C H A P T E R **11**

# SONET Topologies

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

This chapter explains Cisco ONS 15454 SONET topologies.

> **Note** The reference material in this chapter does not apply to dense wavelength division multiplexing (DWDM) (Software Release 4.5) nodes and DWDM topologies.

To provision topologies, refer to the *Cisco ONS 15454 Procedure Guide*.

Chapter topics include:

- SONET Rings and TCC+/TCC2 Cards, page 2
- Bidirectional Line Switched Rings, page 2
- Path Protection Dual Ring Interconnect, page 13
- Subtending Rings, page 16
- Linear ADM Configurations, page 18
- Path-Protected Mesh Networks, page 18
- Four-Shelf Node Configurations, page 20
- OC-N Speed Upgrades, page 21

# 11.1  SONET Rings and TCC+/TCC2 Cards

Table 11-1 shows the SONET rings that can be created on each ONS 15454 node using redundant TCC+ cards.

*Table 11-1    ONS 15454 Rings with Redundant TCC+ Cards*

| Ring Type | Maximum Rings per Node |
|---|---|
| BLSRs[1] | 2 |
| 2-Fiber BLSR | 2 |
| 4-Fiber BLSR | 1 |
| Path Protection | 5[2, 3] |

1.   BLSR = bidirectional line switch ring

2.   Total SDCC usage must be equal to or less than 10 SDCCs.

3.

Table 11-2 shows the SONET rings that can be created on each ONS 15454 node using redundant TCC2 cards.

*Table 11-2    ONS 15454 Rings with Redundant TCC2 Cards*

| Ring Type | Maximum Rings per Node |
|---|---|
| BLSRs | 2 |
| 2-Fiber BLSR | 2 |
| 4-Fiber BLSR | 1 |
| Path Protection | 16[1, 2] |

1.   Total SDCC usage must be equal to or less than 32 SDCCs.

2.

# 11.2  Bidirectional Line Switched Rings

The ONS 15454 can support two concurrent BLSRs in one of the following configurations:

• Two, two-fiber BLSRs

• One two-fiber and one four-fiber BLSR

Each BLSR can have up to 32 ONS 15454s. Because the working and protect bandwidths must be equal, you can create only OC-12 (two-fiber only), OC-48, or OC-192 BLSRs. For information about BLSR protection channels, see the "BLSR Protection Channel Circuits" section on page 21.

**Note**    For best performance, BLSRs should have one LAN connection for every ten nodes in the BLSR.

## 11.2.1 Two-Fiber BLSRs

In two-fiber BLSRs, each fiber is divided into working and protect bandwidths. For example, in an OC-48 BLSR (Figure 11-1), STSs 1 to 24 carry the working traffic, and STSs 25 to 48 are reserved for protection. Working traffic (STSs 1 to 24) travels in one direction on one fiber and in the opposite direction on the second fiber. The Cisco Transport Controller (CTC) circuit routing routines calculate the shortest path for circuits based on many factors, including user requirements, traffic patterns, and distance. For example, in Figure 11-1, circuits going from Node 0 to Node 1 typically travel on Fiber 1, unless that fiber is full, in which case circuits are routed on Fiber 2 through Node 3 and Node 2. Traffic from Node 0 to Node 2 (or Node 1 to Node 3) can be routed on either fiber, depending on circuit provisioning requirements and traffic loads.

*Figure 11-1    Four-Node, Two-Fiber BLSR*
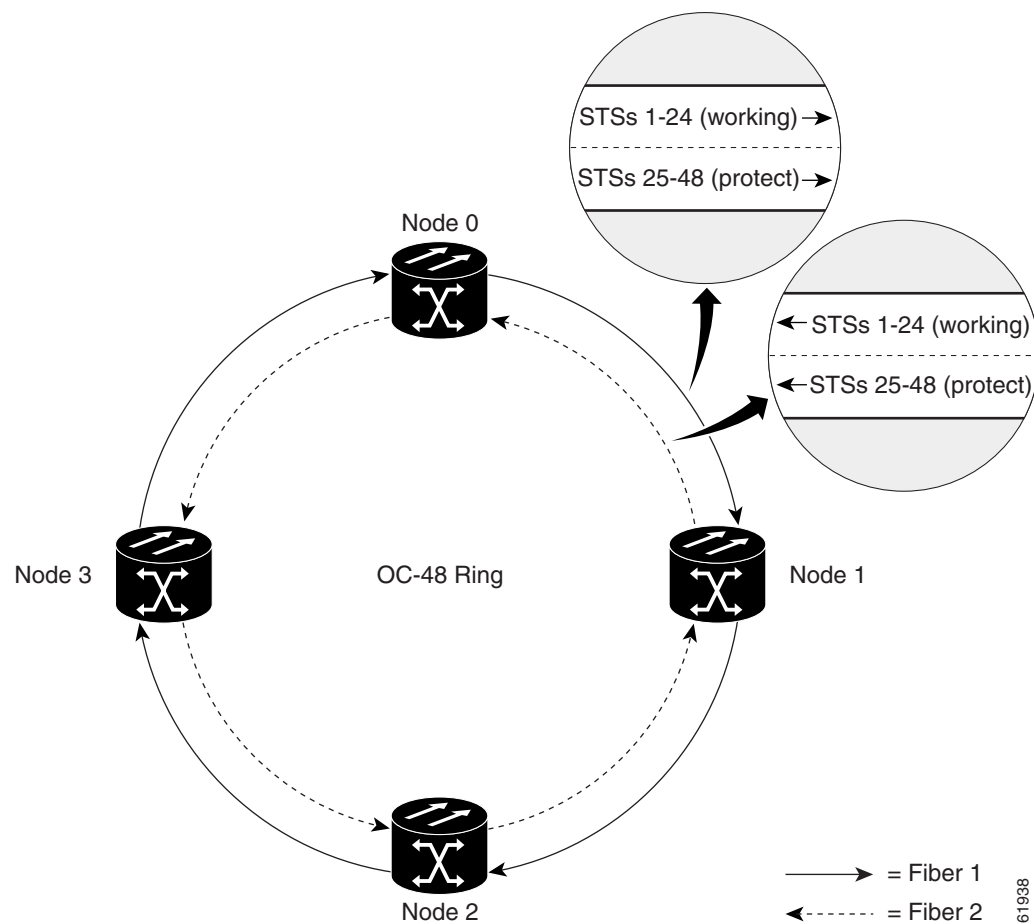


The SONET K1, K2, and K3 bytes carry the information that governs BLSR protection switches. Each BLSR node monitors the K bytes to determine when to switch the SONET signal to an alternate physical path. The K bytes communicate failure conditions and actions taken between nodes in the ring.

If a break occurs on one fiber, working traffic targeted for a node beyond the break switches to the protect bandwidth on the second fiber. The traffic travels in a reverse direction on the protect bandwidth until it reaches its destination node. At that point, traffic is switched back to the working bandwidth.

shows a traffic pattern sample on a four-node, two-fiber BLSR.

*Figure 11-2   Four-Node, Two-Fiber BLSR Traffic Pattern Sample*
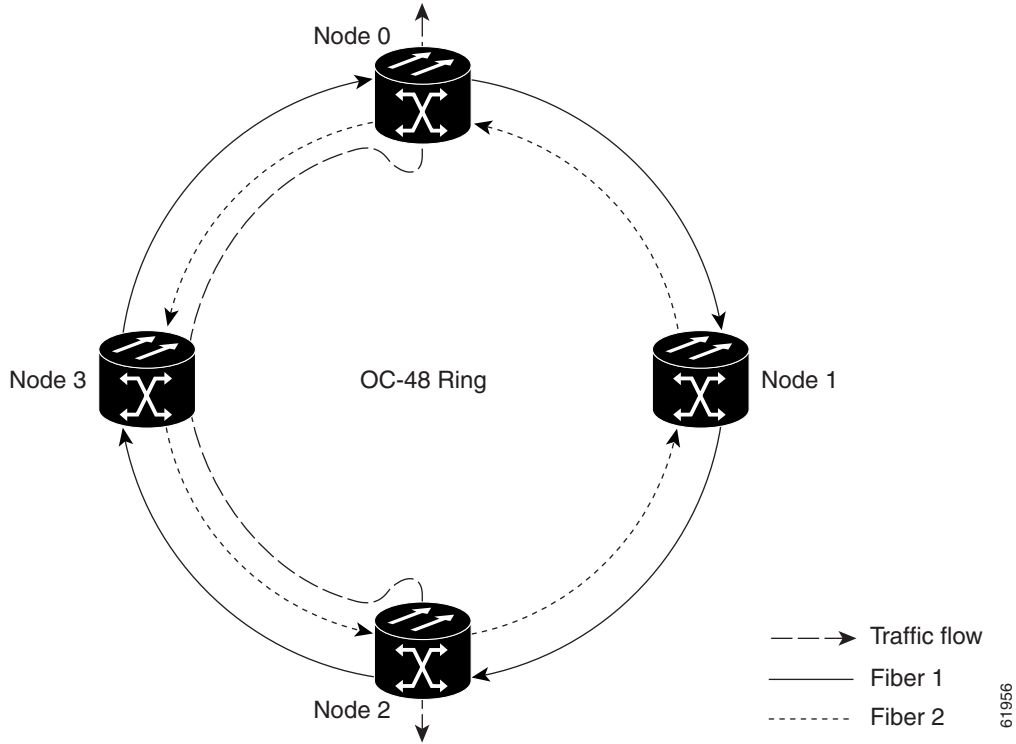


Figure 11-3 on page 11-5 shows how traffic is rerouted following a line break between Node 0 and Node 1.

