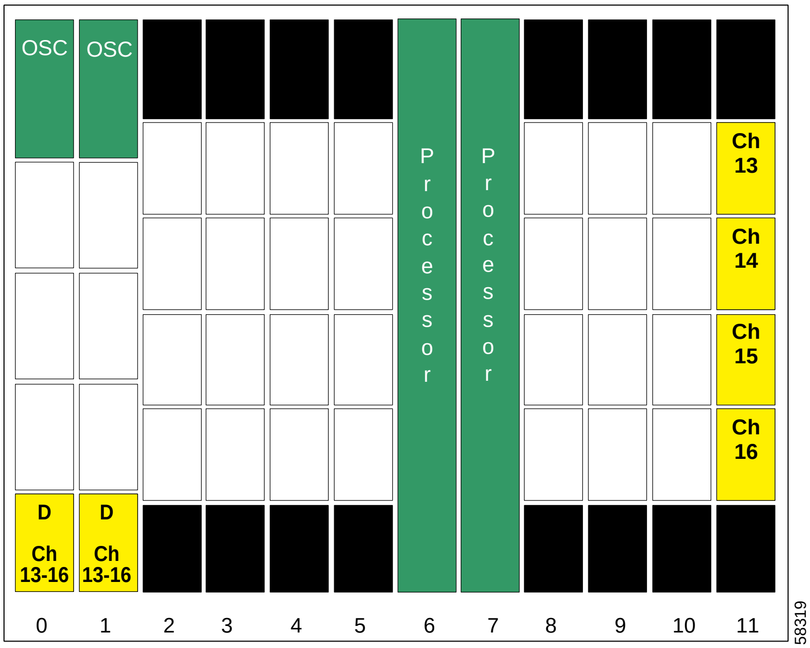
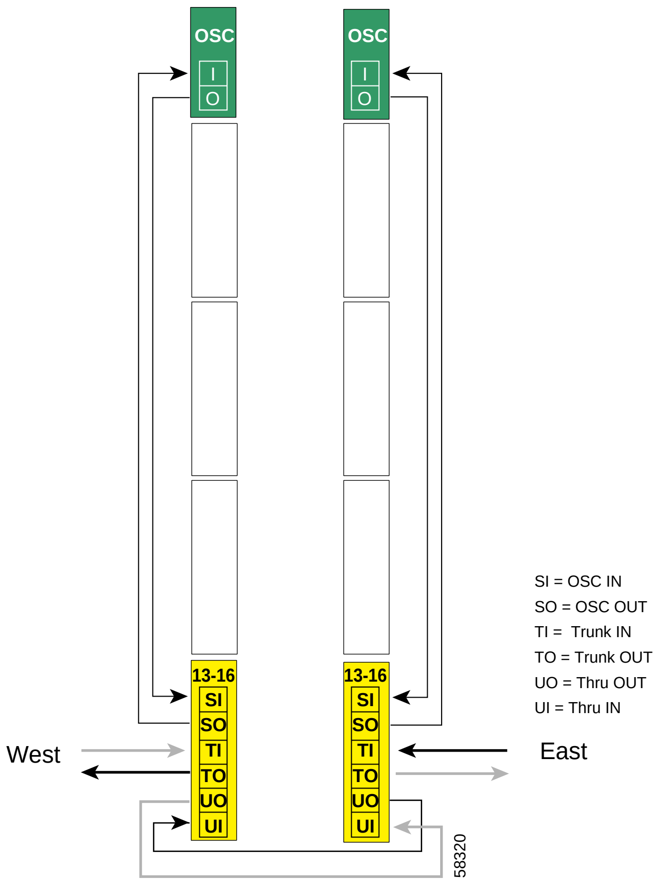


Figure 5-41 shows how the 4-channel mux/demux modules are cabled for node 5 in the splitter protected hubbed ring.

Figure 5-41 Add/Drop Mux/Demux Module Cabling with OSC for Node 5 in Splitter Protected Hubbed Ring



Line Card Protected Hubbed Ring Configuration

With line card protection, a single Cisco ONS 15540 ESPx shelf can support a maximum of 16 channels at the hub node in a hubbed ring. Using two cascaded shelves, 32 channels can be supported. The configuration for the two shelves that form the hub node is the same as the one described in the "Line Card Protected 32-Channel Point-to-Point Configuration" section on page 5-19.

Figure 5-42 shows the optical power budget for the hubbed ring with line card protection. The figure shows the optical power loss for each of the components traversed by the channels in band A from node 1 to node 2 over nodes 5, 4, and 3 (see Figure 5-30 on page 5-22). Assuming that the nodes are equidistant, this would be the worst path. This configuration uses the east and unprotected line card motherboards.

Figure 5-42 Optical Power Budget for Line Card Protected Hubbed Ring

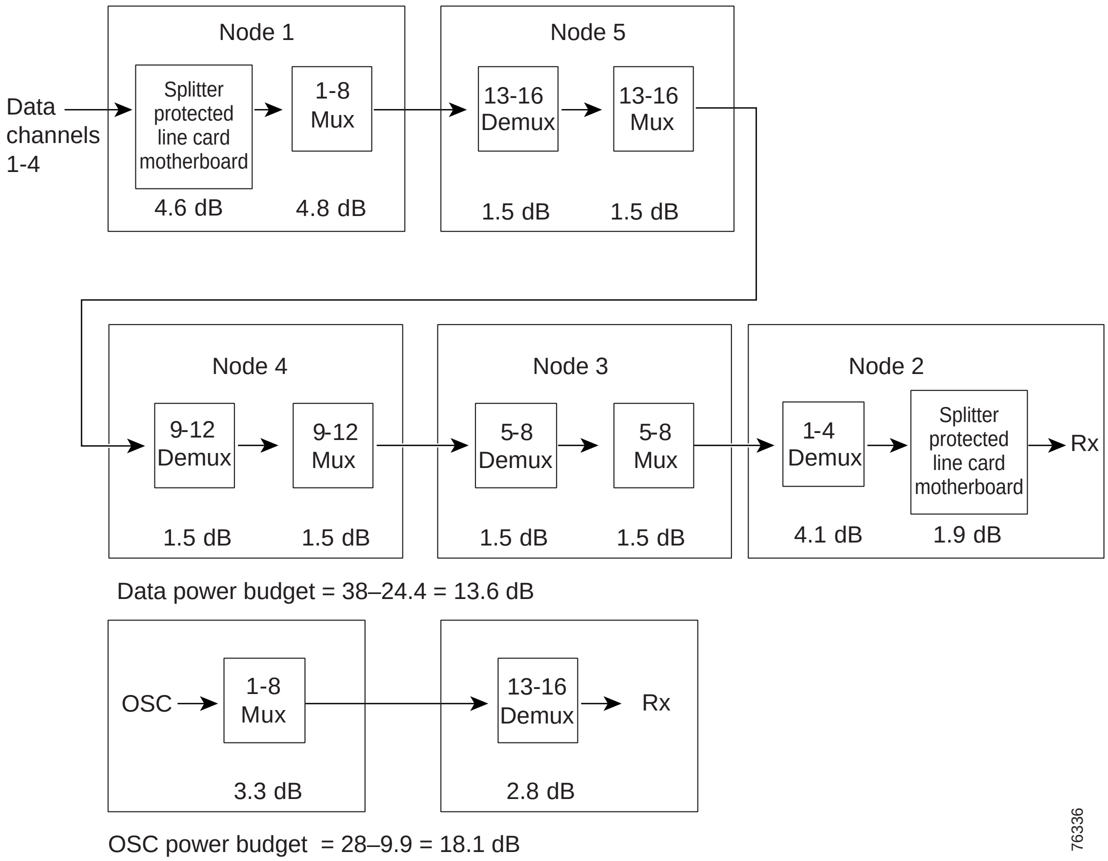


Figure 5-43 shows the shelf configuration for the hub node in this hubbed ring example. The line card motherboards in slots 2 to 5 are unprotected motherboards that cross connect to the 8-channel add/drop mux/demux modules in the west mux/demux slot 0; the line card motherboards in slots 8 to 11 are unprotected motherboards that cross connect to the 8-channel add/drop mux/demux modules in the east mux/demux slot 1.

Figure 5-43 Shelf Configuration for Hub Node in Line Card Protected Hubbed Ring

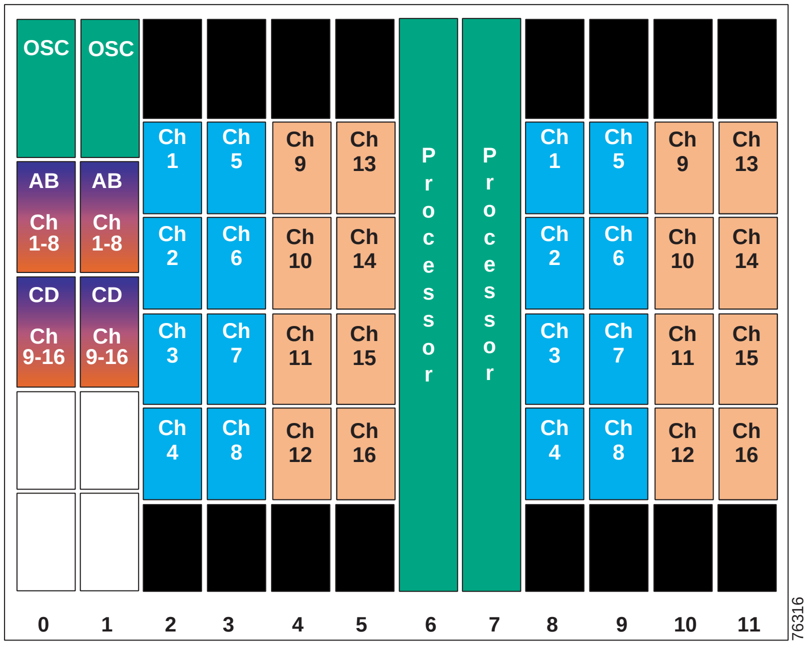


Figure 5-44 shows how the 8-channel mux/demux modules are cabled for the hub node in the line card protected hubbed ring.

Figure 5-44 Add/Drop Mux/Demux Module Cabling with OSC for Hub Node in Line Card Protected Hubbed Ring

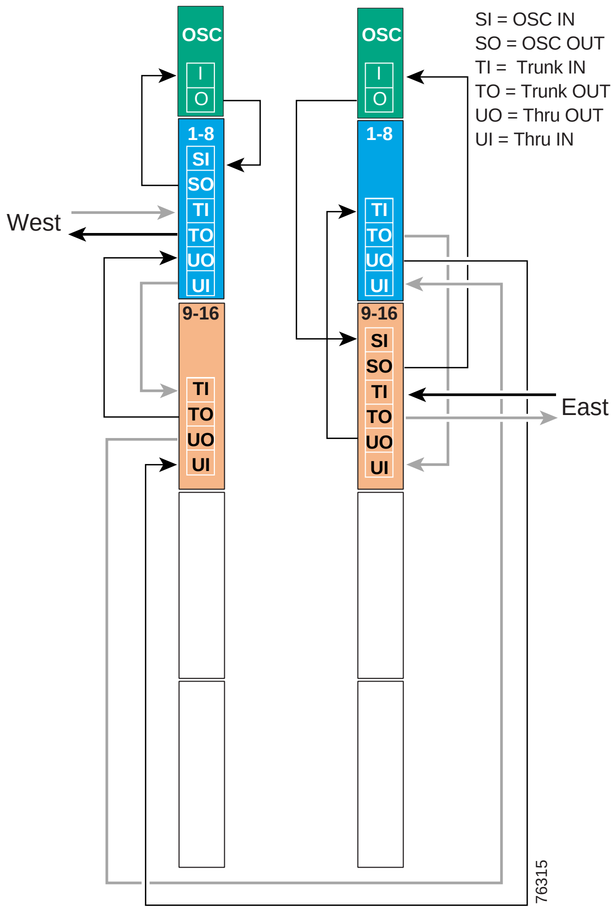


Figure 5-45 shows the shelf configuration for node 2 in the line card protected hubbed ring. Slot 2 uses an unprotected line card motherboard that cross connects to the add/drop mux/demux module in the west mux/demux slot 0; slot 4 uses an unprotected line card motherboard that cross connects to the add/drop mux/demux module in the east mux/demux slot 1.

Figure 5-45 Shelf Configuration for Node 2 in Line Card Protected Hubbed Ring

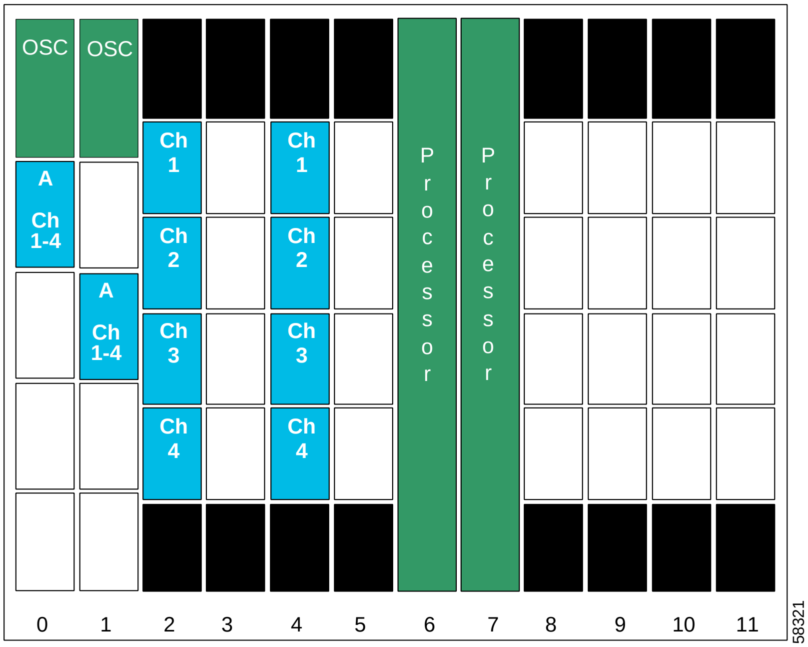


Figure 5-46 shows how the 4-channel mux/demux modules are cabled for node 2 in the line card protected hubbed ring.

