8 Grooming DCL to OCH Traffic

A DCL grooming operation maps SONET/SDH traffic demands (a DCL traffic matrix) into optical wavelength demands (an OCH traffic matrix). DCL grooming uses a “top-down” approach to network design, in which DCL traffic demands drive OCH demands. The connections in the resulting OCH matrix form logical DCL links; the network uses these links to route the DCL traffic.

The aim of DCL grooming is to determine a combined network design for the DCL and OCH layers that minimizes the total network cost. The grooming algorithms use the cost parameters you specify (as equipment properties) to ensure that the combined DCL/OCH network design results in the lowest possible network cost. (For more information about the available equipment properties, see Equipment Properties on page TrP-3-30.)

SP Guru Transport Planner supports DCL grooming with optimized routes (defined by the grooming algorithm) and fixed routes (user-defined physical routes).

Workflow Description

Procedure 8-1 describes how to groom DCL traffic matrices. This workflow is shown in Figure 8-1 on page TrP-8-3.

Procedure 8-1   Grooming DCL Traffic Matrices

1 Choose Design > Groom DCL to OCH Traffic > Optimized Routes to open the Grooming DCL to OCH Traffic dialog box.

2 Specify grooming options.

Select the DCL traffic matrices you want to groom, the target bit rate for the OCH traffic matrix, the cost parameters and the grooming algorithm you want to use (for more information, see DCL Grooming Input and Options on page TrP-8-5).

If you select “1 + 1 Protection in DCL”, you must specify some additional options. The Link Disjoint setting is an import consideration because it impacts the subsequent workflow, as explained in the following steps.

3 Groom the DCL traffic matrices.

After you specify grooming options, click Groom. This determines the logical DCL topology (that is, an OCH matrix) on which to route the DCL connections.

➥ If the grooming operation is finished, SP Guru Transport Planner shows the results in the Grooming Results and Grooming Performance fields on the right (see DCL Grooming Results and Performance on page TrP-8-8 for details).

If you selected 1 + 1 Protection in DCL with Link Disjointness down to the OTS, OMS, or OCH layer, the grooming algorithm ensures that working and protection paths of the DCL traffic are disjoint down to the selected layer. To ensure this, the grooming algorithm also determines the routes of the resulting OCH traffic matrix; then it accommodates both the DCL and the resulting OCH traffic matrices in the network.

In all other cases—that is, if you specified grooming with no protection or with 1+1 protection and DCL link disjointness—the grooming algorithm does not set up the OCH traffic matrix, and you might need to do step 4 to accommodate this matrix. This gives you the freedom to decide the routing and protection strategy for the OCH traffic.

4 Route or dimension the resulting OCH traffic matrix.

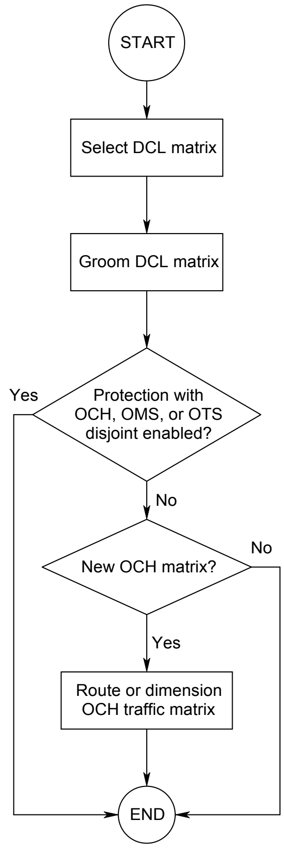
In some cases you can skip this step. There might be enough spare DCL capacity to support the SONET/SDH demand; if so, the resulting OCH traffic matrix is empty.

- To dimension the new OCH traffic matrix, click Dimension in the Groom DCL to OCH Traffic dialog box. This opens the Dimension DCL/OCH Layer dialog box; for more information, see Dimension DCL/OCH Layer Dialog Box on page TrP-7-3.
- To route the new OCH matrix, close the Groom DCL to OCH Traffic dialog box and choose Design > Route DCL/OCH Traffic; for more information, see Route DCL/OCH Traffic Dialog Box on page TrP-6-3.

Note—After the routing or dimensioning or routing operation accommodates the entire OCH traffic matrix in the network, SP Guru Transport Planner automatically accommodates the contained DCL traffic.

End of Procedure 8-1

Figure 8-1 DCL Grooming Workflow



Undoing a DCL Grooming Operation

You can undo the effects of a grooming operation using the Tear Down or Undo buttons in the Groom DCL to OCH Traffic dialog box:

- Tear Down—Tears down the OCH and DCL matrix (that is, undoes the effects of step 4) but retains the grooming action. The result is that the new OCH matrix is unrouted, but still exists.This button is not available if you specified grooming protection with OTS, OMS, or OCH link disjointness.
- Undo—Undoes the grooming action and removes the new OCH matrix. If you specified grooming protection with OTS, OMS, or OCH link disjointness, the Undo operation also tears down the DCL and OCH traffic matrices. If you specified protection with DCL link disjointness or no protection, you must tear down the DCL and OCH matrices before you undo the grooming operation.

Note—If you tear down or undo a DCL traffic matrix that has been groomed simultaneously with other DCL traffic matrices, the tear down or undo operation will also apply to these other DCL traffic matrices because all of the DCL traffic matrices are groomed to the same OCH traffic matrix.

Grooming DCL Traffic with Optimized Routes

Figure 8-2 shows the Groom DCL to OCH Traffic - Optimized Routes dialog box, which you open by choosing Design > Groom DCL to OCH traffic > Optimized Routes. The Grooming Input group box includes input options for the grooming algorithm: DCL traffic matrix, OCH bit rate, and algorithm. The grooming results appear in the Results and Performance group boxes.

See Workflow Description on page TrP-8-1 for instructions for grooming traffic.

Figure 8-2   Groom DCL to OCH Traffic - Optimized Routes Dialog Box

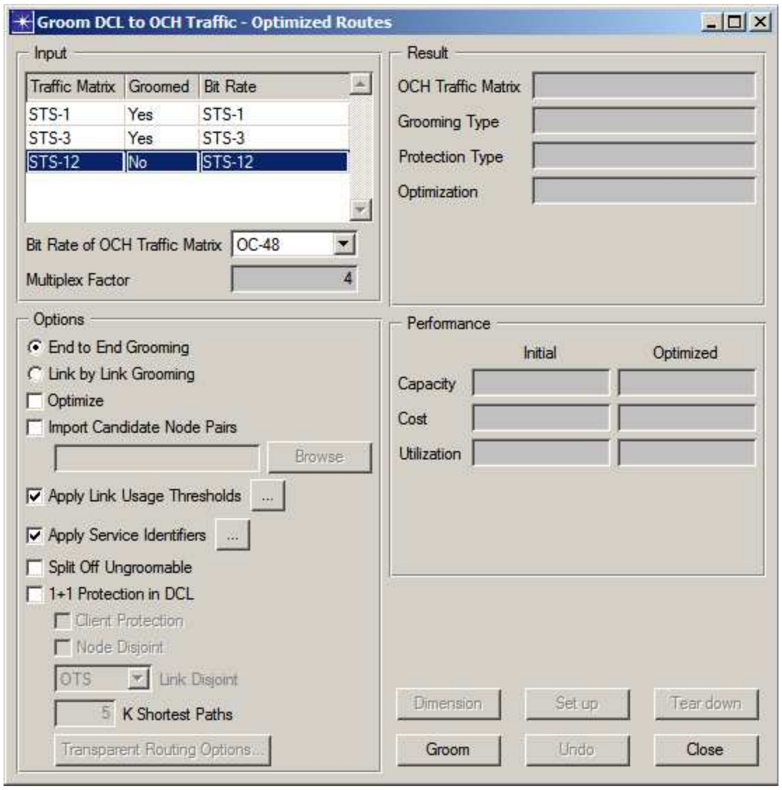


Table 8-1   Groom DCL to OCH Traffic - Optimized Routes Dialog Box

Section	Description
Input	DCL Grooming Input and Options on page TrP-8-5
Options	DCL Grooming Input and Options on page TrP-8-5
Result	DCL Grooming Results and Performance on page TrP-8-8
Action buttons	DCL Grooming Actions on page TrP-8-8
End of Table 8-1	

DCL Grooming Input and Options

Table 8-2 lists the fields that appear in the Input and Options group boxes in the Groom DCL to OCH Traffic - Optimized Routes Dialog Box.

