6 Routing

After you equip your network and create an OCH or a DCL traffic matrix, you can route the traffic to establish connections in a network. In general, the objective of a routing operation is to maximize throughput while minimizing network cost.

SP Guru Transport Planner routes one or multiple traffic matrices with common routing and protection options at a time. If you want to route multiple traffic matrices with different routing or protection options, you must route them sequentially. You can only route matrices that are partially or entirely unrouted (that is, matrices that have unrouted connections).

The following rules apply to routing in SP Guru Transport Planner:

- You can route traffic at the DCL and OCH layer. At the DCL layer, the granularity of traffic is one or more timeslots at the SONET/SDH higher-order path layer. At the OCH layer, the granularity is one or more wavelengths.
- At the OCH layer you can run routing operations on both opaque and transparent networks. To access options specific to transparent networks, click the Transparent Routing Options button in the Routing and Dimensioning dialog boxes. These options are described in Transparent Routing Options Dialog Box on page TrP-10-12.
- A routing operation on an OCH or DCL traffic matrix requires unused, equipped capacity in the corresponding network layer.

  OCH-layer capacity is provided by lit fiber pairs. To increase OCH capacity, you can

  — Increase the number of equipped fiber pairs or wavelength bands

  — Dimension the network (see Dimensioning a Topology on page TrP-7-1 for details)

DCL-layer capacity is provided by DCL trunks. DCL trunks can be created by non-native OCH connections between EOCC nodes, or by lit fiber pairs between ECC nodes. To increase DCL capacity, you can

— Increase the number of equipped fiber pairs between ECC nodes

— Create non-native connections in the OCH layer; these connections result in logical DCL links, which provide the capacity necessary to support DCL traffic. You can create these non-native OCH connections automatically (through a grooming operation of DCL traffic into OCH traffic) or you can manually create non-native OCH connections in the Traffic Matrix Editor (set the Native field to No).

Note—You cannot route LOP traffic directly using the routing operation. You must groom the LOP traffic into DCL traffic first, then route the resulting DCL traffic matrix on the DCL layer. For more information, see Chapter 9 Grooming LOP to DCL Traffic on page TrP-9-1.

Route DCL/OCH Traffic Dialog Box

After you create one or more DCL or OCH traffic matrices, you can route these matrices using the Route dialog box (Design > Route DCL/OCH Traffic). You can also use this dialog box to tear down partially routed matrices. The Traffic Matrix table lists unrouted or partially routed matrices. Choose one or more traffic matrices from the Traffic Matrix table, select the appropriate options, and click Route to route the traffic.

Figure 6-1 Route DCL/OCH Traffic Dialog Box

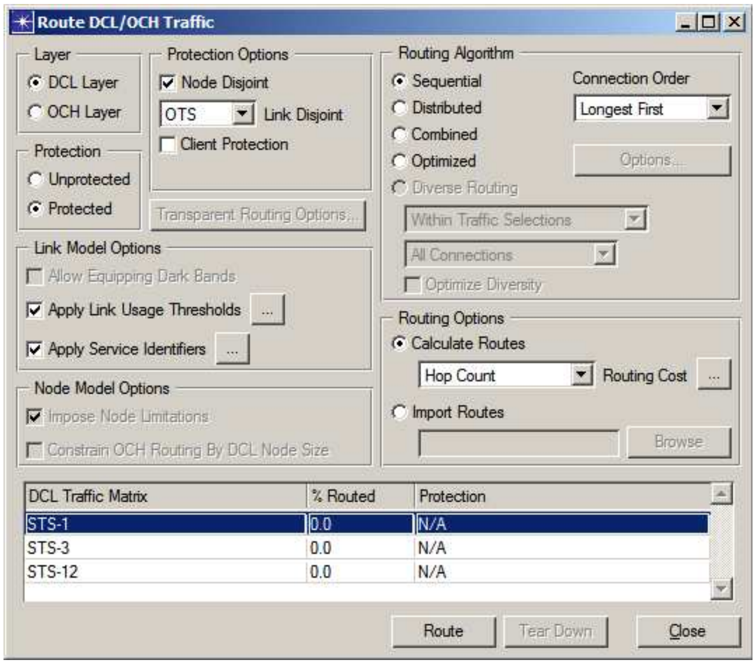


Table 6-1 Route Dialog Box

Item	Description	Reference
Connection Order	Sequence in which the routing function processes connections (relevant for Sequential and Distributed routing only) • Unsorted—Route connections in the order in which they appear in the Traffic Matrix Editor: row1-to-col1, row1-to-col2, etc. • Longest First—Route longest connections (in physical distance) first • Shortest First—Route shortest connections (in physical distance) first • Biggest First—Route connections with the highest capacity first • Smallest First—Route connections with the lowest capacity first	Connection Order on page TrP-6-9
Layer	Select layer (DCL/OCH) of traffic matrix to route	—

Table 6-1 Route Dialog Box (Continued)

Item	Description	Reference
Link Model Options	Allow Equipping Dark Bands (*OCH traffic only*): • If selected, the routing operation considers all wavelength bands that are currently "dark" (unequipped) on a link. If the bands need extra capacity to route the traffic, they are equipped automatically. • If not selected (the default setting), the routing operation considers only capacity of the currently equipped bands. Apply Link Usage Thresholds: • With this option only part of the capacity available on a link, specified by a percentile threshold value, can be used Apply Service Identifiers (*DCL traffic only*): • With this option enabled, client DCL traffic can only be routed over OCH wavelengths with matching service identifiers	
Node Model Options	N*OTE: These options apply only if the nodes in the selected layer are discrete nodes.* Impose Node Limitations—If enabled, discrete node sizes are fixed and routing is constrained by both link and node capacity Constrain OCH Routing by DCL Node Size—A non-native OCH connection might require additional DXC trunk ports to route a specific OCH traffic matrix. If this option is selected, the discrete DXC type is fixed. If this option is not selected, SP Guru Transport Planner upgrades the DXC if needed to route the specified traffic.	Node Model Options on page TrP-6-13
Transparent Routing Options	Access options specific to transparent networks	Table 10-1 Transparent Routing Options Dialog Box on page TrP-10-12
Protection	Unprotected—With this option selected, SP Guru Transport Planner tries to set up a connection using just one working path. Protected—SP Guru Transport Planner tries to set up a connection using both a working path and a disjoint protection path.	Routing Protection on page TrP-6-5
Protection Options	Node Disjoint—Ensures that a connection's working and protection paths are node disjoint Link Disjoint —Specifies the layer down to which links of the working and protection path of a connection should be disjoint. Client Protection—Client handles protection (*selected*); network handles protection (*not selected*	Protection Options on page TrP-6-6 Link Disjointness for Working and Protection Paths on page TrP-6-6

Table 6-1 Route Dialog Box (Continued)

Item	Description	Reference
Routing Algorithm	Connection Order—The order in which the connections are filled in the Routing Sequence table You can select one of the following routing algorithms: • Sequential—SP Guru Transport Planner tries to route and set up an entire connection (all capacity units) before starting with the next connection in the Routing Sequence table. • Distributed—SP Guru Transport Planner tries to route and set up one capacity unit of each connection in the Routing Sequence table before continuing with the next capacity unit. • Combined—SP Guru Transport Planner tries four strategy/routing-order combinations and retains the combination that accommodates the most traffic. • Optimized—SP Guru Transport Planner takes the outcome of the Combined routing strategy and then adds a local optimization step (and possibly additional optimization steps) in an attempt to establish as much traffic as possible in the network. Click the Options button to access more options for this strategy. • Diverse Routing—Route all related connections as diversely as possible, that is, with the minimal amount of overlap between routes.This algorithm ensures that if there is a failure, not all related connections fail simultaneously.	Routing Algorithm on page TrP-6-8 Routing Optimization on page TrP-6-11 Diverse Routing Algorithm on page TrP-6-10
Routing Options	Specifies the method for routing the traffic matrix. Options are: • Calculate routes—Calculate the lowest-cost route using the selected Routing Cost algorithm • Import routes—Route the traffic using the routes in a predefined data file	Routing Cost on page TrP-6-13 Importing and Exporting Route Data Files on page TrP-5-29 Detailed Routing Cost Options on page TrP-6-14
Traffic Matrix	Select one or more traffic matrices to route (the table displays all *unrouted* or *partially routed* matrices of type indicated by Layer).	—
Transparent Routing Options	Set options for routing in a transparent network	Transparent Routing Options Dialog Box on page TrP-10-12
End of Table 6-1		

Routing Protection

When the Protected option is selected, SP Guru Transport Planner tries to set up a connection with a working path and a disjoint protection path. If SP Guru Transport Planner cannot set up both paths, the set-up attempt fails; SP Guru Transport Planner never sets up a protected connection with just one path.

When the Unprotected option is selected, SP Guru Transport Planner tries to set up a connection using just one path.

Protection Options

You can specify the following options when Protection is selected:

- Node Disjoint—With this option selected, SP Guru Transport Planner ensures that a connection's working and protection paths are node disjoint; otherwise only link disjointness is guaranteed. Node disjoint means that the two paths have no intermediate nodes in common.

