

## 2 Defining a Multi-Layer IP-Over-WDM Network

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### Overview

A pan-European service provider has deployed an IP network on top of a DWDM transport network. The provider is on the verge of acquiring a new client who requires IP connectivity between three European sites. The provider wants to know what upgrades are needed for the network in order to meet the new client's requirements.

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### Objectives

- 1) Define the relationships between a Layer-2/3 network in SP Guru Network Planner and a DWDM network in SP Guru Transport Planner.
- 2) Dimension the Transport network to support the IP layer requirements.
- 3) Inspect the routes taken by IP flows in the optical layer.
- 4) Verify the network's resilience against single fiber breaks in the optical network.

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### Instructions

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#### Procedure 2-1 Defining the Integrated SP Guru Network Planner / SP Guru Transport Planner Project


- 1 Open the **SWIM\_Tutorial\_Basics** project in SP Guru Network Planner.
  - 1.1 Select **File > Open**.
  - 1.2 Select the **SWIM\_Tutorial\_Basics** project. Click **Open**. Note that the current scenario is named **bare**. The IP network is represented in SP Guru Network Planner.
- 2 Inspect the underlying transport network in SP Guru Transport Planner.
  - 2.1 Select **SWIM > Switch To Corresponding Transport Network** or click the toolbar button. The transport network appears in SP Guru Transport Planner.



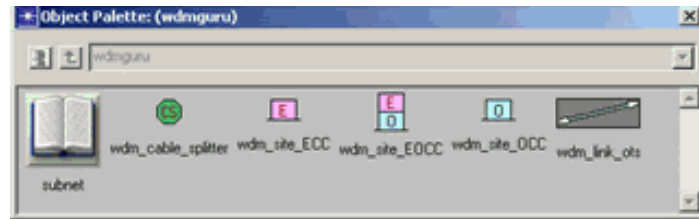
- 2.2 Select **Network > Connection Browser**. This dialog box shows the traffic accommodated in the network on a per-layer basis. There is one traffic matrix, **Voice**, accommodated by the DCL layer. The OCH layer contains **Optical\_Leased\_Lines** and **VOCH\_Voice\_Grooming**. **VOCH\_Voice\_Grooming** does not represent any user traffic; it represents the optical traffic that supports the groomed DCL traffic.
- 2.3 Close the Connection Browser.
- 3 Switch to the Layer-2/3 network: select **SWIM > Switch To Corresponding Layer-2/3 Network** or click the toolbar button. 
- 4 Currently, the IP network is represented in SP Guru Network Planner and the transport network is represented in SP Guru Transport Planner. There is no relationship between the two networks yet. To create a relationship, start by defining associations between the nodes. Layer-2/3 nodes are associated with Transport nodes. This means that the IP router (in SP Guru Network Planner) is interconnected to the corresponding cross-connect (in SP Guru Transport Planner) to access the transport network.
  - 4.1 Select **SWIM > Node/Link Mapping > Map Nodes...** to map the Layer-2/3 nodes to the corresponding Transport nodes.
  - 4.2 Select node **Barcelona** in the left pane. Note that Barcelona is automatically selected in the right pane.
  - 4.3 Click on the **>>** button. The association is made between node Barcelona in SP Guru Network Planner and its counterpart in SP Guru Transport Planner.
  - 4.4 Select the **top** subnet in the left pane.
  - 4.5 Click the **Auto >>** button. This maps all selected Layer-2/3 nodes to their namesakes in SP Guru Transport Planner. This only works when the names of the corresponding nodes in SP Guru Network Planner and SP Guru Transport Planner match exactly.
  - 4.6 Select **Ghent** and **Brussels** (while holding the **Ctrl** key) in the left pane.
  - 4.7 Select **Belgium** in the right pane. Make sure no other item in the pane is selected.
  - 4.8 Click the **>>** button to relate both Layer-2/3 nodes to the one Transport node.

**Note**—The Layer-2/3 node **Padova** does not yet have a Transport counterpart. We will create a new Transport node for this node.

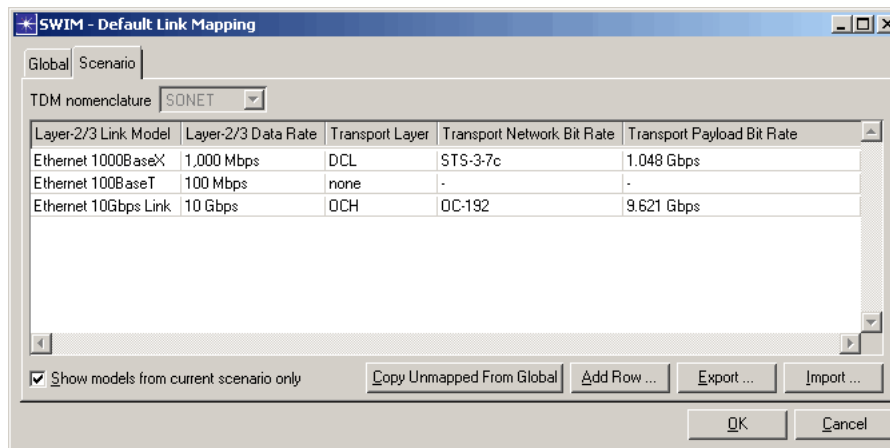
  - 4.9 Select the node **Padova** in the left pane. Note that the **New... 1 to 1** entry is selected in the right pane.
  - 4.10 Click the **>>** button. The **SWIM – Map To New Transport Node** dialog box appears.
  - 4.11 Select **ECC** as node type and **Padova** as name. Click **OK**.
  - 4.12 Verify that only the **Office\_XXX** nodes are left unmapped, and click **OK** to save the node mappings.
- 5 Check the node mappings in the network.
  - 5.1 Select all nodes in the Layer-2/3 network.

