10 Transparent Networks

You can use SP Guru Transport Planner to design and evaluate networks that use ultra-long-haul WDM equipment. This equipment offers extended transparent reach, which enables a network to route connections transparently over multiple fiber spans. This means that SP Guru Transport Planner can model selective regeneration of only the channels that need to be regenerated in intermediate nodes.

For general information about the models used in transparent networks, see Optical Transparency on page TrP-2-11.

For information about the models and algorithms used in transparent networks, see Optical Nodes: WP-OXC on page TrP-2-26 and Algorithm Descriptions on page TrP-10-5.

The following requirements and characteristics apply to transparent networks in SP Guru Transport Planner:

- Transparency is only possible between WDM line systems of the same type that were defined as transparent systems in the WDM Link Equipment Properties (see WDM Link Equipment Properties on page TrP-3-35). Between fibers equipped with line systems that are not transparent, signals will always be regenerated in the intermediate node. Also, between fibers equipped with different line systems, signals will always be regenerated in the intermediate node. While it is possible to have different fibers equipped with different line systems, it is not possible to perform transparent routing between them.
- The transmission characteristics of the selected line system type drive the maximum transparency length and the regeneration requirements in the network. The MTL (maximum transparency length) defines the maximum distance that a signal can travel transparently through the network. If a signal exceeds the MTL, it must be regenerated. Regeneration can occur either along the line (in a regeneration site on a link) or within a node. See Maximum Transparency Length on page TrP-10-14 for details about how SP Guru Transport Planner calculates the MTL.
- Before you design or evaluate a transparent network, you must design the links. This operation places the required amplification and regeneration sites along each link, and ensures that each link contains the necessary in-line regeneration equipment to overcome the MTL. Paths that travel across multiple links may need additional in-node regenerators, depending on the length of the links and the placement of the in-line regenerators. For more information, see Dimensioning a Topology on page TrP-7-1.

Transparent Network Concepts

This section describes the basic concepts of transparent networks. For more information about the different transparent cross-connect architectures supported in SP Guru Transport Planner, see Optical Nodes: Non-Blocking OXC on page TrP-2-24 and Optical Nodes: WP-OXC on page TrP-2-26.

To change the transparency setting of a node, right-click on the node in the OCH Node Browser and choose Make Transparent, Make Opaque, or Make Selective. For more information about this window, see OCH Node Browser on page TrP-4-15.

Selective Regeneration (SR)

In opaque transport networks, about 60 to 80 percent of the network installation cost goes to the line cards and transponders that convert the electrical signals to optical signals. To reduce this cost, transparent networks regenerate signals within nodes and move regeneration away from the WDM links—specifically the long-reach transponders that terminate channels within these links. Instead, regeneration occurs within nodes selectively. This means that a transparent network regenerates only those channels that require regeneration, while an opaque network regenerates all channels within a node—even channels that do not need regeneration. In a transparent network, channels that are not regenerated in an intermediate node pass transparently through that node. These channels do not need transponders in the node.

Note—Transparent passthrough in a node is only possible if the line system has been set as transparent (see WDM Link Equipment Properties on page TrP-3-35) and is between fibers that have been equipped with the same WDM line system. If this is not the case, the signal will automatically be regenerated in the node or will not be routed at all, in the case in which no regeneration is possible in the node.

Wavelength Conversion (WC)

Regeneration in an intermediate node gives a connection additional flexibility, because it enables the connection to switch wavelengths when it passes through the node. In a transparent network, each signal is regenerated every MTL kilometers. This regeneration divides the path into sub-paths, and thereby frees up the routing and wavelength-assignment (WA) algorithm to assign different wavelengths to these sub-paths. Wavelength conversion (WC) can be either implicit or explicit:

- In implicit WC, regeneration is required in the node and the required optical-to-electrical signal conversion is used to switch wavelengths.
- In explicit WC, regeneration is not required in the node (the MTL is not exceeded) but an optical-to-electrical conversion is done to allow wavelength conversion. Explicit WC provides even more flexibility to the routing and wavelength-conversion algorithm than implicit WC.

Transparent Network Node Types

This section describes the specialized node types that SP Guru Transport Planner uses to model transparent networks.