Figure 5-46 Add/Drop Mux/Demux Module Cabling with OSC for Node 2 in Line Card Protected Hubbed Ring

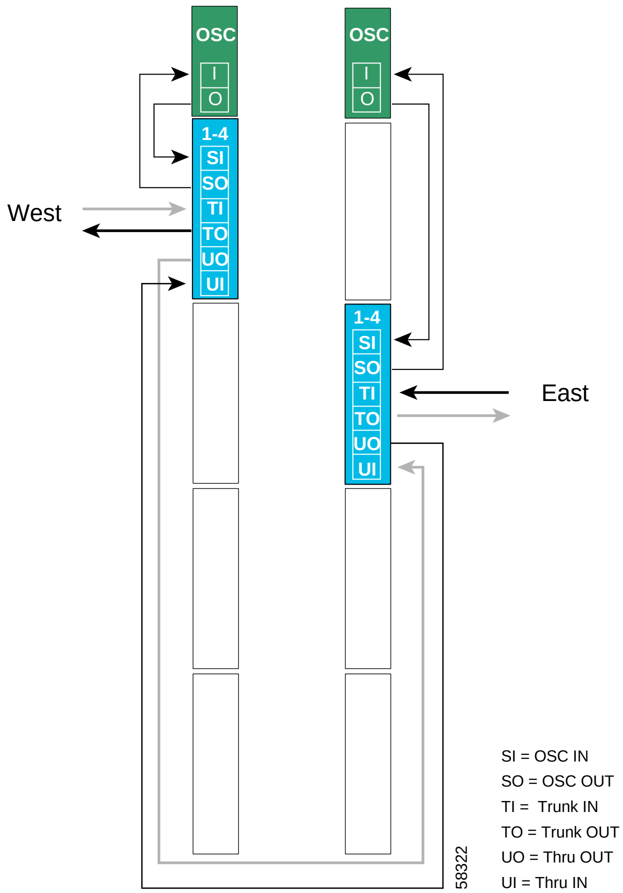


Figure 5-47 shows the shelf configuration for node 3 in the hubbed ring. Slot 3 uses an unprotected line card motherboard that cross connect to the add/drop mux/demux module in the east mux/demux slot 1; slot 5 uses an unprotected line card motherboard that cross connect to the add/drop mux/demux module in the west mux/demux slot 0.

Figure 5-47 Shelf Configuration for Node 3 in Line Card Protected Hubbed Ring

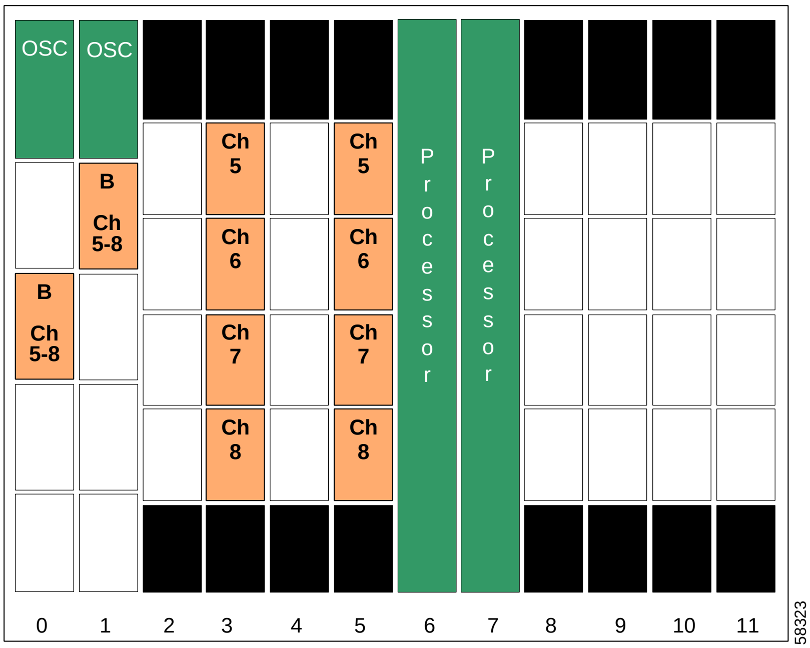


Figure 5-48 shows how the 4-channel mux/demux modules are cabled for node 3 in the line card protected hubbed ring.

Figure 5-48 Add/Drop Mux/Demux Module Cabling with OSC for Node 3 in Line Card Protected Hubbed Ring

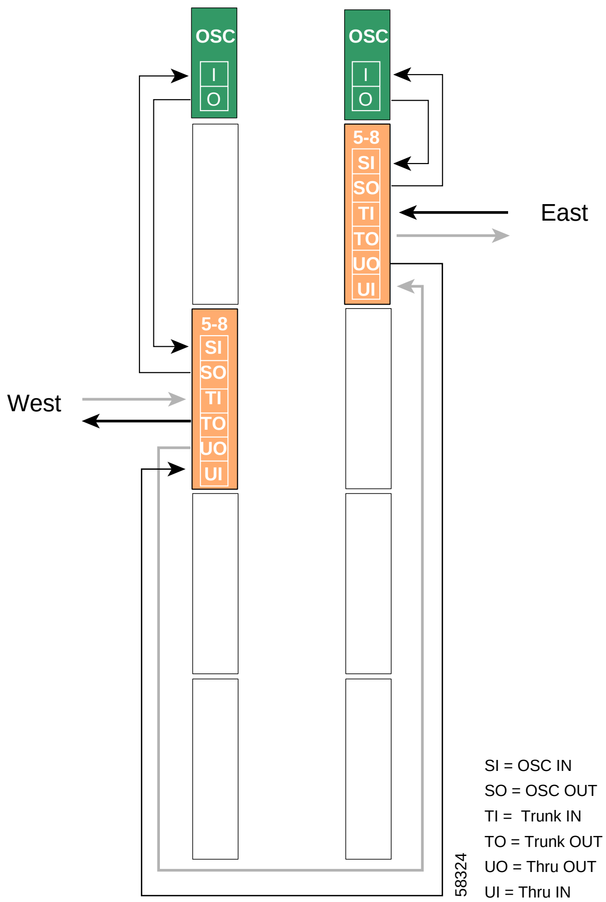


Figure 5-49 shows the shelf configuration for node 4 in the line card protected hubbed ring. Slot 8 uses an unprotected line card motherboard that cross connect to the add/drop mux/demux module in the west mux/demux slot 0; slot 10 uses an unprotected line card motherboard that cross connect to the add/drop mux/demux module in the east mux/demux slot 1.

Figure 5-49 Shelf Configuration for Node 4 in Line Card Protected Hubbed Ring

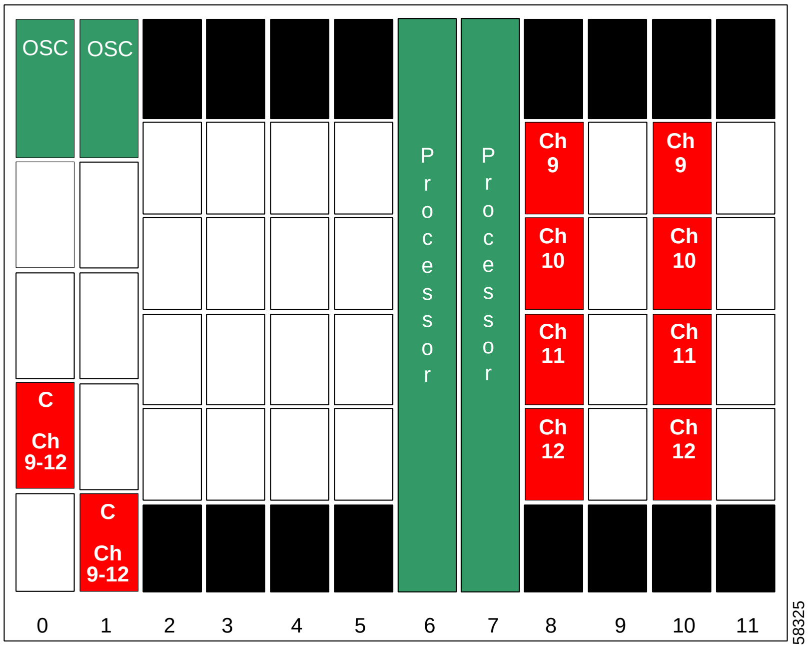


Figure 5-50 shows how the 4-channel mux/demux modules are cabled for node 4 in the line card protected hubbed ring.

Figure 5-50 Add/Drop Mux/Demux Module Cabling with OSC for Node 4 in Line Card Protected Hubbed Ring

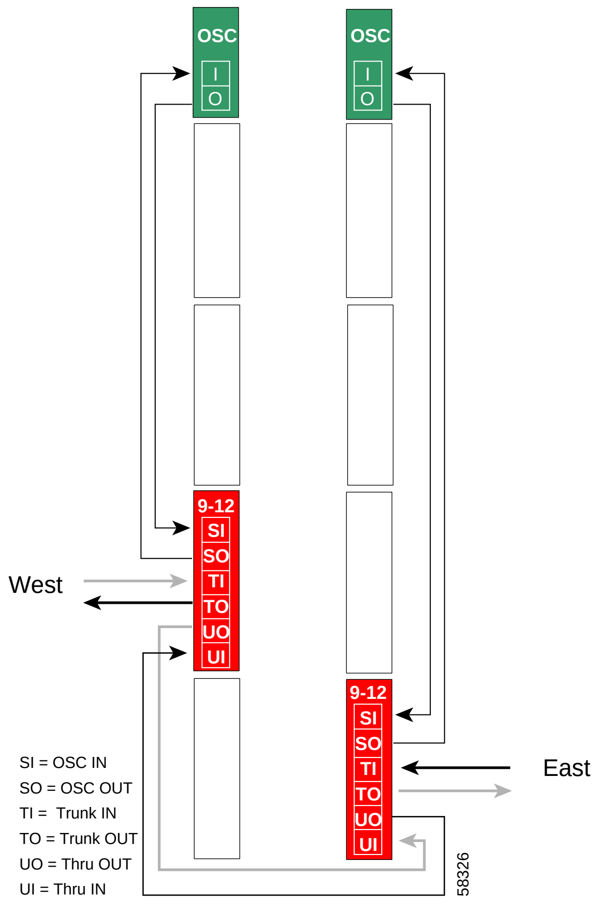


Figure 5-51 shows the shelf configuration for node 5 in the line card protected hubbed ring. Slot 9 uses an unprotected line card motherboard that cross connect to the add/drop mux/demux module in the east mux/demux slot 1; slot 11 uses an unprotected line card motherboard that cross connect to the add/drop mux/demux module in the west mux/demux slot 0.

Figure 5-51 Shelf Configuration for Node 5 in Line Card Protected Hubbed Ring

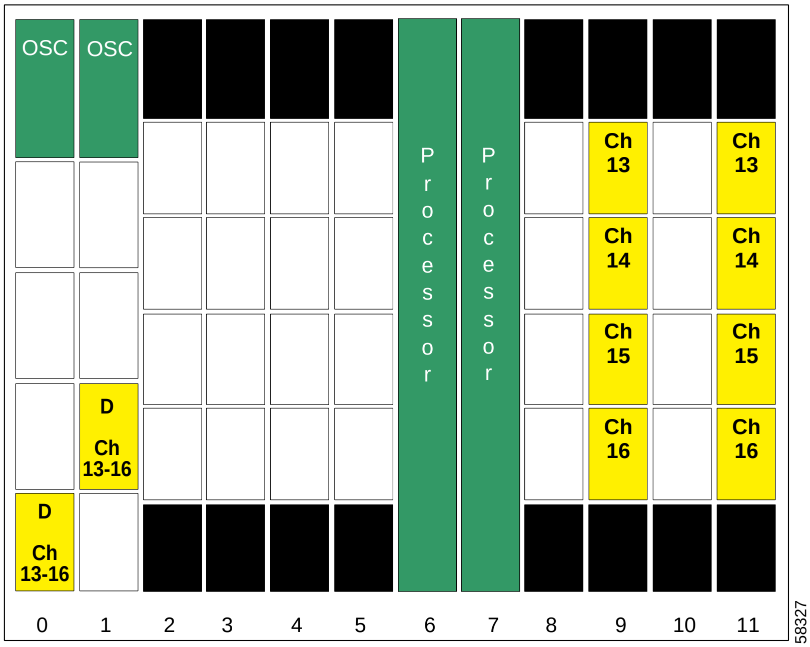
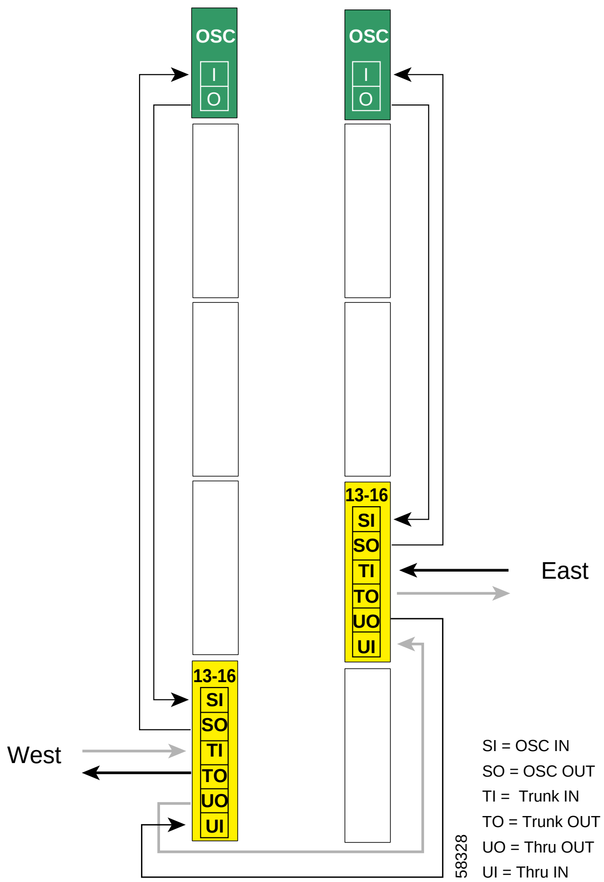


Figure 5-52 shows how the 4-channel mux/demux modules are cabled for node 5 in the line card protected hubbed ring.