Table 8-2 DCL Grooming Input Options

Item	Description
Traffic Matrix	Select the DCL traffic matrices you want to groom.
Bit rate of OCH Traffic Matrix	Target bit rate for the resulting OCH matrix. If the DCL layer has enough spare capacity to be reused (even for OCH matrices with a different target bit rate from the selected matrix), then the resulting OCH traffic matrix will be empty.
Multiplex Factor	The multiplex factor between the selected DCL matrix's bit rate and the OCH matrix's bit rate. This field is not editable; the value is determined by the specified bit rate for the OCH matrix.
End to End grooming	See End-to-End (ETE) Optimization Algorithm on page TrP-8-21.
Link by Link grooming	See Link-by-Link (LBL) Optimization Algorithm on page TrP-8-24.
Optimize	Include optimization in the grooming algorithm. For information about the optimization for each algorithm, see the algorithm descriptions: ETE vs. LBL Grooming on page TrP-8-26 Grooming Multiple DCL Matrices on page TrP-8-28
Import Candidate Node Pairs	This option allows you to import a set of candidate node pairs between which traffic can be groomed into wavelengths. The resulting OCH traffic matrix will only contain traffic between these specified node pairs. See Import Candidate Node Pairs.
Apply Link Usage Thresholds	When this option is selected, this ensures that link usage thresholds are considered during the grooming process, such that no DCL link is utilized more then the defined threshold percentage. This means the filling rate of the wavelengths created as part of the grooming process will be restricted by these threshold values. Refer to Link Usage Threshold on page TrP-6-29 in the *Routing* chapter for more details.
Apply Service Identifiers	With this option enabled, client DCL traffic can only be routed over OCH wavelengths with matching service identifiers. Refer to Service Identifiers on page TrP-6-32 in the *Routing* chapter and Apply Service Identifiers
Split Off Ungroomable	With this option enabled, DCL traffic that cannot be groomed (e.g., because of topology constraints) will be split off in a separate DCL traffic matrix. See Split Off Ungroomable.

Table 8-2 DCL Grooming Input Options (Continued)

Item	Description
1 + 1 Protection in DCL	Accommodates a disjoint working and protecting path for the DCL demands
Node Disjoint	If this option is enabled, the working and protection paths are both node and link disjoint. Otherwise the paths are link disjoint only. “Link disjoint” means that the paths have no common links. “Node disjoint” means that the paths have no common nodes other than the source and destination.
Link Disjoint	Specifies the lowest network layer at which the working and protection paths are guaranteed to be link disjoint. For more information, see Link Disjointness for Working and Protection Paths on page TrP-6-6.
K Shortest Paths	The number of alternative paths to consider for the protection path, taking into account the layer of link disjointness
Transparent Routing Options	This button is available only if the OCH layer mode is transparent. For more information, see Transparent Routing Options Dialog Box on page TrP-10-12.
End of Table 8-2	

Import Candidate Node Pairs

The “Import Candidate Node Pairs” option enables you to specify the node pairs between which the grooming operation is allowed to create OCH connections over which to route DCL traffic, while implicitly excluding all other node pairs from the grooming operation. Thus, you can import a logical DCL topology instead of letting the grooming operation decide. Without this option, the resulting OCH traffic matrix (which represents the logical DCL topology) can potentially contain traffic between all possible node pairs.

To specify the candidate node pairs, you use a simple text file selected by using the “Browse” button in the dialog. The following example illustrates the file format:

```
From, To
node_1, node_2
node_1, node_3
node_2, node_3
node_2, node_4
```

The example file allows grooming of DCL traffic only in direct wavelengths between the defined node pairs. For example, grooming traffic between node_1 and node_4 over a direct wavelength between both nodes is not permitted, since this node pair is not in the list. However, it is possible route traffic between node_1 and node_4 via node_2, since node_1 and node_2, as well as node_2 and node_4, are in the list of candidate node pairs.

Apply Service Identifiers

Selecting the "Apply Service Identifiers" option in the Groom DCL to OCH Traffic dialog box has two effects:

- For existing OCH connections, which can be reused as part of the grooming operation, the Client Service Identifiers of the groomed DCL traffic are forced to match the Server Service Identifiers of these OCH connections. You can select the way Client Service Identifiers should match Client Service Identifiers by clicking on the "…" button next to the checkbox, similar to the way this is done for Routing. For more information, see Applying Service Identifiers to Connections on page TrP-6-34 in the *Routing* chapter.
- For the OCH traffic matrix created by the grooming design action, the Server Service Identifiers are automatically assigned to the OCH connections such that the Server Service Identifiers of all connections of the newly created OCH traffic matrix contain all the Client Service Identifiers of the groomed DCL connections. For example, if the groomed DCL traffic matrix contains some connections with Client Service Identifier "A" and some connections with Client Service Identifier "B", then all connections of the newly created OCH traffic matrix are assigned Server Service Identifiers "A" and "B". You can manually adapt this default assignment afterwards by editing the Server Service Identifier of the OCH traffic in the Connection Browser.

Split Off Ungroomable

When this option is selected, as much traffic as possible of the selected DCL traffic matrices will be groomed, while the ungroomable traffic will be split off into new matrices. Previously, grooming was an "all-or-nothing" operation: if it could not groom the entire matrix, the operation failed.

When this option is selected, the grooming operation works in the following way:

1) It tries to groom the entire traffic matrix.

2) If it cannot groom the entire matrix, it splits the matrix into two separate matrices:

a) The first matrix contains the DCL traffic demands that can and will be groomed. This matrix retains the same name as the original input matrix.

b) The second (new) matrix contains the ungroomed traffic demands, and has the name "<original_DCL_matrix_name>_split<index>." The grooming operation adds the <index> if index numbers are needed to distinguish matrices with similar names (for example, input0_split0, input0_split1, and so on).

DCL Grooming Actions

Table 8-3 lists the action buttons that appear in the Groom DCL to OCH Traffic - Optimized Routes Dialog Box.

Table 8-3 DCL Grooming Actions

Item	**Description**
Groom	Groom the selected DCL matrices
Dimension	Dimension the displayed OCH matrix; see Dimension DCL/OCH Layer Dialog Box on page TrP-7-3 for more information.
Set Up	Accommodate the DCL traffic matrices in the network
Tear Down	Tear down the routed OCH matrix that resulted from the grooming. This leaves the OCH matrix present but unrouted.
Undo	Undo the grooming operation. You can undo a grooming operation only after you tear down the OCH matrix (unless you specified grooming protection with OTS, OMS, or OCH link disjointness, in which case the Undo operation performs both actions).
End of Table 8-3	

DCL Grooming Results and Performance

Table 8-4 and Table 8-5 list the fields that appear in the Results and Performance group boxes in the Groom DCL to OCH Traffic - Optimized Results dialog box. This information displays the grooming results for the DCL matrices currently selected in the Grooming Input area (left side of the window). These fields are not editable.

SP Guru Transport Planner also generates a grooming results text file that contains additional information about the grooming operation: a cost split, details of the optimization step, etc.

This file takes the following name:

```
<dcl_traffic_matrices_name>-grooming-details-<date>-<time>.txt
```

and is located in the following directory:

```
<wdm_guru_user_home>/op_reports/<project_name>/<scenario_name>/SP
Guru Transport Planner Reports/Interim Reports/
```

Table 8-4 Grooming Result

Item	Description
Grooming Type	Grooming algorithm used on the selected DCL matrix.
OCH Traffic Matrix	OCH traffic matrix that resulted from the grooming operation.
Optimization	Indicates whether the grooming was optimized.
Protection Type	1 + 1 Protection or No Protection
End of Table 8-4	

Table 8-5 Grooming Performance

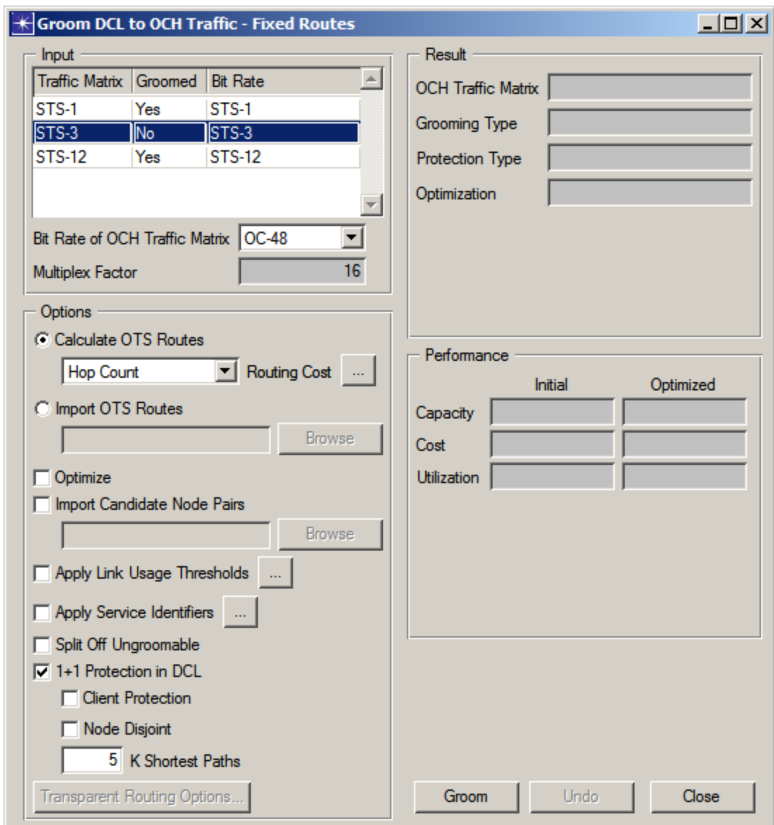
Item	Description
Results	Initial column shows results without optimization. Optimized column shows results with optimization. For information about the optimization for each algorithm, see the algorithm descriptions: ETE vs. LBL Grooming on page TrP-8-26 Grooming Multiple DCL Matrices on page TrP-8-28
• Capacity	Total demand for the resulting OCH traffic matrix.
• Cost	Total cost over the DCL and OCH layers.
• Utilization	The percentage of utilization on the DCL trunks.
End of Table 8-5	

Grooming DCL Traffic with Fixed Routes

The Optimized Routes grooming algorithm optimizes DCL routes to minimize the network cost. This might create some undesirable routes in the OCH layer (for example, routes with backhauling). In some cases, you might want to groom traffic using fixed routes instead. You can calculate the routes in the OTS layer or import them from an external file. The Fixed Routes grooming algorithm does not change these routes—it just decides whether to bypass the signal optically or electrically within nodes to minimize the network cost.