- All circuits originating on Node 0 carried traffic to Node 2 on Fiber 2 are switched to the protect bandwidth of Fiber 1. For example, a circuit carrying traffic on STS-1 on Fiber 2 is switched to STS-25 on Fiber 1. A circuit carried on STS-2 on Fiber 2 is switched to STS-26 on Fiber 1. Fiber 1 carries the circuit to Node 3 (the original routing destination). Node 3 switches the circuit back to STS-1 on Fiber 2 where it is routed to Node 2 on STS-1.

- Circuits originating on Node 2 that normally carried traffic to Node 0 on Fiber 1 are switched to the protect bandwidth of Fiber 2 at Node 3. For example, a circuit carrying traffic on STS-2 on Fiber 1 is switched to STS-26 on Fiber 2. Fiber 2 carries the circuit to Node 0 where the circuit is switched back to STS-2 on Fiber 1 and then dropped to its destination.
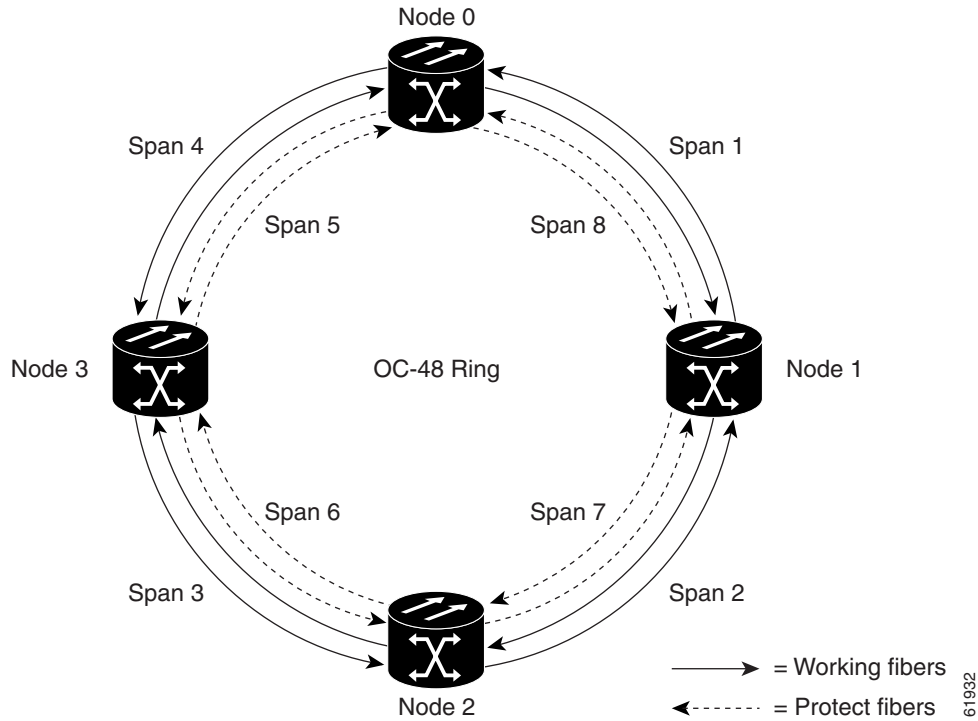
*Figure 11-3    Four-Node, Two-Fiber BLSR Traffic Pattern Following Line Break*
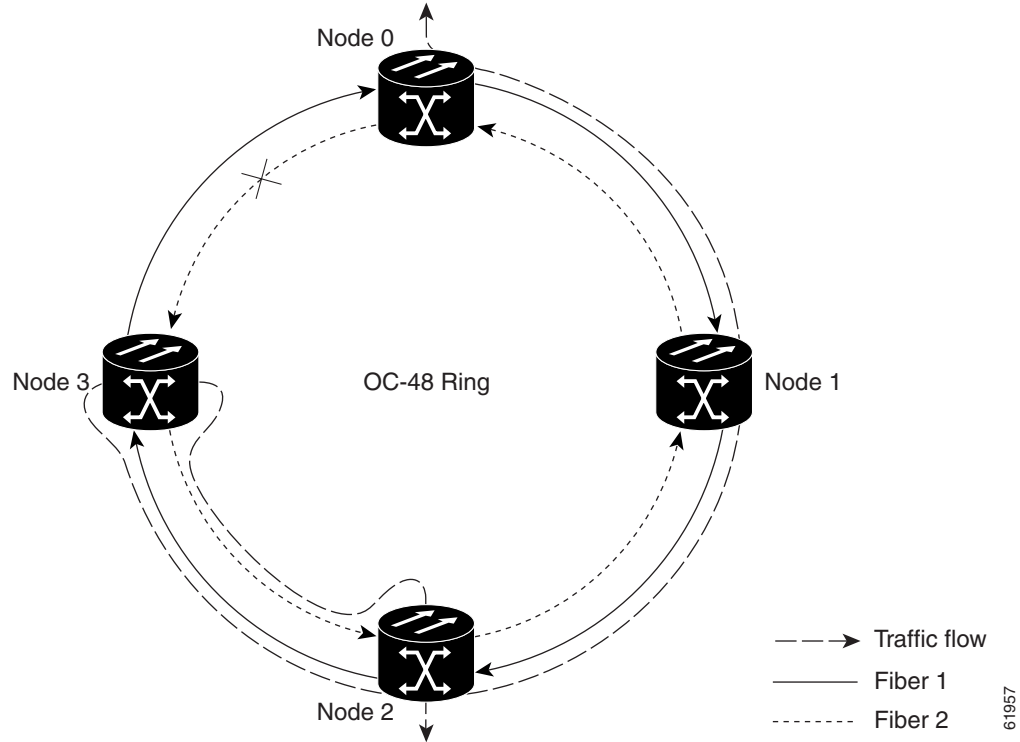


## 11.2.2  Four-Fiber BLSRs

Four-fiber BLSRs double the bandwidth of two-fiber BLSRs. Because they allow span switching as well as ring switching, four-fiber BLSRs increase the reliability and flexibility of traffic protection. Two fibers are allocated for working traffic and two fibers for protection, as shown in Figure 11-4 on page 11-6. To implement a four-fiber BLSR, you must install four OC-48, OC-48AS, or OC-192 cards at each BLSR node.

*Figure 11-4    Four-Node, Four-Fiber BLSR*

Node 0

Span 4

Span 1

Span 5

Span 8

Node 3

OC-48 Ring

Node 1

Span 6

Span 7

Span 3

Span 2

Node 2

———▶ = Working fibers

◀------- = Protect fibers

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Four-fiber BLSRs provide span and ring switching:

*   Span switching (Figure 11-5 on page 11-7) occurs when a working span fails. Traffic switches to the protect fibers between the nodes (Node 0 and Node 1 in the example in Figure 11-5 on page 11-7) and then returns to the working fibers. Multiple span switches can occur at the same time.