Transparent Node

A fully transparent cross-connect has no regeneration capacity. Therefore in-node regeneration or wavelength conversion cannot occur in this type of node—every optical channel passes through the node transparently. Long-reach transponders are used at the OXC (or OADM) tributary ports for local traffic only. The presence of transparent cross-connects in an optical network might result in unroutable traffic if the MTL is exceeded in that node.

Transparent Node with Selective Regeneration

This type of node has regeneration capacity and supports in-node regeneration or wavelength conversion for optical channels that pass through the node. This type of node uses long-reach transponders at the OXC (or OADM) tributary ports for local traffic and for pass-through traffic that needs regeneration or wavelength conversion. You can choose either of two models to do regeneration or wavelength conversion in a node:

1) Regeneration through a DXC—In-node regeneration occurs through the DXC. This adds a level of flexibility because the DXC manages the OXC (or OADM) tributary ports—and therefore the transponders—and assigns the transponders to either the local traffic or transit traffic that requires intermediate regeneration. Keep in mind that if you use discrete-sized DXC node types in this model, the DXC size adds another constraint on the amount of regeneration that can occur in the node.

2) Regeneration through a regeneration bank—In-node regeneration occurs in a fixed bank of long-reach transponders connected to the OXC (or OADM) tributary ports.

To specify the model, set the “Regenerate via DXC” option in the Network Properties dialog box (Network > Network Properties). For more information about this dialog box, see Network Properties on page TrP-3-23.

Opaque Node

An opaque node is a node with full regeneration capacity. The OXC (or OADM) is connected to the WDM line systems through long-reach transponders, and short-reach transponders are attached to the OXC (or OADM) tributary ports. If the node type is an IXC, the node is always considered an opaque node.

Tunable and Fixed-Wavelength Transponders

Depending on the node architecture, SP Guru Transport Planner uses tunable or fixed-wavelength transponders:

- For non-blocking OXCs or OADMs, SP Guru Transport Planner assumes tunable transponders, which enable the OXC or OADM to use the transponder for each outgoing signal.
- For blocking OXCs (wavelength plane OXC or WP-OXC), SP Guru Transport Planner assumes fixed transponders, each of which is associated with a specific wavelength plane. This means that a fixed wavelength transponder can be used only for a signal transmitted on the corresponding wavelength.

Algorithm Descriptions

This section describes the transparent routing algorithm. Selective Regeneration contains more detail about the concept of selective regeneration in transparent networks; the routing algorithm is described in Routing Algorithm on page TrP-10-6.

Selective Regeneration

The Link Design operation (described in Link Design on page TrP-3-45) places amplifiers and regenerators on the links to overcome transmission length limitations. For each link that exceeds the MTL, SP Guru Transport Planner places regenerators every MTL kilometers/miles (at least). This is called *in-line regeneration*.

Besides in-line regeneration, SP Guru Transport Planner can also perform *in-node regeneration* on a connection as it passes through a node. Whether this occurs depends on two factors:

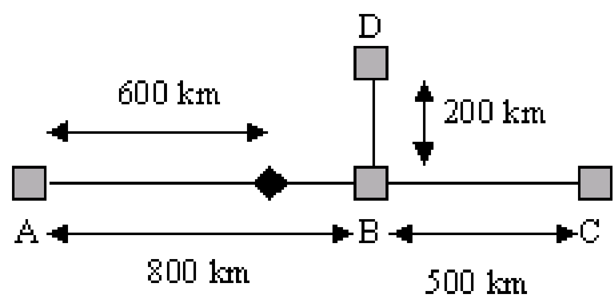
- If the incoming and outgoing fibers on which the connection through the node is routed are not equipped with the same WDM line system, regeneration is always performed.
- If the incoming and outgoing fibers on which the connection through the node is routed are equipped with the same WDM line system, regeneration is performed if the distance between the last point of regeneration (in-node or in-line) and the next possible point of regeneration exceeds the MTL.

Figure 10-1 shows an example of how regeneration works. This network uses the same WDM line system on all links in the network, and this system has an MTL of 600 km. On the link A<—>B, an in-line regenerator is placed at 600 km from node A. This splits the link into two transparent sections: one 600 km and one 200 km long. This means that

- A connection between A and C requires an in-node regenerator in node B because the distance between the last regenerator (200 km) and the next possible regenerator (500 km towards node C) is 700 km and exceeds the MTL

- A connection between A and D does not require an in-node regenerator in node B because the distance between the last regenerator (200 km) and the next possible regenerator (200 km towards node D) is 400 km and does not exceed the MTL

Figure 10-1 Selective Regeneration Example



Routing Algorithm

SP Guru Transport Planner's transparent network routing algorithm has the following characteristics:

- An important factor in the algorithm is the ratio between the link cost versus the cost for wavelength regeneration or conversion (WR/WC). The routing algorithm considers this cost ratio when it chooses between additional transparent hops and an additional WR/WC. This ratio does not influence whether a signal must be regenerated to obey transparency limitations.