- 5.2 Select **SWIM > Switch To Corresponding Transport Network**. Note that all corresponding nodes in the Transport network are selected. Also note the newly created ECC node **Padova**.
- 6 Create links in SP Guru Transport Planner.
  - 6.1 Open the object palette by clicking the toolbar button (or by selecting **Edit > Open Object Palette**). 
  - 6.2 Select the **wdm\_link\_ots** icon and create a link between **Padova** and **Munchen** by clicking on both nodes. Similarly, create a link between **Padova** and **Rome**. Right-click (or click the **Esc** key) to stop adding links.

**Figure 2-1 wdmguru Object Palette**



- 6.3 Close the object palette.
- 7 Define the concatenated bit rate STS-3-7c in SP Guru Transport Planner as a concatenation of seven STS-3 connections. This bit rate will be used to support the Gigabit Ethernet links in step 9.
  - 7.1 Select **Network > Custom Bit Rates...** This dialog box lets you define new bit rates.
  - 7.2 Click **Add Bit Rate** in the DCL layer section. This creates a new bit rate for the SONET traffic. Fill in **STS-3-7c** as name for the new bit rate. Note that **STS-3** will automatically appear as **Base Bit Rate** and **7** as **Concatenation Count**. Click **OK**.
- 8 Switch to the Layer-2/3 network: select **SWIM > Switch To Corresponding Layer-2/3 Network**.
- 9 Verify the default settings for the link mapping. These default settings define how the IP links are translated to the transport network. Each IP link is translated to a connection to be routed in the transport network. The default link mapping defines defaults for the layer and bit rate of this connection in SP Guru Transport Planner, depending on the link model in SP Guru Network Planner.
  - 9.1 Select **SWIM > Node/Link Mapping > Set Link Mapping Defaults...** The **SWIM – Default Link Mapping** dialog box appears. Select the **Scenario** tab.
  - 9.2 Verify that **DCL** (Transport Layer) and **STS-3-7c** (Transport Bit Rate) are selected for the **Ethernet 1000BaseX** model.
  - 9.3 Verify that **OCH** (Transport Layer) and **OC-192** (Transport Bit Rate) are selected for the **Ethernet 10Gbps Link** model.

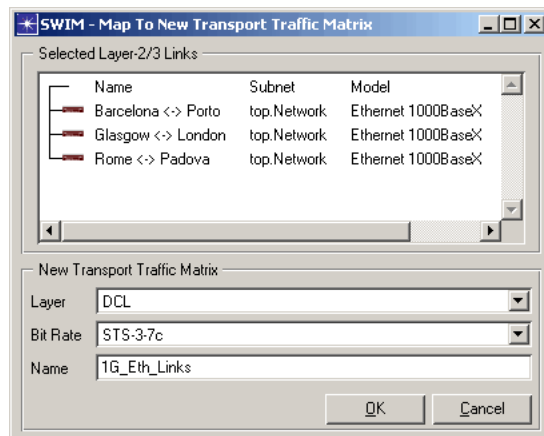
**Figure 2-2 Scenario Tab of Default Link Mapping Dialog Box**

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

## 10 Define the link mapping.

- 10.1 Verify the checkmarked menu item **SWIM > Automatically Update Operational Status Visualization** is turned on, to show the operational status of mapped links. If a link is unmapped or if its operational status is up, no icon is overlaid. In our case the network view does not change since no Layer-2/3 link have been mapped to the transport network.
- 10.2 Select **SWIM > Node/Link Mapping > Map Links...** The dialog box that appears is analogous to the one for mapping nodes. It displays the Layer-2/3 links on the left and the Transport objects to which they are mapped on the right (in this case, traffic matrices).
- 10.3 Select **Ethernet 1000BaseX** in the left pane. Note that **New... Per model** is automatically selected in the right pane. This automatically creates a new traffic matrix in SP Guru Transport Planner.
- 10.4 Click on the **>>** button. The **SWIM – Map To New Transport Traffic Matrix** dialog box appears. In this dialog box you can specify the Transport traffic matrix.
- 10.5 Note that **DCL** is automatically entered as layer for the new traffic matrix, **STS-3-7c** as bit rate. This is done based on the entry for link model Ethernet 1000BaseX in the default link mapping settings you reviewed in step 9. Enter **1G\_Eth\_Links** as the name. Click **OK**.