*   Ring switching (Figure 11-6 on page 11-7) occurs when a span switch cannot recover traffic, such as when both the working and protect fibers fail on the same span. In a ring switch, traffic is routed to the protect fibers throughout the full ring.
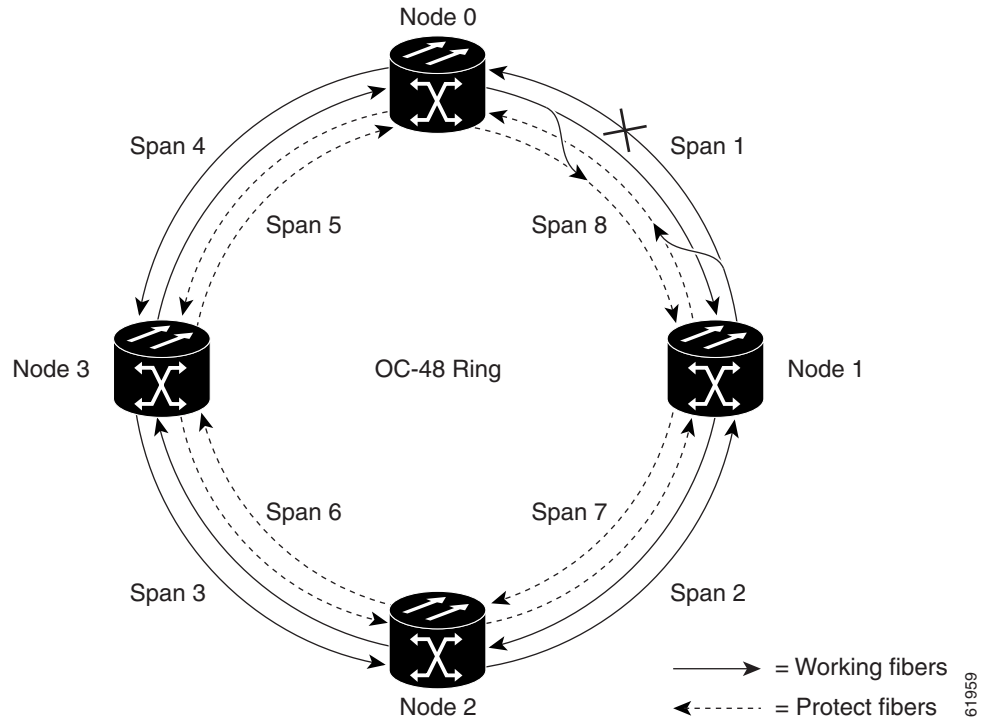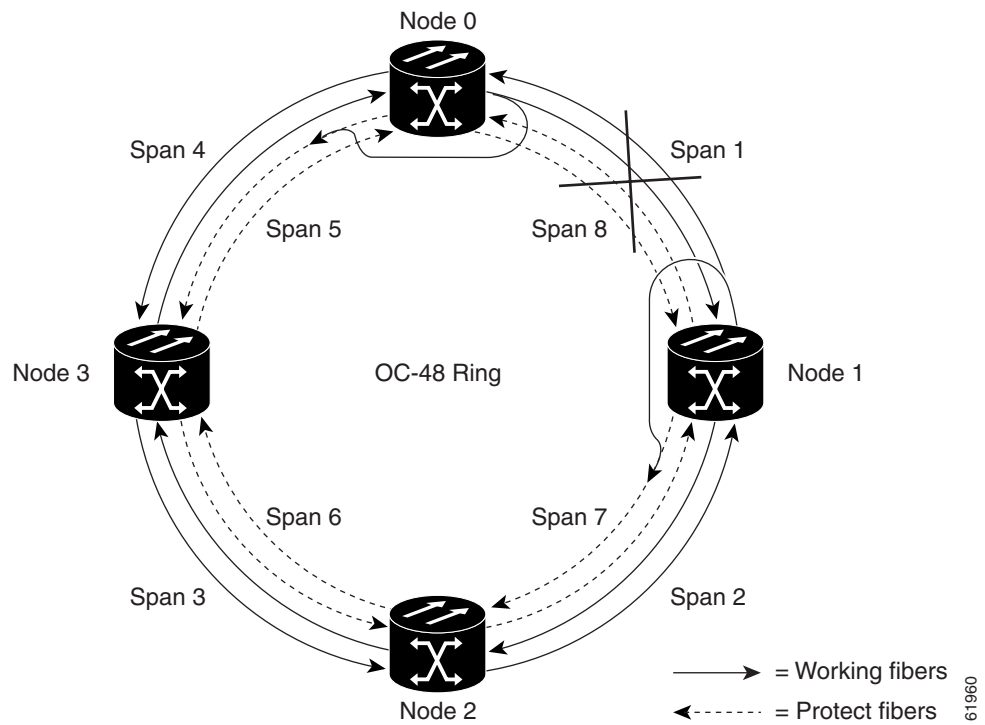
*Figure 11-5    Four-Fiber BLSR Span Switch*

Node 0

Span 4

Span 5

Span 8

Span 1

Node 3

OC-48 Ring

Node 1

Span 6

Span 7

Span 3

Span 2

Node 2

→ = Working fibers
◄------ = Protect fibers

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*Figure 11-6    Four-Fiber BLSR Ring Switch*

Node 0

Span 4

Span 5

Span 8

Span 1

Node 3

OC-48 Ring

Node 1

Span 6

Span 7

Span 3

Span 2

Node 2

→ = Working fibers
◄------ = Protect fibers

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# 11.2.3  BLSR Bandwidth

BLSR nodes can terminate traffic coming from either side of the ring. Therefore, BLSRs are suited for distributed node-to-node traffic applications such as interoffice networks and access networks.

BLSRs allow bandwidth to be reused around the ring and can carry more traffic than a network with traffic flowing through one central hub. BLSRs can also carry more traffic than a path protection operating at the same OC-N rate. Table 11-3 shows the bidirectional bandwidth capacities of two-fiber BLSRs. The capacity is the OC-N rate divided by two, multiplied by the number of nodes in the ring minus the number of pass-through STS-1 circuits. Table 11-4 shows the bidirectional bandwidth capacities of four-fiber BLSRs.

*Table 11-3    Two-Fiber BLSR Capacity*

| OC Rate | Working Bandwidth | Protection Bandwidth | Ring Capacity |
|---------|-------------------|----------------------|---------------|
| OC-12   | STS1-6            | STS 7-12             | 6 x N[1] - PT[2] |
| OC-48   | STS 1-24          | STS 25-48            | 24 x N - PT   |
| OC-192  | STS 1-96          | STS 97-192           | 96 x N - PT   |

1.  N equals the number of ONS 15454 nodes configured as BLSR nodes.

2.  PT equals the number of STS-1 circuits passed through ONS 15454 nodes in the ring (capacity can vary depending on the traffic pattern).

*Table 11-4    Four-Fiber BLSR Capacity*

| OC Rate | Working Bandwidth | Protection Bandwidth | Ring Capacity |
|---------|-------------------|----------------------|---------------|
| OC-48   | STS 1-48 (Fiber 1)  | STS 1-48 (Fiber 2)  | 48 x N - PT   |
| OC-192  | STS 1-192 (Fiber 1) | STS 1-192 (Fiber 2) | 192 x N - PT  |

shows an example of BLSR bandwidth reuse. The same STS carries three different traffic sets simultaneously on different spans around the ring: one set from Node 3 to Node 1, another set from Node 1 to Node 2, and another set from Node 2 to Node 3.

*Figure 11-7    BLSR Bandwidth Reuse*
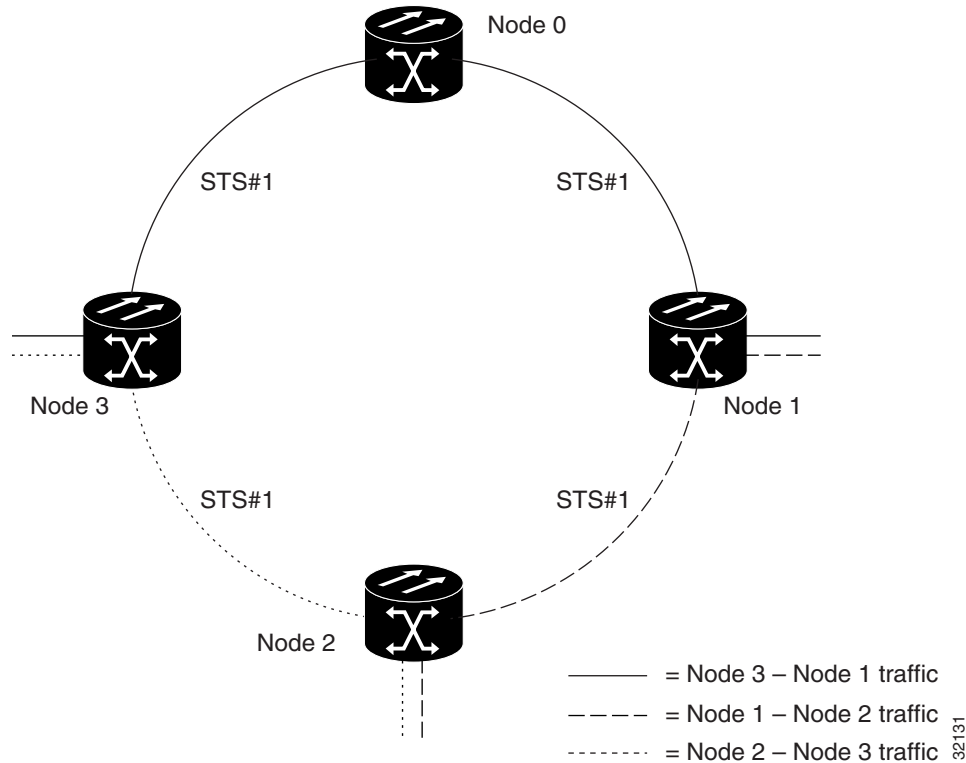


## 11.2.4  BLSR Application Example

Figure 11-8 on page 11-10 shows a two-fiber BLSR implementation example with five nodes. A regional long-distance network connects to other carriers at Node 0. Traffic is delivered to the service provider's major hubs.

- Carrier 1 delivers six DS-3s over two OC-3 spans to Node 0. Carrier 2 provides twelve DS-3s directly. Node 0 receives the signals and delivers them around the ring to the appropriate node.

- The ring also brings 14 DS-1s back from each remote site to Node 0. Intermediate nodes serve these shorter regional connections.