- Link Disjoint—Specifies the layer down to which link disjointness of the working and protection path of a connection should be guaranteed. Link disjointness on the selected layer means that the two paths have no common links on the selected layer. For more information, see Link Disjointness for Working and Protection Paths on page TrP-6-6.

- Client Protection—With this option selected, 1 + 1 protection occurs at the client; the client protects the connection and hands off two interfaces that must be disjointly routed through the network.

  If this option is not selected, the network (not the client) handles the protection and the client hands off just one interface.

Note—The Client Protection option does not affect the working and protection paths and the link resources that are used. It affects only the number of ports used on the equipment at the end point of the connection. This option affects the number of DXC or IXC ports (for DCL traffic), DXC or IXC trib ports (for OCH traffic) and DXC trunk ports (for non-native OCH traffic).
SP Guru Transport Planner also uses the protection transponder for non-client protected OCH traffic.

Link Disjointness for Working and Protection Paths

If a working and protection path are *link disjoint*, their paths have no links in common. You can specify the lowest network layer at which the paths are guaranteed to be link disjoint.

- DCL disjointness disregards underlying optical channels, fiber routes, and cable splitters. Working and protection paths are link disjoint at the DCL layer but are not guaranteed to be link disjoint at lower layers.

- OCH disjointness disregards underlying fiber routes and cable splitters. Paths are link disjoint at the OCH layer but are not guaranteed to be link disjoint at lower layers.

- OMS disjointness considers fiber routes but disregards cable splitters. Paths are link disjoint at the OMS layer but are not guaranteed to be link disjoint at the OTS layer.

- OTS disjointness considers cable splitters and fiber routes so that working and protection paths are disjoint down to the physical layer.

Lower layers of link disjointness increase the ability of the network to route connections in the event of link or node failures. For example, suppose you have a network in which the paths are DCL link disjoint. A DCL connection uses an OCH link that fails. If both working and protection paths use this link, the network cannot set up the DCL connection. However, if the connection is OTS link disjoint, only one path would fail. This means that the connection could still be set up using its working or protection path. Keep in mind that because lower layers of link disjointness ensure higher protection, this might result in higher network costs.

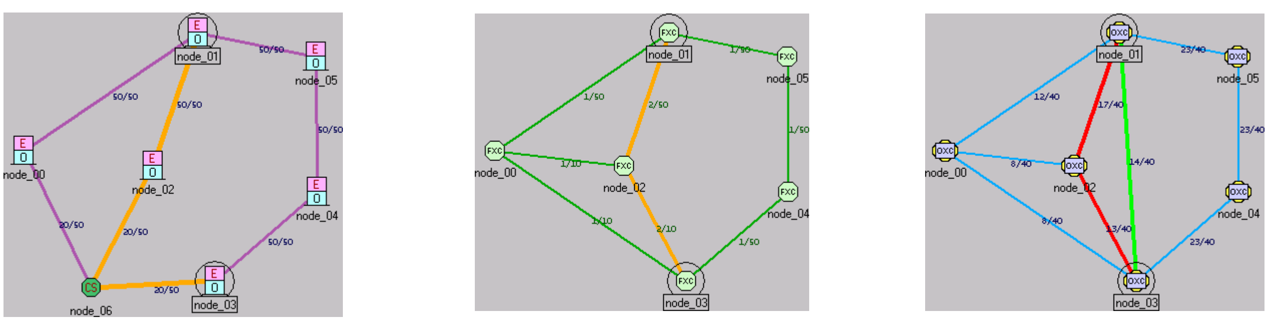
Note—If a network has no cable splitters or fiber routes, OTS, OMS and OCH topologies are identical. Therefore, OTS, OMS, and OCH link disjointness have the same effect on the resulting design.

In the most general case, if a network contains cable splitters and fiber routes, it can have different topologies at lower layers (OCH, OMS and OTS). For more information about cable splitters and fiber routes, see Configuring Cable Splitters and Fiber Routes on page TrP-3-19.

To illustrate the difference between link disjointness at the OCH,OMS and OTS layer, consider the following example. The topology contains a cable splitter in node_06 that has been configured to create OMS links that connect its adjoining nodes. In addition, a fiber route has been introduced at the OCH layer between node_01 and node_03. This fiber is routed via the links node_01<—>node_02 and node_02<—>node_03 (the latter link is also routed using the cable splitter)."

Protected routing with OCH link disjointness results in a working path over the fiber route between node_01 and node_03 and a protecting path via node_02. These routes are disjoint at the OCH layer only, as shown in Figure 6-2 (the orange path reflects the overlap of working and protection paths).

Figure 6-2   Protected Routing with OCH Link Disjointness: Example



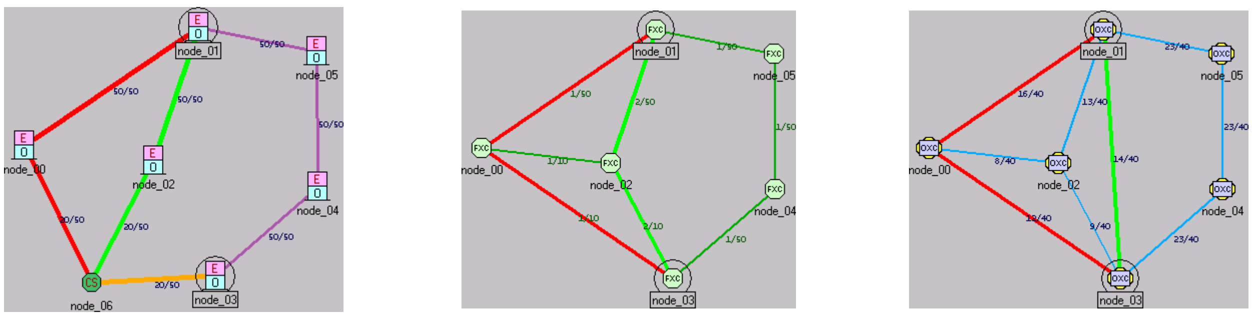
OTS layer

OMS layer

OCH layer

Protected routing with OMS link disjointness results in a working path over the fiber route between node_01 and node_03 and a protecting path through node_00. These routes are disjoint at the OCH and OMS layers as shown in Figure 6-3. However at the OTS layer, working and protection path share the link between node_06 and node_03, because the link is used to establish the OMS links through the cable splitter.

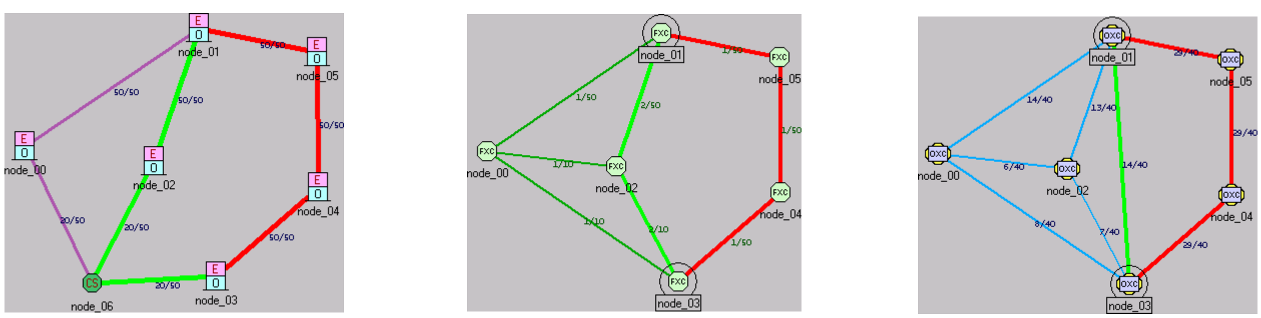
Figure 6-3 Protected Routing with OMS Link Disjointness: Example



OTS layer OMS layer OCH layer

Protected routing with OTS link disjointness results in a working path over the fiber route between node_01 and node_03 and a protecting path via node_04 and node_05. These routes are disjoint at the OCH, OMS, and OTS layer as shown Figure 6-4.

Figure 6-4 Protected Routing with OTS Link Disjointness: Example



OTS layer OMS layer OCH layer

Routing Algorithm

To specify the routing algorithm, choose one of the following options:

- Sequential (per connection)—SP Guru Transport Planner routes an entire connection and all the capacity units requested by that connection completely before it starts with the next connection in the Routing Sequence table.

- Distributed (per capacity unit)—If a connection requests multiple units of capacity, SP Guru Transport Planner tries to set up one capacity unit of each connection (as listed in the Routing Sequence table) before it tries to set up the remaining capacity units of each connection.

  The Distributed approach normally results in higher throughput and a better overall allocation of capacity than the Sequential approach.

- Combined—SP Guru Transport Planner tries four combinations of the sequential/distributive options and retains the result that accommodates the most traffic. The combinations are:
  - Sequential (shortest first)
  - Sequential (longest first)
  - Distributed (shortest first)
  - Distributed (longest first)

- Optimized—SP Guru Transport Planner takes the outcome of the Combined routing strategy, then adds a local optimization step (and possibly additional optimization steps) in an attempt to establish as much traffic as possible in the network. For more information, see Routing Optimization on page TrP-6-11.