Figure 5-52 Add/Drop Mux/Demux Module Cabling with OSC for Node 5 in Line Card Protected Hubbed Ring



Meshed Ring Topologies

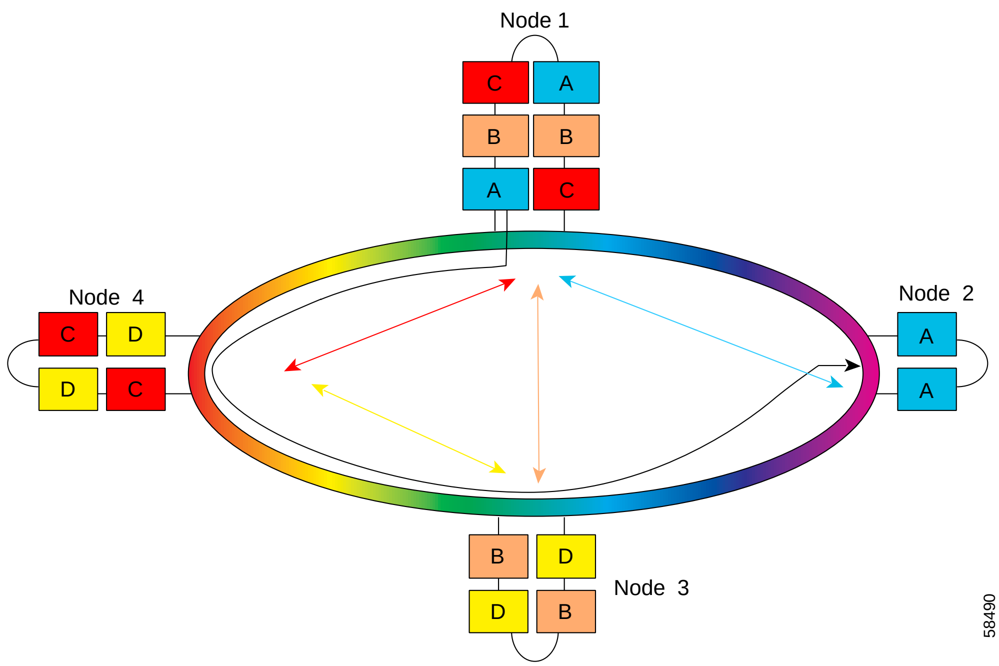
As explained in the "Meshed Ring" section on page 2-9, in a full logical mesh, every node can communicate with every other node. In some cases, this is not necessary and a partial mesh is formed.

Note For information on meshed ring topology configurations consisting of Cisco ONS 15540 ESPx, Cisco ONS 15540 ESP, and Cisco ONS 15530 shelves, refer to the *Cisco ONS 15530 Planning Guide*.

Figure 5-53 shows the channel plan for a 16-channel partial meshed ring. The nodes communicate as follows:

- Node 1and node 2 over band A (path of greatest optical power loss, assuming all nodes are equidistant)
- Node 1and node 3 over band B
- Node 1and node 4 over band C
- Node 3 and node 4 over band D

Figure 5-53 Channel Plan for Meshed Ring



Band allocation and the ordering of the optical mux/demux modules becomes especially important in a mesh environment because of the increased possibility of multiple mux/demux modules at a particular node. The example in Figure 5-53 shows the network configured exclusively with 4-channel add/drop mux/demux modules.

Band allocation can have an effect on both the cost and optical power budget of the network. In this example, it is possible to replace the 4-channel mux/demux modules for bands A and B in node 1 with the 8-channel AB band mux/demux modules. Likewise, the 4-channel mux/demux modules in node 4 could be replaced with 8-channel modules. The effect of this swap would be to lower the cost, but also to decrease the optical power budget, as the add and drop loss for an 8-channel module is greater than that for a 4-channel module.

The concept of ordering can become prominent in mesh topologies. As indicated by the black line in Figure 5-53, the path with the most loss (assuming equidistant nodes on the ring) is the one for band A from the west mux/demux motherboard of node 1 to the east mux/demux motherboard of node 2, traversing nodes 4 and 3. Notice that in the west direction the add/drop mux/demux module for band A on node 1 is positioned closer to the trunk than bands B or C. As a result, band A does not pass through any of the other add/drop mux/demux modules located at node 1. Band B channels must pass through the band A mux/demux, while band C must pass through the mux/demux modules for both band B and band A.

Splitter Protected Meshed Ring Configuration

Figure 5-54 shows the optical power loss for each of the components traversed by the channels in band A from node 1 to node 2 over nodes 4 and 3. This configuration uses the splitter protected line card motherboards.

Figure 5-54 Optical Power Budget for Splitter Protected Meshed Ring

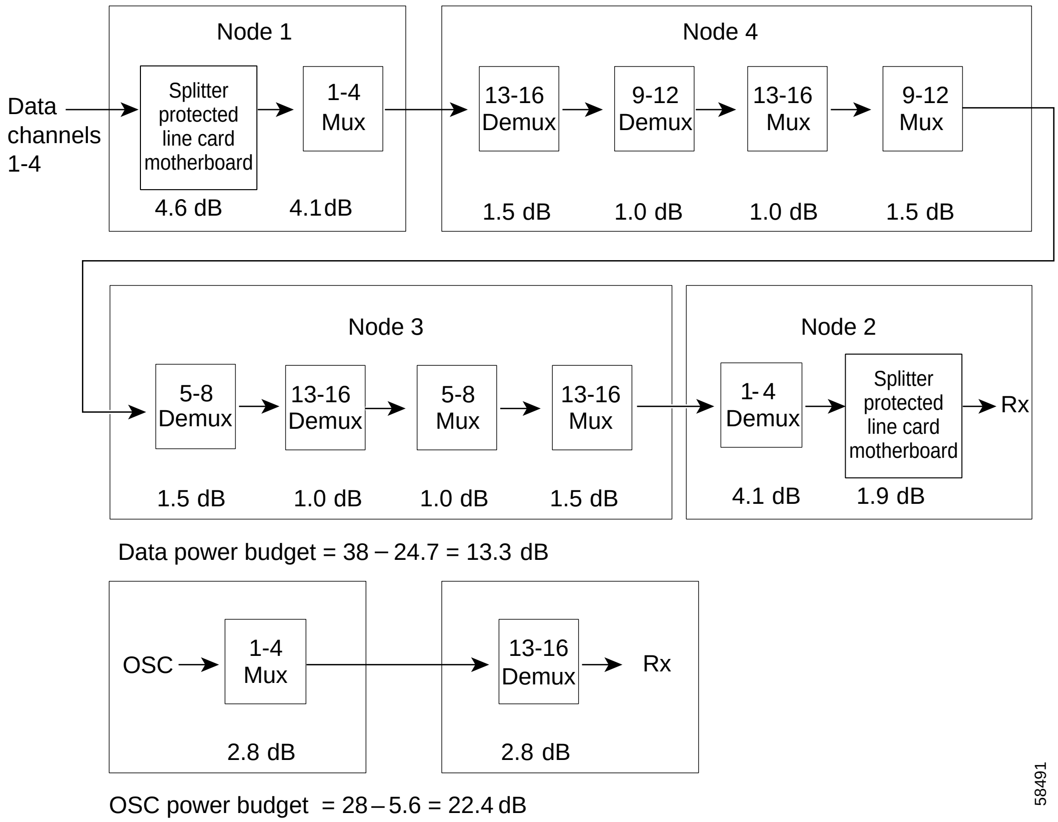


Figure 5-55 shows the shelf configuration for node 1 in the splitter protected meshed ring. Splitter protected line card motherboards are used to cross connect the signal to the add/drop mux/demux modules in both west and east mux/demux slots 0 and 1.

Figure 5-55 Shelf Configuration for Node 1 in Splitter Protected Meshed Ring

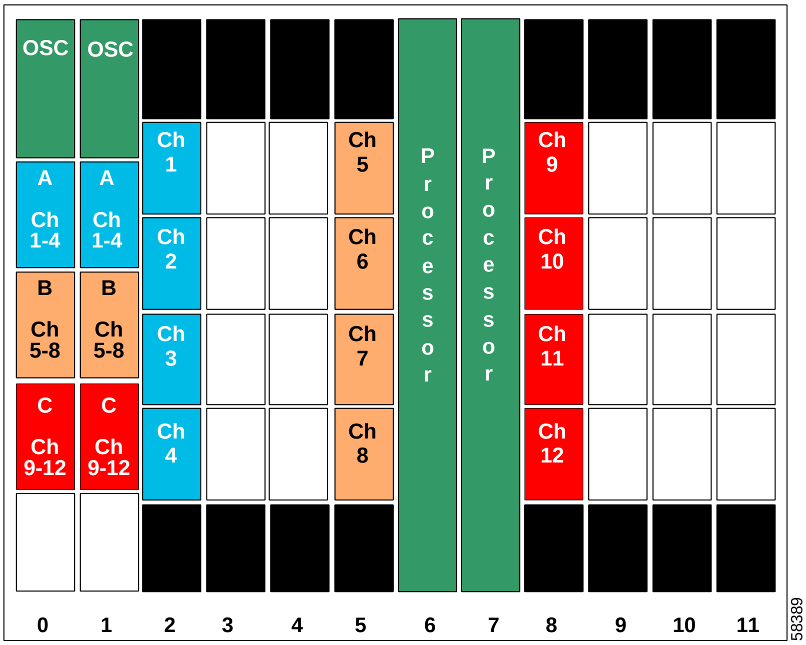


Figure 5-56 shows how the 4-channel mux/demux modules are cabled for node 1 in the splitter protected meshed ring.

Figure 5-56 Add/Drop Mux/Demux Module Cabling with OSC for Node 1 in Splitter Protected Meshed Ring

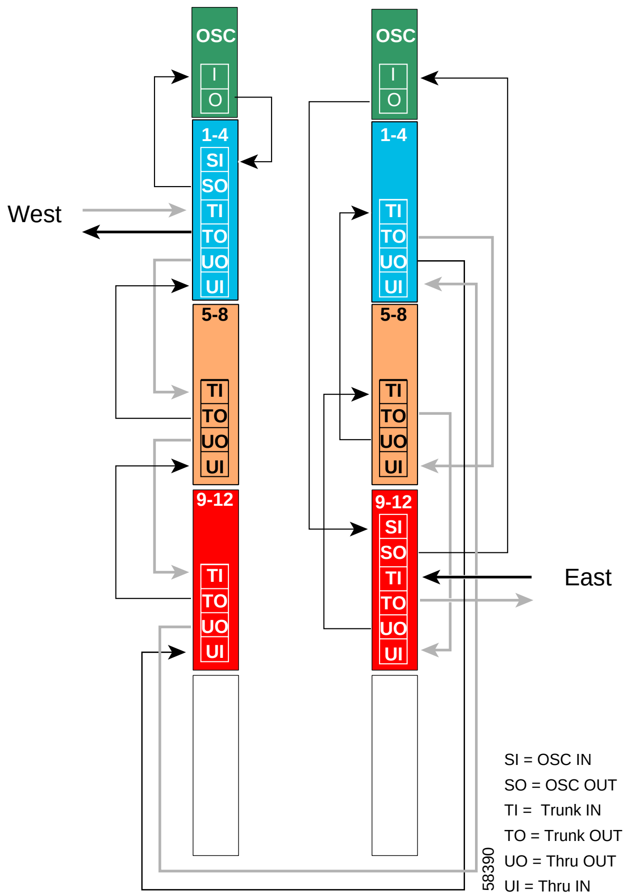


Figure 5-57 shows the shelf configuration for node 2 in the splitter protected meshed ring. Slot 2 uses the splitter protected line card motherboard, which cross connects the signal to the add/drop mux/demux modules in both west and east mux/demux slots 0 and 1.

Figure 5-57 Shelf Configuration for Node 2 in Splitter Protected Meshed Ring

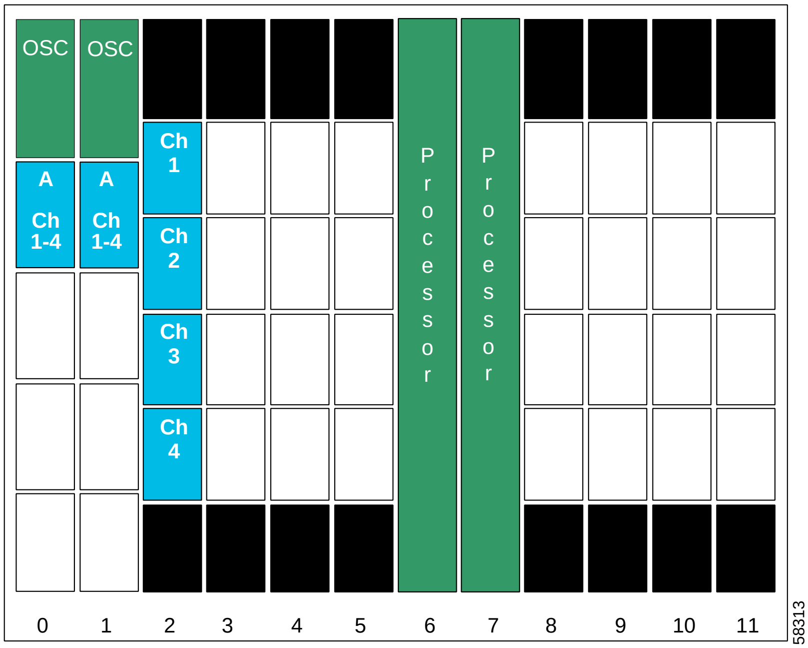


Figure 5-58 shows how the 4-channel mux/demux modules are cabled for node 2 in the splitter protected meshed ring.