- The ONS 15454 OC-3 card supports a total of four OC-3 ports so that two additional OC-3 spans can be added at little cost.
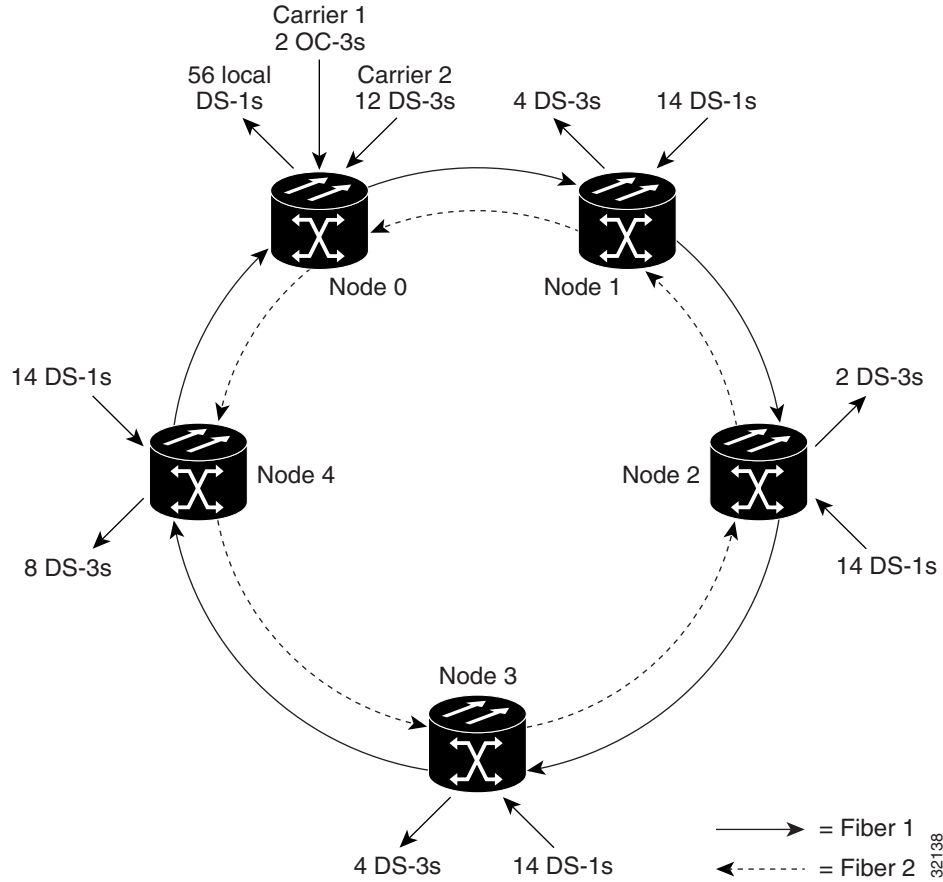
*Figure 11-8    Five-Node Two-Fiber BLSR*



Figure 11-9 on page 11-11 shows the shelf assembly layout for Node 0, which has one free slot. Figure 11-10 on page 11-11 shows the shelf assembly layout for the remaining sites in the ring. In this BLSR configuration, an additional eight DS-3s at Node IDs 1 and 3 can be activated. An additional four DS-3s can be added at Node 4, and ten DS-3s can be added at Node 2. Each site has free slots for future traffic needs.

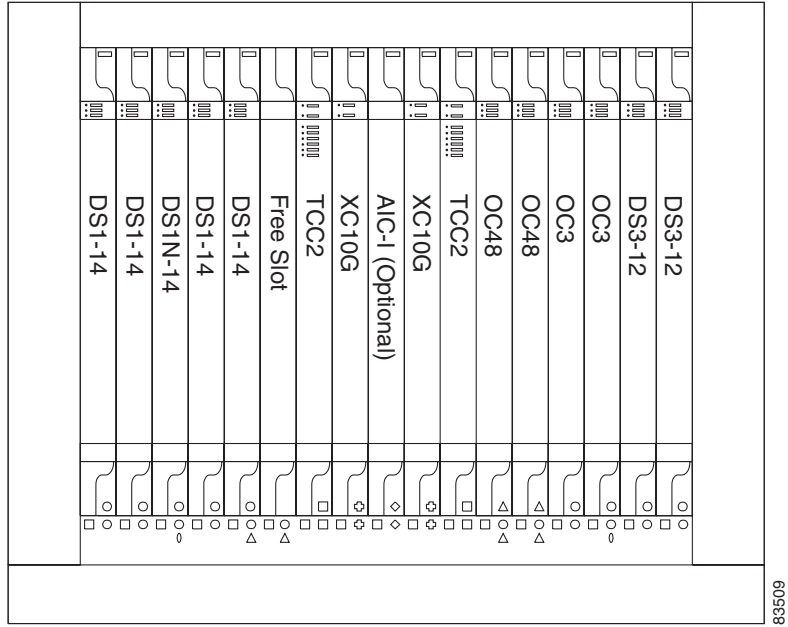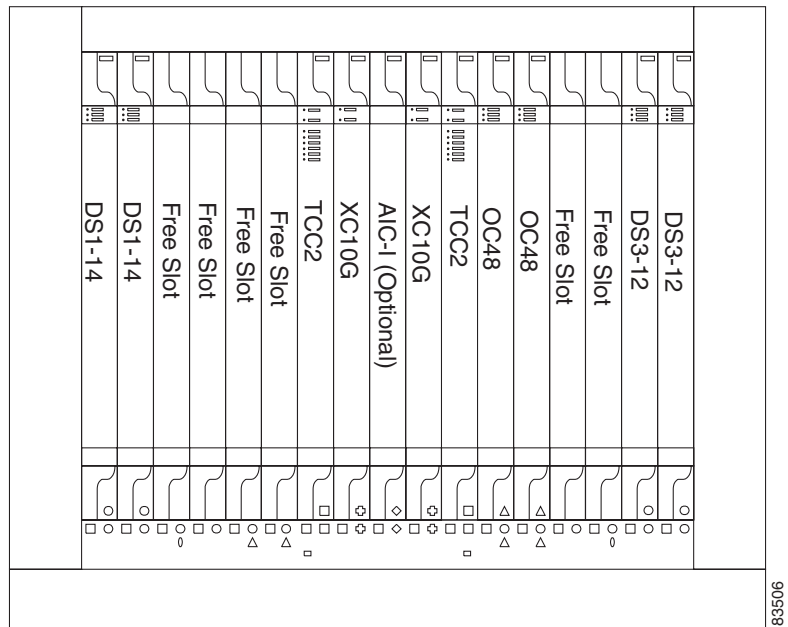*Figure 11-9   Shelf Assembly Layout for Node 0 in Figure 11-8*



*Figure 11-10 Shelf Assembly Layout for Nodes 1 to 4 in Figure 11-8*

## 11.2.5  BLSR Fiber Connections

Plan your fiber connections and use the same plan for all BLSR nodes. For example, make the east port the farthest slot to the right and the west port the farthest slot to the left. Plug fiber connected to an east port at one node into the west port on an adjacent node. Figure 11-11 shows fiber connections for a two-fiber BLSR with trunk cards in Slot 5 (west) and Slot 12 (east). Refer to the *Cisco ONS 15454 Procedure Guide* for fiber connection procedures.

**Note**   Always plug the transmit (Tx) connector of an OC-N card at one node into the receive (Rx) connector of an OC-N card at the adjacent node. Cards display an SF LED when Tx and Rx connections are mismatched.

For four-fiber BLSRs, use the same east-west connection pattern for the working and protect fibers. Do not mix working and protect card connections. The BLSR does not function if working and protect cards are interconnected. Figure 11-12 on page 11-13 shows fiber connections for a four-fiber BLSR. Slot 5 (west) and Slot 12 (east) carry the working traffic. Slot 6 (west) and Slot 13 (east) carry the protect traffic.