Figure 2-3 Map to New Transport Traffic Matrix Dialog Box



**10.6** Select the **Ethernet 10Gbps Link** model in the left pane and click on the **Auto >>** button. Note that the Ethernet 10Gbps links are mapped to an OC-192 traffic matrix (named **swim\_OCH\_OC-192**) at the OCH layer, as specified in the SWIM > **Set Link Mapping Defaults** dialog box (see step 9).

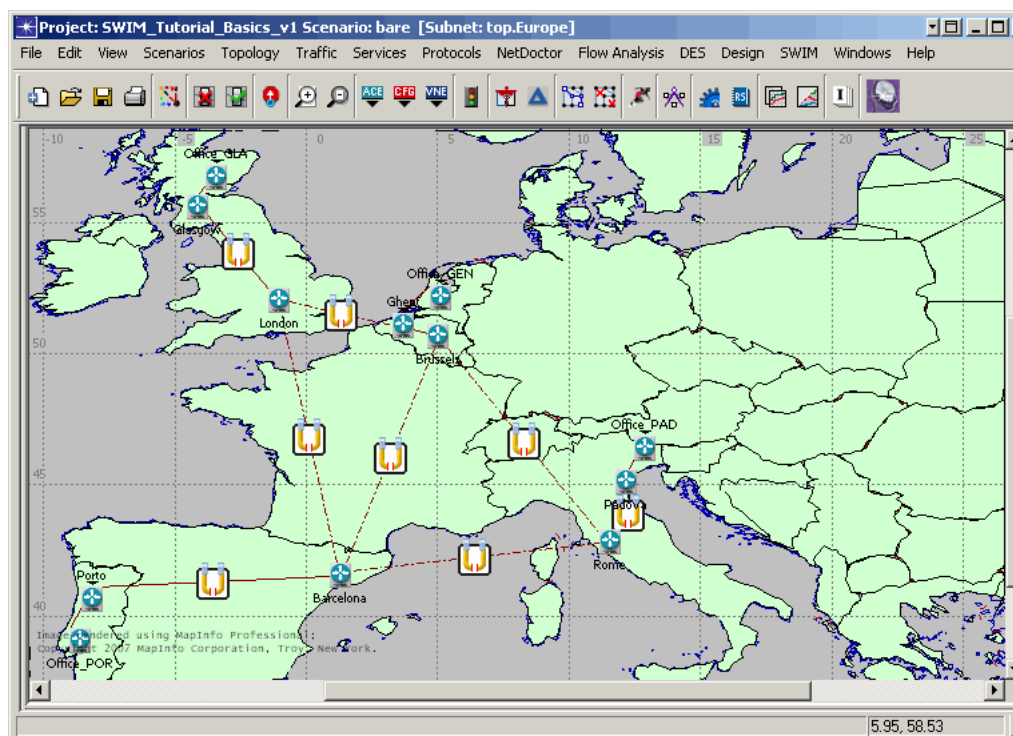
**Note**—You might need to uncheck the **Selected** checkbox to see the **Ethernet 10Gbps Link** model.

**10.7** Right-click on the **swim\_OCH\_OC-192** traffic matrix and select **Set name**. Fill in **10G\_Eth\_Links** as the new name for this traffic matrix. Click **OK**.

**10.8** Click **OK** in the **SWIM – Map Links** dialog box. Note that all of the mapped links are overlaid with an icon. The icon indicates that the links have been mapped to traffic matrices at the transport network, but this traffic is not yet set up. This will be done in SP Guru Transport Planner.



Figure 2-4 Mapped Links in SP Guru Network Planner



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**End of Procedure 2-1**

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**Procedure 2-2 Dimension the Transport Network to Accommodate the New Traffic**