- Diverse Routing—This algorithm maximizes the connectivity of the virtual topology that results from routing traffic. SP Guru Transport Planner routes the traffic as unprotected; meanwhile, it tries to route all related connections with the minimal amount of overlap between routes. For more information, see Diverse Routing Algorithm on page TrP-6-10.

Connection Order

You can specify the sequence in which SP Guru Transport Planner passes traffic matrix connections to the routing function. The available options are:

- Longest First (default)—Sorts connections by physical distance and routes the longest connection first. Because SP Guru Transport Planner solves the hardest problems first, this option generally performs well if most or all of the connections can be routed. This option is recommended for total (100 percent routed) or near-total routing solutions.

- Shortest First—Sorts connections by physical distance and routes the shortest connection first. This option improves the output for partial routing solutions if SP Guru Transport Planner cannot accommodate all connections, since the short and easy connections are routed first. Recommended for partial routing with low throughput.

- Biggest First—Routes connections with the highest capacity first. Recommended for accommodating large connections; smaller connections might be rejected in partial routing situations.

- Smallest First—Routes connections with the lowest capacity first. Recommended for accommodating small connections, because it gives smaller connections higher priority to get their share of the capacity.
- Unsorted—Connections are sorted in the order in which they appear in the Traffic Matrix Editor: row1/column2 first, row1/column3 second, etc.

Diverse Routing Algorithm

You can apply the diverse routing algorithm to both DCL- and OCH-layer traffic. This algorithm maximizes the connectivity of the virtual topology that results from routing traffic and ensures that if there is a failure, not all related connections fail simultaneously. There is no absolute requirement for diversity, thus the feature will try to route as much as possible, even if the diversity preference cannot be fully met.

This algorithm works in two phases:

1) SP Guru Transport Planner routes the traffic as unprotected; meanwhile, the algorithm tries to route all related connections with the minimal amount of overlap between routes. Therefore, the algorithm sorts the connections and routes them sequentially to ensure a minimal amount of overlap between related connections that were routed in a previous sequence. SP Guru Transport Planner tries to sort the connections based on routing difficulty and route the most difficult connections first.The diverse routing options allow you to define related connections in different ways.

2) An optional step tries to optimize the initial solution by rerouting those connections that have a high degree of overlap with their related connections. SP Guru Transport Planner reroutes connections and considers the overlap of related connections. Because of topological constraints, it might not be possible to obtain a completely diverse routing of all related connections. In this case, SP Guru Transport Planner tries to optimize the diversity without guaranteeing it.

This algorithm can consider both node and link diversity. Two settings under Protection Options, described in Protection Options on page TrP-6-6, affect how the connections are routed:

- The layer selected in the Link Disjoint option determines the layer at which the link overlap between related connections is calculated.
- If the Node Disjoint option is selected, SP Guru Transport Planner also tries to route the traffic so that the related connections are as node-disjoint as possible.

Diversity selection:

- Within Traffic Matrices—All connections of all selected traffic matrices will be routed diverse according to the diversity relationship
- Between Traffic Matrices—Connections belonging to different traffic matrices that have a particular diversity relationship will be routed diverse. The connections within one traffic matrix will not be routed diverse however.

Diversity relationship:

- All connections—All connections of the selection will be routed diverse.
- With Same End Nodes—All connections of the selection that have a common end node will be routed diverse. For example a connection between node A and B, will be routed diverse from a connection between node A and C, because they share a common end node.
- Between Node Pairs—All connections of the selection that are routed between the same node pair will be routed diverse. For example, if there are two connections between node A and B, they will be routed diverse.
- Optimize—If selected the diversity will be optimized. This means the algorithm will perform some additional optimization steps to achieve a diversity that is as high as possible between the selected traffic.

The way the options for the algorithm work is that the diversity selection and diversity relationship complement each other, that is, if the option "Within Traffic Matrices" and "Between Node Pairs" is selected, all connections of all traffic matrices between the same node pairs will be routed as diversely as possible. If the option "Between Traffic Matrices" and "Between Node Pairs" is selected connections belonging to different traffic matrices between the same node pairs will be routed as diversely as possible.

Routing Optimization

The Optimized routing approach starts from the best solution of the Combined Routing approach (evaluating different ways of sorting the connections prior to applying the routing algorithm). The optimization process is based on making random changes to this routing solution, followed by an attempt to accommodate the connections not yet routed in the network. A random change selects an established connection at random and then "tears down" that connection. The algorithm contains a number of “major iterations” that make a substantial number of changes to the solution; each major iteration is followed by a local optimization step that contains a number of “minor iterations” to improve the solution. The objective is to maximize the throughput while minimizing the routing cost. The number of changes made and the number of steps taken is specified by following settings and illustrated in the subsequent dialog box.

To configure this algorithm (number of changes made, number of steps taken and so on), click on the Options button in the Routing Strategy area of the Routing dialog box. This opens the Optimization Options dialog box (described in Table 6-2 on page TrP-6-12).

Figure 6-5 Optimization Options Dialog Box

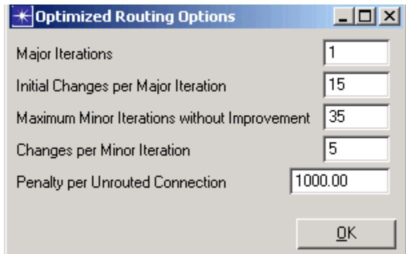


Table 6-2 Routing Options Dialog Box

Field	Description
Major Iterations	This setting determines the number of major iterations to improve the solution. Each major iteration starts by making a number of changes to the best solution (found by the combined routing approach), followed by a local optimization step. Enter 0 if you want to add a single local optimization step to the best solution. Enter 1 if you want to add one additional optimization step, 2 for two additional steps, etc.
Initial Changes per Major Iteration	This setting determines the number of random changes at the start of a major optimization iteration. For example, suppose the "Major Iterations" field is set to 1 and this field is set to 15. This means that, after SP Guru Transport Planner applies the local optimization step to the outcome of the combined routing approach, SP Guru Transport Planner makes 15 random changes before it starts a new local optimization step.
Maximum Minor Iterations without Improvement	If SP Guru Transport Planner executes the maximum number of minor iterations of the local optimization step without improvement of the routing objective, it stops the local optimization process.
Changes per Minor Iteration	This setting determines the number of random changes per minor iteration of the local optimization step. A value of 5 means that 5 connections are selected at random and torn down. Then the routing function makes another attempt to accommodate traffic in the network.
Penalty per Unrouted Connection	This cost is added to the routing objective per connection that cannot be routed.
End of Table 6-2	

Node Model Options

Note—These options are available only if the nodes on the selected layer (DCL or OCH) are discrete nodes. If the nodes are continuous, they can scale without limitations and do not constrain the routing algorithms.

The options are:

- Impose Node Limitations—If enabled, discrete node sizes are fixed and are not upgraded. The capacity limits on these discrete nodes form additional constraints to the routing algorithm, in addition to the limited link capacities. SP Guru Transport Planner considers OXC or IXC capacities when routing an OCH matrix, and DXC or IXC capacities when routing a DCL matrix.
- Constrain OCH Routing by DCL Node Size—In some cases, you might route an OCH matrix that originated from outside the OCH layer. For example, you might route an OCH matrix that resulted from a grooming operation. This is called *non-native traffic* because it originated from a different network layer (in this case, the DCL layer).

  When SP Guru Transport Planner routes non-native OCH traffic, it trails OCH connections to DCL trunks. Therefore, routing non-native OCH connections might require additional DXC trunk ports. If this option is enabled, the discrete DXC type (and therefore the number of available ports on a DXC) is fixed; this constrains the amount of OCH traffic that SP Guru Transport Planner can route. If this option is disabled, SP Guru Transport Planner adds DXC ports (by upgrading the DXC type) as needed to route the specified OCH traffic matrix.

Note—This option applies only when you are routing a non-native OCH traffic matrix.

Routing Cost

You can specify one of the following cost functions when routing an OCH traffic matrix. These functions use different methods to calculate link costs and thereby determine the lowest-cost path.

- Fiber Length—The lowest-cost path is the path with the shortest fiber length.
- Hop Count—The lowest-cost path is the one with the fewest hops. If multiple paths have the same number of hops, SP Guru Transport Planner finds the path with the shortest fiber length.
- Least Used—The cost of a link is set to be inversely proportional to its unused capacity. Specifically, link cost is 1 divided by the unused link capacity.
- Maximum Availability—Using the availability properties (see Availability Settings on page TrP-3-42), SP Guru Transport Planner calculates the availability of each link and calculates the path with the highest availability.

- Real Cost—SP Guru Transport Planner calculates the per-capacity-unit routing cost on each link to determine the shortest (lowest-cost) path, using the cost parameters specified in the Equipment Properties (described in Network Properties on page TrP-3-23).