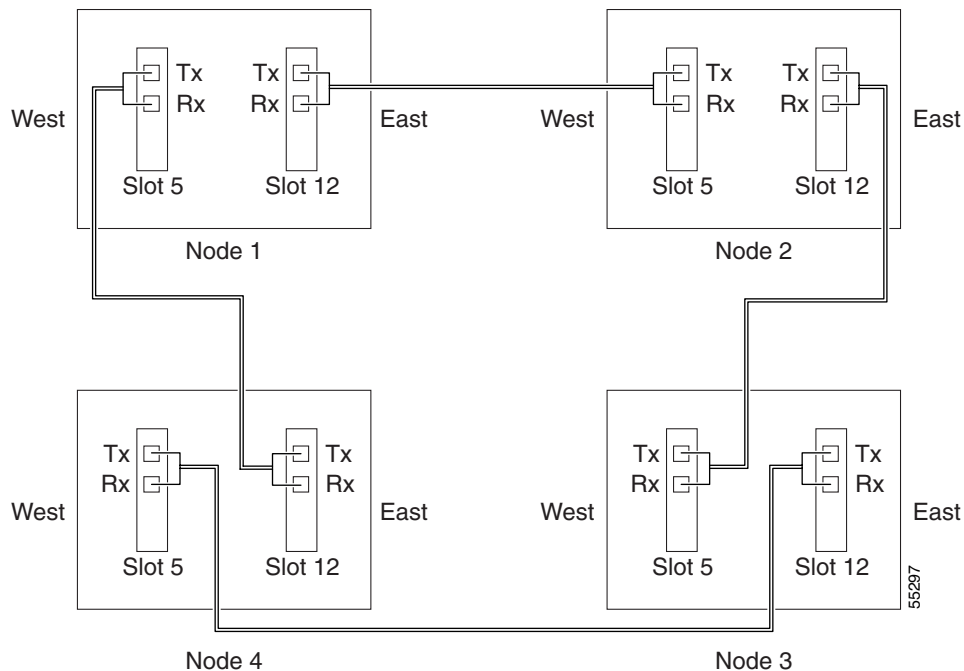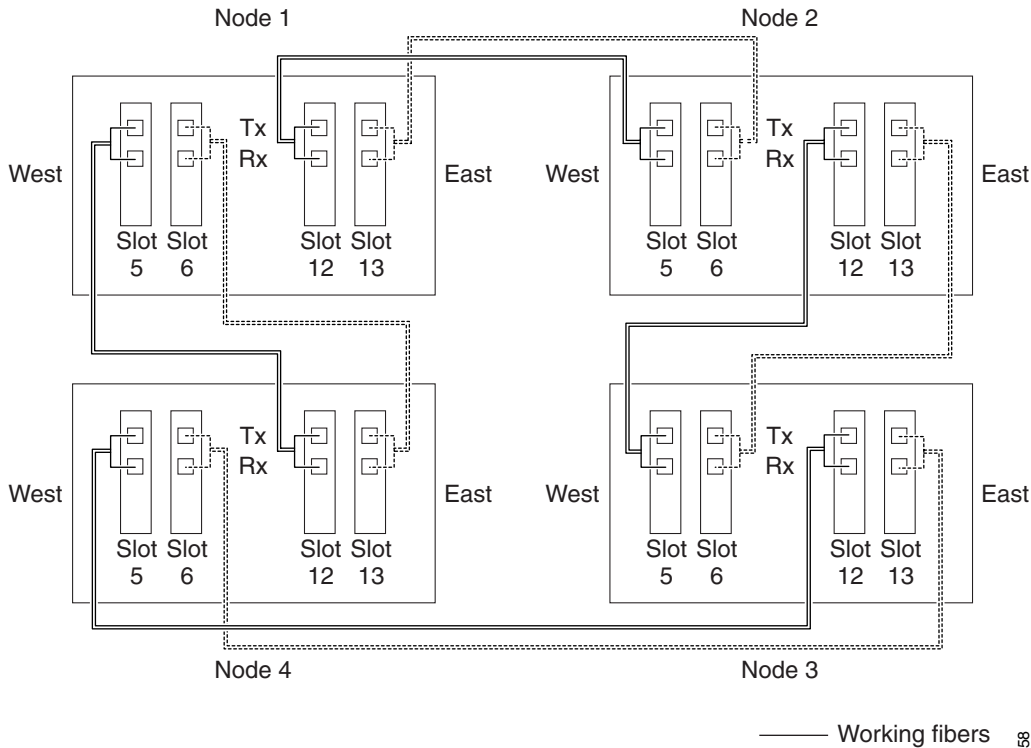*Figure 11-11  Connecting Fiber to a Four-Node, Two-Fiber BLSR*

*Figure 11-12 Connecting Fiber to a Four-Node, Four-Fiber BLSR*



## 11.2.6 Two-Fiber BLSR to Four-Fiber BLSR Conversion

Two-fiber OC-48 or OC-192 BLSRs can be converted to four-fiber BLSRs. To convert the BLSR, install two OC-48 or OC-192 cards at each two-fiber BLSR node, then log into CTC and convert each node from two-fiber to four-fiber. The fibers that were divided into working and protect bandwidths for the two-fiber BLSR are now fully allocated for working BLSR traffic. Refer to the *Cisco ONS 15454 Procedure Guide* for BLSR conversion procedures.

# 11.3 Path Protection Dual Ring Interconnect

The path protection dual ring interconnect (path protection DRI) topology provides an extra level of path protection between interconnected path protection configurations. In DRIs traffic is dropped and continued at the interconnecting nodes to eliminate single points of failure. Two DRI topologies can be implemented on the ONS 15454. The traditional DRI uses four ONS 15454s at the interconnect nodes, while the integrated DRI uses two nodes.

Figure 11-13 on page 11-14 shows ONS 15454s in a traditional DRI topology. In Ring 1, Nodes 4 and 5 are the interconnect nodes, and in Ring 2, Nodes 6 and 7. Duplicate signals are sent from Node 4 (Ring 1) to Node 6 (Ring 2), and between Node 5 (Ring 1) and Node 7 (Ring 2). In Ring 1, traffic at Node 4 is dropped (to Node 6) and continued (to Node 5). Similarly, at Node 5, traffic is dropped (to Node 7) and continued (to Node 4).

To route circuits on the DRI, you must choose the DRI option during circuit provisioning. Circuits with the DRI option enabled are routed on the DRI path.