Figure 5-58 Add/Drop Mux/Demux Module Cabling with OSC for Node 2 in Splitter Protected Meshed Ring

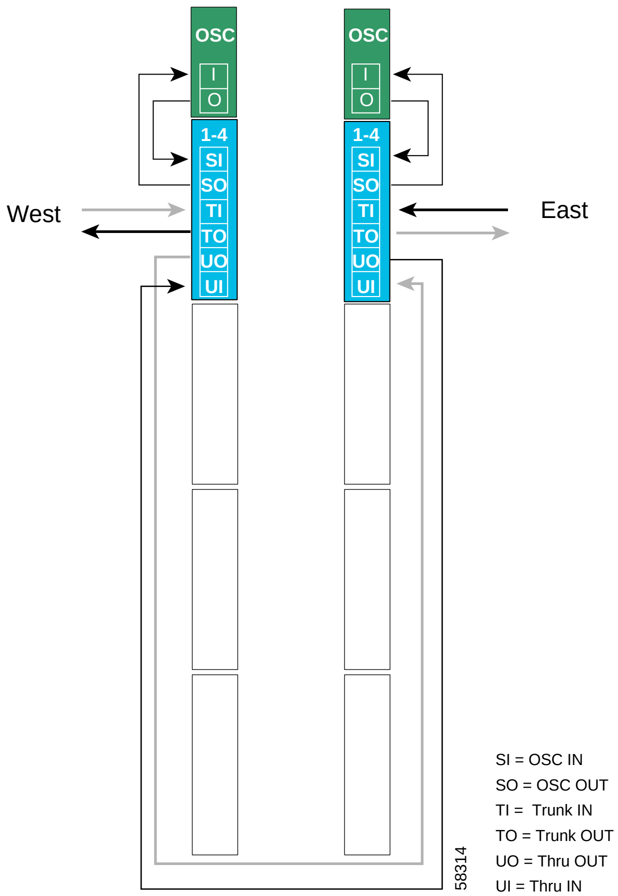


Figure 5-59 shows the shelf configuration for node 3 in the splitter protected meshed ring. Slots 5 and 11 use splitter protected line card motherboards, which cross connect the signal to the add/drop mux/demux modules in both west and east mux/demux slots 0 and 1.

Figure 5-59 Shelf Configuration for Node 3 in Splitter Protected Meshed Ring

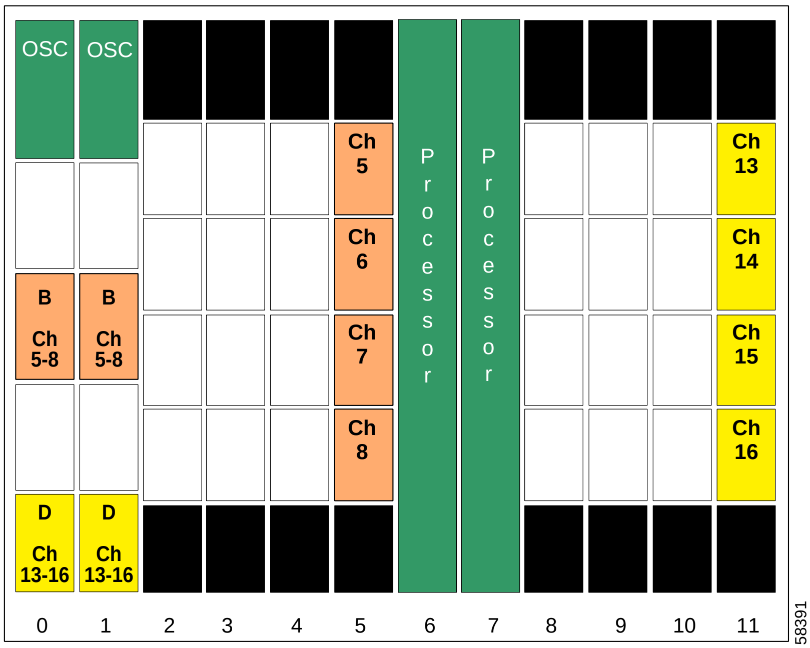


Figure 5-60 shows how the 4-channel mux/demux modules are cabled for node 3 in the splitter protected meshed ring.

Figure 5-60 Add/Drop Mux/Demux Module Cabling with OSC for Node 3 in Splitter Protected Meshed Ring

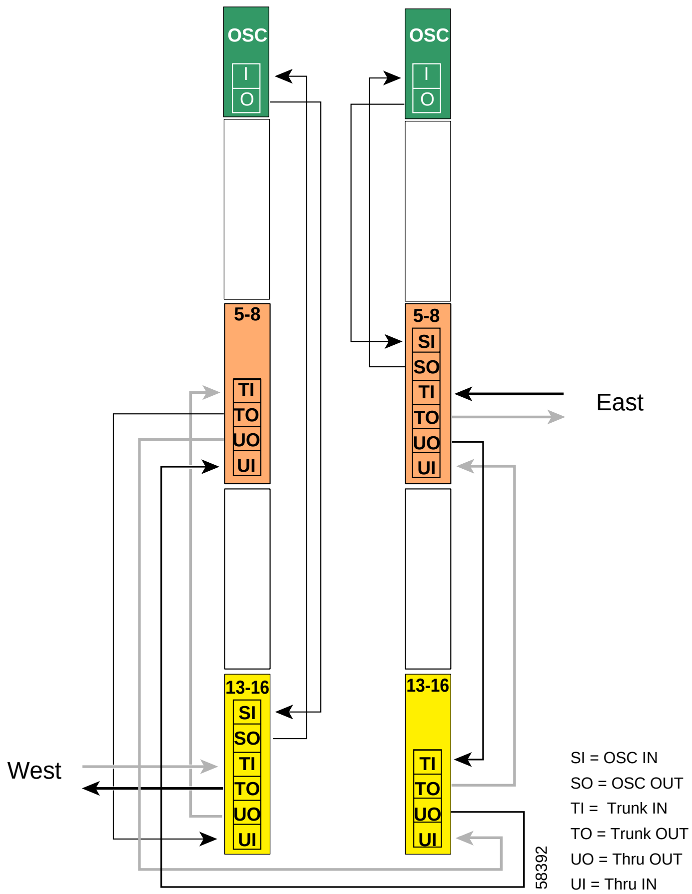


Figure 5-61 shows the shelf configuration for node 4 in the splitter protected meshed ring. Slots 8 and 11 use the splitter protected line card motherboards, which cross connect the signal to the add/drop mux/demux modules in both the west and east mux/demux slots 0 and 1.

Figure 5-61 Shelf Configuration for Node 4 in Splitter Protected Meshed Ring

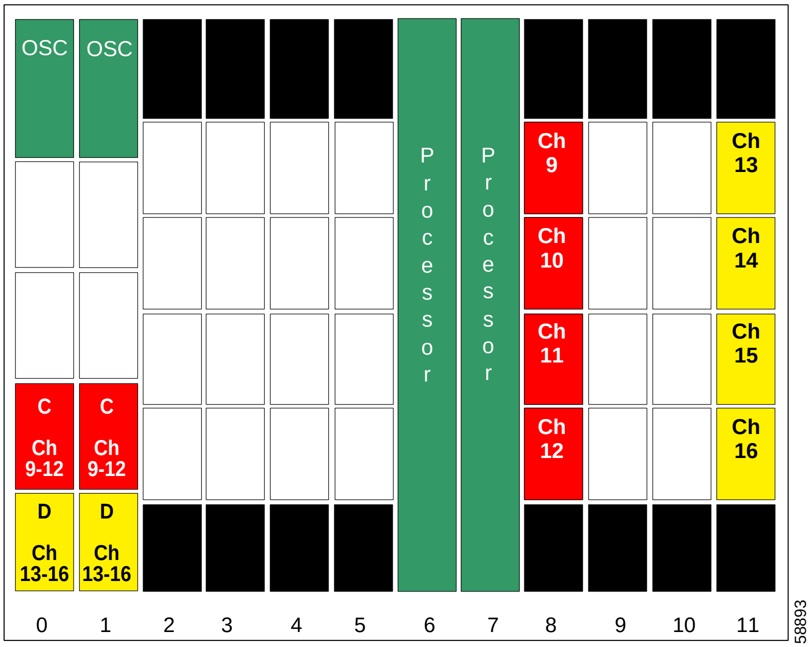
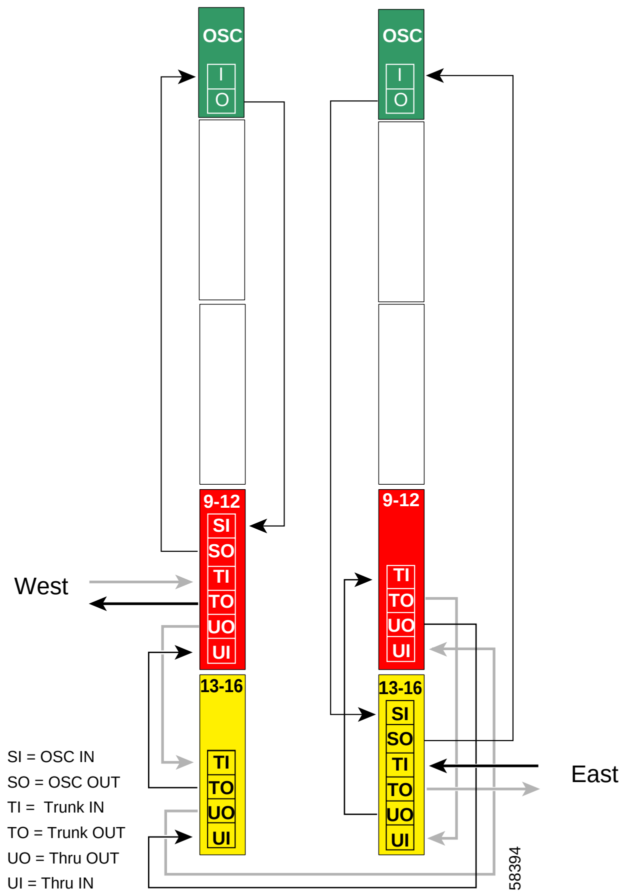


Figure 5-62 shows how the 4-channel mux/demux modules are cabled for node 4 in the splitter protected meshed ring.

Figure 5-62 Add/Drop Mux/Demux Module Cabling with OSC for Node 4 in Splitter Protected Meshed Ring



Line Card Protected Meshed Ring Configuration

Figure 5-63 shows the optical power budget for the hubbed ring with line card protection. The figure shows the optical power loss for each of the components traversed by the channels in band A between node 1 and node 2 over node 4 and node 3 (see Figure 5-53 on page 5-45). Assuming the nodes in the ring are equidistant, this would be the worst path. This configuration uses the east and unprotected line card motherboards.

Figure 5-63 Optical Power Budget for Line Card Protected Meshed Ring

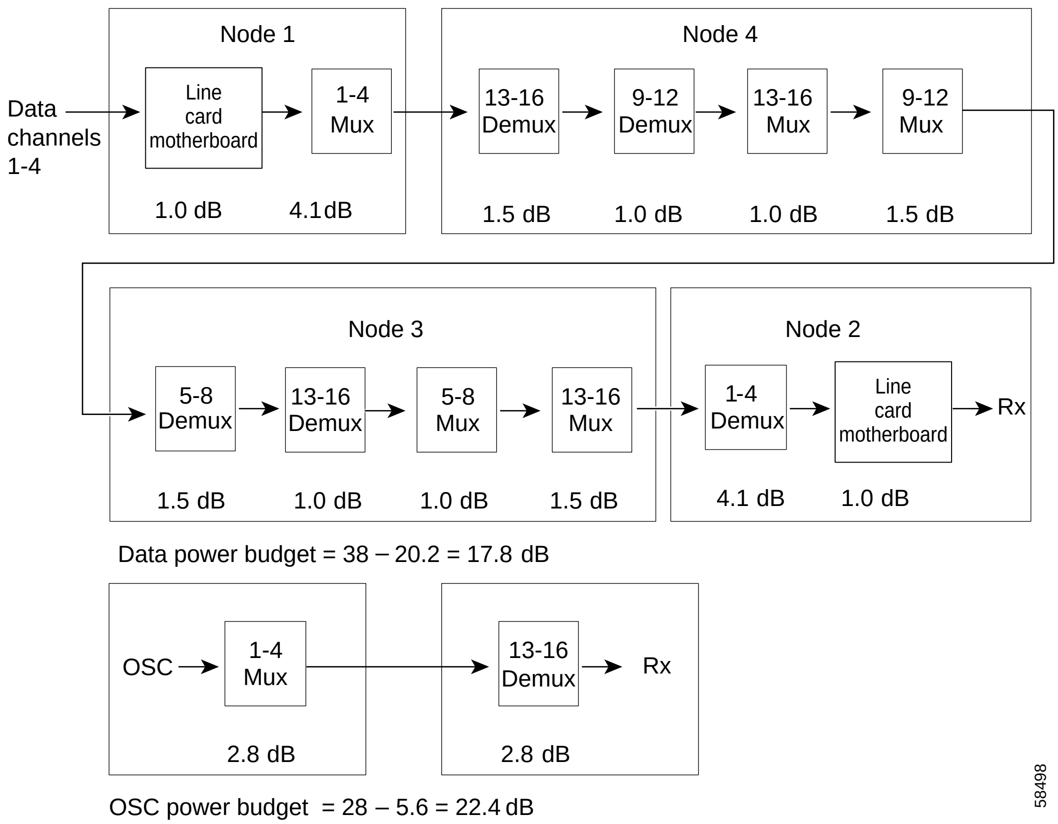


Figure 5-64 shows the shelf configuration for node 1 using line card protection in the example meshed ring. Slots 2, 5, and 8 use unprotected line card motherboards that cross connect to the add/drop mux/demux modules in the west mux/demux slot 0; slots 3, 4, and 10 use unprotected line card motherboards that cross connect to the add/drop mux/demux modules in the east mux/demux slot 1.