- User Specified—You can override the routing behavior by specifying a custom cost for a link; see Link Browser on page TrP-4-2 for details.

- Combined Metric—To determine the lowest-cost path, SP Guru Transport Planner determines routing costs using the following formula:

  <routing_cost> = *<multiplier_for_hop_count>* * *<hop_count>* +
  <multiplier_for_fiber_length> * *<fiber_length>*

  The combined routing cost metric is available at all layers. By default, the hop count of a link at any individual layer equals one. Using the detailed routing options, you can choose to count each in-line regenerator on a link as an extra hop. The fiber length is based on the underlying OTS links. For more information, see the following section.

Detailed Routing Cost Options

To specify detailed routing-cost options, click the "..." button (next to Routing Cost" in the Route DCL/OCH Traffic Dialog Box. The options in this dialog box are described in Table 6-3 on page TrP-6-15.

Figure 6-6 Detailed Routing Cost Options Dialog Box

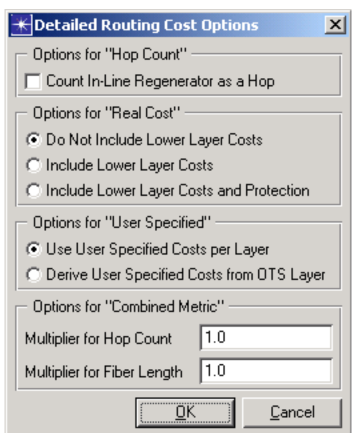


Table 6-3 Detailed Routing Cost Options Dialog Box

Options For	Explanation
Hop Count:	
Count In-Line Regenerator as a Hop	When enabled, this option counts each in-line regenerator on a link as an extra hop.
Real Cost:	
Do Not Include Lower Layer Costs	When this option is selected, the per-link cost is derived from the cost model but does not include the cost of equipment on lower layers (that is, lower than the layer on which traffic is routed). For example, if you are routing a DCL traffic matrix, the cost of the optical equipment in the underlying OCH layer is considered.
Include Lower Layer Costs	When this option is selected, the per-link cost is derived from the cost model and includes the proportional cost of equipment on lower layers. If traffic is protected on lower layers, the cost of the resources required for the protection traffic is not considered.
Include Lower Layer Costs and Protection	When this option is selected, the per-link cost is derived from the cost model and includes the proportional cost of equipment in lower layers. If traffic is protected on lower layers, the cost of the resources required for the protection traffic is also considered.
User Specified:	
Use User Specified Costs per Layer	When this option is selected, the per-link cost is equal to the user-specified cost that you have set in the layer on which you are routing the traffic.
Derive User Specified Costs from OTS Layer	When this option is selected, the per-link cost is derived from the user-specified cost of OTS links. The cost of a higher-layer link is the sum of the user-specified costs of the supporting OTS links.
Combined Metric:	
Multiplier for Hop Count	Multiplier applied to the number of hops on a link to obtain the combined routing metric (see Routing Cost on page TrP-6-13).
Multiplier for Fiber Length	Multiplier applied to the fiber length of a link to obtain the combined routing metric (see Routing Cost on page TrP-6-13).
End of Table 6-3	

Routing Results

The Routing Results dialog box (Design > Routing Results) shows the results of routing operations for different traffic matrices. This window appears automatically after you route a matrix using the Route DCL/OCH Traffic operation (see Routing on page TrP-6-1). For a selected OCH or DCL traffic matrix, SP Guru Transport Planner reports the percentage of the matrix's traffic that is routed and accommodated in the network.

Several types of constraints can result in unrouted traffic:

- Topological constraints, such as the absence of a link between two nodes
- Limited link capacities
- Limited node capacities
- Limited regeneration capacities (in transparent networks)
- Limited tributary capacities (in transparent networks that deploy wavelength-plane OXCs with integrated terminal multiplexers)
- The inability to find disjoint working and protection paths when routing with 1 + 1 protection
- Explicit, user-specified routing constraints for a specific connection (for more information, see Constraint-Based Routing on page TrP-6-26)

The Routing Results dialog box displays the average link, node, regeneration, and tributary utilization after a routing operation. You can use these numbers to determine the cause of unrouted traffic. For example, if link utilization is high, unrouted traffic is probably due to capacity shortage on the links.

You can view specific information about any (routed) matrix using the Select Layer radio buttons and the Traffic Matrix pull-down menu.

Figure 6-7   Routing Results Dialog Box

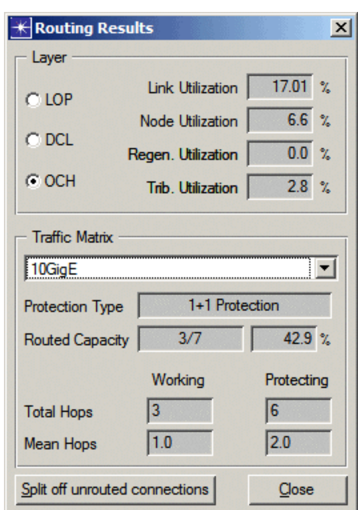


Table 6-4   Routing Results

Field/Option	Description
Layer	The layer (LOP, DCL or OCH) for which to view routing results
Link Utilization	Link capacity used (as a percentage of total link capacity) in the selected layer
Node Utilization	Node capacity used (as a percentage of total node capacity) in the selected layer. This field is available only if the network uses discrete node types in that layer.
Regen. Utilization	Reports on the utilization of the regeneration capacity (for transparent networks and OCH layer only)
Trib. Utilization	Reports on the utilization of the tributary capacity (only for transparent networks that deploy wavelength-plane OXCs with integrated terminal multiplexers)
Traffic Matrix	Lists all routed matrices in the currently selected layer. Select a matrix to view the routing results.
Protection Type	The protection type used to route the currently selected matrix
Routed Capacity	The routed capacity (as a percentage of the total capacity) of the matrix. For example: 3/4 would indicate a traffic matrix of four units of total capacity, of which three have been routed. In this case the % field would read 75.
Total Hops	The total hop count of all working/protection paths in the selected matrix. SP Guru Transport Planner uses the following equation to determine the hop count of a path: *hop_count_for_path = total_links_in_path* x *capacity_units_routed* For example, a connection with three units of capacity routed over a path with two links results in a hop count of six for that path. An unrouted connection adds no units to the total number of hops.
Mean Hops	The total number of hops (for working and protection paths) versus the total routed capacity in that matrix. See the entry on Total Hops of a description of how SP Guru Transport Planner calculates hops.
Split Off Unrouted Connections	Splits a partly-routed traffic matrix into two matrices: one matrix that contains all the routed connections and a “residual” matrix that contains all unrouted connections.
End of Table 6-4	

Splitting Unrouted Connections into a Residual Traffic Matrix

If a traffic matrix contains unrouted connections, you can group these connections into a new matrix. As a result, the original matrix contains routed connections only and the new matrix contains unrouted connections only. This allows for workflows in which the unrouted traffic is treated differently from the routed traffic. Example workflows include:

- You can start from an OCH traffic matrix that you try to route within the existing network capacity. Then you can split the unrouted connections into a residual matrix and use this matrix to dimension the network.
- You can start from a DCL traffic matrix that you try to route within the existing network capacity, which might be protected at the OCH layer. Then you can split the unrouted connections into a residual matrix and perform grooming for it, this time applying protection at the DCL layer.

Procedure 6-1 describes how to create a residual traffic matrix.

Procedure 6-1 Creating a Residual Traffic Matrix

1 Choose Design > Routing Results and select a traffic matrix that is partly routed (that is, one for which the Routed Capacity field indicates more than 0% but less than 100%).

2 Click on the "Split off unrouted connections" button.

➥ The Routed Capacity field of the traffic matrix is now 100%.

➥ A residual traffic matrix is created with a name of "<*original_traffic_matrix*>_split."

3 Go to Network > Traffic Matrix Editor to view the newly created traffic matrix. In this dialog you can also change the name of the traffic matrix.

Note—If the original traffic matrix contains a tandem connection that is partly routed, this connection will not be split off in the residual traffic matrix; it will remain in the original traffic matrix.

End of Procedure 6-1

Pinning and Unpinning Connections

You can pin a connection to fix the route of that connection and ensure that the connection is not affected when you tear down the traffic. This enables you to do a “partial tear-down” of a traffic matrix, which tears down and reroutes unpinned connections but retains pinned connections whose routes you want to retain.

Procedure 6-2 Pinning or Unpinning an OCH or DCL Connection

1. Open the Connection Browser (Network > Connection Browser).
2. Under Traffic, select the layer of the connection you want to pin (DCL or OCH).
3. The treeview lists all connections at that layer. The Pinned column indicates whether the connection is pinned or not.
4. Right-click on a connection and choose Pin (for unpinned connections) or Unpin (for pinned connections).

   After you tear down a traffic matrix, all pinned connections of that matrix remain active.

End of Procedure 6-2

Tearing Down a Traffic Matrix

When you tear down a traffic matrix, SP Guru Transport Planner removes that traffic from the network and the traffic becomes “unrouted.” To do this, open the Tear Down Traffic dialog box (Design > Tear Down Traffic); then select the traffic matrix and click Tear Down. This operation removes traffic only, and does not remove any network capacity.

