3 Protection in an MPLS-Enabled IP-Over-WDM Network

Overview

A pan-European service provider has deployed an IP/MPLS network on top of a DWDM transport network. They would like to explore the advantages and disadvantages of the various protection alternatives to deliver label switched paths (LSPs) that are resilient to single optical cable failures.

Objectives

1) Define the relationships between an IP network in SP Guru Network Planner and a DWDM network in SP Guru Transport Planner using XML files.

2) Investigate whether or not MPLS protection suffices to survive failures in the optical and IP network.

3) Use the multi-layer model of the network to correctly define protection LSPs at the IP/MPLS layer, based on information propagated from the optical transport network.

4) Compare protection at the optical layer with MPLS protection.

Instructions

In the first procedure, Procedure 3-1, you set up an MPLS network with LSPs and define the mapping between the Layer-2/3 network and the Transport network.

Procedure 3-1 Defining the MPLS Label Switched Paths

1 Open the **SWIM_Tutorial_MPLS_Protection** project SP Guru Network Planner.

1.1 Select **File > Open**.

1.2 Select the project file **SWIM_Tutorial_MPLS_Protection**. Click **Open**. Note that the current scenario is called **bare.**

2 Inspect the Layer-2/3 and Transport networks.

2.1 Note that 10 LSPs are defined in SP Guru Network Planner. These LSPs are displayed in different colors in the workspace. The network has been configured to enable MPLS: the OSPF routing protocol is running on all routers, RSVP is running on all interfaces for control messages to set up the LSPs, and MPLS is also enabled on these interfaces.

2.2 Select SWIM **> Switch To Corresponding Transport Network** to view the transport network topology.

2.3 Select SWIM **> Switch To Corresponding Layer-2/3 Network**.

3 Verify that SWIM **> Automatically Update Operational Status Visualization** is turned on. This displays overlay icons for Layer-2/3 links if they are mapped onto Transport connections when those connections are not up.

4 Define the node mapping to relate the Layer-2/3 network to the underlying Transport network.

4.1 Select SWIM **> Node/Link Mapping > Map Nodes...**.

4.2 Map the Layer-2/3 nodes to their respective namesakes at the Transport Nodes side by selecting a node in the left pane and clicking the **>>** button.

4.3 Click **OK** to close the dialog box.

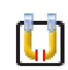
5 Import the link mapping from an XML file containing the mapping information.

5.1 Select SWIM **> Node/Link Mapping > Map Links...**.

5.2 Click the **Import** button.

5.3 Browse for the file **SWIM_Tutorial_MPLS_Protection_Mapping_to_Import.xml** in the folder <*install_dir*>\<*release*>\models\std\swim\examples directory. Click **Open**. This results in the successful import of 15 link mappings. Close the **SWIM – Import Link Mapping Results** dialog box that appears.

5.4 Apply the link mapping by choosing **OK** from the **SWIM – Map Links** dialog. Note that the operational status of all 1000BaseX links is down since they have now been mapped onto Transport connections that have not been set up yet (they will have an overlay icon).



5.5 Note that the overlay icons are not displayed automatically if SWIM > **Automatically Update Operational Status Visualization** is off. In that case, you can either turn it on or manually display the icons by selecting **Topology > Visualize Operational Status > Visualize**.

6 Save the project.

6.1 Select **File > Save as** and save the file as **<*initials*>_SWIM_Tutorial_MPLS_Protection**.

End of Procedure 3-1

After setting up the integrated network, you can do the first design. This design maps the IP links to transport network connections, routed without protection in SP Guru Transport Planner. The LSPs are set up using the traffic engineering design action in SP Guru Network Planner. The LSPs are protected by routing them along a link disjoint primary and secondary explicit route (ER) without accounting for any transport layer information.

Procedure 3-2 Dimension with MPLS Protection

1 Create the **MPLS_protection_link_disjoint** scenario.

1.1 Select **Scenarios > Duplicate Scenario**.

1.2 Name the scenario **MPLS_protection_link_disjoint**. Click **OK.** This copies the **bare** scenario to the **MPLS_protection_link_disjoint** scenario (in the same project).

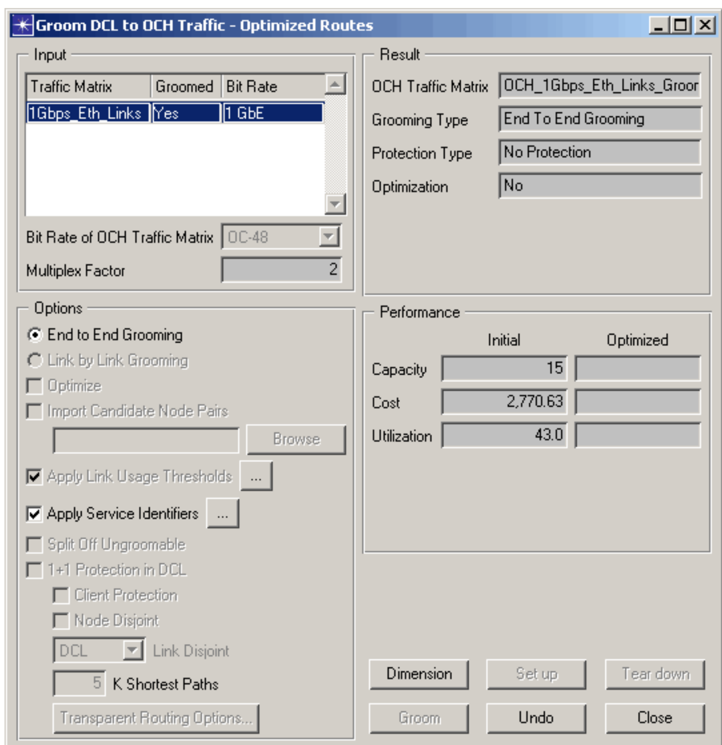
2 Switch to the Transport network: select SWIM **> Switch To Corresponding Transport Network**.