Figure 5-64 Shelf Configuration for Node 1 in Line Card Protected Meshed Ring

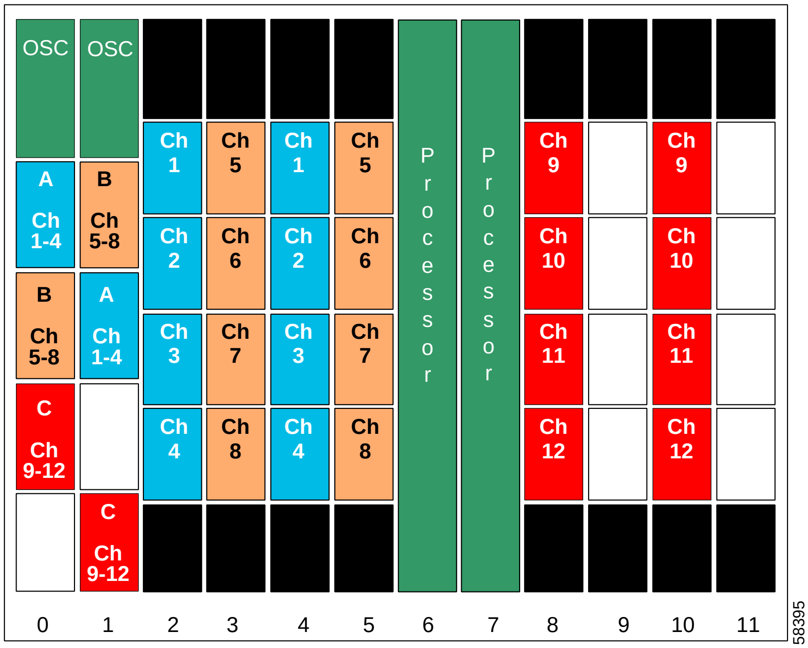


Figure 5-65 shows how the 4-channel mux/demux modules are cabled for node 1 in the line card protected meshed ring.

Figure 5-65 Add/Drop Mux/Demux Module Cabling with OSC for Node 1 in Line Card Protected Meshed Ring

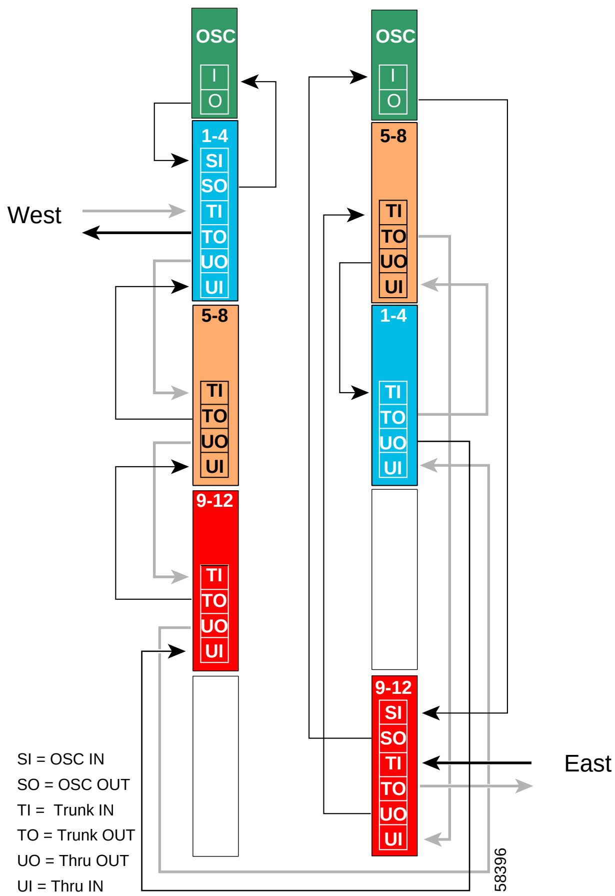


Figure 5-66 shows the shelf configuration for node 2 in the line card protected meshed ring. Slot 2 uses an unprotected line card motherboard that cross connects to the add/drop mux/demux module in the west mux/demux slot 0; slot 4 uses an unprotected line card motherboard that cross connects to the add/drop mux/demux module in the east mux/demux slot 1.

Figure 5-66 Shelf Configuration for Node 2 in Line Card Protected Meshed Ring

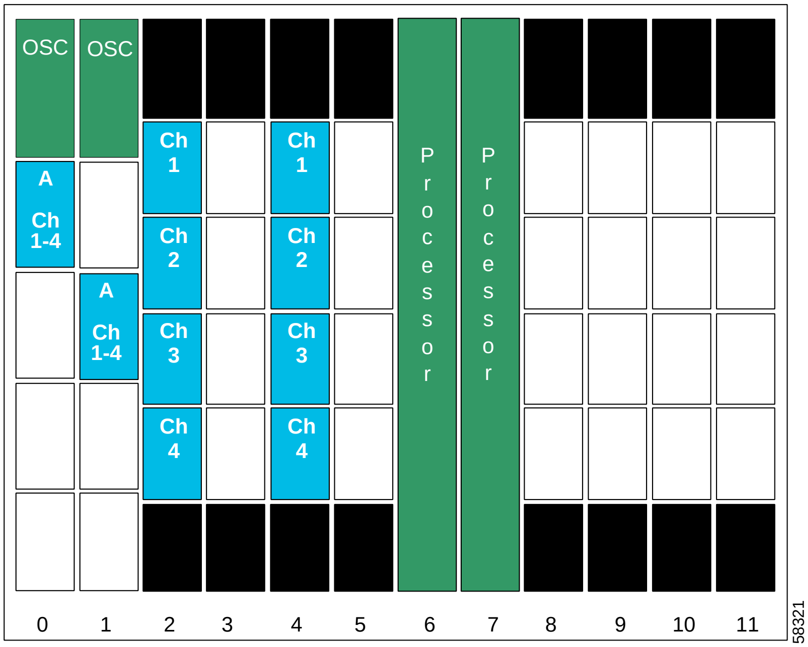


Figure 5-67 shows how the 4-channel mux/demux modules are cabled for node 2 in the line card protected meshed ring.

Figure 5-67 Add/Drop Mux/Demux Module Cabling with OSC for Node 2 in Line Card Protected Meshed Ring

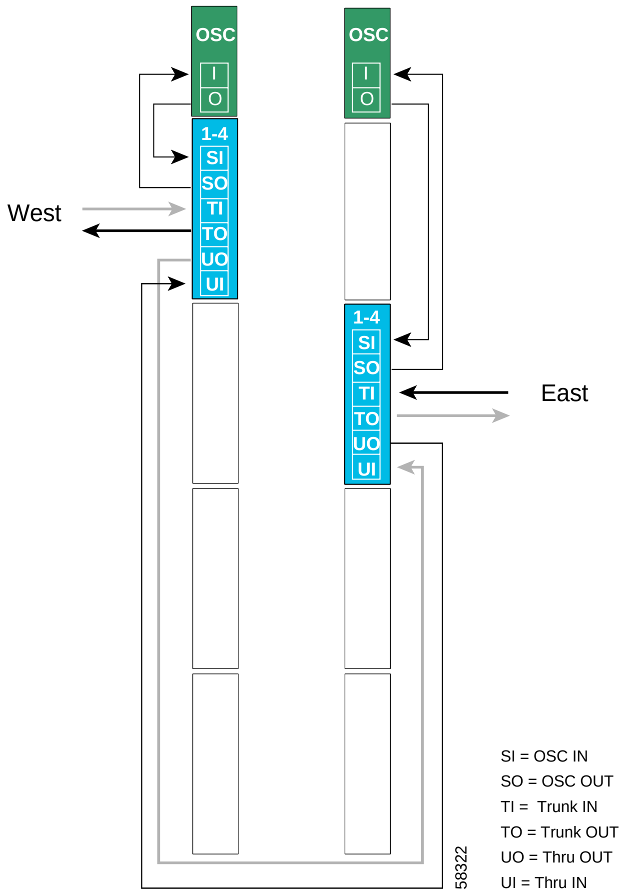


Figure 5-68 shows the shelf configuration for node 3 in the line card protected meshed ring. Slots 5 and 11 use unprotected line card motherboards that cross connect to the add/drop mux/demux modules in the west mux/demux slot 0; slots 3 and 9 use unprotected line card motherboards that cross connect to the add/drop mux/demux modules in the east mux/demux slot 1.

Figure 5-68 Shelf Configuration for Node 3 in Line Card Protected Meshed Ring

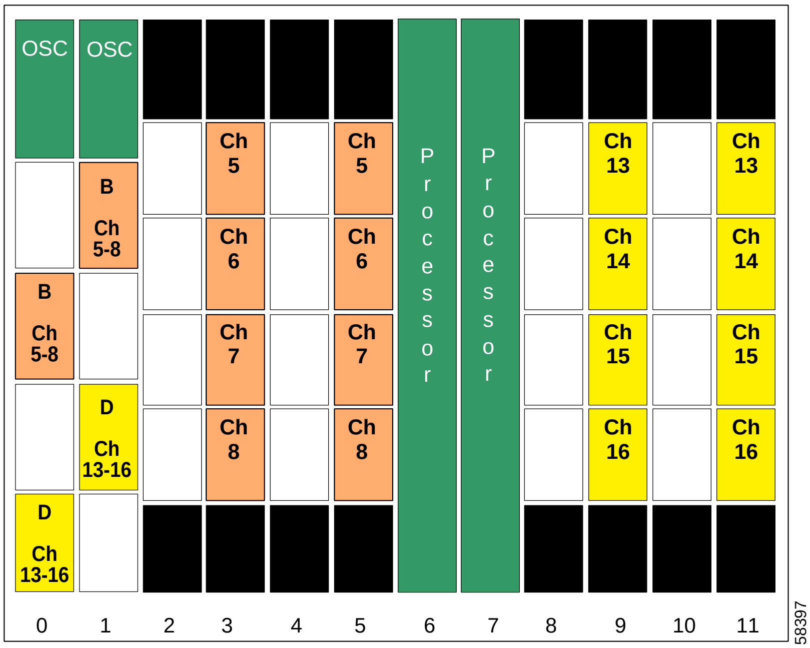


Figure 5-69 shows how the 4-channel mux/demux modules are cabled for node 3 for the line card protected meshed ring.

Figure 5-69 Add/Drop Mux/Demux Module Cabling with OSC for Node 3 in Line Card Protected Meshed Ring

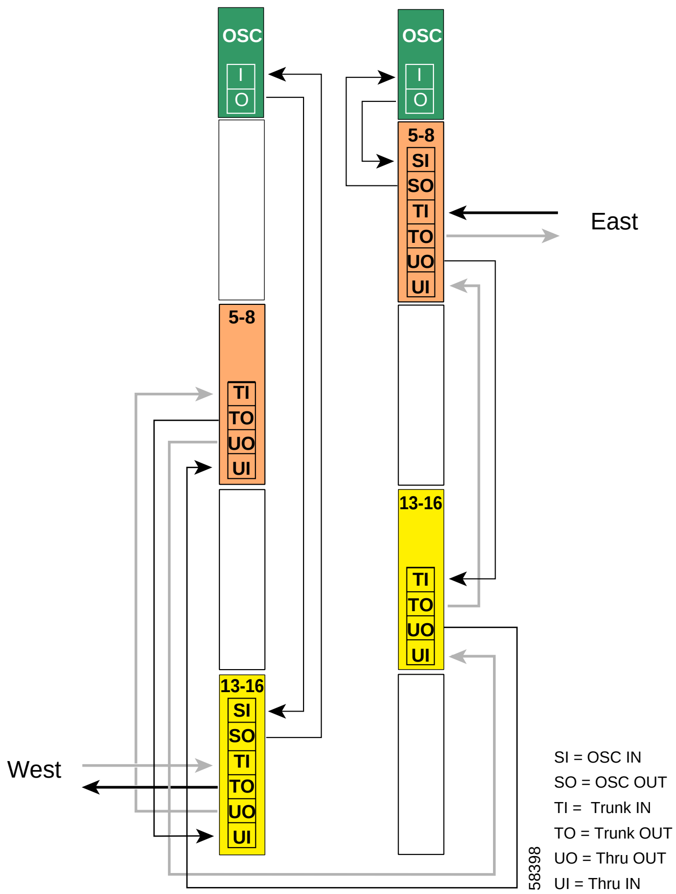


Figure 5-70 shows the shelf configuration for node 4 in the line card protected meshed ring. Slots 8 and 11 use unprotected line card motherboards that cross connect to the add/drop mux/demux modules in the west mux/demux slots 0; slots 9 and 10 use unprotected line card motherboards that cross connect to the add/drop mux/demux modules in the east mux/demux slot 1.