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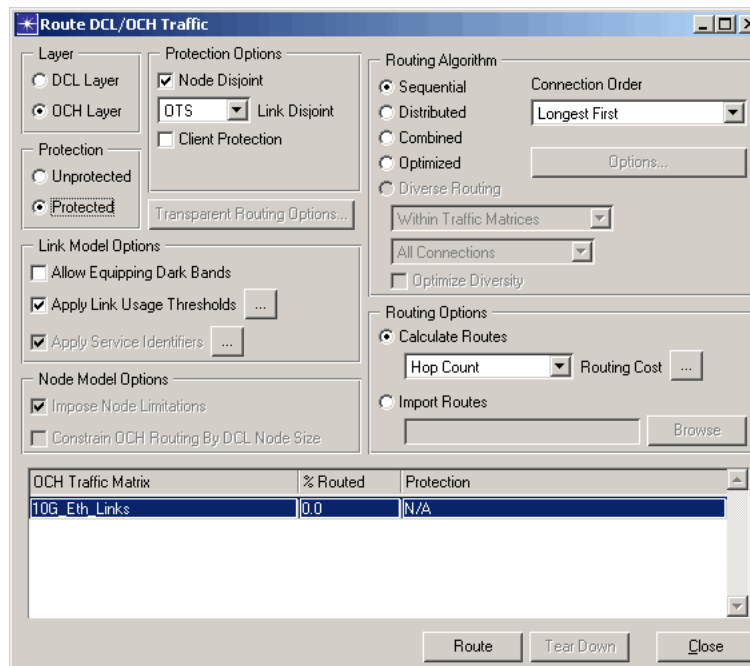
- 1 Switch to the Transport network: select SWIM > **Switch To Corresponding Transport Network**.
- 2 Verify that the link mapping resulted in new traffic demands in SP Guru Transport Planner.
  - 2.1 Select **Network > Traffic Matrix Editor** (or click the toolbar button).  
This dialog box lets you manage traffic matrices. 
  - 2.2 Select the **OCH** layer. Note that a new OC-192 traffic matrix named **10G\_Eth\_Links** has been created on the OCH layer. The **Native** setting indicates that the traffic matrix is **External**. This means that they have an external origin, in this case SP Guru Network Planner.
  - 2.3 Select the **DCL** layer. A new STS-3-7c traffic matrix named **1G\_Eth\_Links** has been created.
  - 2.4 Close the **Traffic Matrix Editor** dialog box.
- 3 Verify that there is sufficient capacity in the transport network to support the Ethernet 1-Gbps links. To do so, try to route the corresponding 10G\_Eth\_Links traffic matrix in the OCH layer of SP Guru Transport Planner. We are using protected routing in the OCH layer to ensure that if an IP link is affected by a cable break, traffic can still run over the link because the IP link is routed over its protection path at the optical layer.
  - 3.1 Select **Design > Route DCL/OCH Traffic** (or click the toolbar button).
  - 3.2 Select the **OCH Layer** and the traffic matrix **10G\_Eth\_Links**. Select **Protected** and **Node Disjoint** (no Client Protection). Click **Route**.

Figure 2-5 Route DCL/OCH Traffic Dialog Box



The dialog box is titled "Route DCL/OCH Traffic". It contains several sections for configuring network routing and protection.

- Layer:** Radio buttons for "DCL Layer" and "OCH Layer". "OCH Layer" is selected.
- Protection:** Radio buttons for "Unprotected" and "Protected". "Protected" is selected.
- Protection Options:**
  - ☒ Node Disjoint
  - ☐ Link Disjoint (with a dropdown menu showing "OTS")
  - ☐ Client Protection
  - Transparent Routing Options...
- Link Model Options:**
  - ☐ Allow Equipping Dark Bands
  - ☒ Apply Link Usage Thresholds ...
  - ☒ Apply Service Identifiers ...
- Node Model Options:**
  - ☒ Impose Node Limitations
  - ☐ Constrain OCH Routing By DCL Node Size
- Routing Algorithm:**
  - ☒ Sequential
  - ☐ Distributed
  - ☐ Combined
  - ☐ Optimized
  - ☐ Diverse Routing
  - Options...
  - Within Traffic Matrices (dropdown)
  - All Connections (dropdown)
  - ☐ Optimize Diversity
- Routing Options:**
  - ☒ Calculate Routes
    - Hop Count (dropdown)
    - Routing Cost ...
  - ☐ Import Routes
    - Browse
- Table:**

| OCH Traffic Matrix | % Routed | Protection |
|--------------------|----------|------------|
| 10G_Eth_Links      | 0.0      | N/A        |
- Buttons:** Route, Tear Down, Close

When the action is finished, the 10G\_Eth\_Links matrix are completely set up; the Transport network contains enough free capacity to support all 10G Ethernet links in the Layer-2/3 network.