3 Accommodate the IP links on the transport network in an unprotected way.

3.1 Select **Design > Groom DCL to OCH Traffic > Optimized Routes...**.

3.2 Select the **1Gbps_Eth_Links** traffic matrix, choose **OC-48** as bit rate for the supporting OCH traffic matrix and select **End to End Grooming**. Do not select **Optimize** or **1+1 Protection in DCL**. Click **Groom**.

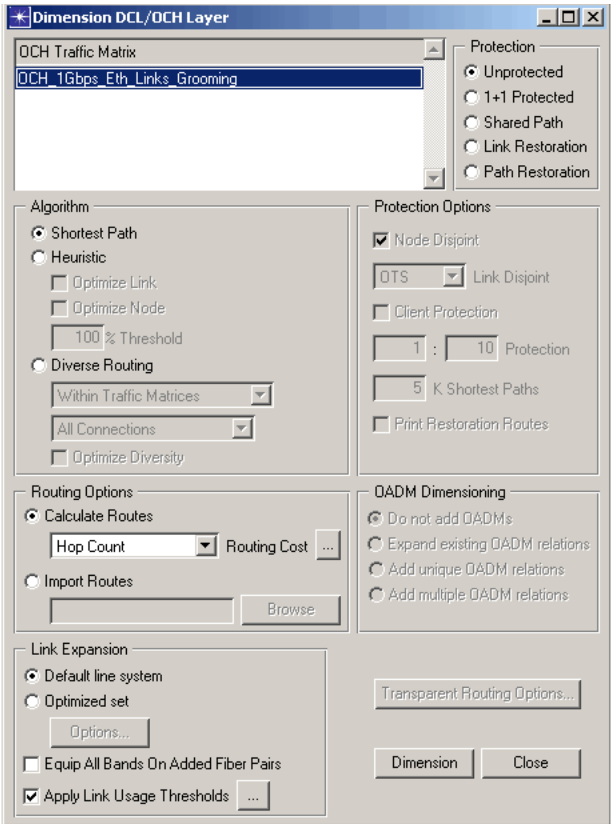
Figure 3-1 Groom DCL to OCH Traffic Dialog Box



3.3 A new OCH traffic matrix **OCH_1Gbps_Eth_Links_Grooming** is created as a result of this grooming action. Click **Dimension** to accommodate this optical traffic matrix in the network.

3.4 The **Dimension DCL/OCH Layer** dialog box appears. Select the newly created OCH traffic matrix **OCH_1Gbps_Eth_Links_Grooming**. Select **Unprotected** (Protection) and keep the default settings for the other options.

Figure 3-2 Dimension DCL/OCH Layer Dialog Box



3.5 Click **Dimension**. The **Results of Dimensioning** dialog box appears. Note that both the traffic matrices, **OCH_1Gbps_Eth_Links_Grooming** and **1Gbps_Eth_Links**, are now entirely accommodated in the network. This is possible due to the addition of 13 fiber pairs and 76 OXC ports.

3.6 Close all dialog boxes.

4 Switch to the Layer-2/3 network.

4.1 Select SWIM **> Switch To Corresponding Layer-2/3 Network**.

4.2 Note the links no longer have overlay icons—all links are up and running.

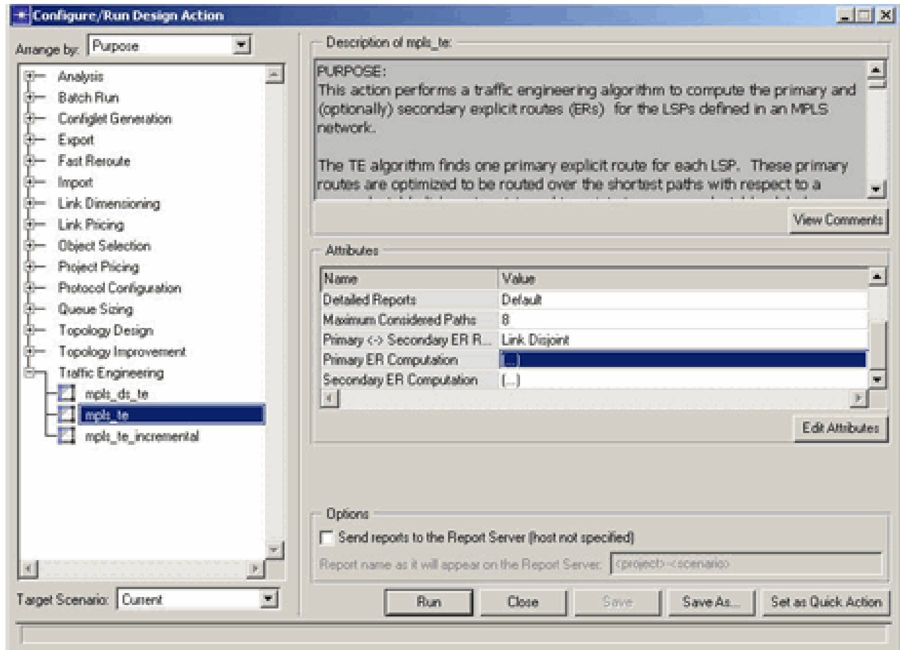
5 The transport network has been designed to support the IP links and route the LSPs in the IP network on a primary and a secondary route, using the traffic engineering design action.

5.1 Select **Design > Configure/Run Design Action...**.

5.2 Click on the **+** icon next to **Traffic Engineering** on the left side of the **Configure/Run Design Action** dialog box. Select **mpls_te**.