Figure 5-70 Shelf Configuration for Node 4 in Line Card Protected Meshed Ring

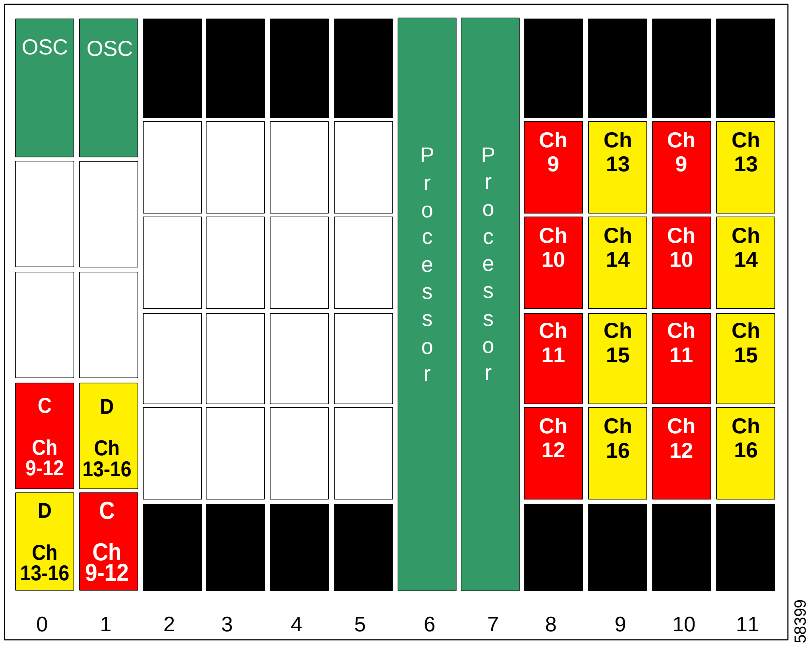
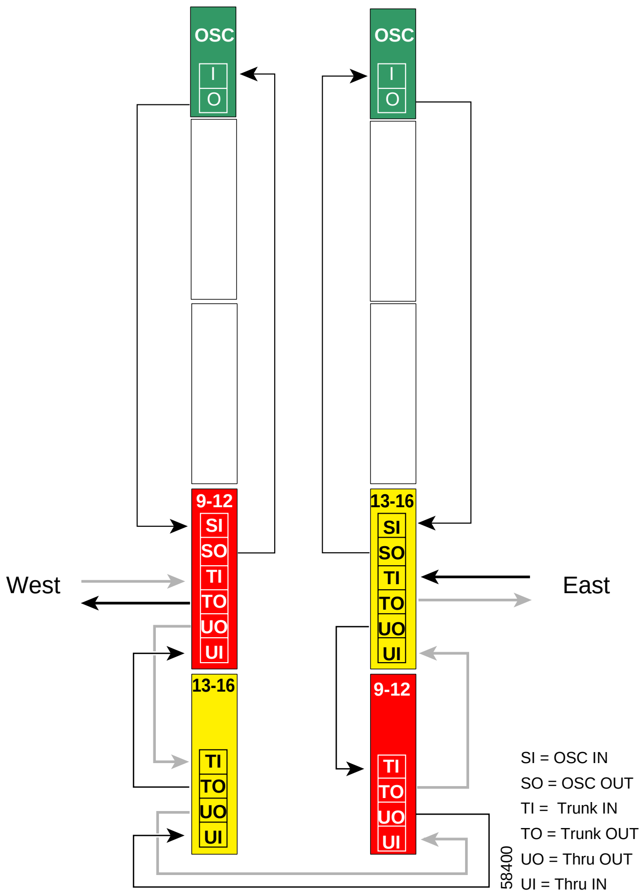


Figure 5-71 shows how the 4-channel mux/demux modules are cabled for node 4 in the line card protected meshed ring.

Figure 5-71 Add/Drop Mux/Demux Module Cabling with OSC for Node 4 in Line Card Protected Meshed Ring



Meshed Ring Topologies with Unprotected Channels

It is possible to configure a ring in which one or more bands are unprotected. If a splitter protected or line card protected ring topology has already been configured, adding unprotected channels is straightforward.

To add unprotected channels to an existing ring configuration, follow these steps:

Step 1 Determine the nodes that will be logically connected by the unprotected channels.

Step 2 Choose a channel band that is not already in use.

Step 3 Confirm that the shelf at both nodes can support the selected channel band.

Note For information on meshed ring topology configurations consisting of Cisco ONS 15540 ESPx, Cisco ONS 15540 ESP, and Cisco ONS 15530 shelves, refer to the *Cisco ONS 15530 Planning Guide*.

Splitter Protected Meshed Ring with Unprotected Channels Configuration

Figure 5-72 uses the same channel plan as the 16-channel partial meshed ring example (see the "Meshed Ring Topologies" section on page 5-44), but adds an unprotected band between node 2 and node 3. The nodes communicate as follows:

- Node 1 and node 2 over band A (path of greatest optical power loss, assuming equidistant nodes)
- Node 1 and node 3 over band B
- Node 1 and node 4 over band C
- Node 3 and node 4 over band D
- Node 2 and node 3 over band E (unprotected)

Figure 5-72 Channel Plan for Splitter Protected Meshed Ring with Unprotected Channels

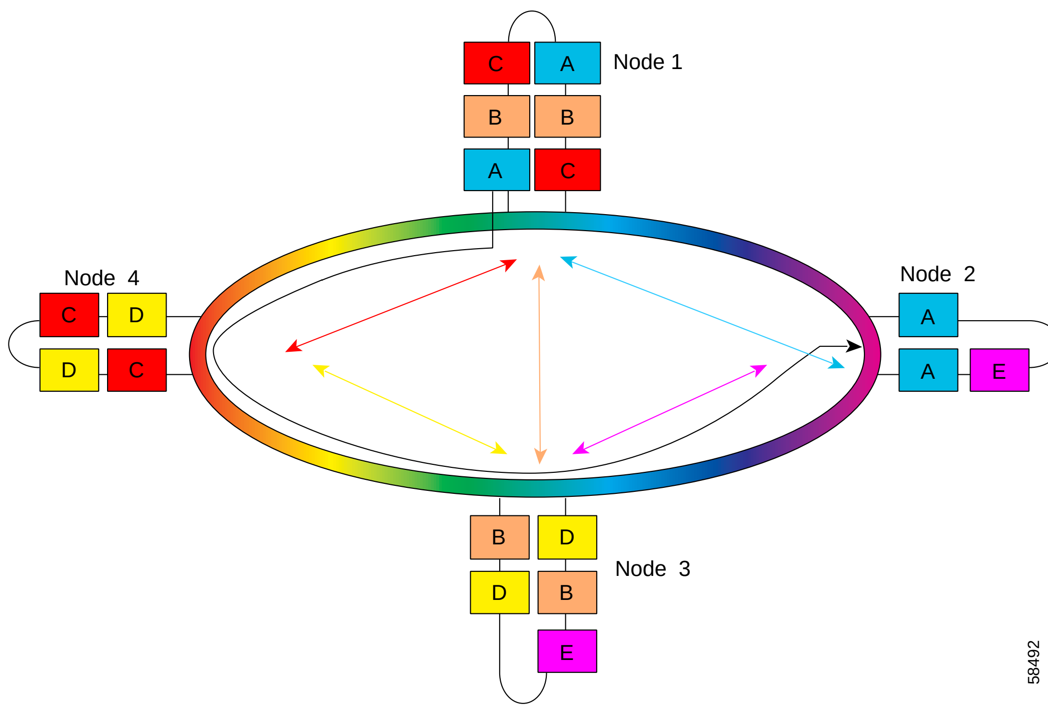
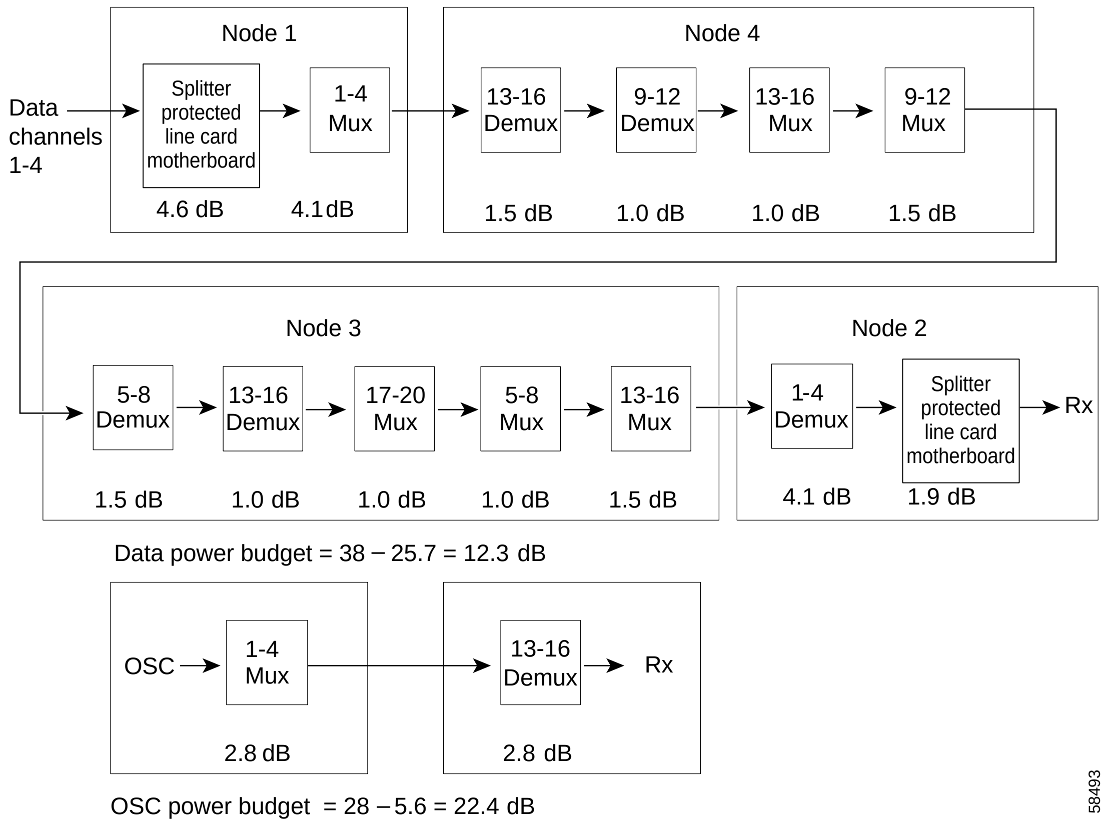


Figure 5-73 shows the optical power loss for each of the components traversed by the channels in band A between node 1 and node 2 over node 4 and node 3, and for the OSC. All nodes use the 4-channel mux/demux modules.

Figure 5-73 Optical Power Budget for Splitter Protected Meshed Ring with Unprotected Channels



The shelf configuration and optical mux/demux module cabling for node 1 and node 4 are the same as for the 16-channel partial meshed ring example with splitter protection. See the following figures for these configurations:

- Node 1 shelf configuration, Figure 5-55 on page 5-47
- Node 1 optical mux/demux module cabling, Figure 5-56 on page 5-48
- Node 4 shelf configuration, Figure 5-61 on page 5-53
- Node 4 optical mux/demux module cabling, Figure 5-62 on page 5-54

Figure 5-74 shows the shelf configuration for node 2 in the splitter protected meshed ring with unprotected channels. Slot 2 uses the splitter protected line card motherboard, which cross connects the signal to the add/drop mux/demux modules in subslot 0 of both west and east mux/demux slots 0 and 1. Slot 4, which supports the unprotected channels, uses an unprotected line card motherboard.

Figure 5-74 Shelf Configuration for Node 2 in Splitter Protected Meshed Ring with Unprotected Channels

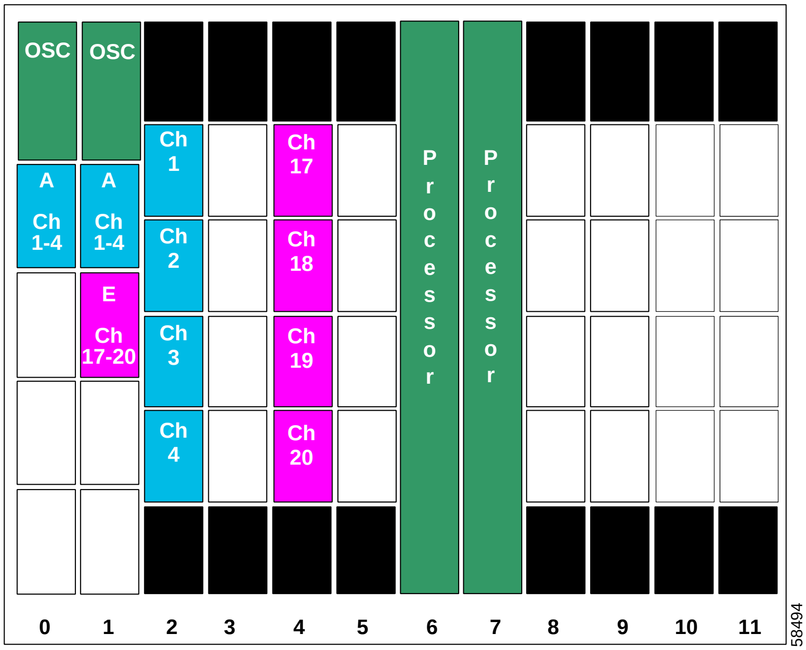


Figure 5-75 shows how the 4-channel mux/demux modules are cabled for node 2 in the splitter protected meshed ring with unprotected channels.

Figure 5-75 Add/Drop Mux/Demux Module Cabling for Node 2 in Splitter Protected Meshed Ring with Unprotected Channels

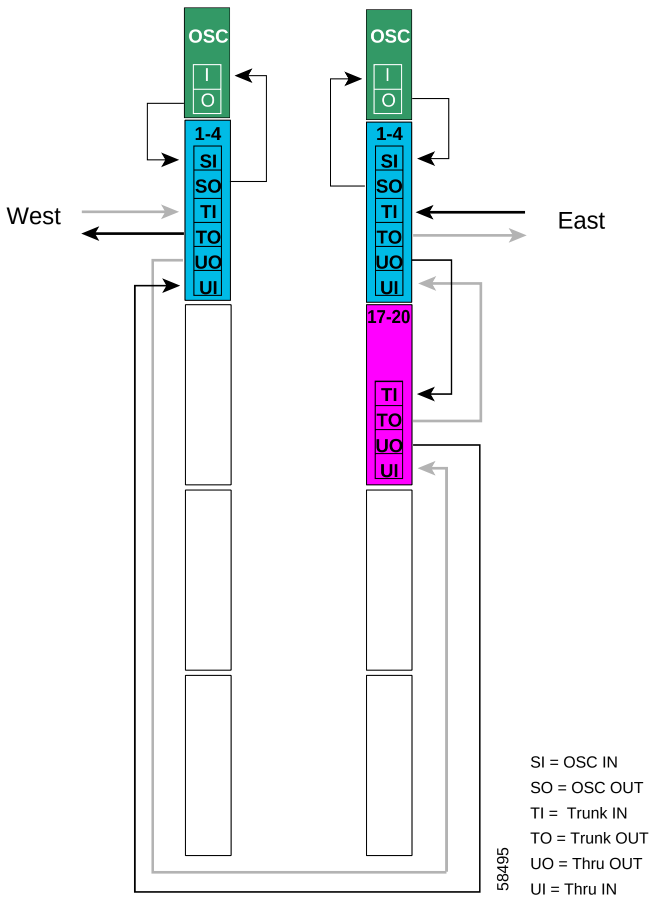


Figure 5-76 shows the shelf configuration for node 3 in the splitter protected meshed ring with unprotected channels. Slot 5 and slot 11 use splitter protected line card motherboards, which cross connect the signal to the add/drop mux/demux modules in subslot 1 and subslot 3, respectively, of both west and east mux/demux slots 0 and 1. Slot 8, which supports the unprotected channels, uses an unprotected line card motherboard.