You can also tear down a partially routed traffic matrix—that is, a matrix that was not 100 percent routed—from the Route dialog box: open the Route dialog box, select the matrix, and click Tear Down. See Routing on page TrP-6-1 for more information.

Note—If an OCH matrix contains DCL connections that resulted from a grooming operation, tearing down the OCH matrix also tears down these DCL connections. This is also true for a DCL traffic matrix that contains groomed LOP connections. For more information about setting up and tearing down dependent OCH/DCL matrices, see Grooming Multiple DCL Matrices on page TrP-8-28.

Figure 6-8 Tear Down Traffic Matrix Dialog Box

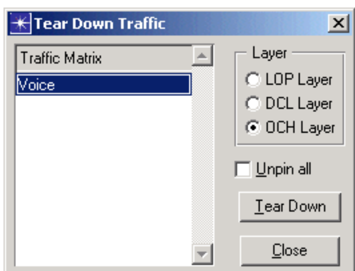


Table 6-5 Tear Down Traffic Dialog Box

Control	Description
Layer	Specifies the type of traffic matrices that appear in the Traffic Matrix list.
Tear Down	Tears down the selected traffic matrix
Traffic Matrix	Select the traffic matrix to tear down. This table lists all routed traffic matrices of the type specified by the Layer option.
Unpin All	If this option is selected, SP Guru Transport Planner unpins all pinned connections so that all connections (pinned and unpinned) are torn down. Otherwise SP Guru Transport Planner tears down unpinned connections only. For more information, see Pinning and Unpinning Connections on page TrP-6-19.
End of Table 6-5	

Traffic Variations

You can predict the effect of varying traffic levels on your network, and assess your network's performance for different traffic matrices and protection strategies. This operation does not add resources to the network—it determines how the existing network will handle projected traffic variations.

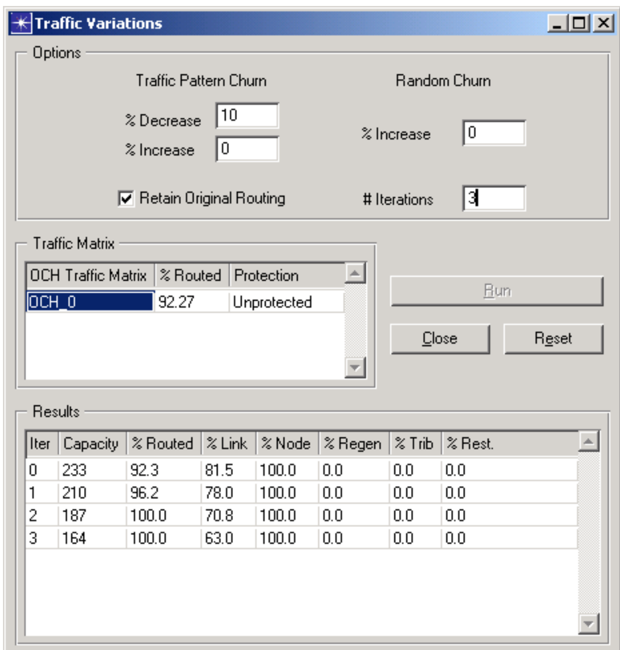
When it simulates the effects of traffic variations, SP Guru Transport Planner takes node, link, and (for transparent networks) regeneration and tributary capacity into account.

Procedure 6-3 Studying the Effects of Future Traffic Variations

1 Choose Design > Traffic Variations.

➥ The Traffic Variations dialog box appears. For information about the options in this window, see Table 6-6 Traffic Variations Options/Fields on page TrP-6-22.

Figure 6-9 Traffic Variations Dialog Box



2 Select a routed OCH matrix in the Select Matrix menu.

3 Enter the traffic-variation parameters you want in the Input Parameters area and click RUN. To execute a new run, click Reset.

End of Procedure 6-3

Table 6-6 Traffic Variations Options/Fields (Part 1 of 2)

Item	Description
INPUT PARAMETERS	
Traffic Pattern Churn	Increase or decrease traffic (corresponding to the traffic patterns specified in the matrix) by the specified percentage. Each iteration increases or decreases the traffic volume; overall traffic patterns are retained but scaled upward or downward. The increase or decrease occurs in discrete steps. If a traffic matrix has ten elements that equal 1 (total traffic = 10 units), an increase of 10% means that one of the ten elements, selected randomly, will grow from 1 unit to 2 units (total traffic = 11 units). SP Guru Transport Planner does not scale elements in a traffic matrix that equal zero (0); only non-zero elements are increased or decreased.
Random Churn	Increase overall traffic over the network in a randomized way. Original traffic patterns are not retained. In contrast with the Traffic Pattern Churn settings, random-churn scaling can occur for any element in a traffic matrix whether the element is zero or non-zero. This scaling occurs in discrete steps, as described in the Traffic Pattern Churn entry.
# iterations	The number of iterations for running the traffic-variation calculations
Retain original routing	With this box checked, SP Guru Transport Planner retains the original matrix. Otherwise it tears down the original matrix, then creates and routes a new matrix (**<***original_matrix***>_trafVar**). This matrix persists in the network after the simulation.

Table 6-6 Traffic Variations Options/Fields (Part 2 of 2)

Item	Description
RESULTS	
Iter	Iteration index
Capacity	Total (scaled) capacity of the matrix
% Routed	Percentage of the matrix that was routed successfully
% Link	Link utilization in the OCH layer
% Node	Node utilization in the OCH layer
% Regen	Regeneration capacity utilization in the OCH layer (for transparent networks only)
% Trib	Tributary capacity utilization (for transparent networks that deploy wavelength-plane OXCs only)
% Rest.	Percentage of the matrix that is restorable (calculated only if matrix was routed using restoration)
End of Table 6-6	

Manual Routing

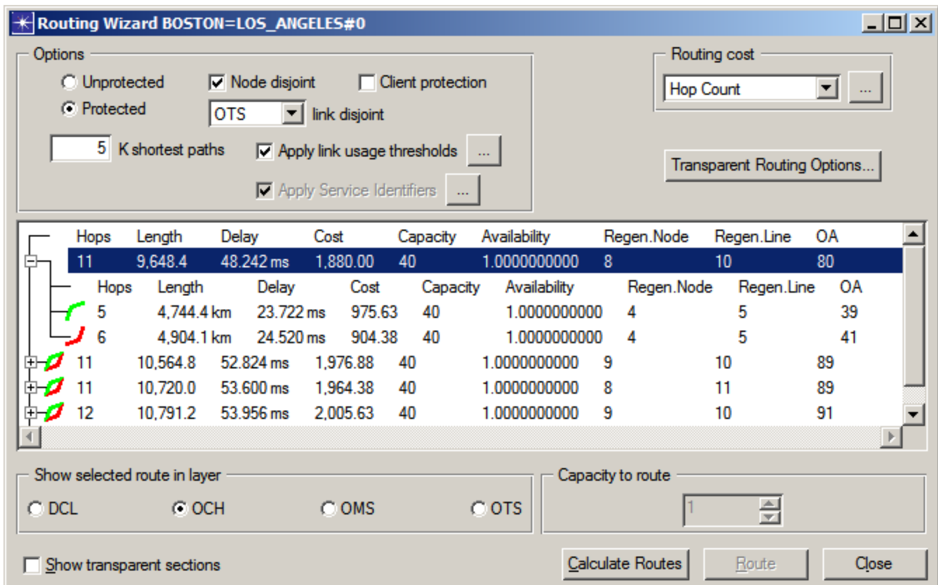
In addition to routing an entire traffic matrix, you can also establish and tear down individual connections using the Connection Browser. To route an unrouted connection, do Procedure 6-4. To tear down a routed connection, right-click on the connection in the Connection Browser and choose Tear Down.

Procedure 6-4   Routing an Individual Connection

1 Right-click on an unrouted connection in the Connection Browser and select Route. (For more information, see Connection Browser on page TrP-4-23.)

➥ The Routing Wizard opens.

Figure 6-10   Routing Wizard



2 Set up the Options, as well as the Routing Cost to use for calculating the routes, and click Calculate Routes.

➥ The treeview shows all candidate routes for the connection and information about each route. For a protected connection, the tree shows information for both the working and protection path and for both paths together. For more information, see Table 6-7 on page TrP-6-25.

To view a route in the Project Editor, click on the route in the treeview.

3 To establish a connection in the network, select the desired route, fill in the “Capacity to Route” field, and click Route.