5.3 Select **Current** (Target Scenario) in the lower-left corner of the **Configure/Run Design Action** dialog box.

Figure 3-3 Configure/Run Design Action Dialog Box

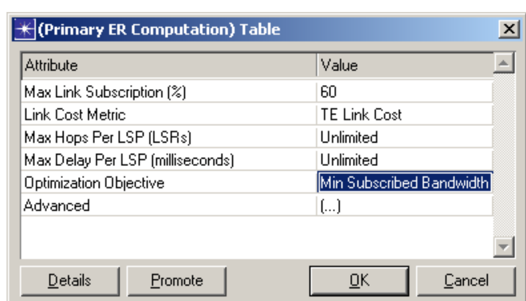


5.4 Click the **Edit Attributes...** button to specify the details of the design action. The **Design Action: mpls_te** dialog box appears.

5.5 Select **Link Disjoint** (Primary <-> Secondary ER Relationship). This ensures that the primary and secondary explicit routes are not using a common IP link.

5.6 Click on the **Value** field for **Primary ER Computation**. The **(Primary ER Computation) Table** dialog box opens. Choose **Min Subscribed Bandwidth** (Optimization Objective) and click **OK**. This ensures that the primary paths are routed such that the amount of subscribed bandwidth on the links is minimized.

Figure 3-4 Primary ER Computation Attribute



5.7 Repeat the previous step for **Secondary ER Computation**.

5.8 Click **OK** in the **Design Action: mpls_te** dialog box.

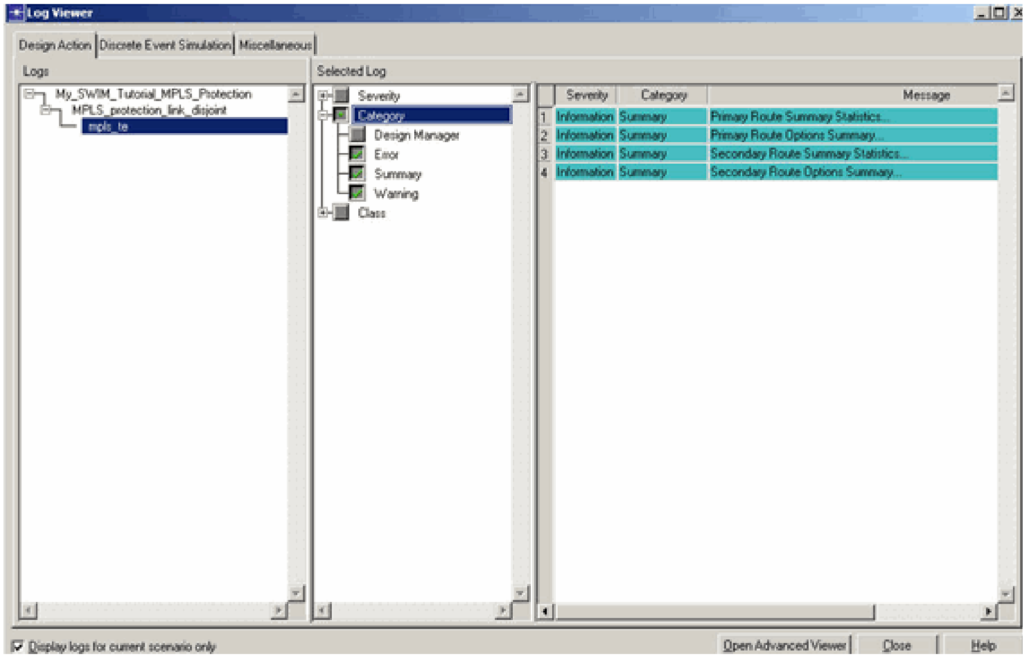
5.9 Ensure that the **Target Scenario** setting at the bottom of the **Configure/Run Design Action** dialog box is **Current** and click **Run**.

6 Inspect the results of traffic engineering.

6.1 Click the **View Log** button in the **Action Completed** dialog box that appears.

6.2 The **Log Browser** dialog box opens.

Figure 3-5 Log Browser for MPLS TE Design Action



6.3 Select **Category > Summary** and click **Primary Route Summary Statistics** (Message column). The **Log Entry 2** dialog box opens. Note that all of the LSPs have been successfully routed. The log reports that 1,800 Mb/s out of 30,000 Mb/s have been subscribed.

6.4 Close the **Log Entry 2** dialog box.

6.5 Repeat the previous steps for the **Secondary Route Summary Statistics**. The log shows that both the primary and secondary routes subscribed 2,800 Mb/s out of 30,000 Mb/s. Compared to the total subscribed bandwidth for primary route in 6.3, the additional subscribed bandwidth for secondary route is only 1,000 Mb/s. Because the mpls_te action uses shared path protection to compute secondary routes, these routes can share their subscribed bandwidth whenever their primary routes do not fail at the same time. This is the reason for the low subscribed bandwidth of the secondary routes.

6.6 Close the dialog boxes.

7 Inspect the route followed by the LSP from **Dublin** to **Milan.**

7.1 Select **View > Show Network Browser**.

7.2 Select **LSPs by Source** in the drop-down list.

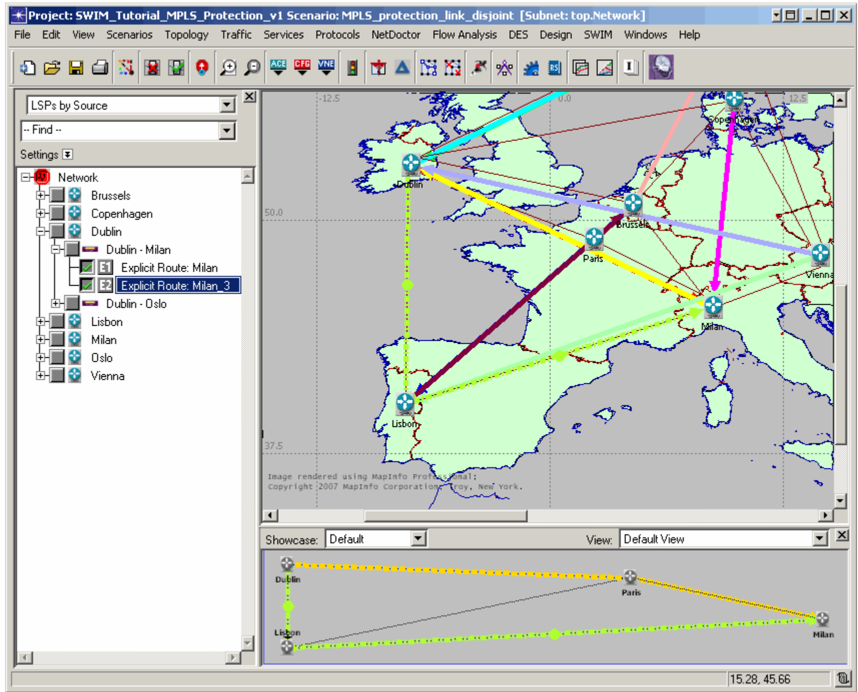
7.3 Click on the **+** icon next to the node **Dublin**. Expand the connection **Dublin - Milan**.