Figure 5-76 Shelf Configuration for Node 3 in Splitter Protected Meshed Ring with Unprotected Channels

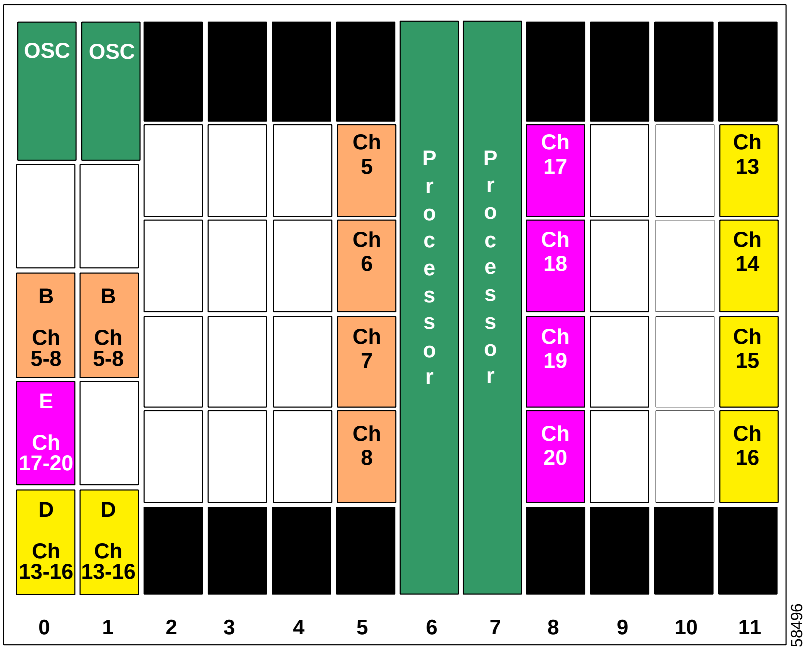
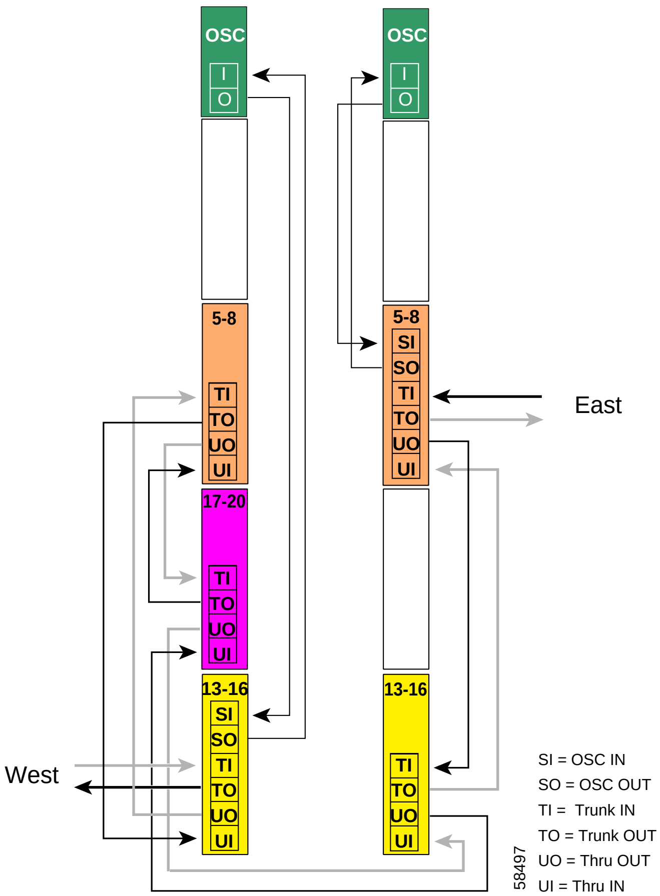


Figure 5-77 shows how the 4-channel mux/demux modules are cabled for node 3 in the splitter protected meshed ring with unprotected channels.

Figure 5-77 Add/Drop Mux/Demux Module Cabling for Node 3 in Splitter Protected Meshed Ring with Unprotected Channels

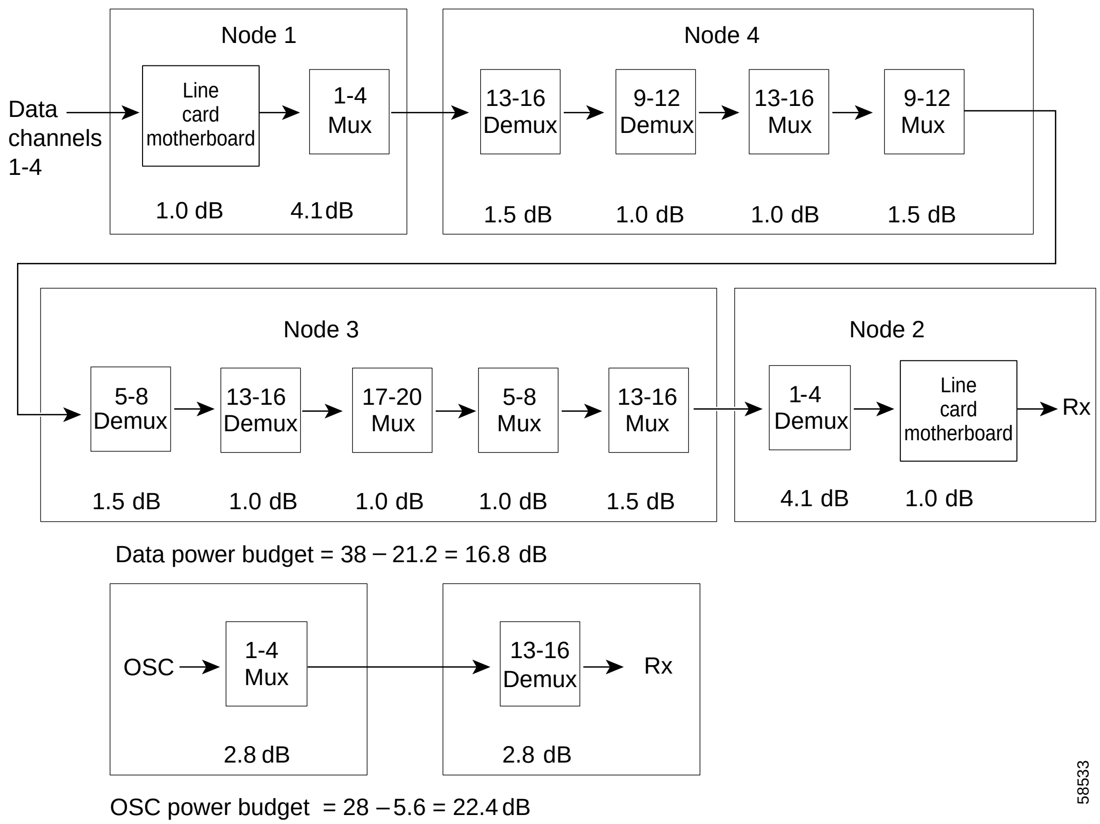


Line Card Protected Meshed Ring with Unprotected Channels Configuration

The topology and channel plan described in the "Meshed Ring Topologies with Unprotected Channels" section on page 5-63 and shown in Figure 5-72 on page 5-64 can be configured with line card protection.

Figure 5-78 shows the optical power loss for each of the components traversed by the channels in band A between node 1 and node 2 over node 4 and node 3, and for the OSC. All nodes use the 4-channel mux/demux modules. The unprotected line card motherboards are used.

Figure 5-78 Optical Power Budget for Line Card Protected Meshed Ring with Unprotected Channels



The shelf configuration and optical mux/demux cabling for node 1 and node 4 are the same as for the 16-channel partial meshed ring example with line card protection. See the following figures for these configurations:

- Node 1 shelf configuration, Figure 5-64 on page 5-56
- Node 1 optical mux/demux module cabling, Figure 5-65 on page 5-57
- Node 4 shelf configuration, Figure 5-70 on page 5-62
- Node 4 optical mux/demux module cabling, Figure 5-71 on page 5-63

Figure 5-79 shows the shelf configuration for node 2 in the line card protected meshed ring with unprotected channels. Channels 1 to 4 are line card protected using an unprotected line card motherboard in slot 2 and an unprotected line card motherboard in slot 4. Slot 8 uses an unprotected line card motherboard for the unprotected channels.

Figure 5-79 Shelf Configuration for Node 2 in Line Card Protected Meshed Ring with Unprotected Channels

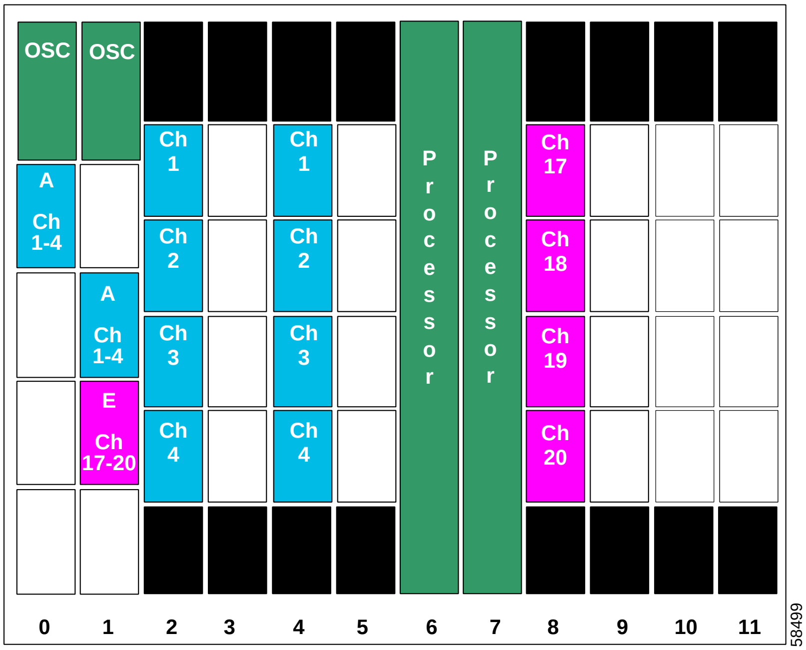


Figure 5-80 shows how the 4-channel mux/demux modules are cabled for node 2 in the line card protected meshed ring with unprotected channels.

Figure 5-80 Add/Drop Mux/Demux Module Cabling for Node 2 in Line Card Protected Meshed Ring with Unprotected Channels

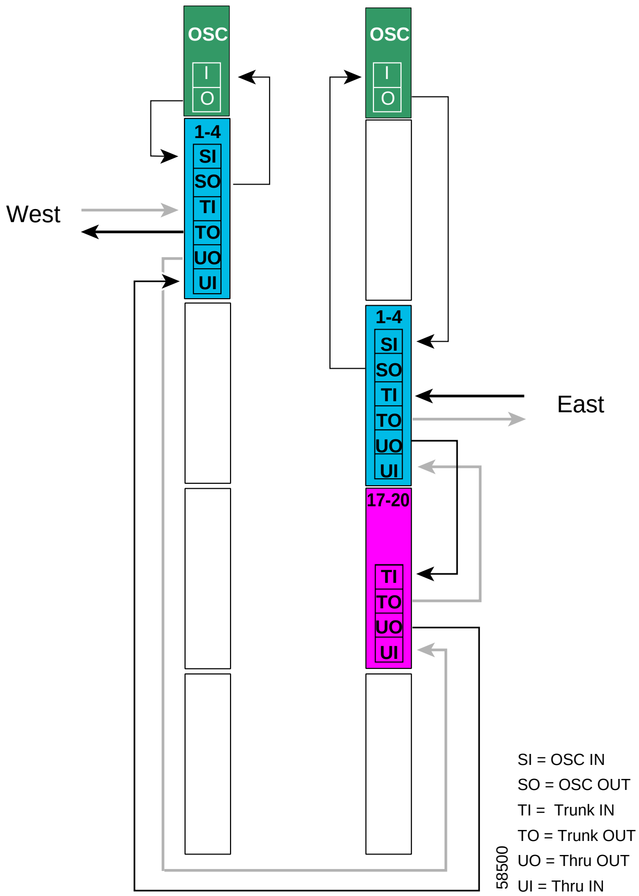


Figure 5-81 shows the shelf configuration for node 3 in the line card protected meshed ring with unprotected channels. Channels 5–8 are line card protected using an unprotected line card motherboard in slot 3 and an unprotected line card motherboard in slot 5. Channels 13–16 are line card protected using an unprotected line card motherboard in slot 9 and an unprotected line card motherboard in slot 11. Slot 8 uses an unprotected line card motherboard for the unprotected channels.