### 3.3 Close the dialog boxes.

## 4 Switch to the Layer-2/3 network.

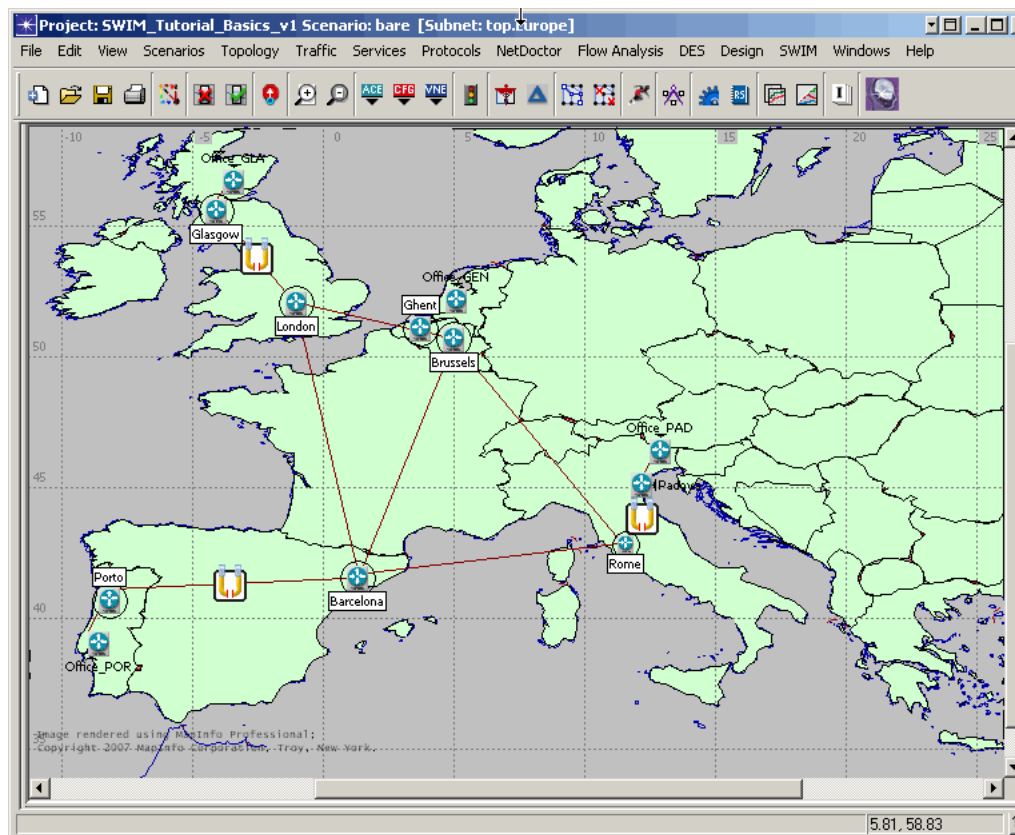
### 4.1 Select SWIM > Switch To Corresponding Layer-2/3 Network.

## 5 Verify that the 10Gbps Ethernet links are up.

### 5.1 The SWIM > Automatically Update Operational Status Visualization option should still be enabled (indicated by a check mark). The 1Gbps Ethernet links still have an icon overlaid, indicating that they have been mapped to Transport connections, but have not been set up yet. The 10Gbps Ethernet links no longer have an overlay icon, since their associated Transport connections are up and running.



Figure 2-6 Network in SP Guru Network Planner



6 Verify that the 1Gbps Ethernet links are down.

6.1 Select **SWIM > Show Connections Browser On Switching To Transport Network**. The Connections Browser opens if any mapped links are selected when you switch to SP Guru Transport Planner.

6.2 Select the 1Gbps Ethernet links (hold down the **Ctrl** key and click on each of the links marked with an icon).



6.3 Select **SWIM > Switch To Corresponding Transport Network**.

6.4 The **SWIM - Connections Browser** dialog box opens. Use the **+** icon at the left of a connection to view more details about the connection. Note that each of the connections is unrouted. This is also seen from the red link icon for the Layer-2/3 link element in the tree.



6.5 Close the Connections Browser.

7 Verify that there is insufficient capacity in the transport network to support the 1Gbps Ethernet links by attempting to route the corresponding 1G\_Eth\_Links traffic matrix in the DCL layer of SP Guru Transport Planner.

7.1 Select **Design > Route DCL/OCH Traffic....**

7.2 Select **DCL Layer** and the SONET traffic matrix **1G\_Eth\_Links**. Choose the same options as in step 3: **Protected** and **Node Disjoint**. Click **Route**.



**7.3** The **Routing Results** dialog box opens. No routes were found due to lack of capacity. (To verify this: use the **DCL** toolbar button to inspect the DCL layer. All DCL links from node **Glasgow** are completely used—no free capacity left—and no capacity is available on the links from node **Padova**.) The capacity of the Transport network needs to be expanded since there is not enough free capacity in the network to accommodate the 1G Ethernet links.

**7.4** Close the dialog boxes.

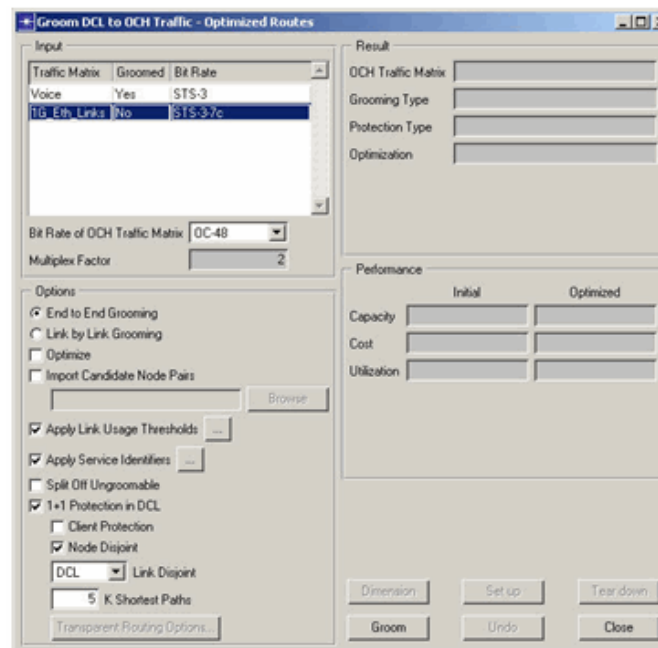
**8** Groom the SONET traffic matrix **1G\_Eth\_Links**.