To groom traffic using fixed routes, choose Design > Groom DCL to OCH Traffic > Fixed Routes. This opens the Groom DCL to OCH Traffic - Fixed Routes dialog box (Figure 8-3).

Figure 8-3 Groom DCL to OCH Traffic - Fixed Routes Dialog Box



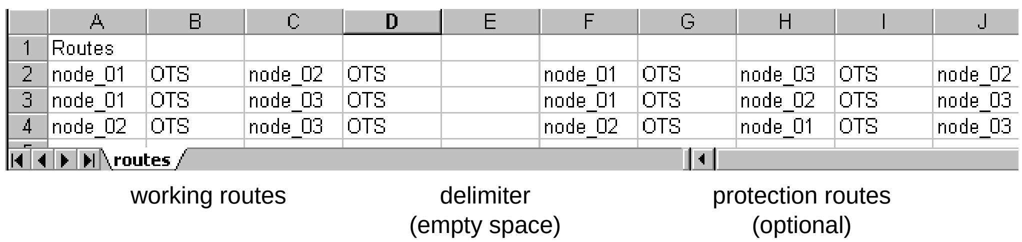
The options in this dialog box are similar to those for grooming using optimized routes. For more information, see Table 8-1 Groom DCL to OCH Traffic - Optimized Routes Dialog Box on page TrP-8-4.

You must also specify the physical routes of the DCL traffic matrix. There are two options for doing this:

- Calculate OTS Routes—You can choose to have a shortest path algorithm calculate the routes. In this case, you specify the routing cost criterion. These routes are calculated on the OTS layer. Therefore, if you specify 1+1 protected routing, disjointness down to the OTS layer is guaranteed.

- Import OTS Routes—You can import the paths from a flat (.csv) file. The file format is shown in Figure 8-4. Each line specifies the working route (and the protection route in the case of protected routing) specified as a list of nodes, from start to end node; each node is followed by the layer (in this case, "OTS" for all nodes). For more information, see Importing and Exporting Route Data Files on page TrP-5-29.

Figure 8-4 Importing OTS Routes: File Format



Cost Parameters That Affect DCL Grooming Results

The following table lists the cost parameters that affect the grooming algorithm. You enter these parameters in the Equipment Properties dialog boxes (Network > Equipment Properties); for more information, see Equipment Properties on page TrP-3-30.

If SP Guru Transport Planner needs to equip extra fibers due to the dimensioning algorithm, these new fibers are of the default type (WDM or SONET/SDH) as specified in the Network Properties dialog box (Network > Network Properties).

Table 8-6 Cost Parameters That Affect Grooming Results

Parameter	Description
DXC cost:	
• Tributary port cost	The cost of one tributary port (at the bit rate of the DCL traffic matrix) on the DXC
• Trunk port cost	The cost of one trunk port (at the bit rate of the OCH matrix selected for the grooming) on the DXC

Table 8-6 Cost Parameters That Affect Grooming Results (Continued)

Parameter	Description
Optical channel cost:	
• WDM channel card cost	The cost of one channel at the WDM multiplexer to terminate the wavelength (bit-rate independent cost)
• Regenerator card cost	In-line regeneration requires one card per optical channel. The cost of this card depends on the line system type and the bit rate of the OCH matrix.
• Transponder cost	The cost of the transponder in the nodes depends on the line system type and bit rate of the OCH matrix
OXC cost:	
• Tributary port cost	The cost of one tributary port (at the bit rate of the OCH matrix) on the OXC
• Trunk port cost	The cost of one trunk port (at the bit rate of the OCH matrix) on the OXC
WDM link cost:	Common equipment per fiber pair used (these costs are specified per line system type).
• OA cost	The cost of an optical amplifier (one per fiber per OA site).
• Regenerator cost	The cost of common equipment per regenerator site.
• WDM terminal multiplexer cost	The cost of a WDM terminal multiplexer/demultiplexer.
End of Table 8-6	

Calculating a DCL Link’s Total Cost

SP Guru Transport Planner uses the following formula to calculate the total cost of a DCL link:

```
Total DCL link cost = DCL cost + OCH cost
```

The DCL cost is the cost of the tributary and trunk ports of a DXC.

The OCH cost is the cost of establishing an optical path between the end nodes. This cost is based on the

- Proportional cost of the common equipment per fiber (WDM multiplexers, optical amplifiers, regenerators)
- Cost associated with each channel used in the link (transponder, channel cards, regeneration cards)
- OXC port cost (tributary and trunk ports)

DCL Grooming Solutions Without Protection

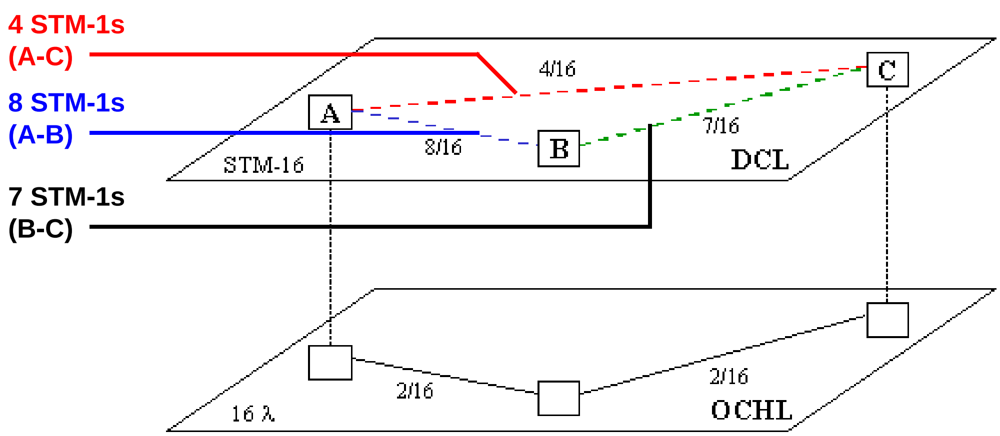
This section describes two grooming solutions without protection in the DCL layer. You can still use protection for the resulting OCH matrix, and thereby protect against failures (such as fiber cuts) in the OCH layer.

The grooming solutions described in this section are two extreme solutions; you can further optimize these solutions using the algorithms described in Optimization Algorithms: Descriptions on page TrP-8-21.

Solution 1: Pure End-to-End (No Intermediate Grooming)

This solution specifies end-to-end grooming (also called “edge grooming”); this grooms all DCL traffic at the edge of the network and not in any intermediate nodes. The following network contains three nodes, in which a single fiber carrying 16 wavelengths is lit on links between A-B and B-C. There is a total DCL traffic demand of 19 STM-1 units; each optical channel carries an STM-16 signal.

Figure 8-5   End-to-End (No Protection): Capacity Requirements



This example uses the following strategy: For each DCL connection, reserve one optical channel in the OCH layer. This channel can use multiple wavelengths; the level of utilization on the channel depends on the number of time slots requested. For example, one time slot (STM-1) can result in an optical channel (STM-16) that is poorly used (1 out of 16). SP Guru Transport Planner accommodates these channels in the OCH layer. In this example, A-C and B-C result in two single-hop optical channels and A-C is routed over two hops.

The associated equipment in the DCL and OCH layers is shown in Figure 8-6 on page TrP-8-14. All traffic is aggregated in wavelengths by the DXC. There are two OA sites on both links and one regeneration site on link A-B. The optical channel A-C is connected through the OXC in node B.