7.4 Mark both explicit routes.

➥ Both routes are now displayed in the lower part of the dialog box.

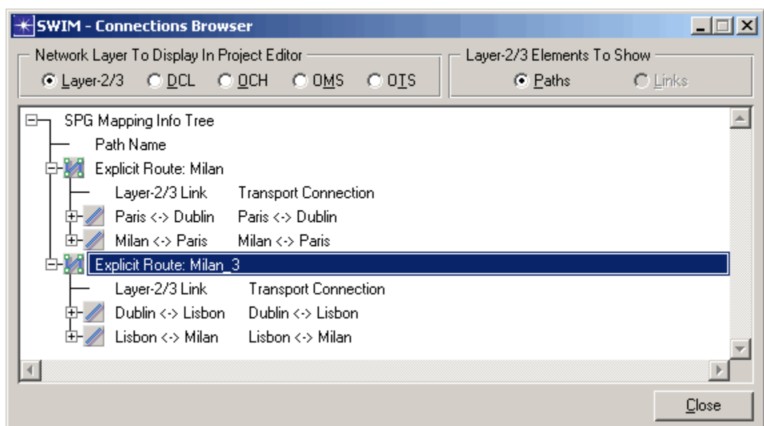
7.5 Select the routes by using Ctrl-click.

Figure 3-6 MPLS Paths Between Dublin and Milan



7.6 Select SWIM **> Open Connections Browser For Selection...** to view the two explicit routes in the SWIM connections browser (do not close the Connections Browser).

Figure 3-7 SWIM Connections Browser



7.7 Select **OTS** (Network Layer to Display In Project Editor) to visualize the primary and secondary routes on the physical layer. Both primary and secondary routes for the LSP from Dublin to Milan pass through the cable between **Dublin** and **Paris**. Therefore, the LSP is lost if that cable breaks. This is because MPLS-TE designed the routes to be IP link disjoint rather than OTS link disjoint.

7.8 Close the **SWIM Connections Browser**.

8 Close the **Network Browser**.

9 Ensure that SWIM **> Automatically Update Operational Status Visualization** is on.

10 Switch to the Transport network: select SWIM **> Switch To Corresponding Transport Network**.

11 Perform failure analysis.

11.1 Select **Info > Failure Analysis**. The **Failure Analysis** dialog box appears.

11.2 Click on the **OTS** button on the toolbar to visualize the OTS layer. Right-click on the link between the nodes **Lisbon** and **Paris**. Select **Fail This Cable**.

11.3 Click **Evaluate** in the **Failure Analysis** dialog box. This reveals that 2 wavelengths and 2 STS connections are affected by the cable failure. None are recovered since the network was designed without protection at the DCL and OCH layers.

11.4 Keep the **Failure Analysis** dialog box open.

11.5 Select SWIM **> Switch To Corresponding Layer-2/3 Network**. The operational status visualization shows that the IP links **Dublin <-> Lisbon** and **Paris <-> Lisbon** are failing due to the cable break.

11.6 Select **View > Show Network Browser**.

11.7 Select **LSPs by Source** in the drop-down list.

11.8 Close the **Network Browser**.

11.9 Return to SP Guru Transport Planner: select SWIM **> Switch To Corresponding Transport Network**.

11.10 Close the **Failure Analysis** dialog box to end the failure simulation.

12 Switch to the Layer-2/3 network: select SWIM **> Switch To Corresponding Layer-2/3 Network**.

13 Save the project.

13.1 Select **File > Save** (or click **Ctrl+S**).

14 Perform survivability analysis in the Layer-2/3 network.

14.1 Right-click on the router in the **Paris** node and select **Fail This Node**.

14.2 Select **View > Show Network Browser** to inspect the LSPs that are affected and lost by the router failure in node **Paris**. You will find that the LSPs **Brussels -> Lisbon**, **Dublin -> Milan** and **Lisbon -> Brussels** are all affected by the router failure. None of these are lost, however, because their secondary routes do not cross the **Paris** node.

14.3 Right-click on the **Paris** node and select **Recover This Node** to repair the router failure.

15 Close the **Network Browser**.

End of Procedure 3-2

In Procedure 3-3, you will do another design. The optical layer is designed as it was in the first design, which means that the IP links are mapped to transport network connections without protection. This time, however, the primary and secondary explicit routes of the LSPs are diverse down to the physical layer.

Procedure 3-3 Dimension with MPLS protection and SRGs

1 Create the **MPLS_protection_SRG_disjoint** scenario.

1.1 Select **Scenarios > Duplicate Scenario**.

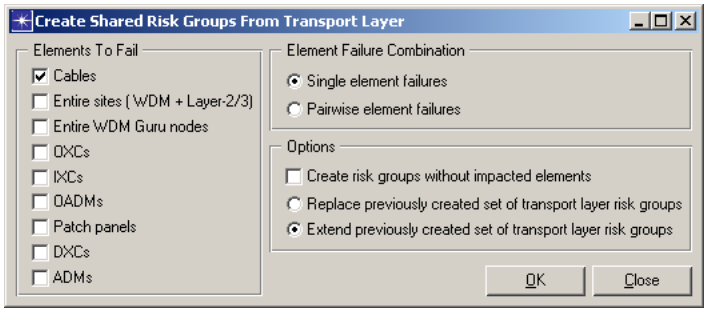
1.2 Name the scenario **MPLS_protection_SRG_disjoint** and click **OK**.