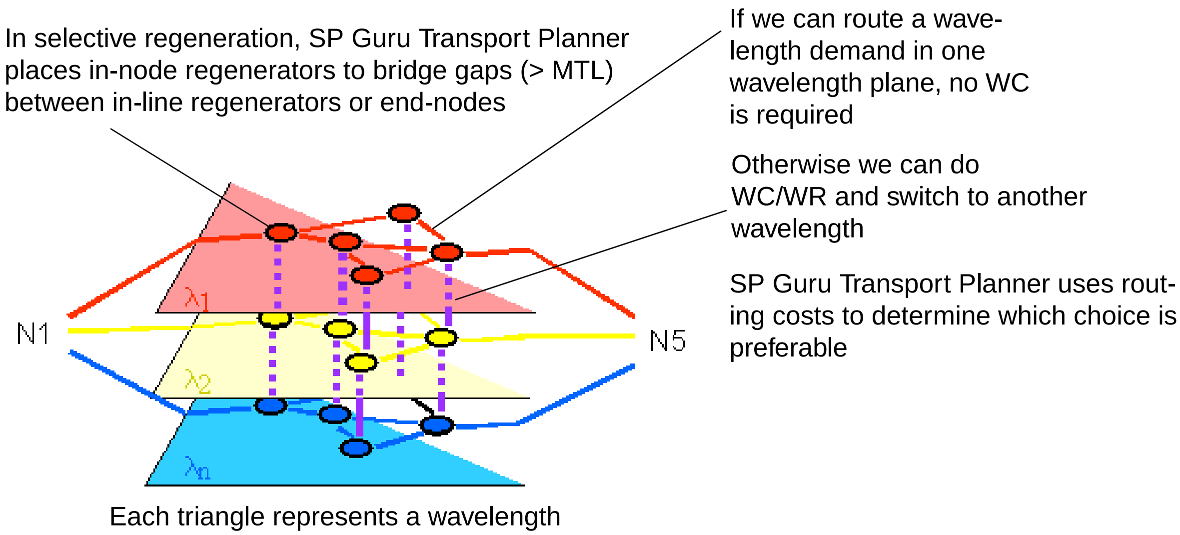
- Given the default cost settings, SP Guru Transport Planner prefers one additional WC/WR over one additional hop and one additional hop over two WC/WRs. The latter means that routing a connection over two hops without regeneration is preferable to routing over a shorter path with extra regeneration.

- For a transparent node with selective regeneration, you can specify the amount of regeneration capacity manually: right-click on a node in the OCH Node Browser and choose Set Regenerator Capacity. To remove the unused regenerator capacities in the selected node, choose Strip Regenerator Capacity from the right-click menu. For more information about this browser, see OCH Node Browser on page TrP-4-15.
- By using the routing algorithm (see Route DCL/OCH Traffic Dialog Box on page TrP-6-3), you can then evaluate the traffic that can be routed according to the amount of regenerator capacity in the nodes. Otherwise, you can let SP Guru Transport Planner determine the amount of regeneration capacity by using the dimensioning algorithm (see Dimension DCL/OCH Layer Dialog Box on page TrP-7-3). In the latter case, the algorithm adds as much regeneration capacity to the nodes as needed to try to accommodate the specified traffic matrix in the network. You cannot specify the amount of regeneration capacity of fully transparent nodes (no regeneration capacity) and opaque nodes (full regeneration capacity).

Routing vs. WC/WR: Example

Figure 10-2 shows how cost parameters affect the choice between routing and WC/WR for a wavelength demand. The routing algorithm considers routing cost (per hop) and regeneration cost (per transition between wavelengths) to choose between routing and WC/WR. In some cases, a longer route might be preferred if no in-node regeneration is required.