Figure 8-6 End-to-End (No Protection): Associated Equipment

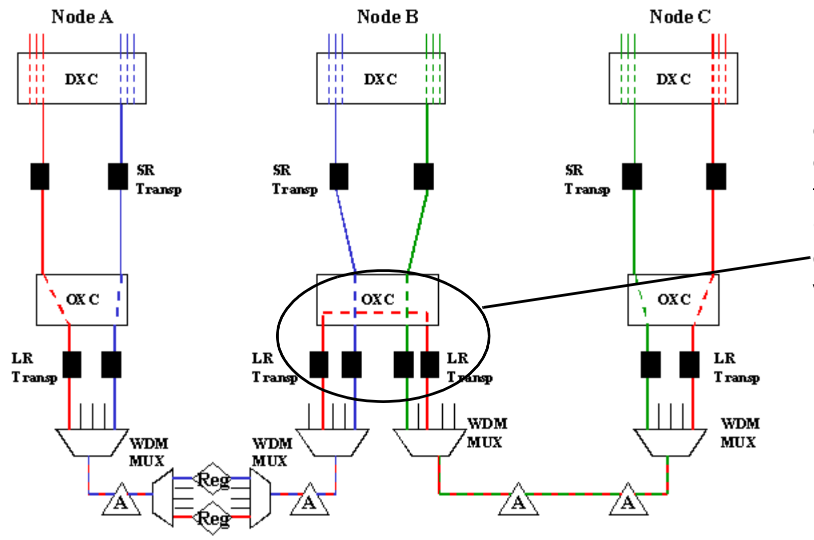


Table 8-7 Main Equipment Associated with Solution 1 (End-to-End / No Protection)

Equipment	Quantity	Associated Equipment
Logical DCL links	3	6 DXC trunk ports 6 OXC tributary ports
Intermediate DCL units switched	0	
Optical channels/hops	3 channels using 1 + 1 + 2 = 4 hops	6 short-reach transponders 8 long-reach transponders
WDM in-line equipment	• 1 regeneration on link A-B • 4 OAs in total on links A-B and B-C	2 channels on link A-B (requires 2 regenerator cards)
End of Table 8-7		

Note—The values in Table 8-7 are calculated assuming that the OCH layer mode is opaque.

Pure Link-by-Link (Full Intermediate Grooming)

In link-by-link grooming (also called “core grooming”), we groom the traffic together into the available OCH channels whenever possible, and add new channels if needed. The grooming algorithm terminates traffic at the DXC in every intermediate node, and regrooms the traffic to utilize existing wavelengths as fully as possible.

If we apply this solution to the same network as the previous example (see Solution 1: Pure End-to-End (No Intermediate Grooming) on page TrP-8-13), SP Guru Transport Planner accommodates the three DCL demands as follows:

- Demand A-B (8 STM-1s): routed on the optical channel between nodes A and B. This demand uses 8 out of 16 timeslots on the optical channel.
- Demand B-C (7 STM-1s): routed on the optical channel between B and C. This demands uses 7 out of 16 timeslots on the optical channel.
- Demand A-C (4 STM-1s): SP Guru Transport Planner establishes no new optical channel for this demand. Instead, it uses the unused timeslots on the already-created optical channels. There are eight unused timeslots on optical channel A–B and nine unused timeslots on B–C.
  SP Guru Transport Planner accommodates this demand as follows:
  - At *node A*, aggregate the A–B and A–C demands on the optical channel A–B. The network uses 12 (8 +4) timeslots on this optical channel.
  - At *node B*, split the DCL traffic: drop the A–B demand and switch the A–C demand to the optical channel B–C. Add the B–C demand to the DXC. Now the A–C and B–C demands are aggregated on the optical channel B–C; the network uses 11 (7 + 4) timeslots on this channel.
  - At *node C,* split and drop the DCL traffic.

Figure 8-7 Link-by-Link (No Protection): Capacity Requirements

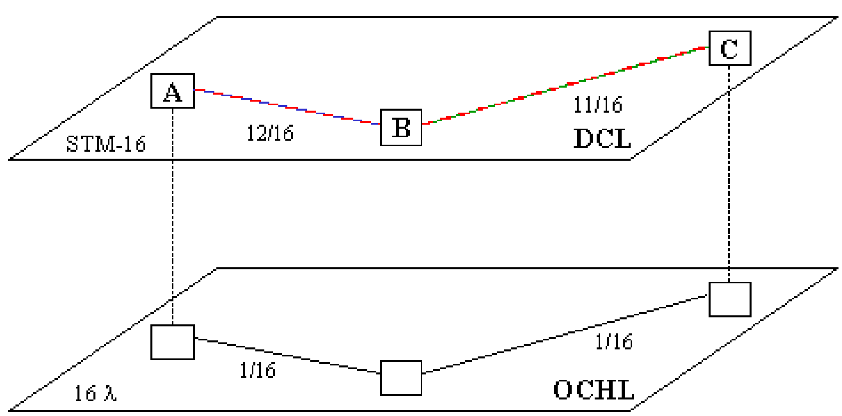


Figure 8-8   Link-by-Link (No Protection): Associated Equipment

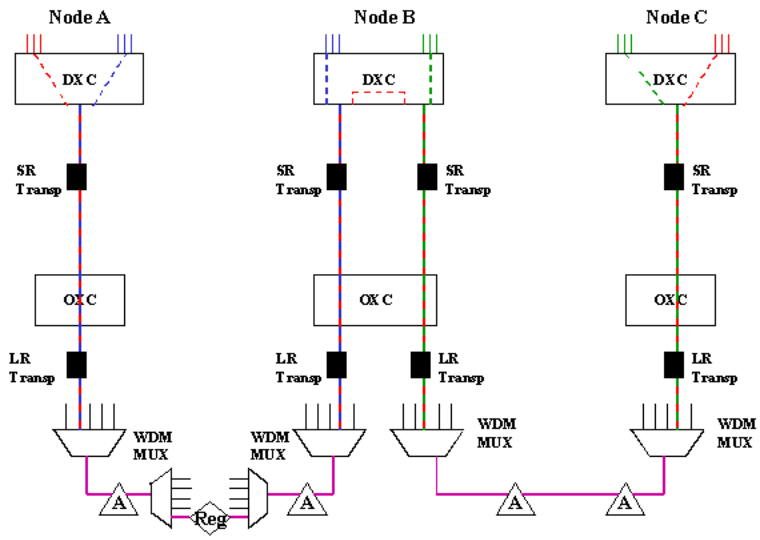


Table 8-8   Main Equipment Associated with Solution 2 (Link-by-Link / No Protection)

Equipment	Quantity	Associated Equipment
Logical DCL links	2	4 DXC trunk ports 4 OXC tributary ports
DCL units switched	4	DXC required in node B to switch and re-aggregate
Optical channels/hops	2 optical channels using 1 + 1 = 2 hops	4 short-reach transponders 4 long-reach transponders
WDM in-line equipment	• 1 regeneration point on link A-B • 4 OAs in total on links A-B, A-C	1 channel on link A-B (requires 1 regenerator card)
End of Table 8-8		

Note—The values in Table 8-8 are calculated with the OCH layer mode as opaque.

Solutions 1 and 2 Compared

A comparison of Solution 1 (end-to-end/no intermediate grooming) and Solution 2 (link-by-link/full intermediate grooming) shows the following results:

- The link-by-link (LBL) solution results in 2 optical channels, while the end-to-end (ETE) solution results in 3 channels. Therefore, the LBL solution reduces the need for DXC trunk ports and OXC tributary ports (four for LBL vs. six for ETE), transponders (8 vs. 14), and in-line regeneration cards (one vs. two).
- The grooming (switching in DCL nodes) in the LBL solution requires a DXC in node B, which adds to the network cost. Without grooming (no switching in DCL nodes), we could replace the DXC with cheaper SONET/SDH terminal multiplexers. We take this additional cost into account by noting the cost associated with the number of DCL units switched (four) in node B.
- Both solutions use the same amount of WDM common equipment required per fiber pair used: WDM terminal multiplexers, OAs, and so on.

In these examples, neither solution is clearly superior; the cost parameters you specify determine which solution results in the lowest total network cost.

DCL Grooming Solutions with Protection

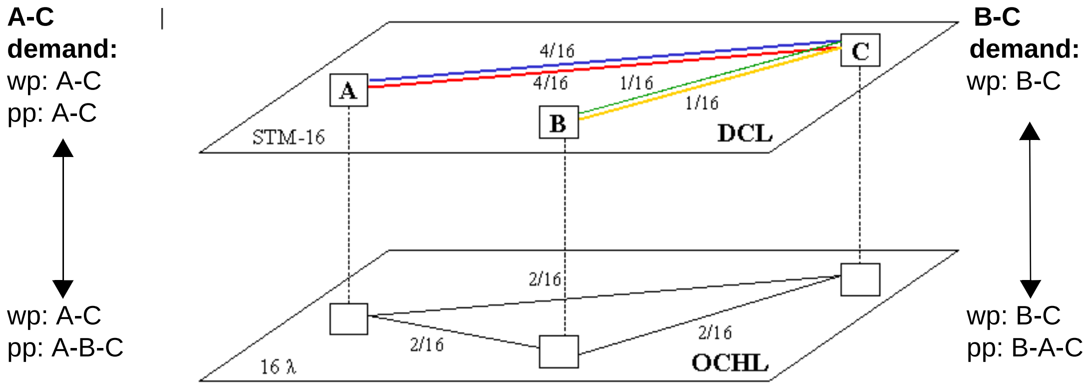
When you groom with 1 + 1 protection, one important consideration is the layer of link disjointness. This defines the lowest layer at which the working and protection paths are guaranteed to use paths with no common links. For more information about link disjointness, see Link Disjointness for Working and Protection Paths on page TrP-6-6. The algorithm used to guarantee the disjointness of working and protection path at the layer of link disjointness is based on K shortest paths. Setting a higher value of K Shortest Paths in the grooming options increases the likelihood that the grooming algorithm will find disjoint paths in complex networks.