2 Create Shared Risk Groups (SRGs) based on a single cable break in the optical Transport network. SRGs express the relationship between Risk Elements (in this case, cable failures) and Impacted Elements (in this case, IP links).

2.1 Select SWIM **> Create Shared Risk Groups From Transport Network...**.

2.2 Select only **Cables** in the Elements to Fail list and select **Single element failures** (Element Failure Combination). Click **OK**. This creates one SRG for every cable on the transport layer. The impacted elements of each SRG represent the IP links that fail as a result of the cable failure.

Figure 3-8 Create Shared Risk Group from Transport Layer Dialog Box



2.3 Inspect the SRGs created in the network browser at the left side of the Project Editor. The SRGs are named **Transport Risk Group – Cable X <-> Y**, representing a SRG for a cable between nodes **X** and **Y**. For instance, there is a risk group for the cable break between **Brussels** and **London**—if this cable breaks, the IP links **Copenhagen<->Dublin** and **Dublin<->Brussels** will fail.

2.4 Turn off **View > Show Network Browser** (or click **Ctrl+B**) to close the network browser.

3 Design the LSP routes again. Use the traffic engineering algorithm, taking the SRGs into account to obtain primary and secondary routes at the physical layer.

3.1 Select **Design > Configure/Run Design Action...**.

3.2 Click on the **+** icon next to **Traffic Engineering** at the left side of the **Configure/Run Design Action** dialog box. Select **mpls_te**.

3.3 Ensure that **Current** (Target Scenario) is selected in the lower-left corner of the **Configure/Run Design Action** dialog box.

3.4 Click the **Edit Attributes...** button. The **Design Action: mpls_te** dialog box appears. Select **SRG Disjoint** (Primary <-> Secondary ER Relationship).

3.5 Click on the **Value** field for **Primary ER Computation**. The **Primary ER Computation** dialog box opens. Select **Min Subscribed Bandwidth** (Optimization Objective) and click **OK**.

3.6 Repeat the previous step for **Secondary ER Computation**.

3.7 Click **OK** in the **Design Action: mpls_te** dialog box.

3.8 Click **Run** in the **Configure/Run Design Action** dialog box.

3.9 Click the **View Log** button when the **Action Completed** dialog box appears.

3.10 The **Log Browser** dialog box opens.

3.11 Select **Category > Summary** and click on **Primary Route Summary Statistics**. The **Log Entry 2** dialog box appears. Inspect the results and close the dialog box. Do the same for **Secondary Route Summary Statistics**. The log messages report that primary routes have subscribed 1,800 Mb/s for the LSPs and the secondary 3,700 Mb/s. Note that the value for the secondary route is higher without considering SRGs (see step 7.7 in Procedure 3-2 of this tutorial). This is due to the fact that the secondary routes have to follow longer paths to respect the SRG disjointedness. This is also due to the fact that the chance to share the subscribed bandwidth among secondary routes is also smaller for SRG disjointness.

3.12 Close the dialog boxes.

4 Switch to the Transport network: select SWIM **> Switch To Corresponding Transport Network**.

5 Perform failure analysis.

5.1 Select **Info > Failure Analysis** to start the failure simulation.

5.2 Use the **OTS** toolbar button to visualize the OTS layer. Right-click on the link between **Lisbon** and **Paris** and select **Fail This Cable**.

5.3 Click **Evaluate** in the **Failure Analysis** dialog box.

5.4 Without closing the **Failure Analysis** dialog box, select SWIM **> Switch To Corresponding Layer-2/3 Network**.

5.5 Select **View > Show Network Browser**.

5.6 Select **LSPs by Source** in the drop-down list to inspect the primary and secondary routes taken by each LSP. You will find that the primary routes of the LSPs between **Lisbon** and **Brussels** are affected by the cable break. Both LSPs are recovered because their secondary route remains unaffected.

5.7 Close the **Network Browser**.

6 Switch to the Transport network: select SWIM **> Switch To Corresponding Transport Network**.

6.1 Close the **Failure Analysis** dialog box to end the failure simulation.

7 Save the project.

7.1 Select **File > Save** (or click **Ctrl+S**).

8 Perform failure analysis for a node failure.

8.1 Select **Info > Failure Analysis** to start the failure simulation.

8.2 Use the **OTS** toolbar button to view the OTS layer. Right-click on the node **Paris** and select **Fail This Node**.

8.3 Click **Evaluate** in the **Failure Analysis** dialog box.

8.4 Select SWIM **> Switch To Corresponding Layer-2/3 Network** (do not close the **Failure Analysis** dialog box).

8.5 Select **View > Show Network Browser** to inspect the affected LSPs. None of the LSPs are lost. Note that this is not guaranteed by the MPLS-TE design, since we only based it on SRGs for single cable breaks. (You could design the LSP routes to be resilient to all optical node failures—except LSP end node failures—by first generating SRGs for single node failures and subsequently running the mpls_te design action to find primary and secondary ERs that are SRG disjoint.)

8.6 Switch to the Transport network: select SWIM **> Switch To Corresponding Transport Network**.

8.7 Close the **Failure Analysis** dialog box to end the failure simulation.

8.8 Select SWIM **> Switch To Corresponding Layer-2/3 Network**.

9 Close the Connections Browser.

End of Procedure 3-3

A final design investigates the effect of protection at the optical layer (instead of protection at the MPLS layer). To create this effect, the LSPs are routed without protection, but the IP links are protected by mapping them on protected connections at the transport layer. This also ensures protection against all single cable failures.