End of Procedure 6-4

Table 6-7 Routing Wizard

Control	Description	Reference
Options Routing Cost	Set routing and cost options for the connection	Table 6-1 Route Dialog Box on page TrP-6-3
Transparent Routing Options	Set routing options for transparent network	Table 10-1 Transparent Routing Options Dialog Box on page TrP-10-12
Connection treeview	The treeview shows the candidate routes to accommodate the connection in the network together with a number of metrics per route. For a protected connection, the treeview shows the working and protection path and both paths together. The treeview shows the following information for each connection: • Hops—Number of hops in path • Length—Total length of path • Delay—Total delay on path • Capacity—Available capacity on the path • Availability—Service availability offered by the path • Regen. Node—Number of in-node regenerators passed • Regen. Line—Number of in-line regenerators passed • OA—Number of optical amplifiers passed	
Show selected route in layer	View the related path(s) for a connection in a specific network layer.	
Capacity to route	The number of connection units to establish on the route selected	
Show transparent sections	Shows the sections of the connection which are routed transparently and the intermediate transparent nodes that are passed for each section	
End of Table 6-7		

Constraint-Based Routing

You might want to control the route used by a connection during a routing or dimensioning action. You can do this by setting additional constraints in the Connection Browser. These defined constraints affect the following design operations:

- Routing and dimensioning actions—if SP Guru Transport Planner cannot find a route that meets the routing constraints, it does not set up a connection.
- Optimized routing and dimensioning—SP Guru Transport Planner reroutes connections during the optimization process only if the constraints are satisfied.

Grooming and Ring Dimensioning actions are not affected by these constraints, because these actions do not always set up a connection in one step.

If multiple constraints are defined for a connection, the connection is set up only if all constraints are met. If constraints are set for both working and protection paths, but the constraints can be satisfied for one path only, the connection will not bet set up.

To specify constraints for a connection, open the Connection Browser (Network > Connection Browser), then right-click on the connection of interest and choose Routing Constraints. This opens the Routing Constraints dialog box (Figure 6-12 on page TrP-6-27). You can set routing constraints for one connection or for multiple connections (by selecting multiple objects in the browser).

Figure 6-11 Specifying Constraints for a Connection

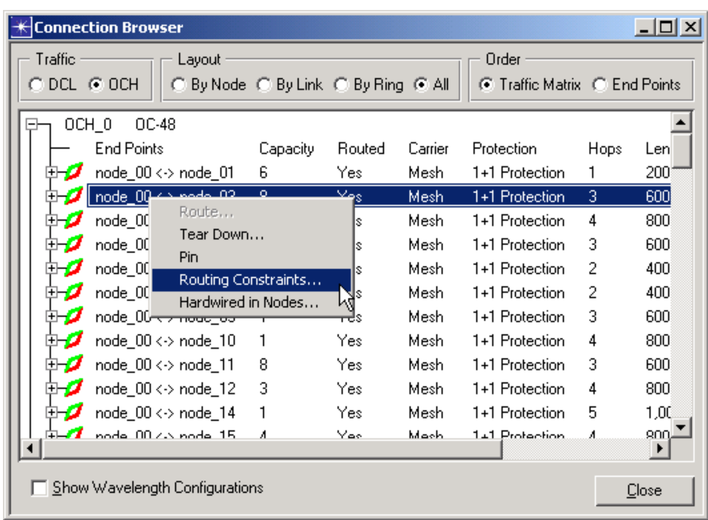


Figure 6-12 Routing Constraints Dialog Box

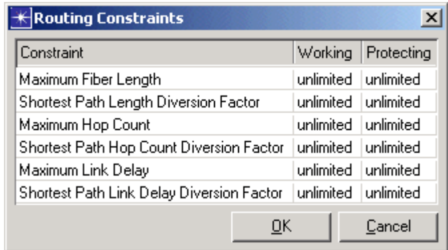


Table 6-8 Routing Constraints Dialog Box

Field	**Description**
Maximum Fiber Length	The maximum fiber length (in km or miles, according to the project settings) that the route can take
Shortest Path Length Diversion Factor	The maximum fiber length is calculated by multiplying the factor with the shortest length of the connection
Maximum Hop Count	The maximum number of hops that the route can take
Shortest Path Hop Count Diversion Factor	The maximum hop count is calculated by multiplying this factor with the hop count of the shortest path of the connection
Maximum Link Delay	The maximum link delay that the route can have
Shortest Path Link Delay Diversion Factor	The maximum link-delay path is calculated by multiplying this factor with the link delay on the lowest-latency path of the connection
End of Table 6-8	

Topological Routing Constraints

In some cases, you might want to define topology constraints that are considered during a network design action such as routing, grooming, or dimensioning. For example, you might want to specify constraints that force grooming to occur at specific locations (such as hub locations) other than those that SP Guru Transport Planner might consider ideal; meanwhile, the unconstrained section of a route can still be optimized.

These constraints are specified as nodes that should or should not be used by a routed connection. You can define topology constraints for one connection or a group of connections that originate from the same node. The topology constraints can be different for the working and protection path of a connection. The constraints can include both "obliged" nodes that must be in the route and "forbidden" nodes that may not be in the route.

There are two methods for specifying topological restraints:

- Import the constraints from a data file. The data-file format is described in Topology Constraints Data Files on page TrP-5-22; the procedure for importing the data is described in Procedure 5-1 Importing Network Data into a Project on page TrP-5-2.
- Specify constraints for individual connections in the Connection Browser, as described in Procedure 6-5.

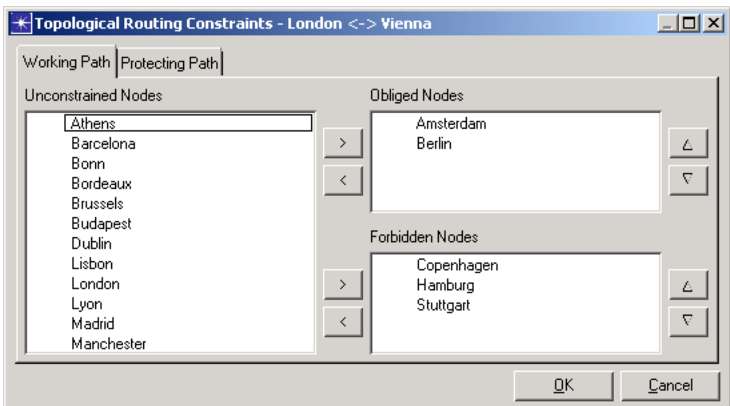
Procedure 6-5 Specifying Topology Constraints for a Connection

1 Open the DCL Connection Browser: choose Network > Connection Browser and click the DCL button (under “Traffic”).

2 Right-click on a DCL connection and choose "Topological Constraints…" from the right-click menu.

➥ The Topological Constraints dialog box (Figure 6-13) appears.

Figure 6-13 “Topological Routing Constraints - <Connection>” Dialog Box



3 Specify the obliged and forbidden nodes for the working path: select nodes in the Unconstrained Nodes (left pane) and use the > buttons to set them as Obliged Nodes or Forbidden Nodes.

Note—You must specify the obliged nodes in the correct sequence. This is the sequence in which the nodes should occur in the path. You can change the sequence using the up and down arrows. The sequence is not import for Forbidden Nodes.

You can remove nodes from the Obliged Nodes or Forbidden Nodes list using the < buttons.

You cannot add the same node to both the Obliged Nodes and Forbidden Nodes.

4 Click the "Protection Path" tab and set the topological constraints for the protection path using the same method described in step 3.

5 Click OK to confirm the topological constraints and close the dialog box.

End of Procedure 6-5

Link Usage Threshold

A *link usage threshold* is a value of any real number between 0 and 1 (i.e., [0.1]) that designates the maximum allowed percentage of utilization for a link. Thus, the capacity usage of a link cannot exceed the link usage threshold defined for a link. For a DCL link, the link usage threshold specifies the percentage of the timeslots that can be utilized. For an OCH link, it specifies the percentage of the available wavelengths that can be utilized.

Given the above definition, consider an STS-192 DCL link. If a usage threshold of 0.5 (i.e., 50%) is specified, the maximum allowed capacity usage of the link is 96 STS's (i.e., 192 * 0.5 = 96). Since capacity usage on a DCL or OCH link must be an integral value, a floor function is applied to the result of the capacity of the link multiplied by the usage threshold. A floor function is used since partial usage of DCL link timeslots or OCH link wavelengths is not permitted. Thus, the maximum capacity usage of a link is derived with the following function:

```
Floor(Link Usage Threshold * Link Capacity)
```

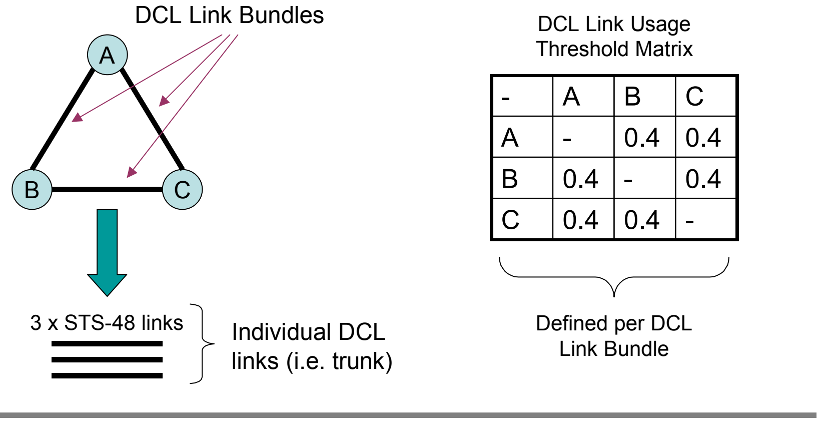
The floor function rounds down the result of `(Link Usage Threshold * Link Capacity)` to the nearest whole integer. Logically, if a usage threshold of 0 is specified, then the link cannot be used to accommodate any traffic. Conversely, for a usage threshold of 1, the entire link capacity can be used for the accommodation of traffic.