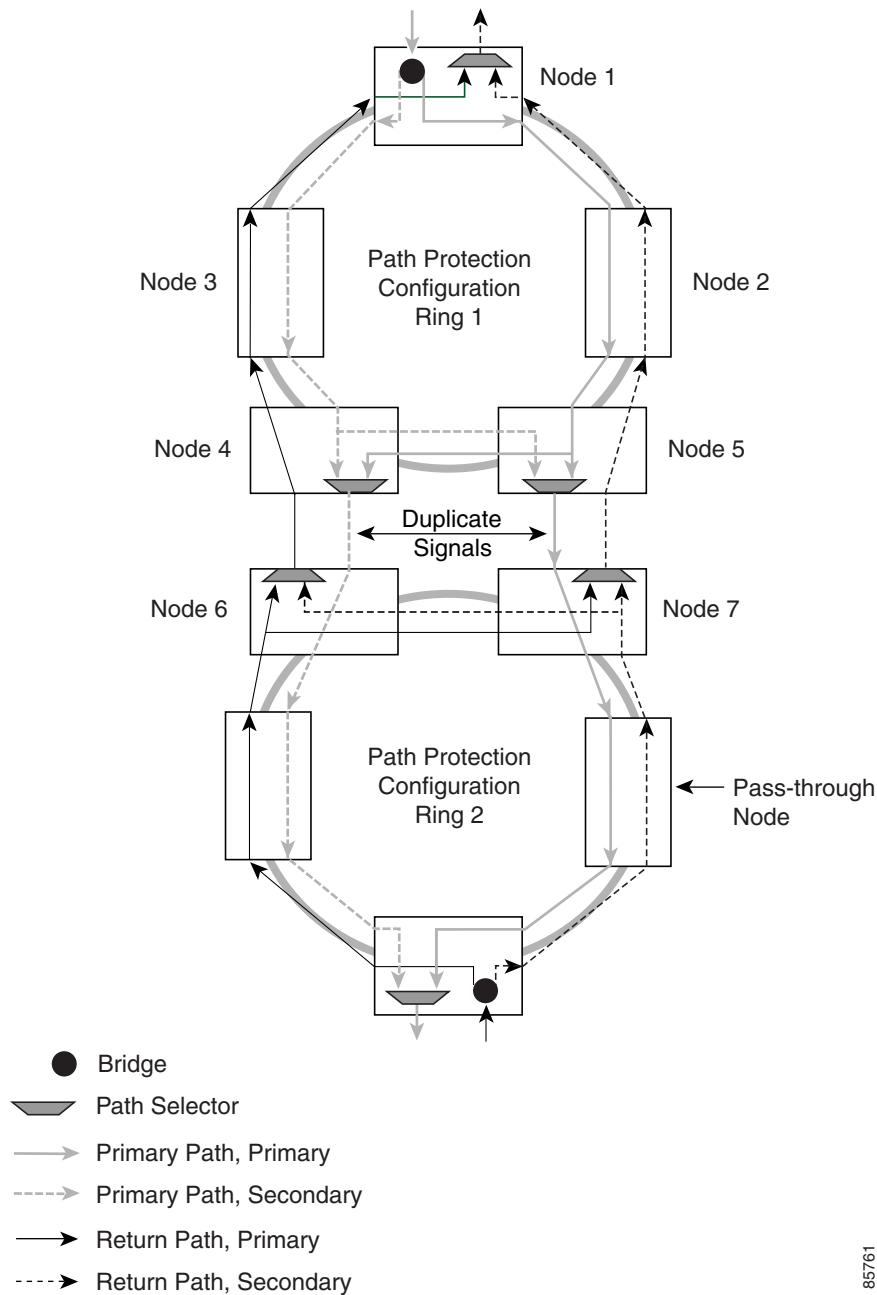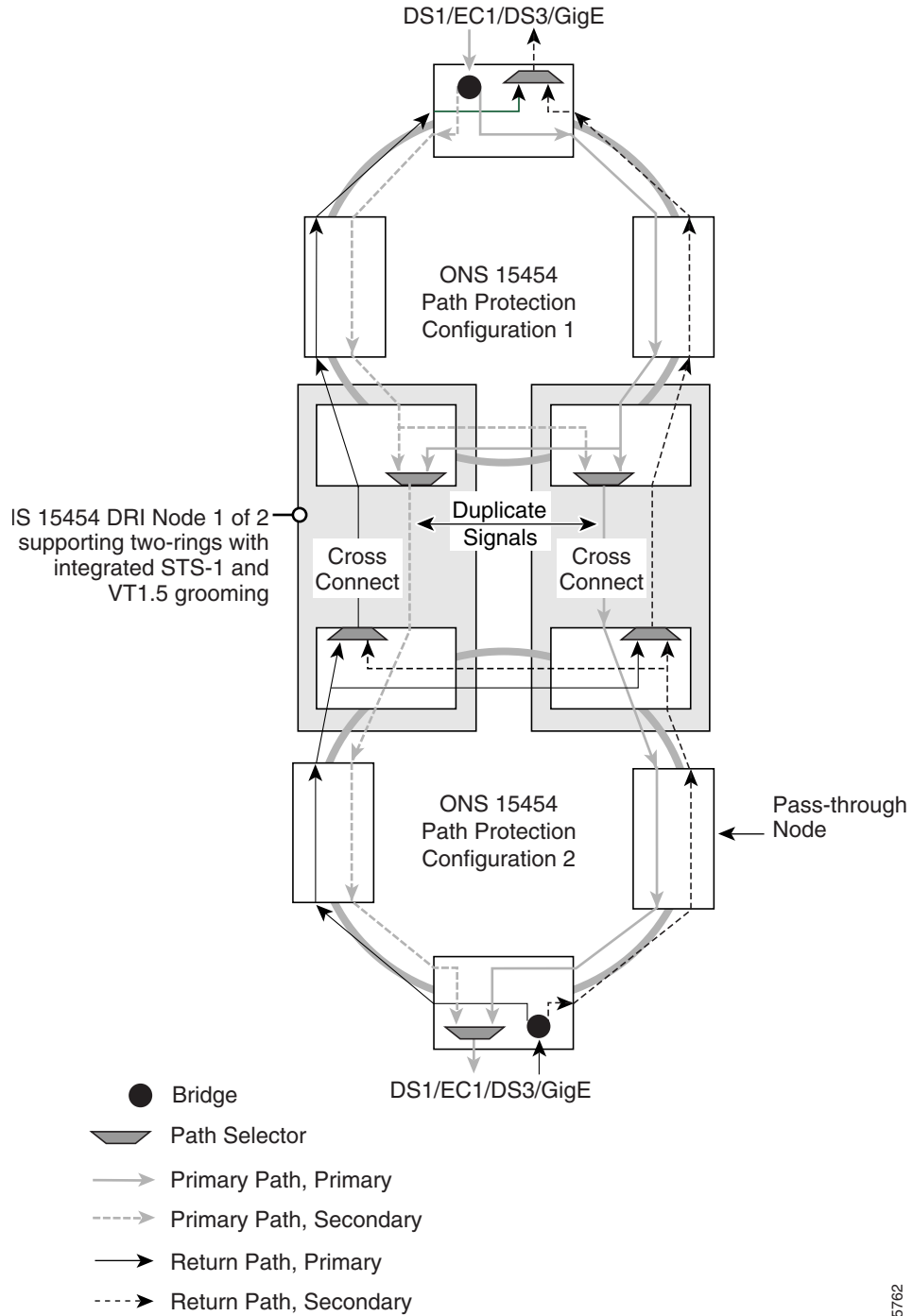*Figure 11-13 Traditional ONS 15454 Dual Ring Interconnect*



Figure 11-14 on page 11-15 shows ONS 15454s in an integrated dual ring interconnect topology. The same drop and continue traffic routing occurs at two nodes, rather than four. This is achieved by installing an addition OC-N trunk at the two interconnect nodes.

**Figure 11-14 Integrated ONS 15454 Dual Ring Interconnect**



DS1/EC1/DS3/GigE

ONS 15454
Path Protection
Configuration 1

IS 15454 DRI Node 1 of 2
supporting two-rings with
integrated STS-1 and
VT1.5 grooming

Duplicate
Signals

Cross
Connect

Cross
Connect

ONS 15454
Path Protection
Configuration 2

Pass-through
Node

DS1/EC1/DS3/GigE

● Bridge

Path Selector

Primary Path, Primary

Primary Path, Secondary

Return Path, Primary

Return Path, Secondary

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# 11.4  Subtending Rings

The ONS 15454 supports up to ten SONET SDCCs with TCC+ cards and 32 SONET SDCCs with TCC2 cards. See Table 11-1 on page 11-2 and Table 11-2 on page 11-2 for ring and SDCC information.

Subtending rings reduce the number of nodes and cards required and reduce external shelf-to-shelf cabling. Figure 11-15 shows an ONS 15454 with multiple subtending rings.
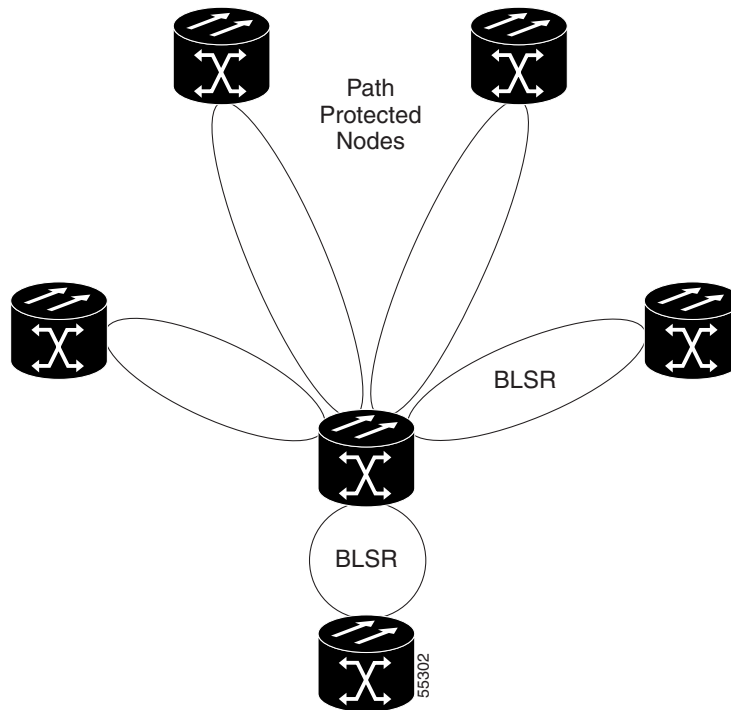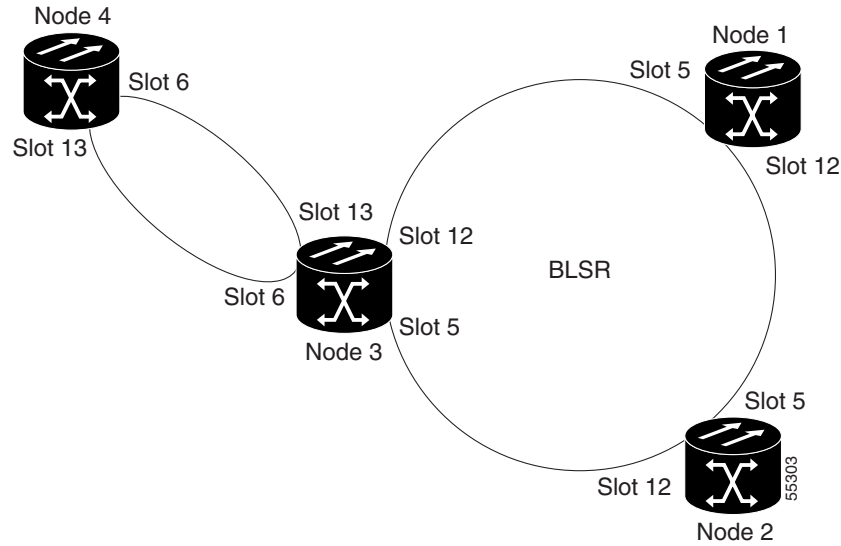
*Figure 11-15 ONS 15454 with Multiple Subtending Rings*



shows a path protection subtending from a BLSR. In this example, Node 3 is the only node serving both the BLSR and path protection. OC-N cards in Slots 5 and 12 serve the BLSR, and OC-N cards in Slots 6 and 13 serve the path protection.