The following sections compare the pure end-to-end and pure link-by-link approaches for grooming operations with 1+1 protection in the DCL layer. These examples assume link disjointness down to the OCH layer and consider the same three-node example as in the previous section (DCL Grooming Solutions Without Protection on page TrP-8-13). However, there is an additional link added between A and C. The DCL traffic demand consists of a 4 STM-1 demand between A and C, and a 1 STM-1 demand between B and C.

Solution 3: Pure End-to-End (No Intermediate Grooming)

The pure end-to-end grooming solution is shown in Figure 8-9 on page TrP-8-18. In the DCL layer, the A-C demand (4 STM-1 units) has working and protecting paths with one-hop routes (both A -C). In the OCH layer, the working path (A-C) has a one hop but the protecting path (A-B-C) is disjointly routed over a two-hop route.

Figure 8-9 End-to-End Grooming with Protection: Capacity Requirements



The B-C demand (one STM-1 unit) has a similar routing structure. The DCL layer uses one-hop routes for working and protection paths (both B-C). In the OCH layer, the working path (B-C) has one hop and the protection path (A-B-C) has two hops.

Figure 8-10 End-to-End Grooming with Protection: Associated Equipment

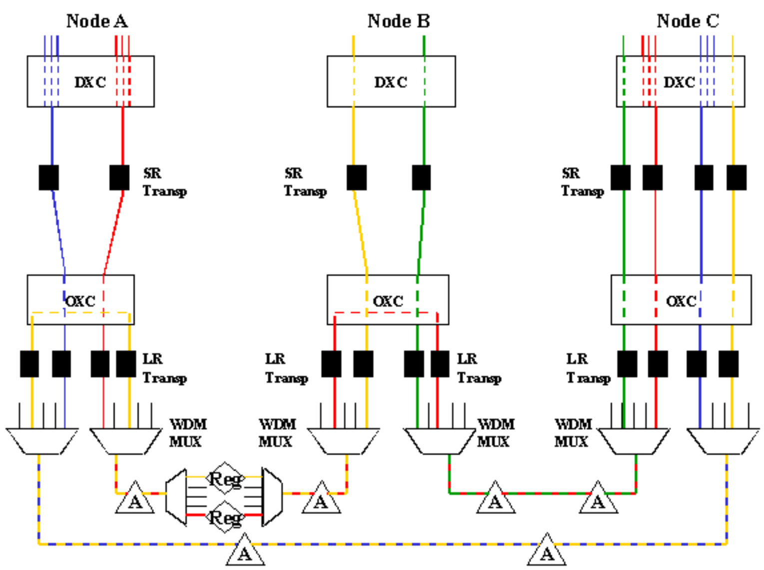


Table 8-9 Main Equipment Associated with Solution 3 (End-to-End with Protection)

Equipment	Quantity	Associated Equipment
Logical DCL links	4	4 DXC trunk ports 4 OXC tributary ports
DCL units switched	0	
Optical channels/hops	4 optical channels using 1 + 2 + 1 + 2 = 6 hops	8 short-reach transponders 12 long-reach transponders
WDM in-line equipment	• 1 regeneration on link A–B • 6 OAs in total on links A–B, A–C and B-C	2 channels on link A–B (requires 2 regenerator cards)
End of Table 8-9		

Note—The values in Table 8-9 are calculated with the OCH layer mode is opaque.

Solution 4: Pure Link-by-Link (Full Intermediate Grooming)

The pure link-by-link solution is illustrated in Figure 8-11. The A–C demand (four STM-1 units) has a one-hop working path (A–C) and a two-hop protecting path (A–B–C) in both the DCL and OCH layer. Similarly, the B-C demand (one STM-1 unit) has a one-hop working path (B-C) and a two-hop protecting path (B-A-C).

Figure 8-11 Link-by-Link Grooming with Protection: Capacity Requirements

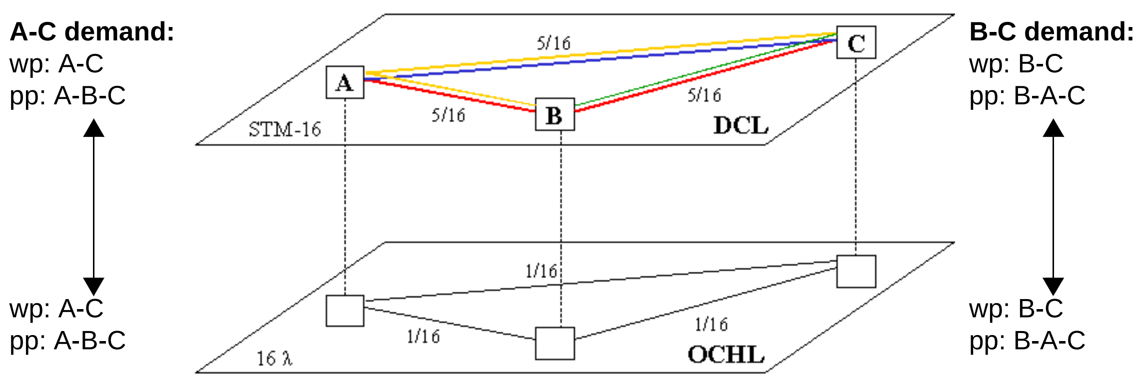


Figure 8-12   Link-by-Link Grooming with Protection: Associated Equipment

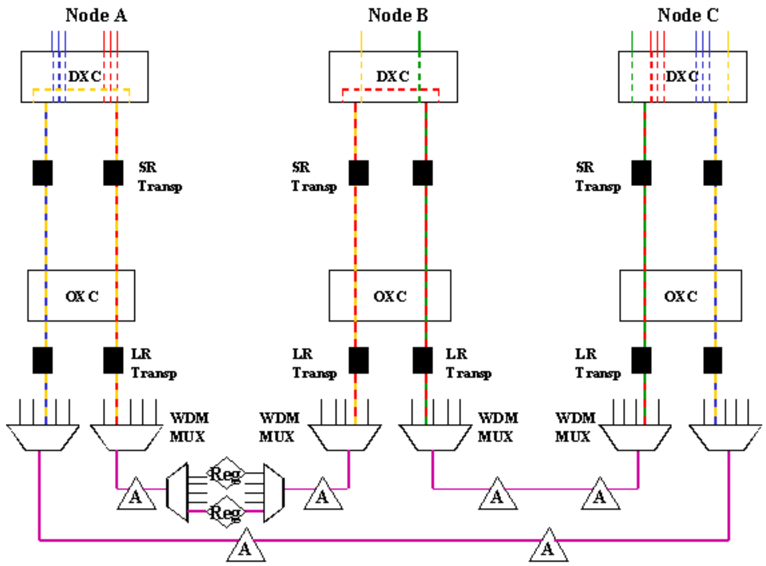


Table 8-10   Main Equipment Associated with Solution 4 (Link-by-Link with Protection)

Equipment	Quantity	Associated Equipment
Logical DCL links	3	6 DXC trunk ports 6 OXC tributary ports
DCL units switched	5 (4 in node A, 1 in node B)	DXC required in nodes A and B to switch and re-aggregate
Optical channels/hops	3 optical channels using 1 + 1 + 1 = 3 hops	6 short-reach transponders 6 long-reach transponders
WDM in-line equipment	• 1 regeneration on link A–B • 6 OAs in total on links A–B, A–C and B-C	1 channels on link A–B (requires 1 regenerator card)
End of Table 8-10		

Note—The values in Table 8-10 are calculated with the OCH layer mode as opaque.

Solutions 3 and 4 Compared

A comparison of these examples shows the following results:

- The link-by-link (LBL) solution results in three optical channels, while the end-to-end (ETE) solution results in four channels. Therefore, the LBL solution reduces the need for DXC trunk ports and OXC tributary ports (six for LBL vs. eight for ETE), transponders (12 vs. 20), and in-line regeneration cards (one vs. two).
- The grooming (switching in DCL nodes) in the LBL solution requires a DXC in node B and a DXC in node A, which adds to the network cost. Without grooming (no switching in DCL nodes), we could replace the DXC with cheaper SONET/SDH terminal multiplexers.
- Both solutions result in the same amount of WDM common equipment required per fiber pair used: WDM terminal multiplexers, OAs, and so on.
- As with the previous two examples (see DCL Grooming Solutions Without Protection on page TrP-8-13), neither solution is clearly superior; the cost parameters you specify determine which solution is preferable.

Optimization Algorithms: Descriptions

This section describes optimized grooming solutions that start with solutions based on pure end-to-end grooming and pure link-by-link grooming. The following topics are discussed:

- End-to-End (ETE) Optimization Algorithm
- Link-by-Link (LBL) Optimization Algorithm
- ETE vs. LBL Grooming

End-to-End (ETE) Optimization Algorithm

The end-to-end (ETE) optimization algorithm is a two-step attempt to improve network cost:

1) Select DCL traffic that results in poorly utilized optical channels.