In SP Guru Transport Planner link usage thresholds are considered to be the same for parallel links, that is, links between the same node pairs. For example, given nodes A and B, all links between A and B would have the same usage threshold value. You can think of this as link thresholds being defined for the entire link bundle between nodes and not for each individual link in the bundle.

Link usage threshold values are defined within SP Guru Transport Planner via a matrix. This matrix defines the link usage threshold values on a per-link-bundle basis for both the DCL and OCH layers.

The following figures illustrate the link usage threshold concept and how it is applied to both the DCL and OCH layers.

Figure 6-14 DCL Layer Usage Threshold Example

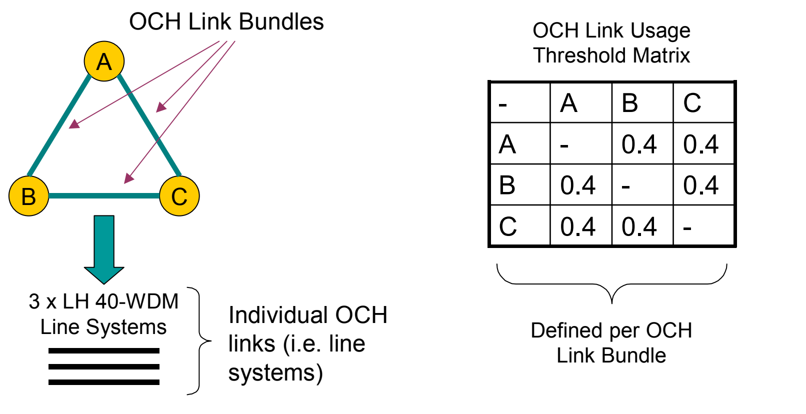


-	A	B	C
A	-	0.4	0.4
B	0.4	-	0.4
C	0.4	0.4	-

Usable Capacity Per DCL Link = Floor(48* 0.4) = Floor(19.2) = 19 STS's

Usable Capacity on DCL Link Bundle = 3 * 19 = 57 STS's

Figure 6-15 OCH Layer Usage Threshold Example



-	A	B	C
A	-	0.4	0.4
B	0.4	-	0.4
C	0.4	0.4	-

Usable Capacity Per OCH Link = Floor(40* 0.4) = Floor(16) = 16 Wavelengths

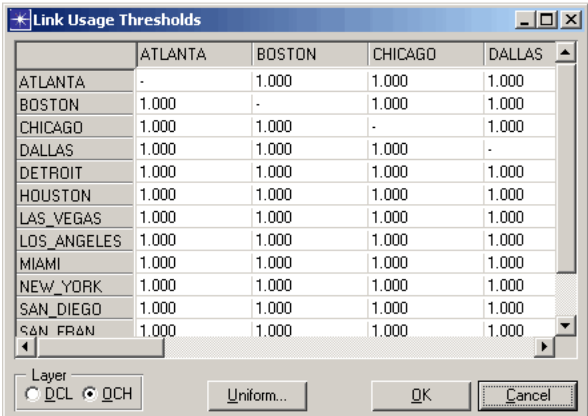
Usable Capacity on OCH Link Bundle = 3 * 16 = 48 Wavelengths

In SP Guru Transport Planner the threshold values for the links are set via the Link Usage Thresholds dialog box, as described in Procedure 6-6.

Procedure 6-6   Setting and Using the Link Usage Thresholds

1 Open the Link Usage Thresholds dialog box by selecting Network > Link Usage Thresholds from the menu bar or by clicking on the “...” button next to the “Apply link usage threshold” option in Routing, Dimensioning, or Grooming dialog boxes.

Figure 6-16   Link Usage Thresholds Dialog Box



Note—The dialog box is shown with all usage threshold values being 1 (i.e. 100% of the links capacity can be utilized).

2 Click on either DCL or OCH Layer radio button to select a layer to edit.

3 (Option 1) Edit individual values.

3.1 Edit each cell individually to specify the desired value.

4 (Option 2) Set all values to a global threshold.

4.1 Click on the "Uniform" button.

4.2 The "Enter Global Threshold" dialog box displays.

4.3 Enter a value for uniform thresholds.

4.4 Click the OK button to apply the values to all cells.

5 Click the OK button to apply and save the values.

The link usage threshold values are persistent, meaning they are saved with the network model in the project files.

End of Procedure 6-6

Besides defining the threshold values for the links in the user interface as described above, you can also import (and export) the link usage thresholds at the DCL and OCH layer. For more information, see Data File Formats on page TrP-5-4.

Note—The link usage thresholds are utilized by a number of design actions within SP Guru Transport Planner, such as routing, dimensioning, and grooming. To make sure that the link usage thresholds are considered by a design action, select the “Apply link usage thresholds” option in the design action dialog box .

Service Identifiers

The Service Identifier feature lets you tag specific wavelengths to restrict for use by routes of upper layer traffic (i.e., DCL connections). This allows you to specify wavelength services and routing of upper layer traffic over designated wavelengths that meet the service identifier requirements of the upper layer traffic. For example, you may have a network in which certain wavelengths are tied to a specific customer (e.g., a bank) and all services for that customer should go over those wavelengths, while other customer traffic should not.

Procedure 6-7 summarizes a typical workflow for using the Service Identifier feature in SP Guru Transport Planner. The steps of this workflow are described in more detail in later subsections, to which links are provided.

Procedure 6-7   Specifying Service Identifier Workflow

1 Specify the Service Identifiers representing the different services in the network. For more information about adding or removing service identifiers, see Specifying Service Identifiers on page TrP-6-33.

2 Assign Client Service Identifiers to DCL connections to identify which connections represent which services. For more information about assigning Client Service Identifiers to DCL connections, see Applying Service Identifiers to Connections on page TrP-6-34.

2.1 (Option 1) Add/Remove Client Service Identifiers for DCL connections in Network > Connection Browser.

2.2 (Option 2) Import Client Service Identifiers as part of the Connection List file format by using File > Import > Network Elements. For more information, see Importing and Exporting Data on page TrP-5-1.

3 Assign Server Service Identifiers to OCH connections to identify which wavelengths support which services. For more information about assigning Client Service Identifiers to OCH connections, see Applying Service Identifiers to Connections on page TrP-6-34.

3.1 (Option 1) Add/Remove Server Service Identifiers for OCH connections using Network > Connection Browser.

3.2 (Option 2) Import Server Service Identifiers as part of the Connection List file format by using File > Import > Network Elements. For more information, see Importing and Exporting Data on page TrP-5-1.

4 Check the Apply Service Identifiers checkbox in the Design > Route DCL/OCH Traffic dialog to route DCL connections over wavelengths matching the Service Identifiers. For more information, see Routing Traffic with Service Identifiers on page TrP-6-35.

5 Generate the Service Identifier Assignments Report by choosing .Info > Export to Web Report > Service Identifier Assignments Report.

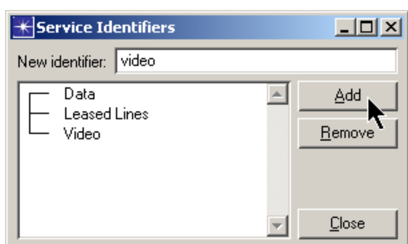
End of Procedure 6-7

Note—As described in steps 2 and 3 of Procedure 6-7, the Service Identifier concept is applied on a per connection basis. This means that different connections within the same traffic matrix can have different Service Identifiers.

Specifying Service Identifiers

Before you can assign a Service Identifier to a connection, you must define it. Manage the list of Service Identifiers representing the services in your network in the Service Identifiers dialog box, shown in Figure 6-17.

Figure 6-17 Service Identifiers Dialog Box



Procedure 6-8 Specifying Service Identifiers

1 Open the Service Identifiers dialog box by choosing Network > Service Identifiers....

2 Add or remove identifiers.

2.1 Enter a new identifier by typing the name in the space next to “New identifier:” and clicking the Add button.

2.2 Remove an existing identifier by selecting the service identifier in the displayed list and clicking the Remove button.

3 Click on Close to close the dialog box.

End of Procedure 6-8

Applying Service Identifiers to Connections

When you have defined the service identifiers for your network, you can add them to a connection. This lets you specify a service for a particular customer, for example. You can add one or more of the defined Service Identifiers to a connection using the Connection Browser.