*Figure 11-16 Path Protection Subtending from a BLSR*



The ONS 15454 can support two BLSRs on the same node. This allows you to deploy an ONS 15454 in applications requiring SONET digital cross connect systems (DCSs) or multiple SONET add/drop multiplexers (ADMs).
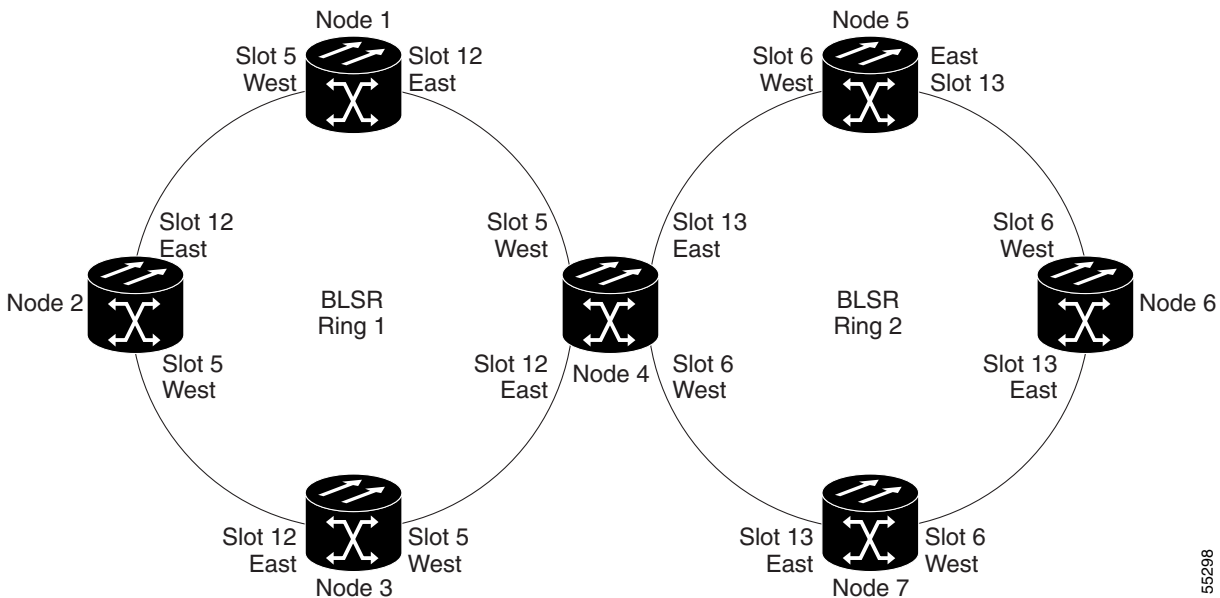
Figure 11-17 shows two BLSRs shared by one ONS 15454. Ring 1 runs on Nodes 1, 2, 3, and 4. Ring 2 runs on Nodes 4, 5, 6, and 7. Two BLSR rings, Ring 1 and Ring 2, are provisioned on Node 4. Ring 1 uses cards in Slots 5 and 12, and Ring 2 uses cards in Slots 6 and 13.

**Note**    Nodes in different BLSRs can have the same, or different node IDs.

*Figure 11-17 BLSR Subtending from a BLSR*

After subtending two BLSRs, you can route circuits from nodes in one ring to nodes in the second ring. For example, in Figure 11-17 you can route a circuit from Node 1 to Node 7. The circuit would normally travel from Node 1 to Node 4 to Node 7. If fiber breaks occur, for example between Nodes 1 and 4 and Nodes 4 and 7, traffic is rerouted around each ring: in this example, Nodes 2 and 3 in Ring 1 and Nodes 5 and 6 in Ring 2.

# 11.5 Linear ADM Configurations

You can configure ONS 15454s as a line of add/drop multiplexers (ADMs) by configuring one set of OC-N cards as the working path and a second set as the protect path. Unlike rings, linear (point-to-point) ADMs require that the OC-N cards at each node be in 1+1 protection to ensure that a break to the working line is automatically routed to the protect line.

Figure 11-18 shows three ONS 15454s in a linear ADM configuration. Working traffic flows from Slot 5/Node 1 to Slot 5/Node 2, and from Slot 12/Node 2 to Slot 12/Node 3. You create the protect path by placing Slot 6 in 1+1 protection with Slot 5 at Nodes 1 and 2, and Slot 12 in 1+1 protection with Slot 13 at Nodes 2 and 3.

*Figure 11-18 Linear (Point-to-Point) ADM Configuration*
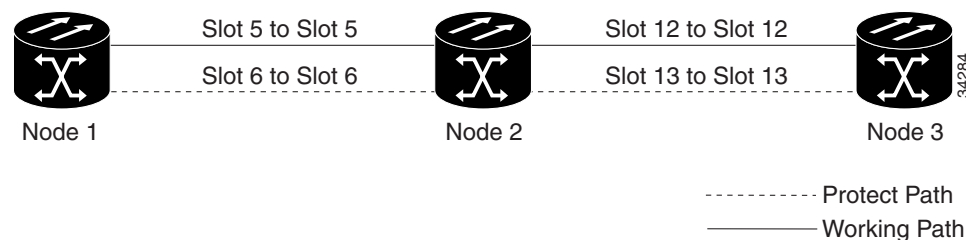


# 11.6 Path-Protected Mesh Networks

In addition to single BLSRs, path protection configurations, and ADMs, you can extend ONS 15454 traffic protection by creating path-protected mesh networks (PPMNs). PPMNs include multiple ONS 15454 SONET topologies and extend the protection provided by a single path protection to the meshed architecture of several interconnecting rings. In a PPMN, circuits travel diverse paths through a network of single or multiple meshed rings. When you create circuits, you can have CTC automatically route circuits across the PPMN, or you can manually route them. You can also choose levels of circuit protection. For example, if you choose full protection, CTC creates an alternate route for the circuit in addition to the main route. The second route follows a unique path through the network between the source and destination and sets up a second set of cross-connections.

For example, in Figure 11-19 on page 11-19 a circuit is created from Node 3 to Node 9. CTC determines that the shortest route between the two nodes passes through Node 8 and Node 7, shown by the dotted line, and automatically creates cross-connections at Nodes, 3, 8, 7, and 9 to provide the primary circuit path.

If full protection is selected, CTC creates a second unique route between Nodes 3 and 9 which, in this example, passes through Nodes 2, 1, and 11. Cross-connections are automatically created at Nodes 3, 2, 1, 11, and 9, shown by the dashed line. If a failure occurs on the primary path, traffic switches to the second circuit path. In this example, Node 9 switches from the traffic coming in from Node 7 to the traffic coming in from Node 11 and service resumes. The switch occurs within 50 ms.
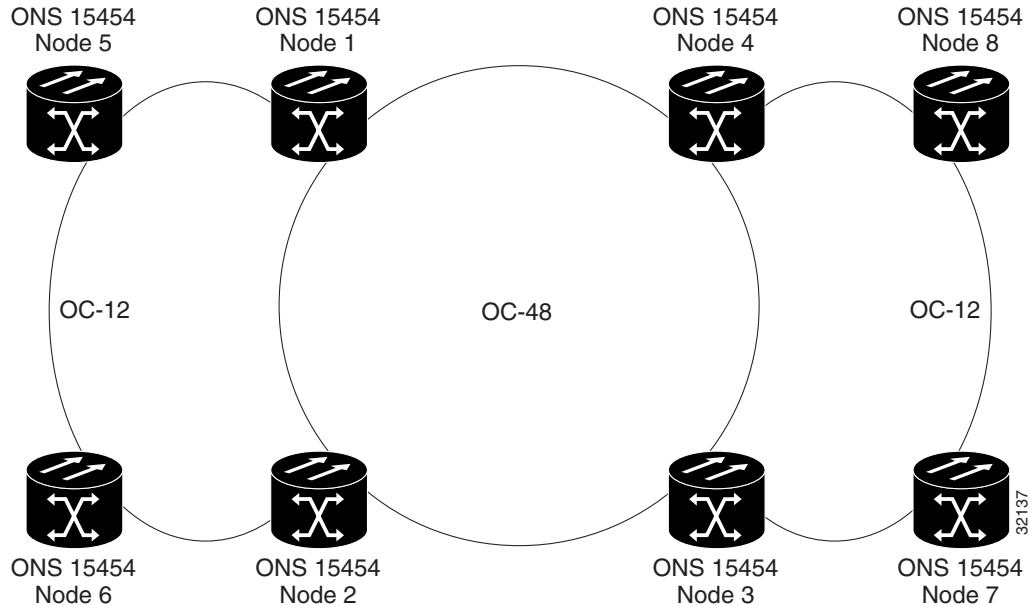
*Figure 11-19 Path-Protected Mesh Network*
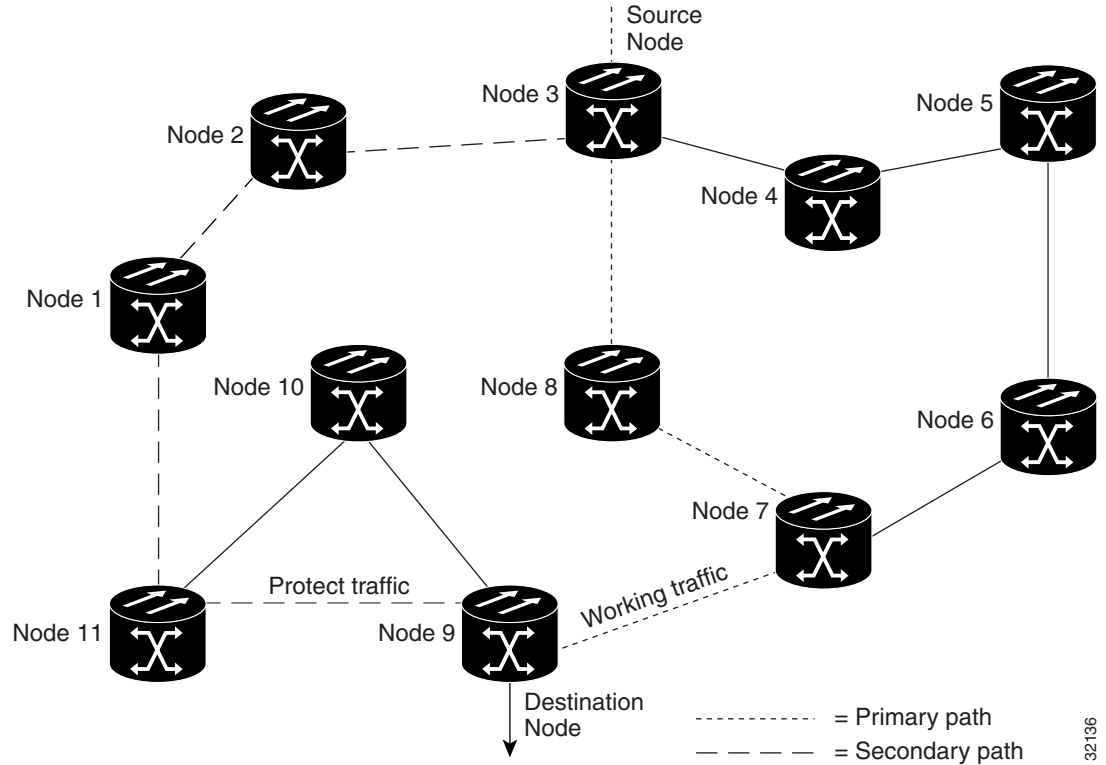