**8.1** Select **Design > Groom DCL to OCH Traffic > Optimized Routes...** (or use toolbar button). This dialog box is used to map SONET traffic to optical channels. If needed, the grooming algorithm installs extra equipment to accommodate the SONET traffic matrix.



**8.2** Select the SONET traffic matrix **1G\_Eth\_Links**. Choose the following options: **OC-48** (bit rate of the optical channels to which the DCL traffic is groomed), **End to End Grooming** (no optimization), **1+1 Protection in DCL** (no client protection), **Node Disjoint** and **DCL Link Disjoint**. Click **Groom**.

**Figure 2-7 Groom DCL to OCH Traffic Dialog Box**



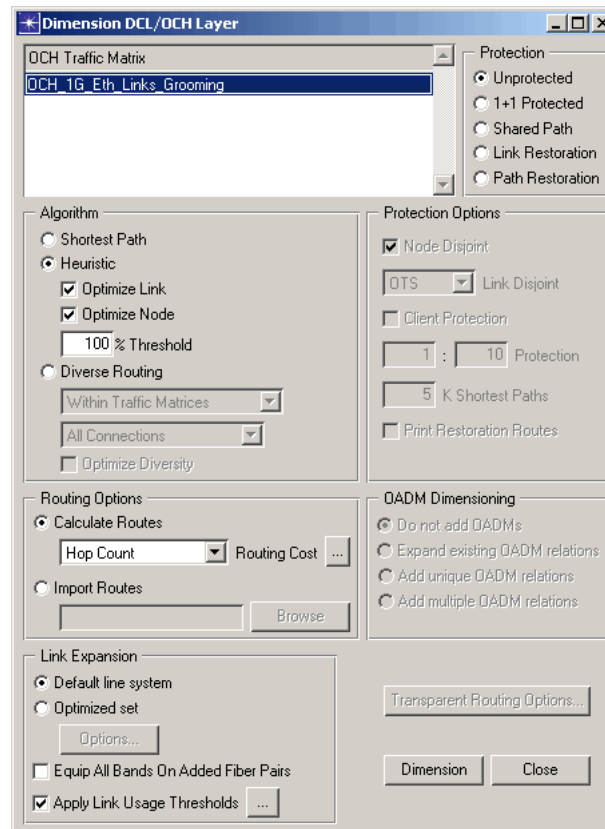
**8.3** When the grooming action is complete, a new OCH traffic matrix (named **OCH\_1G\_Eth\_Links\_Grooming**) is created that supports the DCL traffic matrix **1G\_Eth\_Links**. Note that these traffic matrices are not yet accommodated in the network.

**8.4** Click **Dimension** in the **Groom DCL to OCH Traffic - Optimized Routes** dialog box.

**8.5** The **Dimension DCL/OCH Layer** dialog box opens. This dialog box lets you accommodate OCH layer matrices in the network. If needed, extra network equipment is added to try to entirely accommodate a given traffic matrix in the network.

- 8.6** Select the newly created OCH traffic matrix **OCH\_1G\_Eth\_Links\_Grooming**. Select **Unprotected** (Protection), **Heuristic** (enable **Optimize Link** and **Optimize Node**), and accept the default settings for the other options.

**Figure 2-8 Dimension DCL/OCH Layer Dialog Box**



- 8.7** Click **Dimension**. The **Results of Dimensioning** dialog box opens. Note that both traffic matrices, **OCH\_1G\_Eth\_Links\_Grooming** and **1G\_Eth\_Links**, are now entirely accommodated in the network. This adds 18 OXC ports; no extra fibers need to be installed.

- 8.8** Close all dialog boxes.

- 9** Switch to the Layer-2/3 network.

- 9.1** Select **SWIM > Switch To Corresponding Layer-2/3 Network** to return to SP Guru Network Planner.

**Note**—All of the mapped links are no longer marked with any overlay icon since all associated Transport connections are set up.