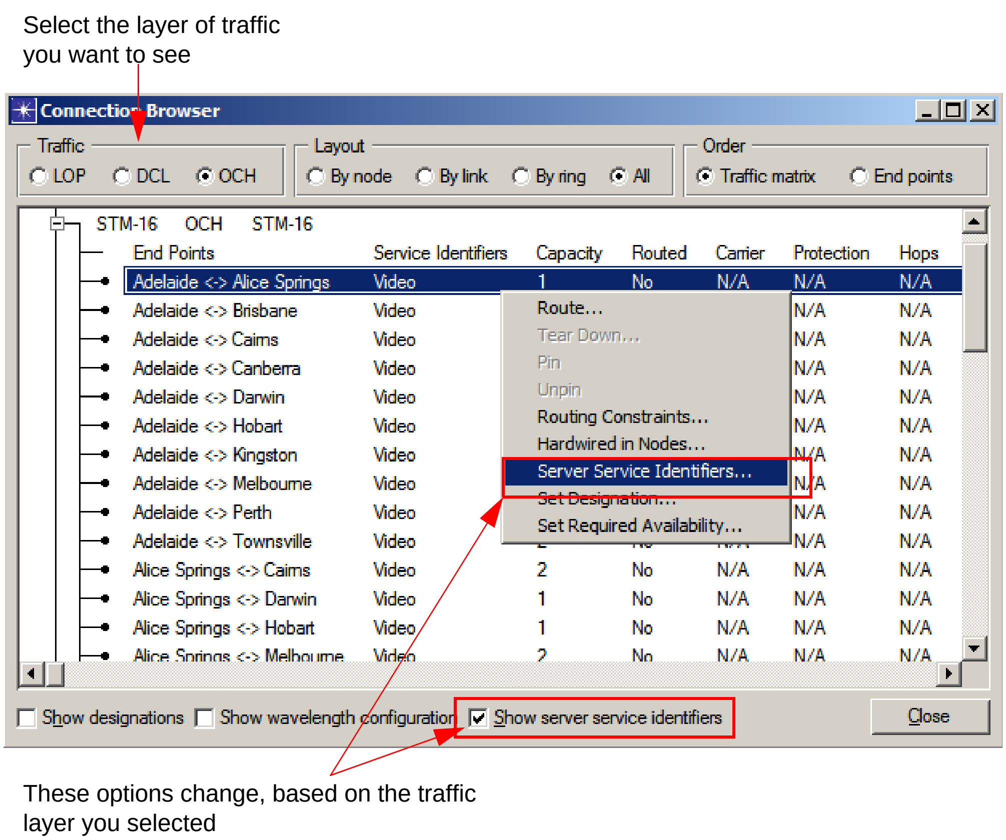
At the DCL layer, you can set "Client Service Identifiers" to identify which connections represent which services. At the OCH layer, you can set "Server Service Identifiers" to identify which wavelengths support which services.

Procedure 6-9 Applying Client Service Identifiers to Connections

1 Open the Connection Browser by choosing Network > Connection Browser.

➥ The connection browser opens.

Figure 6-18 Connection Browser



2 Select the layer of traffic you want to see (DCL or ODH) from the Traffic radio button selection.

3 Select the “Show client service identifiers” checkbox in the DCL layer or “Show server service identifiers” checkbox in the OCH layer to see service identifier assignments.

4 Manage Client or Server Service Identifiers.

4.1 Right-click on a connection in the Connection Browser and select "Client Service Identifiers" or "Server Service Identifiers".

4.2 Add/Remove/Remove All service identifiers from the selected connection, where Remove allows you to select individual service identifiers to remove from the connection.

4.3 Click OK to apply changes.

5 Click Close to exit the Connection Browser.

End of Procedure 6-9

Routing Traffic with Service Identifiers

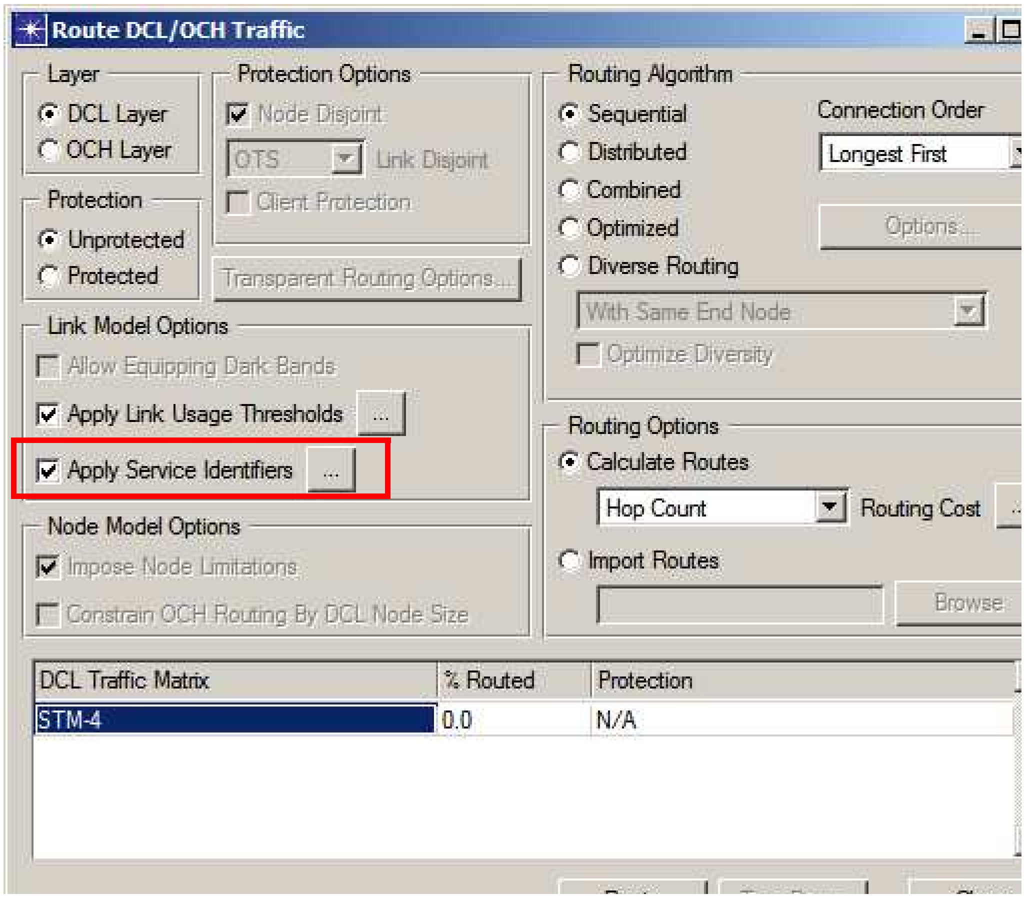
After you have assigned Client Service Identifiers to DCL connections and Server Service Identifiers to wavelengths (OCH connections), you can use these identifiers to drive the Routing design action. In doing so, you can prohibit DCL connections from being routed over certain wavelengths, if the Client Service Identifiers of the DCL connections do not match the Server Service Identifiers of the wavelengths. That is, you can force certain services to be routed over certain wavelengths that are reserved for those services only. Use Procedure 6-10 to apply service identifiers.

Procedure 6-10 Applying Service Identifiers to Traffic

1 Open the Routing design action by selecting Design > Route DCL/OCH Traffic.

➥ The Route DCL/OCH Traffic dialog box appears. For more information about this dialog box, refer to Route DCL/OCH Traffic Dialog Box on page TrP-6-3.

Figure 6-19 Route DCL/OCH Traffic Dialog Box

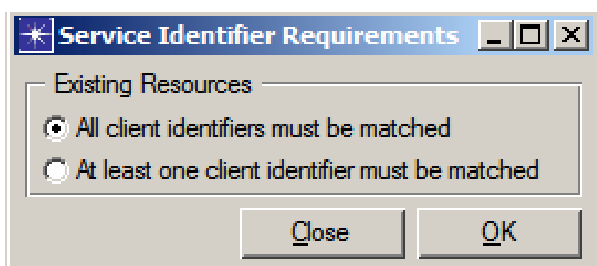


2 Check the "Apply Service Identifiers" option.

3 Click the “...” button to access specific options for applying service identifiers.

➥ The Service Identifier Requirements Dialog Box opens.

Figure 6-20 Service Identifier Requirements Dialog Box



4 Select one of the following options:

- All client identifiers must be matched—A DCL connection can only be routed over a wavelength if the Client Service Identifiers of the DCL connection contain at least all the Server Service Identifiers of the wavelength. The Client Server Identifiers may contain more entries than the Server Service Identifiers, but not fewer.

- At least one client identifier must be matched—A DCL connection can only be routed over a wavelength if the Client Service Identifiers of the DCL connection contains at least one the Server Service Identifiers of the wavelength. If the wavelength has only one Server Service Identifier, the DCL connection should at least contain the same identifier among its Client Service Identifier. If the wavelength has multiple Server Service Identifiers, the DCL connection should at least contain one of the same identifiers among its Client Service Identifiers.

5 Click OK to apply your selection and close the dialog box.

6 Click the Route button to run the design action or Close to exit the dialog box without running the design action.

End of Procedure 6-10