2) Reroute this traffic on unused time-slots of other optical channels and remove the channel if this results in cost savings.

The result is that fewer optical channels (with higher effective utilizations) are required, at the expense of switching cost in intermediate DXCs.

Algorithm Description

The end-to-end algorithm does the following steps:

1) Initial Solution (no intermediate grooming)—Establish a direct trunk for each traffic demand. If you specified 1 + 1 protection with disjoint routes in the physical layer (that is, if Link Disjoint is set to OTS, OMS, or OCH), the algorithm establishes two direct trunks: one for the working path, the other for the protection path. There is no switching (no intermediate grooming) in the DXCs.

   If you specified 1 + 1 protection with disjoint routes in the DCL layer, SP Guru Transport Planner uses the shortest-cycle approach to create link-disjoint working and protecting paths in a fully meshed DCL layer. In this event the protecting path is a multiple-hop path, which implies switching in the DXCs.

2) Select the DCL link with the maximum redundant cost (= unused part * DCL cost) that has not yet been inspected.

3) New solution—Try to reroute the traffic using available time slots on other trunks. This might involve splitting traffic over multiple trunks. If you specified 1 + 1 protection, the algorithm will ensure that the working and protection paths for a DCL demand are disjoint (down to the specified layer of disjointness).

   a) Calculate cost: Calculate the cost difference between the previous solution and the new solution.

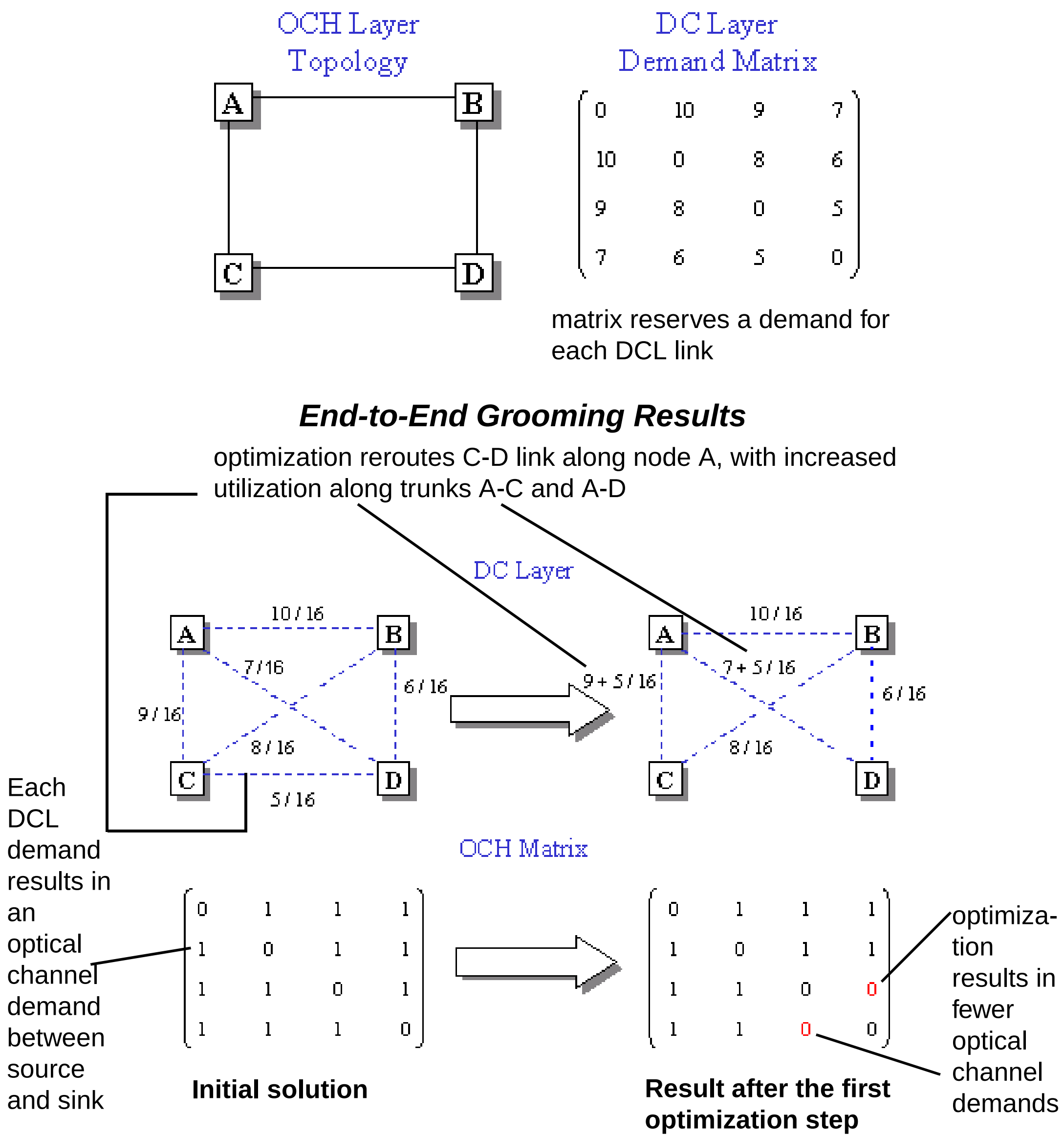
   b) Choose solution for selected link: Accept the new solution (that is, remove the selected link and reroute traffic) if it results in net cost savings.

   c) Mark the selected link as inspected.

4) Repeat steps 2 and 3 until all links have been inspected.

The following diagram provides an example of end-to-end grooming in action (in this case, a DCL demand without protection). The optimization step runs only if this results in a net cost saving, which depends on the cost parameters used.

Figure 8-13 OCH Topology and DCL Demands Before End-to-End Grooming



Link-by-Link (LBL) Optimization Algorithm

The initial solution of the link-by-link grooming algorithm assumes *full grooming in intermediate nodes*. SP Guru Transport Planner does this by routing the DCL demands on a DCL trunk topology that contains only the links present in the OCH layer.

If you specified grooming with protection, SP Guru Transport Planner routes the DCL demands using the shortest-cycle approach; if you specified grooming without protection, SP Guru Transport Planner routes the DCL demands using the shortest-path approach.

This solution has the following characteristics:

- If a DCL connection is unsupported by an underlying OCH link, it is accommodated over multiple DCL trunks (multiple hops in the DCL layer). This implies switching in the intermediate DXCs.
- All optical channels are single-hop connections in the OCH layer; this implies no switching in the OXCs.
- SP Guru Transport Planner obtains the initial trunk size by adding all DCL capacity that was routed over that particular link.
- SP Guru Transport Planner derives the corresponding wavelength demand by applying the multiplex factor between both the DCL and OCH layers. For example, 18 STM-1's on a DCL trunk require two optical channels at STM-16.

Consequently, wavelength utilization is high and all traffic is switched in intermediate DCL nodes, resulting in a high switching cost in the DCL layer. The optimization algorithm reduces the cost figure by inspecting the transit traffic in the DXC nodes and inserting DCL trunks where appropriate.

For example, assume that there is a lot of traffic between nodes X and Y, but there is no direct DCL trunk (no optical channel between these nodes). In this case, the link-by-link algorithm adds a direct trunk between X and Y; then it off loads the traffic towards this trunk. This reduces switching in intermediate nodes, possibly at the expense of an additional optical channel.

Algorithm Description

The link-by-link algorithm does the following steps:

1) Initial solution (full intermediate grooming): Route DCL traffic on a DCL topology identical to the OCH-layer topology, and size DCL trunks accordingly.

2) Check for a new DCL trunk to add: Calculate cost savings by adding a new DCL trunk between nodes that exchange a lot of traffic. If you specified protection, SP Guru Transport Planner must ensure that the working and protection paths used by a DCL demand remain disjoint. Retain the DCL link that results in the greatest cost savings.

   If SP Guru Transport Planner finds a link that results in a cost savings, continue with step 3.

   If SP Guru Transport Planner *does not* find a link that results in a cost savings, continue with step 4.

3) If a new DCL trunk is found (which results in a cost savings):

   a) Add the DCL trunk (results in an additional optical channel demand) and off load traffic to this trunk.