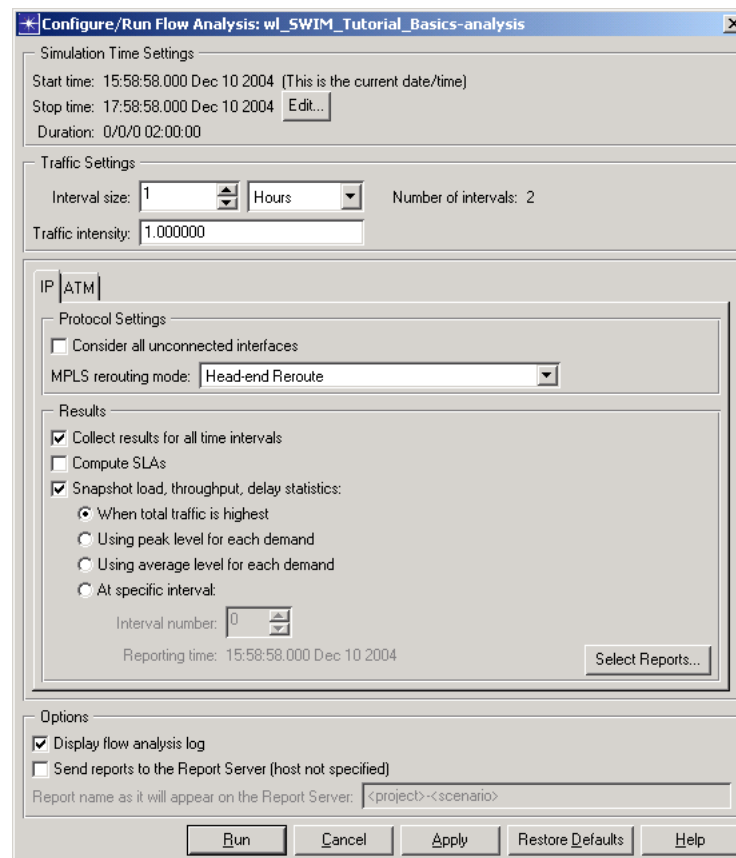
- 10** Save the project under a different name: select **File > Save As** and save the project as **<initials>\_SWIM\_Tutorial\_Basics**.

## End of Procedure 2-2

### Procedure 2-3 Inspect the Routes Between the Office Nodes

- 1 Duplicate the scenario.
  - 1.1 Select **Scenarios > Duplicate Scenario**.
  - 1.2 Name the scenario **analysis**. Click **OK**.
- 2 Run flow analysis to determine the routes of the IP demands.
  - 2.1 Select **Flow Analysis > Configure/Run Flow Analysis...** (or press **Ctrl+Alt+F** on the keyboard).
  - 2.2 The **Configure/Run Flow Analysis** dialog box appears. Keep the default settings. Click **Run**.

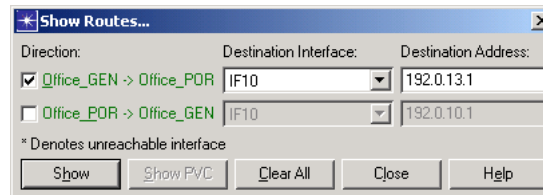
**Figure 2-9 Configure/Run Flow Analysis Dialog Box**



- 2.3 The **Resolve Unassigned IP Addresses for Scenario...** dialog box opens. Click **Yes**.
- 2.4 Wait until the **Flow Analysis Log – SWIM\_Tutorial\_Basics-analysis** dialog box appears. All demands are now routed. Close the dialog box.
- 3 Show the routes between the **Ghent** and **Porto** offices.
  - 3.1 Select the nodes **Office\_GEN** and **Office\_POR** (while holding the **Ctrl** key).

- 3.2 Select **Flow Analysis > Show Routes Between Selected Nodes** (or click **Ctrl+Alt+S** on the keyboard).
- 3.3 The **Show Routes** dialog box appears. Click on **Show**. The routes that appear are **Office\_GEN -> Ghent -> Brussels -> Barcelona -> Porto -> Office\_POR** and **Office\_GEN -> Ghent -> London -> Barcelona -> Porto -> Office\_POR**, and the reverse routes.

**Figure 2-10 Show Routes Dialog Box**



- 3.4 Click **Close** in the **Show Routes** dialog box. This does not clear the routes between **Office\_GEN** and **Office\_POR**.
- 4 Visualize the routes of the links and paths.
- 4.1 Select **SWIM > Open Mapped Connections Browser....** This dialog box lets you visualize the routes of the links and paths of SP Guru Network Planner across all network layers.
- 4.2 Select **Layer 2/3** (Network Layer to Display In Project Editor) and **Paths** (Layer-2/3 Elements To Show) to visualize the routes in the Layer-2/3 network.
- 4.3 Select the path through node **Brussels**. Use the **+** icon next to the path to inspect the list of links that make up the path. Click on the **+** icon to the left of a constituent link to verify how the link is mapped on the transport network. Note that the blue link icon indicates that the Layer-2/3 link is up and running.
- 4.4 Select each link of the path, and **DCL**, **OCH**, **OMS**, and **OTS** (Network Layer To Display In Project Editor), to browse through the different layers of the transport network and investigate how each link of the route is accommodated in the transport network.
- 4.5 The Connections Browser also lists the details of the connections for each of the mapped Layer-2/3 links. For example, expanding the link between nodes **Barcelona** and **Porto** shows that its delay is 4.180 ms.
- 4.6 Close the **SWIM - Connections Browser** dialog box.