Figure 5-81 Shelf Configuration for Node 3 in Line Card Protected Meshed Ring with Unprotected Channels

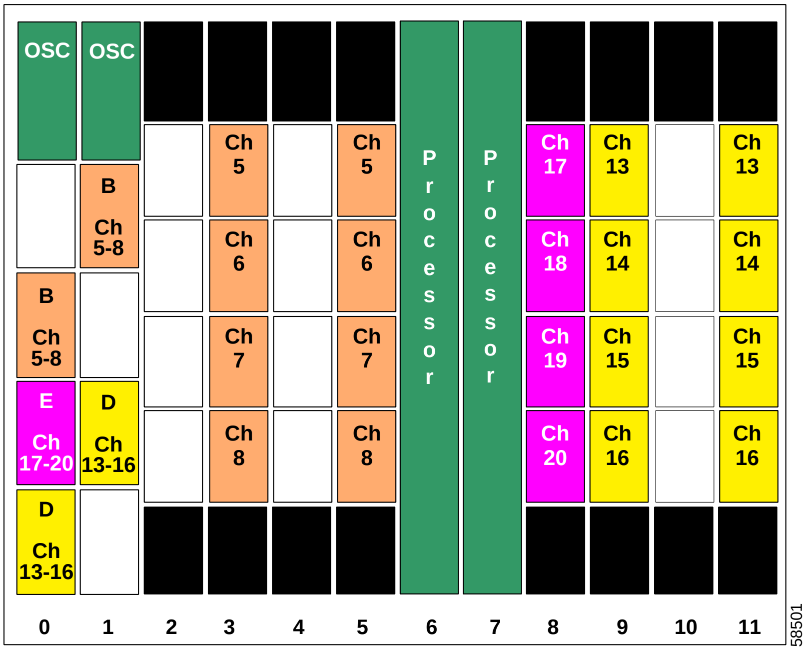
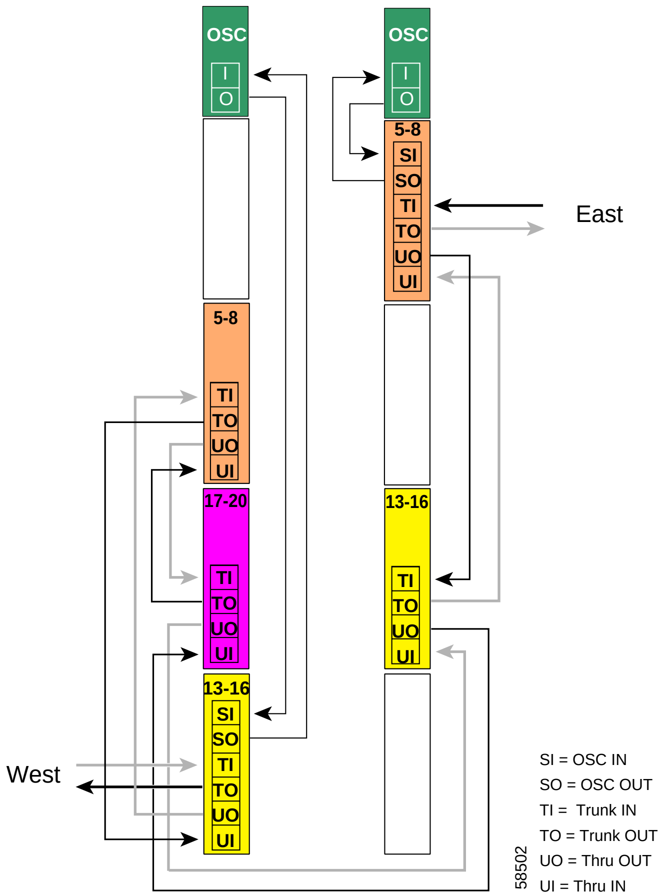


Figure 5-82 shows how the 4-channel mux/demux modules are cabled for node 3 in the line card protected meshed ring with unprotected channels.

Figure 5-82 Add/Drop Mux/Demux Module Cabling for Node 3 in Line Card Protected Meshed Ring with Unprotected Channels



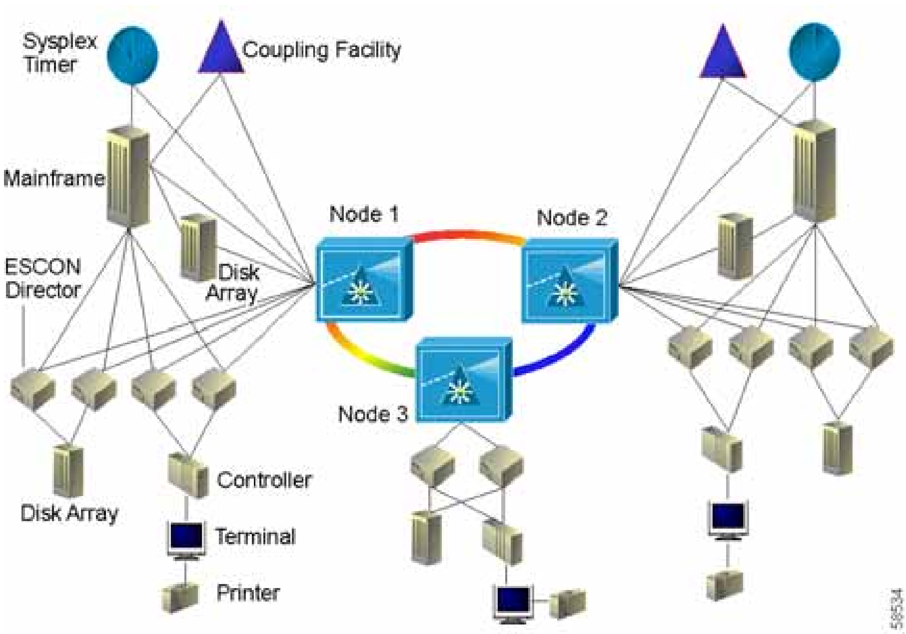
IBM Storage Protocol Support

This appendix provides descriptions and design considerations for protocols used in an IBM storage environment. This appendix contains the following major sections:

IBM Storage Environment

Figure A-1 shows an IBM storage environment application with GDPS (Geographically Dispersed Parallel Sysplex). SANs (storage area networks) are attached to node 1 and node 2, and a LAN is attached to node 3.

Figure A-1 IBM Storage Environment with GDPS and DWDM



Supported Protocols

The Cisco ONS 15540 ESPx can provide the transport layer for the following IBM storage related protocols:

- ESCON
- FICON
- Coupling Facility
- Sysplex Timer links

The Cisco ONS 15540 ESPx can also be used to help implement the high availability features for the following applications:

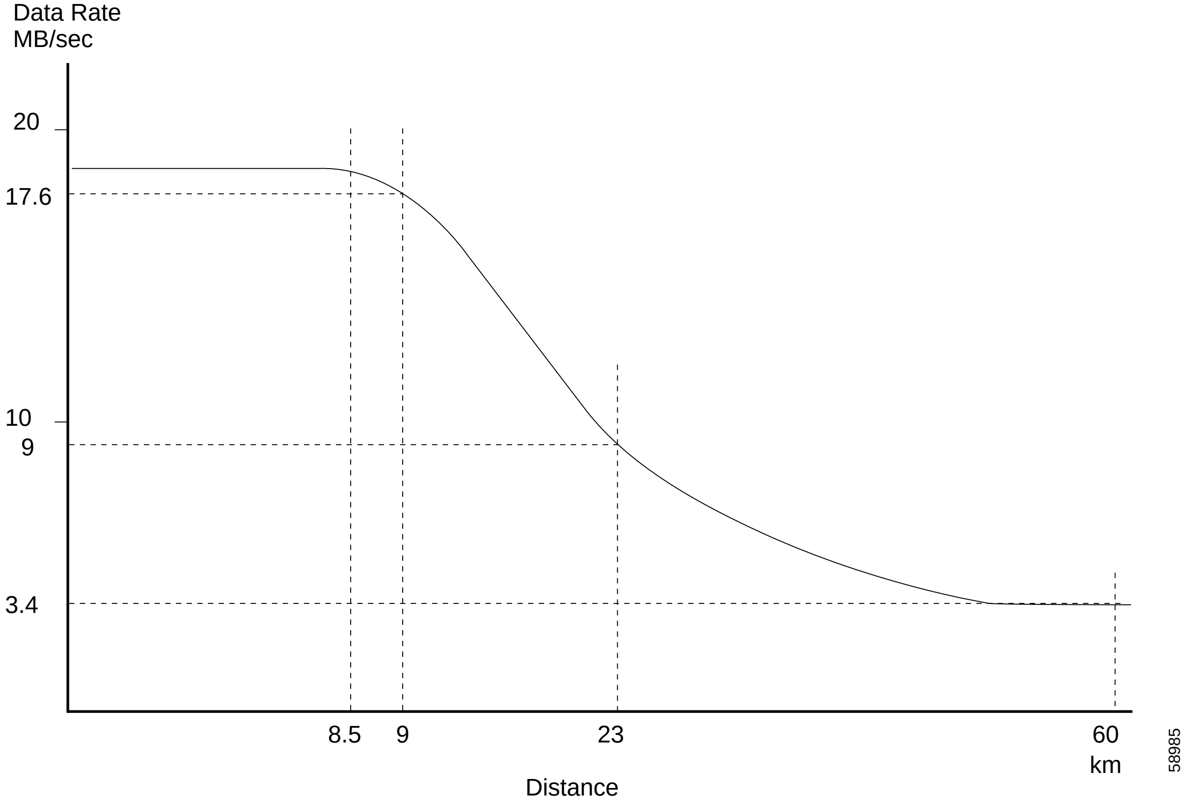
- PPRC
- XRC
- GDPS

ESCON

ESCON (Enterprise System Connection) is a 200-Mbps unidirectional serial bit transmission protocol used to dynamically connect mainframes with their various control units. ESCON provides nonblocking access through either point-to-point connections or high speed switches, called ESCON Directors. In the Parallel Sysplex or GDPS environment, ESCON performance is seriously affected if the distance spanned is greater than approximately 8 km. For instance, measurements have shown that ESCON performance at 20 km is roughly 50 percent of maximum performance. Performance degradation continues as distance is further increased.

Figure A-2 shows an estimate of how the effective data rate decreases as the path length increases. At a distance of 9 km, performance begins to decrease precipitously. This data point is referred to as the *distance data rate droop point*.

Figure A-2 ESCON Data Rate as a Function of Distance



FICON

FICON (Fiber Connection) is the next generation bidirectional channel protocol used to connect mainframes directly with control units or ESCON aggregation switches (ESCON Directors with a bridge card). FICON runs over Fibre Channel at a data rate of 1.062 Gbps. One of the main advantages of FICON is the lack of performance degradation over distance that is seen with ESCON. FICON can reach a distance of 100 km before experiencing any significant drop in data throughput.

Coupling Facility

Coupling Facility (CF) links, also known as ISC (InterSystem Channel) links, are used to connect mainframes to a CF. The CF is used by multiple mainframes to share data in a sysplex or Parallel Sysplex environment. This data sharing capability is key to the high availability features of a GDPS. Coupling links run over Fibre Channel at data rates of 1.0625 Gbps (called ISC1 or ISC compatibility) and 2.1 Gbps (called ISC peer).

Sysplex Timer

Sysplex Timer links are the links used to provide the clock synchronization between the mainframes in a Parallel Sysplex. There are two types of links used. The first is the link between each mainframe and the Sysplex Timer, known as the ETR (external throughout rate) links. The second is the link between redundant Sysplex Timers, referred to as the CLO (control link oscillator) links. In a high availability GDPS environment, redundant Sysplex Timers are connected to each mainframe over ETR links, while the timers are connected to each other over the CLO links. This protocol operates at 16 Mbps.

PPRC

PPRC (peer-to-peer remote copy) is a facility used in certain IBM disk controllers that allows synchronous mirroring of data.

XRC

XRC (extended remote copy) is a facility used with certain IBM disk controllers that allows asynchronous mirroring of data.

GDPS

GDPS (Geographically Dispersed Parallel Sysplex) is a multisite parallel sysplex with sites up to 40 km apart. It uses custom automation to manage mirroring of critical data and to balance workload for regular use or for disaster recovery.

Client Optical Power Budget and Attenuation Requirements

Table A-1 shows the client optical power budget and attenuation requirements for the IBM storage protocols and the IBM implementation of other common protocols with high-end IBM servers that support ESCON, FICON, and Fibre Channel. For each protocol, the table shows the transmit power and receiver sensitivity ranges on the IBM server interface, the transponder type that supports this protocol on the Cisco ONS 15540 ESPx, the resulting client loss budget, and what attenuation is required at 0 km. For the transmit powers and receiver sensitive ranges of the Cisco ONS 15540 ESPx transponder interfaces, refer to the *Cisco ONS 15540 ESPx Hardware Installation Guide*.

Table A-1 Optical Power Budget and Attenuation Requirements with High-End IBM Servers

Protocol	IBM Server Transmit (dBm)	IBM Server Receive (dBm)	Cisco ONS 15540 ESPx Transponder Type	Cisco ONS 15540 ESPx Client Loss Budget/Minimum Attenuation at 0 km
ESCON, SM	–3 to –8	–3 to –28	SM	Rx: 11 to 16 dB/none Tx: 23 to 28 dB/–3 dB
ESCON, MM ETR/CLO, MM	–15 to –20.5	–14 to –29	MM	Rx: 4.5 to 10 dB/none Tx: 24 to 29 dB/–14 dB
FICON, SM/LX	–4 to –8.5	–3 to –22	SM	Rx: 11.5 to 15 dB/none Tx: 17 to 22 dB/–3 dB
ATM 155, SM	–8 to –15	–8 to –32.5	SM	Rx: 4 to 11 dB/none Tx: 27.5 to 32.5 dB/–8 dB
ATM 155, MM	–14 to –19	–14 to –30	MM	Rx: 6 to 11 dB/none Tx: 25 to 30 dB/–14 dB
FDDI, MM	–14 to –19	–14 to –31.8	MM	Rx: 6 to 11 dB/none Tx: 26.8 to 31.8 dB/–14 dB
ISC, 1Gbps	–3 to –11	–3 to –20	SM	Rx: 8 to 16 dB/none Tx: 15 to 20 dB/–3 dB

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