Procedure 3-4 Dimension with Protection at the Optical OCH Layer

1 Create the **OCH_protection** scenario.

1.1 Select **Scenarios > Switch to Scenario > bare** to return to the **bare** scenario.

1.2 Select **Scenarios > Duplicate Scenario**.

1.3 Name the scenario **OCH_protection** and click **OK**.

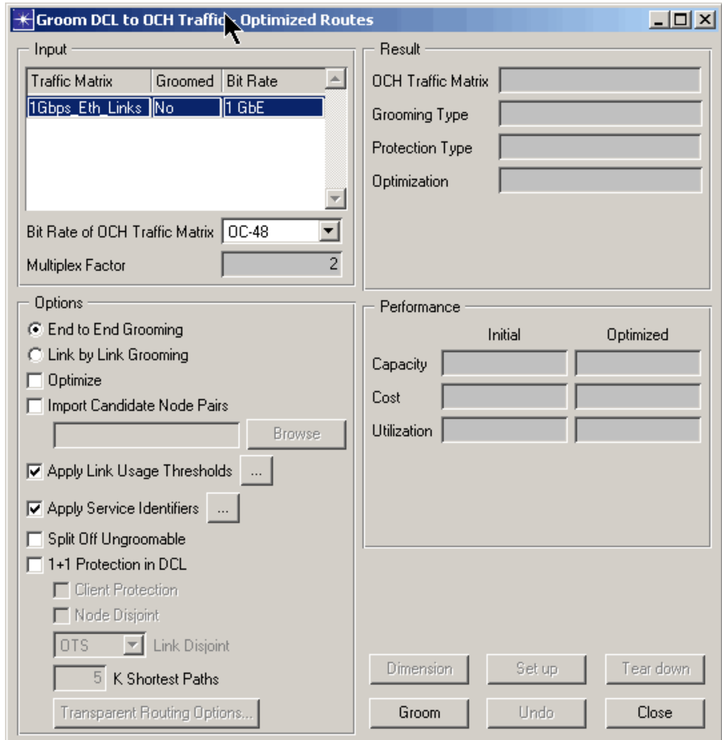
2 Switch to the Transport network: select SWIM **> Switch To Corresponding Transport Network**.

3 Dimension the Transport network with protection at the optical layer.

3.1 Select **Design > Groom DCL to OCH Traffic > Optimized Routes...**.

3.2 Select the **1Gbps_Eth_Links** traffic matrix, choose **OC-48** as the bit rate for the supporting OCH traffic matrix and select **End to End Grooming**. Do not select **Optimize** or **1+1 Protection in DCL**. Click **Groom**.

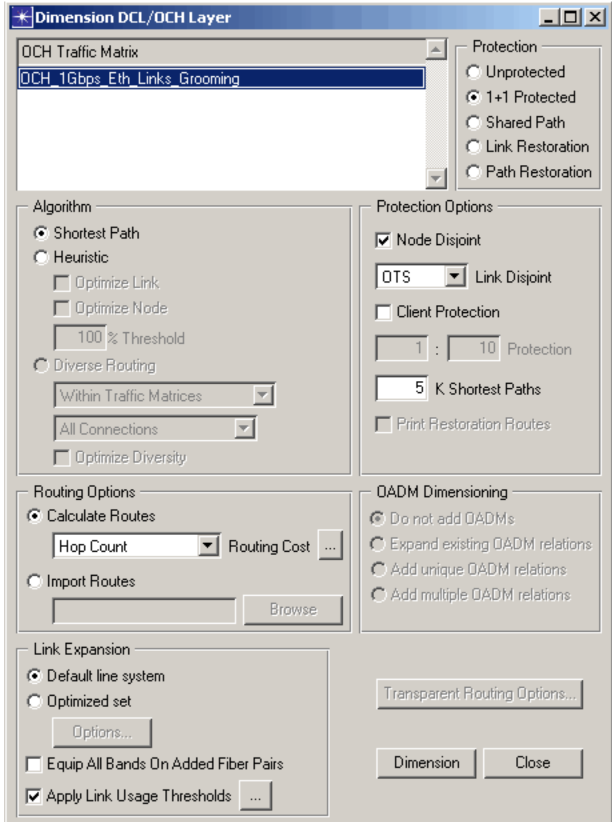
Figure 3-9 Groom DCL to OCH Traffic Dialog Box



3.3 Click the **Dimension** button. This opens the **Dimension OCH/DCL Layer** dialog box, which lets you accommodate the newly created OCH traffic matrix **OCH_1Gbps_Eth_Links_Grooming** in the network (with protection).

3.4 Select the **OCH_1Gbps_Eth_Links_Grooming** traffic matrix and **1+1 Protected** (Protection). Keep the default settings for the other options. Click **Dimension**.

Figure 3-10 Dimension DCL/OCH Layer Dialog Box



3.5 The traffic matrix **OCH_1Gbps_Eth_Links_Grooming** is now entirely accommodated in the network using the 1+1 protection scheme. The **Dimensioning Results** dialog box opens. It reports that 14 fiber pairs and 138 OXC ports have been added to the network. This is more than in previous tasks (see step 5.5 of Procedure 3-2). We have dimensioned the optical layer for the same traffic matrix but additional capacity is now needed to ensure optical protection.

3.6 Close all dialog boxes.

4 Switch to the Layer-2/3 network: Select SWIM **> Switch To Corresponding Layer-2/3 Network** to return to the SP Guru network.

If SWIM **> Automatically Update Operational Status Visualization** was on, notice that the overlay icons [U] have disappeared because the Transport connections that support mapped SP Guru links are now set up.

5 Design the LSP routes again, using the traffic engineering algorithm, this time do not provide protection at the MPLS layer.