### End of Procedure 2-3

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### Procedure 2-4 Failure Analysis

- 1 Switch to the Transport network (if you have not already done so).
  - 1.1 Select **SWIM > Switch To Corresponding Transport Network**.
- 2 Run a failure analysis.

- 2.1 Select **Info > Failure Analysis**, which opens the **Failure Analysis** dialog box. This dialog box lets you evaluate the effect of equipment failures on the traffic accommodated by the network.
- 2.2 Click on the **OTS** toolbar button to view the OTS layer. Fail the cable between **Madrid** and **Barcelona** by right-clicking on it and selecting **Fail This Cable**.
- 2.3 Click on **Evaluate** in the **Failure Analysis** dialog box to verify the impact of the cable failure on the traffic accommodated in the network. In the **Overview of Affected Traffic** section an overview is given of the affected traffic in the DCL and OCH layers. Do not close the **Failure Analysis** dialog box.
- 2.4 Select **Network > Connection Browser**. Inspect the connections in the **DCL** and the **OCH** layers. Note that some connections are lost at the OCH layer only. These lost connections are part of the traffic matrices that support the groomed SONET matrices. The connection between **Barcelona** and **Madrid** fails for the traffic matrix **OCH\_1G\_Eth\_Links\_Grooming**, while the connections **Barcelona <-> London**, **Barcelona <-> Madrid**, **London <-> Madrid** and **Madrid <-> Rome** fail for the **OCH\_Voice\_Grooming** traffic matrix. Note that all native OCH traffic survives the failures since it is protected at the OCH layer. Also, the DCL traffic supported by the (partly failing) OCH grooming traffic survives the failures since it is protected at the DCL layer.
- 2.5 Close the Connection Browser.
- 2.6 Select **SWIM > Switch To Corresponding Layer-2/3 Network** (do not close the **Failure Analysis** dialog box). Note that no IP links fail because they are all protected. This is because the 1G links are protected at the DCL layer, whereas the 10G links are protected at the OCH layer.
- 2.7 Select **SWIM > Open Mapped Connection Browser....** Select **Layer 2/3** (Network Layer to Display in Project Editor) and **Paths** (Layer-2/3 Elements To Show).
- 2.8 Select the first path again. Select each link of the path, and **DCL**, **OCH**, **OMS** and **OTS** (Network Layer To Display), to browse through the different layers of the transport network and investigate how each link of the route is accommodated in the transport network. Looking at the route from **Office\_GEN** to **Office\_POR**, you will notice that a detour is taken via London and (at the OTS layer) Bordeaux.
- 2.9 Close the Connections Browser.
- 3 In SP Guru Network Planner, select **Scenarios > Object/Attribute Difference Report > Generate Report** to compare the original network to the current IP network, which has been subjected to failures.
  - 3.1 Verify that the **bare** scenario is selected for comparison and click **Generate**.
  - 3.2 The **Network Difference Tree** dialog box appears. Select **Objects with differences**. This will show that the **Barcelona <-> Porto** link suffers from a delay increase from 4.180 ms to 14.132 ms, because the supporting connection is switched to its protection path.

**Note**—Note that the unit of delay reported in SP Guru Network Planner, and therefore in the difference report, is in seconds.

- 3.3 Close the dialog box and select **SWIM > Switch To Corresponding Transport Network**.

- 3.4 Click on the **OTS** toolbar button to go the OTS layer view (do not close the **Failure Analysis** dialog box).
  - 3.5 Fail the cable between London and Paris by right-clicking on the link and selecting **Fail This Cable**.
  - 3.6 Click **Evaluate** in the **Failure Analysis** dialog box to verify the impact of the double cable failure on the traffic accommodated in the network.
  - 3.7 Switch to SP Guru Network Planner by selecting **SWIM > Switch To Corresponding Layer-2/3 Network** (without closing the **Failure Analysis** dialog box). The IP link between **Barcelona** and **London** fails because the working and protecting path of its supporting connection at the OCH layer are affected. Also, the link between **Barcelona** and **Porto** fails because both the working and protecting path of its supporting connection at the DCL layer are affected. These failing links are overlaid with the link failed icon. 
- 4 Close the project.
    - 4.1 Select **File > Close**.
    - 4.2 Click **Save** in the **Close Confirm** dialog box.

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## Conclusion

In this tutorial, you have learned how to define a multi-layer view of an IP-over-WDM network using SP Guru Network Planner and SP Guru Transport Planner. IP links and routes can be inspected across all layers. Their attributes, such as delay and operational status, are automatically updated according to the state of the underlying optical network. Interactive failure analysis across layers helps in assessing the effects of cable breaks and other failure scenarios on the IP layer.