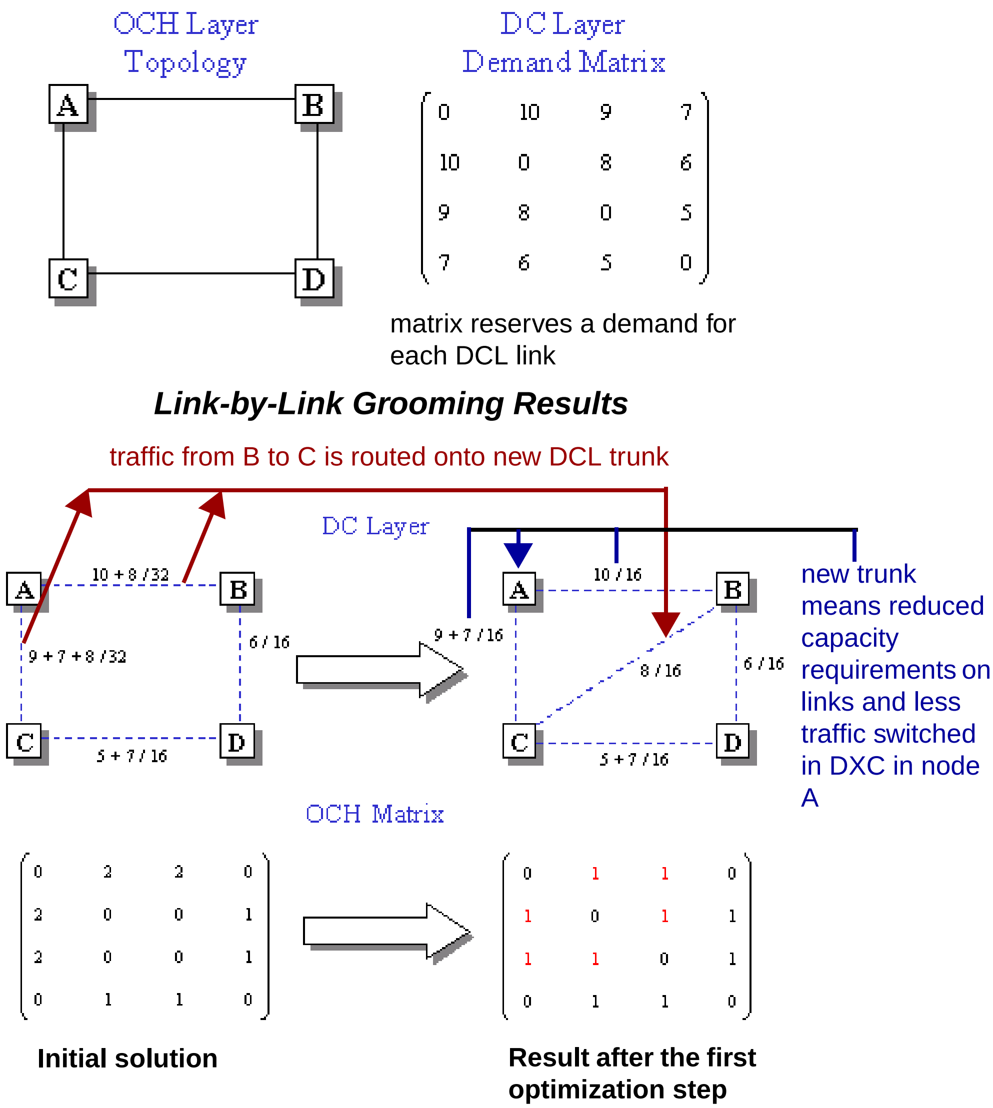
   b) Remove (possibly empty) wavelength channels on which DCL traffic was off-loaded.

   c) Return to Step 2.

4) If no new DCL trunk is found: end

Figure 8-14 provides an example of link-by-link grooming in action (in this case, without using protection). Adding another trunk requires an additional channel between B and C, but reduces the channel requirement between A-C and A-B. Optimization increases the meshing degree of the DCL topology and adapts the demand for the OCH layer. As in the end-to-end grooming example, the optimization step is accepted only if it results in a net cost saving.

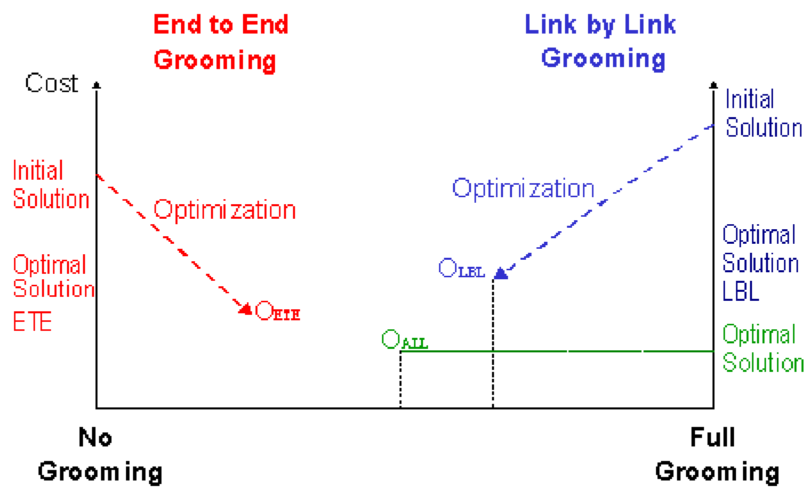
Figure 8-14 OCH Topology and DCL Demands Before Link-by Link Grooming



ETE vs. LBL Grooming

Both ETE and LBL start with an initial solution and perform cost-driven improvements as described in the previous sections. As shown in the following diagram, these algorithms start with opposite solutions (ETE with no intermediate grooming, LBL with full intermediate grooming) and gradually converge towards each other during optimization. These algorithms can result in different local optima (O_{ETE} and O_{LBL}) compared to the global optimum O_{All}.

Figure 8-15 ETE vs. LBL Grooming



Which Solution Should You Use?

There is no “absolute better” approach for a situation: a solution’s applicability depends on traffic levels, multiplex factors, and the cost structure used for the scenario. Table 8-11 lists the parameter values that favor a specific approach. In general, use the LBL-based approach if your parameter value indicates a solution that involves extensive grooming; use the ETE-based approach if your parameter value indicates a solution that involves little grooming.

Note—LBL optimization is more calculation-intensive than ETE optimization, especially for large networks and high traffic levels. Therefore, use ETE optimization for a first approximation of grooming level and associated network cost.

Table 8-11 Parameters That Affect the Choice of Grooming Algorithm

Parameter	High Value	Low Value
DCL Traffic (between node pairs)	ETE	LBL
Multiplex Factor DCL Unit / DCL Trunk (for example, 16 for STM-1 / STM-16)	LBL	ETE
Cost per optical channel (transponders, regeneration cards)	LBL	ETE
DCL switching cost	ETE	LBL
End of Table 8-11		

Grooming Multiple DCL Matrices

There are two ways to groom multiple traffic matrices in SP Guru Transport Planner: simultaneously or sequentially.

Grooming Simultaneously

You can groom multiple traffic matrices simultaneously by selecting these traffic matrices in the grooming dialog. This implies that all traffic matrices will be groomed with the same grooming options, such as optimization or protection. The target bit rate of the resulting OCH traffic matrix should be large enough to groom the largest DCL bit rate of the selected traffic matrices. The result of grooming multiple traffic matrices simultaneously is that one OCH traffic matrix is created to groom all selected DCL traffic matrixes, so you can create a “globally optimized” solution for grooming DCL traffic into OCH wavelengths.

When multiple DCL traffic matrices have been groomed simultaneously in one OCH traffic matrix, it is no longer possible to tear down or undo the grooming of one of these DCL traffic matrices. This should always be done for all DCL traffic matrices together. In the grooming dialog this is handled such that if you select a DCL traffic matrix that has been groomed simultaneously with other DCL traffic matrices, these other traffic matrices get selected as well; you have to perform any operation on all traffic together.

Grooming Sequentially

You can groom multiple traffic matrices (or sets of traffic matrices) sequentially by performing the grooming action multiple times. This allows you to use different settings, such as optimization or protection, for these different traffic matrices. One important effect is the possible reuse of resources in the DCL layer. These resources take the form of unused capacity from an OCH matrix that is already accommodated in the network. There are two possible reasons why this capacity is unused:

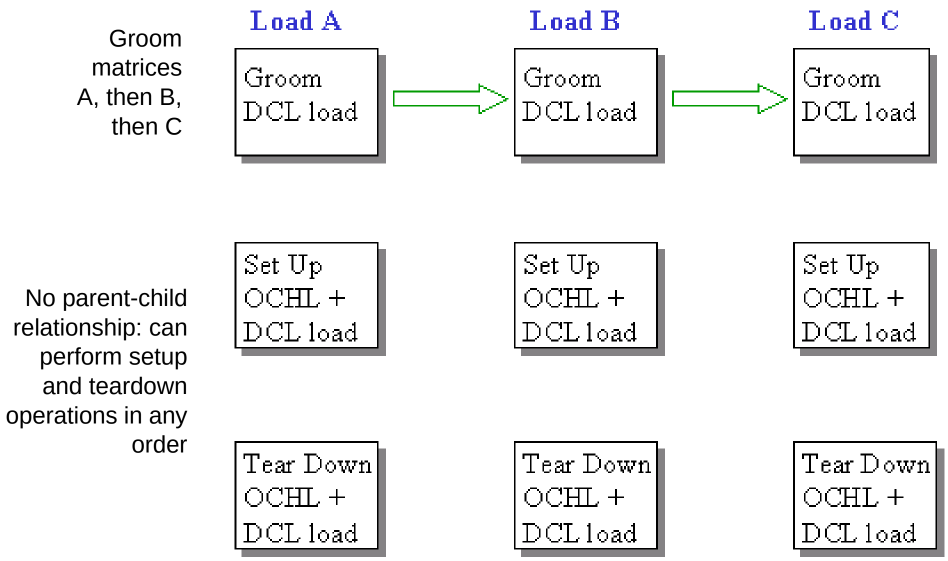
- The capacity of a previously set up (non-native) OCH matrix is trailed to the DCL layer and can be used to accommodate DCL traffic.
- The capacity is a result of a previous grooming operation. Upon setup of the OCH matrix, the DCL trunks are created and DCL traffic is accommodated on the trunks. In general, the DCL trunks are not fully utilized (utilization is less than 100 percent); as a result, these trunks have unused capacity.