PPMN also allows spans with different SONET speeds to be mixed together in "virtual rings." Figure 11-20 on page 11-20 shows Nodes 1, 2, 3, and 4 in a standard OC-48 ring. Nodes 5, 6, 7, and 8 link to the backbone ring through OC-12 fiber. The "virtual ring" formed by Nodes 5, 6, 7, and 8 uses both OC-48 and OC-12 cards.

*Figure 11-20 PPMN Virtual Ring*



# 11.7  Four-Shelf Node Configurations

You can link multiple ONS 15454s using their OC-N cards (that is, create a fiber-optic bus) to accommodate more access traffic than a single ONS 15454 can support. Refer to the *Cisco ONS 15454 Procedure Guide*. For example, to drop more than 112 DS-1s or 96 DS-3s (the maximum that can be aggregated in a single node), you can link the nodes but not merge multiple nodes into a single ONS 15454. You can link nodes with OC-12 or OC-48 fiber spans as you would link any other two network nodes. The nodes can be grouped in one facility to aggregate more local traffic.

Figure 11-21 on page 11-21 shows a four-shelf node setup. Each shelf assembly is recognized as a separate node in the ONS 15454 software interface and traffic is mapped using CTC cross-connect options. In Figure 11-21 on page 11-21, each node uses redundant fiber-optic cards. Node 1 uses redundant OC-N transport and OC-N bus (connecting) cards for a total of four cards, with eight free slots remaining. Nodes 2 and 3 each use two redundant OC-N bus cards for a total of four cards, with eight free slots remaining. Node 4 uses redundant OC-12 bus cards for a total of two cards, with ten free slots remaining. The four-shelf node example presented here is one of many ways to set up a multiple-node configuration.

*Figure 11-21 Four-Shelf Node Configuration*
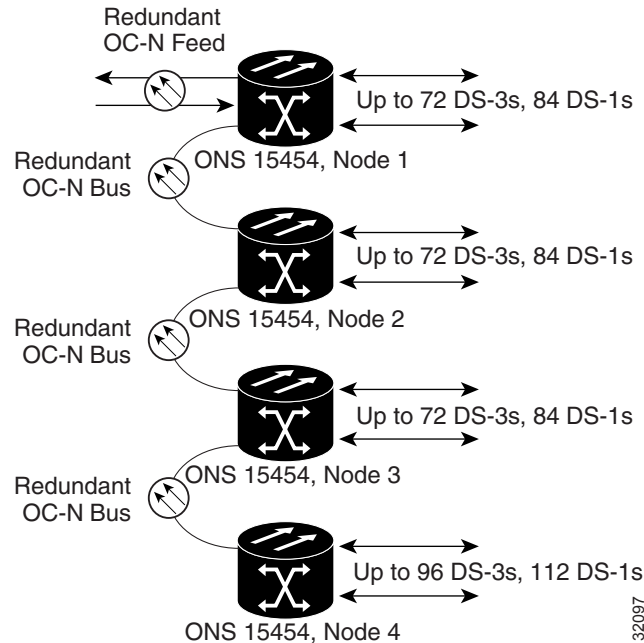


## 11.8  OC-N Speed Upgrades

A span is the optical fiber connection between two ONS 15454 nodes. In a span (optical speed) upgrade, the transmission rate of a span is upgraded from a lower to a higher OC-N signal but all other span configuration attributes remain unchanged. With multiple nodes, a span upgrade is a coordinated series of upgrades on all nodes in the ring or protection group. You can perform in-service span upgrades for the following ONS 15454 cards:

- Four-port OC-3 to eight-port OC-3
- Single-port OC-12 to four-port OC-12
- Single-port OC-12 to OC-48
- Single-port OC-12 to OC-192
- OC-48 to OC-192

Use the XC10G card, the TCC+ card, Software R3.1 or later, and the 15454-SA-ANSI shelf assembly to enable the OC48AS and the OC192 cards. The TCC2 card also supports OC48AS and OC192 cards, but Software R4.0 or later must be used.

To perform a span upgrade, the higher-rate OC-N card must replace the lower-rate card in the same slot. If the upgrade is conducted on spans residing in a BLSR, all spans in the ring must be upgraded. The protection configuration of the original lower-rate OC-N card (two-fiber BLSR, four-fiber BLSR, path protection, and 1+1) is retained for the higher-rate OC-N card.

When performing span upgrades on a large number of nodes, we recommend that you upgrade all spans in a ring consecutively and in the same maintenance window. Until all spans are upgraded, mismatched card types are present.

We recommend using the Span Upgrade Wizard to perform span upgrades. Although you can also use the manual span upgrade procedures, the manual procedures are mainly provided as error recovery for the wizard. The Span Upgrade Wizard and the Manual Span Upgrade procedures require at least two technicians (one at each end of the span) who can communicate with each other during the upgrade. Upgrading a span is non-service affecting and causes no more than three switches, each of which is less than 50 ms in duration.

**Note** Span upgrades do not upgrade SONET topologies, for example, a 1+1 group to a two-fiber BLSR. Refer to the *Cisco ONS 15454 Procedure Guide* for topology upgrade procedures.

## 11.8.1  Span Upgrade Wizard

The Span Upgrade Wizard automates all steps in the manual span upgrade procedure (BLSR, path protection, and 1+1). The wizard can upgrade both lines on one side of a four-fiber BLSR or both lines of a 1+1 group; the wizard upgrades path protection configurations and two-fiber BLSRs one line at a time. The Span Upgrade Wizard requires that spans have DCCs enabled.

The Span Upgrade Wizard provides no way to back out of an upgrade. In the case of an error, you must exit the wizard and initiate the manual procedure to either continue with the upgrade or back out of it. To continue with the manual procedure, examine the standing conditions and alarms to identify the stage in which the wizard failure occurred.

## 11.8.2  Manual Span Upgrades

Manual span upgrades are mainly provided as error recovery for the Span Upgrade Wizard, but they can be used to perform span upgrades. Downgrading can be performed to back out of a span upgrade. The procedure for downgrading is the same as upgrading except that you choose a lower-rate card type. You cannot downgrade if circuits exist on the STSs that will be removed (the higher STSs).

Procedures for manual span upgrades can be found in the "Upgrade Cards and Spans" chapter in the *ONS 15454 SDH Procedure Guide*. Five manual span upgrade options are available:

- Upgrade on a two-fiber BLSR
- Upgrade on a four-fiber BLSR
- Upgrade on a Path Protection
- Upgrade on a 1+1 protection group
- Upgrade on an unprotected span