5.1 Select **Design > Configure/Run Design Action...**.

5.2 Click on the **+** icon next to **Traffic Engineering** at the left side of the **Configure/Run Design Action** dialog box. Select **mpls_te**.

5.3 Select **Current** (Target Scenario) in the lower left corner of the **Configure/Run Design Action** dialog box.

5.4 Click **Edit Attributes...**. The **Design Action: mpls_te** dialog box appears. Select **No Secondary ER** (Primary <-> Secondary ER Relationship).

5.5 Click on the **Value** field for **Primary ER Computation**. The **(Primary ER Computation) Table** dialog box opens. Select **Min Subscribed Bandwidth** (Optimization Objective) and click **OK**.

5.6 Click **OK** in the **Design Action: mpls_te** dialog box.

5.7 Ensure that **Current** is selected as **Target**. Click **Run** in the **Configure/Run Design Action** dialog box.

5.8 Click the **View Log** button when the **Action Completed** dialog box appears.

5.9 The **Log Browser** dialog box opens.

5.10 Select **Category > Summary** and click **Primary Route Summary Statistics**. The **Log Entry 2** dialog box appears. The results reported in the logs show that only primary routes are set up and that they consume 1,800 Mb/s. Thus, we save bandwidth at the MPLS layer compared to previous designs because no secondary explicit routes were set up.

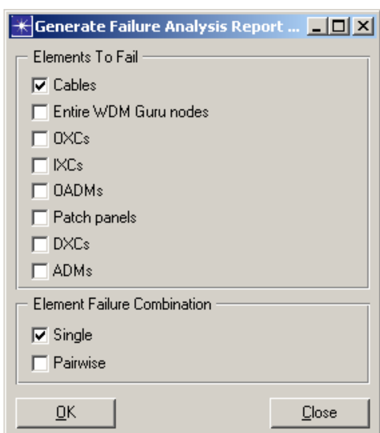
5.11 Close the dialog boxes.

6 Generate a SWIM failure analysis web report to study the effect of optical cable cuts on the SP Guru network.

6.1 From the menu in SP Guru, choose SWIM **> Generate Failure Analysis Report For Transport Network Failures...**

6.2 In the dialog that appears, ensure that **Cables** are selected as Elements To Fail, and **Single** as Element Failure Combination.

Figure 3-11 Generate Failure Analysis Report Dialog Box



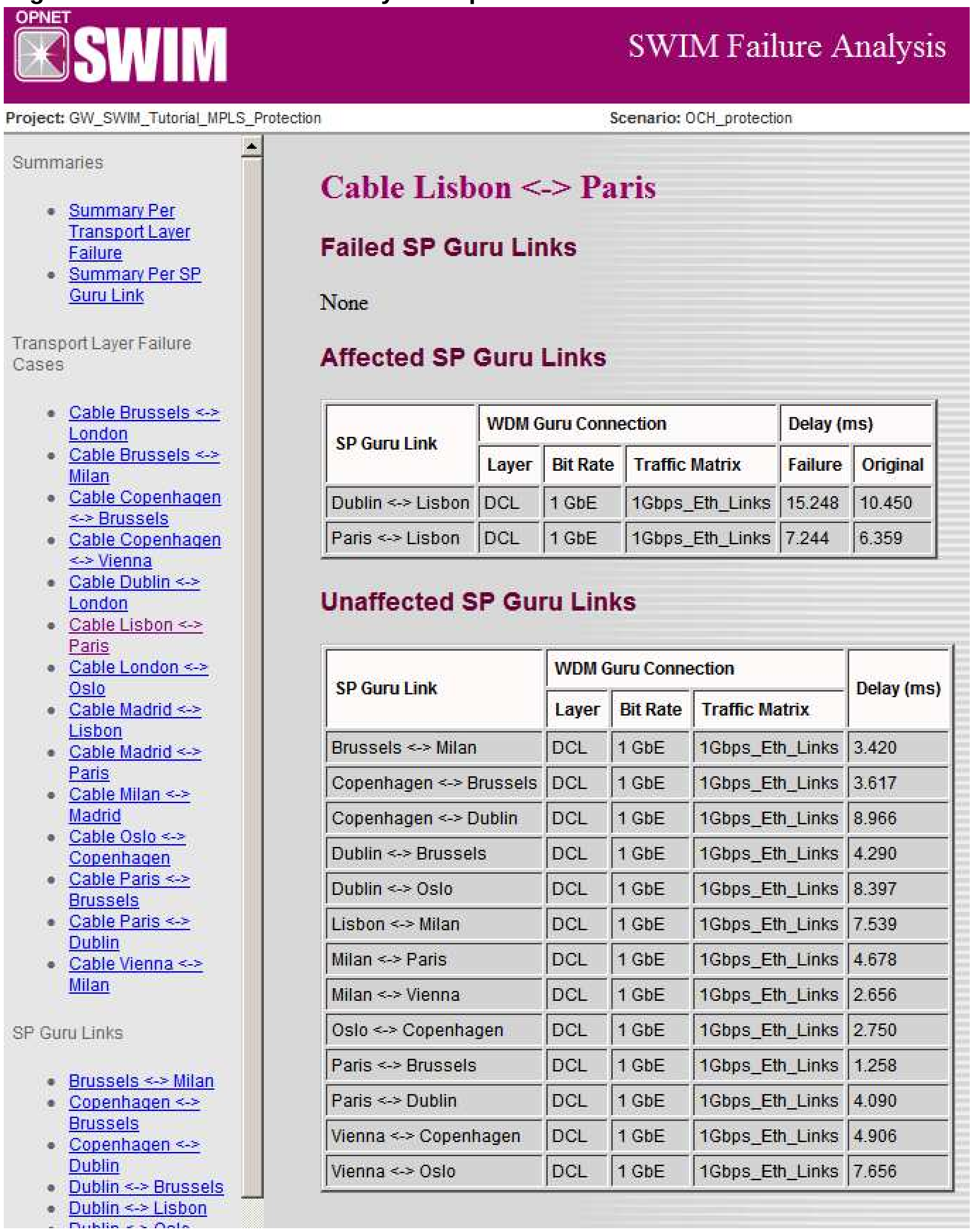
6.3 Click **OK** in the **Generate Failure Analysis Report...** dialog box. This opens a web browser for the requested failure analysis report.