The grooming algorithm considers this and reuses any unused DCL capacity. The grooming algorithm reuses only optical channels that have a multiplex factor (for example, 16 for STM-16) greater than or equal to than the multiplex factor of the DCL demands. The result of this reuse is a “dependency chain” of traffic matrices: each successor matrix depends on a previous matrix. This means that you cannot tear down a traffic matrix if it has any successor (dependent) traffic matrix that is accommodated in the network.

Example: Groom Without Reuse

Assume that the DCL layer has no unused capacity, and that the grooming algorithm is applied on multiple matrices. Working in “no-reuse” mode creates non-chaining OCH and DCL traffic matrices that can be accommodated and torn down in any order, as shown in Figure 8-16. You must complete all grooming actions before you start setting up any matrix.

Figure 8-16 Multiple Grooming with No Reuse



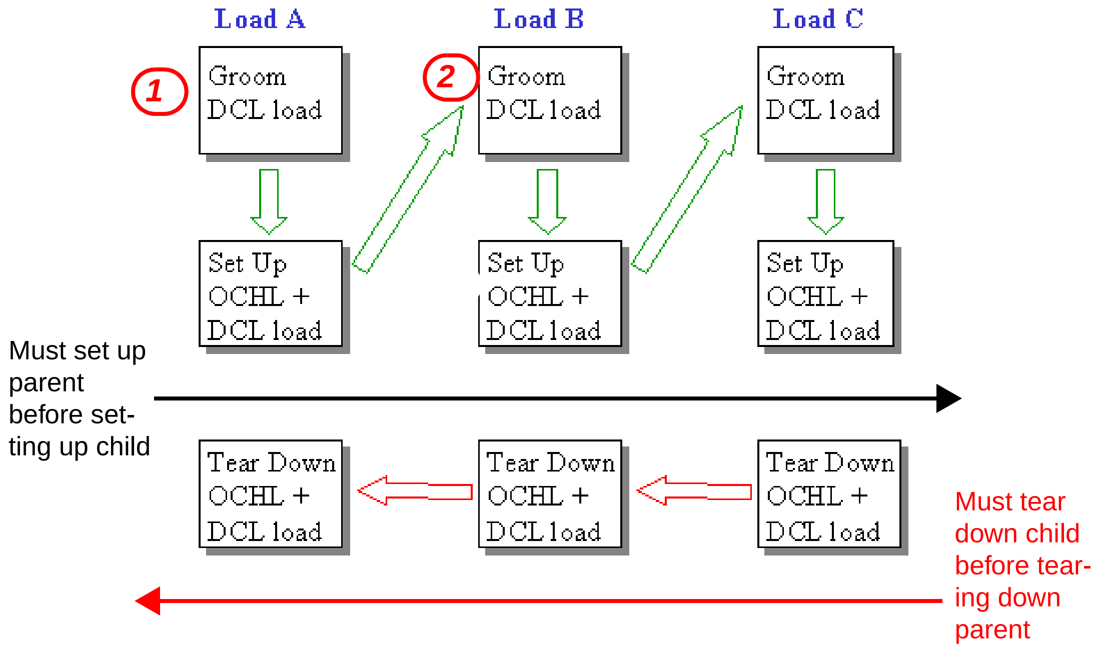
Example: Groom With Reuse

This section describes the scenario of multiple grooming with reuse shown in Figure 8-17:

1) Groom matrix DCL_A. SP Guru Transport Planner creates an OCH matrix (OCH_A) and grooms all the DCL traffic into this matrix. Set up matrices OCH_A and DCL_A. This leaves OCH_A with some unused capacity.

2) Groom matrix DCL_B. SP Guru Transport Planner grooms part of DCL_B’s traffic into the unused capacity in OCH_A, creates a new matrix (OCH_B), and grooms the remaining traffic into the new matrix. This creates a “parent-child” relationship between traffic matrices OCH_A and DCL_B. If you tear down matrix OCH_A, the network no longer has the capacity to accommodate DCL_B. Therefore, make sure you tear down DCL_B before you tear down OCH_A.

Figure 8-17 Multiple Grooming with Reuse



You can repeat this process indefinitely, creating successive generations of dependent matrices. As long as each successive grooming operation results in unused capacity, the dependency chain will continue. The dependency relationship extends to both setting up and tearing down matrices: Just as you must set up a parent before setting up the child, you must tear down all dependent children before tearing down a parent.

Note—Routing functions (Design > Route DCL/OCH Traffic) to accommodate DCL traffic matrices can also consume unused capacity in the DCL layer. Therefore, you must tear down these matrices before you can tear down any matrices associated with a grooming action.

DCL Grooming and Two-Tier Network Design

You can run grooming operations in two-tier networks—that is, networks that contain different types of nodes (EOCC, ECC and OCC). The links that connect EOCC-ECC and ECC-ECC node pairs are electrical DCL links on which SONET/SDH line systems are deployed. This section describes the impact of ECC nodes on the grooming algorithms.

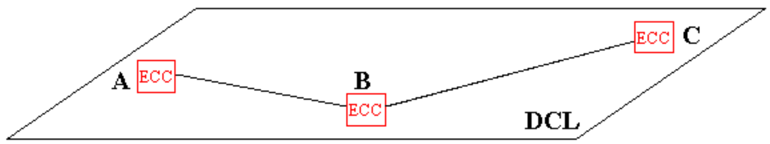
No New Electrical DCL Links

The grooming algorithms cannot add new electrical DCL links because an ECC node cannot switch optically. However, you can add capacity on existing electrical DCL links. The only way to add a new DCL electric link is to create one in the physical (OTS) layer manually. This fact has two effects on the algorithm:

- The link-by-link optimization algorithm cannot insert a direct link (trunk) that connects to an ECC node, because direct links can be inserted between EOCC nodes only.

- Some networks may require switching in the DCL layer. Figure 8-18 shows an example. All nodes in this DCL topology are ECC nodes. If there is a DCL demand between A and C, it can be routed only through B; this implies grooming in node B. As a result, the switching cost in the DCL layer is non-zero for every grooming solution (even the pure end-to-end solution).

Figure 8-18 Required Switching in DCL Layer



Non-Grooming DCL Nodes

In some cases you can have non-grooming ECC nodes. This is possible if the DXC is replaced by a less costly terminal multiplexer. As in a non-grooming EOCC node, a terminal multiplexer cannot switch DCL demands. In some cases, these nodes can prevent the grooming algorithm from finding a solution for a certain DCL demand. Suppose that in the example network shown in Figure 8-18, node B is a non-grooming node. This would make it impossible to route a DCL demand between A and C. If the grooming algorithm cannot find a solution, SP Guru Transport Planner shows an error message saying that it could not route all the connections.

No Grooming Without Reuse

You cannot groom without reuse in a two-tier network. When you groom a DCL matrix, the resulting OCH matrix contains only demands between EOCC nodes. If extra DCL capacity is required on the electrical links to accommodate the DCL demands, the algorithm equips extra fibers on these links. These fibers are of the default SONET/SDH type as specified in the Network Properties dialog box (Network > Network Properties). This means that you cannot groom multiple matrices without reusing capacity (the method described in Example: Groom Without Reuse on page TrP-8-29).

The following hypothetical example shows what happens when you try to groom two matrices without reuse in a two-tier network.

1) You groom an initial DCL matrix (DCL_1). This equips additional fibers in the electrical DCL links to ensure extra spare DCL capacity.

2) Do not accommodate DCL_1 in the network, but groom traffic matrix DCL_2 first. In that case, the algorithm uses some of the existing spare capacity to accommodate DCL_2. (The first grooming operation generated this existing capacity to accommodate DCL_1.)

3) You set up one of the groomed matrices. The setup operation uses the remaining spare DCL capacity from the grooming operation in step 1 to accommodate the matrix.

4) You try to set up the remaining matrix, which fails. The second grooming (in step 2) did not add enough capacity in the electrical links. Therefore you can set up one of the matrices (DCL_1 or DCL_2), but you cannot set up both.

For this reason, you should always use the groom-with-reuse strategy (described in Example: Groom With Reuse on page TrP-8-29) when grooming in a two-tier network.

OCC Nodes

OCC nodes have no effect on the grooming algorithm, because the DCL layer does not represent OCC nodes. However, OCC nodes can accommodate OCH matrices that result from a grooming operation.