6.4 In the **Summary Per Transport Layer Failure** sheet that opens by default, scroll down to the **Transport Layer Failure Cases** table. Note that none of the single cable failures causes SP Guru links to go down, since you have provided protection at the optical layer (OCH).

6.5 From the Transport Layer Failure Cases list in the left- hand side frame, select **Cable Lisbon <-> Paris**.

6.6 The **Affected SP Guru Links** table shows that a cable cut between Lisbon and Paris results in two SP Guru links to be affected: their delay increases because of a switch over to a longer protection path at the optical OCH layer.

Figure 3-12 SWIM Failure Analysis Report



SP Guru Link	WDM Guru Connection			Delay (ms)	
	Layer	Bit Rate	Traffic Matrix	Failure	Original
Dublin <-> Lisbon	DCL	1 GbE	1Gbps_Eth_Links	15.248	10.450
Paris <-> Lisbon	DCL	1 GbE	1Gbps_Eth_Links	7.244	6.359

SP Guru Link	WDM Guru Connection			Delay (ms)
	Layer	Bit Rate	Traffic Matrix	
Brussels <-> Milan	DCL	1 GbE	1Gbps_Eth_Links	3.420
Copenhagen <-> Brussels	DCL	1 GbE	1Gbps_Eth_Links	3.617
Copenhagen <-> Dublin	DCL	1 GbE	1Gbps_Eth_Links	8.966
Dublin <-> Brussels	DCL	1 GbE	1Gbps_Eth_Links	4.290
Dublin <-> Oslo	DCL	1 GbE	1Gbps_Eth_Links	8.397
Lisbon <-> Milan	DCL	1 GbE	1Gbps_Eth_Links	7.539
Milan <-> Paris	DCL	1 GbE	1Gbps_Eth_Links	4.678
Milan <-> Vienna	DCL	1 GbE	1Gbps_Eth_Links	2.656
Oslo <-> Copenhagen	DCL	1 GbE	1Gbps_Eth_Links	2.750
Paris <-> Brussels	DCL	1 GbE	1Gbps_Eth_Links	1.258
Paris <-> Dublin	DCL	1 GbE	1Gbps_Eth_Links	4.090
Vienna <-> Copenhagen	DCL	1 GbE	1Gbps_Eth_Links	4.906
Vienna <-> Oslo	DCL	1 GbE	1Gbps_Eth_Links	7.656

7 Investigate the effect of a router failure.

7.1 Right-click on the router in node **Paris** and select **Fail This Node**.

7.2 Select **View > Show Network Browser** and select **LSPs by Source** in the drop-down list to inspect the LSPs that are affected and lost by the router failure in the **Paris** node. Notice that the LSPs **Brussels -> Lisbon**, **Dublin -> Milan**, and **Lisbon -> Brussels** are lost due to the router failure. There are no secondary routes and the optical layer protection does not protect against IP router failures.

7.3 Close the **Network Browser**.

7.4 Right-click on the **Paris** node and select **Recover This Node** to repair the router failure.

8 Investigate the effect of a node failure.

8.1 Select SWIM **> Switch To Corresponding Transport Network** to return to the Transport network.

8.2 Select **Info > Failure Analysis** to start the failure simulation.

8.3 Use the **OTS** button on the toolbar to view the OTS layer. Right-click on the **Paris** node and select **Fail This Node**.

8.4 Click **Evaluate** in the **Failure Analysis** dialog box.

8.5 Return to SP Guru by selecting SWIM **> Switch To Corresponding Layer-2/3 Network** (do not close the **Failure Analysis** dialog box).

8.6 Select **View > Show Network Browser** and select **LSPs by Source** in the drop-down list to inspect the affected LSPs. The LSPs **Brussels -> Lisbon, Dublin -> Milan**, **Lisbon -> Brussels** are lost. OCH protection does protect against optical node failures unless the node is an end point of an optical connection. In this case, the IP links terminating in the **Paris** node are mapped to optical connections terminating in the **Paris** node and they cannot recover from an optical node failure. Note that an optical node failure in **London** would not result in lost LSPs because no IP links terminate in **London**.

8.7 Close the **Network Browser**.

8.8 Select SWIM **> Switch To Corresponding Transport Network** to return to the Transport network.

8.9 Close the **Failure Analysis** dialog box to end the failure simulation.

9 Close the project.

9.1 Select **File > Close**.

9.2 Click **Save** in the **Close Confirm** dialog box.

End of Procedure 3-4

Conclusion

You have designed an IP/MPLS-over-DWDM network using three different protection strategies.

The first two designs used protection at the MPLS layer without any protection at the optical layer. The advantage of this approach is that no additional capacity needs to be installed at the optical layer. This is only applicable for reasonably low-loaded IP networks. For larger demands, additional IP links (and extra supporting optical capacity) need to be installed. For protection at the MPLS layer to be effective, it is very important that you account for failures at the optical layer. We saw how to do this by creating SRGs in the IP layer based on failure scenarios at the optical transport layer. In this way, MPLS protection can recover from failures at the IP/MPLS layer and at the transport layer.

Protection at the optical layer has the advantage that no recovery actions need to be taken at the IP/MPLS layer. Since SONET equipment can achieve switch-over to the backup routes in less than 50ms, it is also faster than conventional IP networks. Clearly, the disadvantage is the installation of extra optical capacity. This is only affordable for premium services generating enough revenue (not for best-effort IP traffic) or in case the transport capacity is cheap compared to IP capacity. Note that optical protection can only protect against failures at the transport layer and does not provide protection against higher layer failures (e.g. router failure).