Figure 10-2 Routing Cost vs. Regeneration Cost in the Transparent Algorithm



In Figure 10-2, each plane represents an available wavelength plane in the transparent network. The algorithm uses the cost parameters to determine the optimal route for a specific connection and whether WR/WC is required along the path. SP Guru Transport Planner does wavelength regeneration or conversion according to the characteristics of the optimal route:

- If the entire path is assigned to the same wavelength (no conversion is needed), the connection is routed in the same wavelength plane.
- If the path length exceeds the MTL, the algorithm does regeneration in an intermediate node of the path. Depending on the spare resources in the network, an implicit WC might be needed in the intermediate node. If implicit WC is needed, the path is switched from one wavelength plane to another in the intermediate node; if implicit WC is not needed, the path stays in the same wavelength plane.
- If no path can be found within the same wavelength (because resources have been used to accommodate other connections), the algorithm does explicit WC—that is, it switches to another wavelength in the intermediate node.

Workflow Description: Transparent Network Routing or Dimensioning

The routing and dimensioning operations can accommodate traffic in a transparent network. This section describes both operations in more detail.

- To run a routing operation, choose Design > Route DCL/OCH Traffic. In this case, you must first specify the network facilities (the node, link, and in-node regeneration capacity). The routing algorithm tries to maximize the traffic that can be accommodated within the existing network infrastructure. For more information about routing, see Chapter 6 Routing on page TrP-6-1.
- To run a dimensioning operation, choose Design > Dimension DCL/OCH Layer. You do not need to specify the network facilities before you run a dimensioning action: the dimensioning algorithm installs network equipment (if needed) to maximize the traffic that can be accommodated in the network. The dimensioning options you specify determine the types of equipment that the dimensioning run can add. For more information about dimensioning, see Chapter 7 Dimensioning on page TrP-7-1.

Note—Fully transparent nodes cannot regenerate an optical channel. For this reason, fully transparent nodes can result in unrouted connections when you run a dimensioning or routing action.

Preparing a Transparent Network

Before you run a routing or dimensioning operation on a transparent network, you must do the following:

1) Specify the following properties in the Network Properties dialog box:
    a) Set the OCH Layer Mode to Transparent
    b) Specify the default WDM line system type using the Default WDM Line System for OCH Link setting

    For more information about this dialog box, see Network Properties on page TrP-3-23.

2) Run the Link Design operation. This operation places the required amplification and regeneration sites along each physical link in the network. This ensures that each link contains the necessary equipment to overcome OA spans and the maximum transparency length.

    For more information, see Link Design on page TrP-3-45.

3) Specify the following properties for individual nodes in the OCH Node Browser:
    a) Transparency setting (transparent, selective or opaque)

b) Regeneration capacity present in selective nodes. You must do this for routing operations. You can also do this for dimensioning operations to define the present regeneration capacity from which the dimensioning action starts.

c) Tap, tributary and trunk port configuration on wavelength plane OXCs (you can do this in the Ports view of the OCH Node Browser).

d) Configure OADMs in higher-degree nodes. You can define OADMs manually, as described in Procedure 10-1. You can also import OADMs from a data file, as described in OADM Data Files on page TrP-5-11.

For more information about the OCH Node browser, see OCH Node Browser on page TrP-4-15.

4) To view a detailed report after a design operation, select Info > View Details after Design Operations. This report shows detailed data about the results of the design operation such as wavelength utilization, regenerators and converters used, and connections routed.

Defining OADMs Manually

This operation is not supported on WP-OXC nodes. The OADM transparency mode follows that of the node: if you are in opaque node, the OADMs will be opaque; if you are in a transparent node, the OADMs will be transparent.

Note—You can only add OADMs between fibers that have been equipped with the same WDM line system.

Procedure 10-1 Defining OADMs Manually for a Node

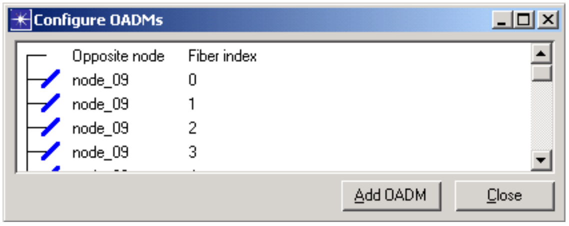
1 Open the Node Browser (choose Network > Node Properties, or right-click on a node and choose Node Properties).

2 Set the Layer to OCH.

3 Right-click on a node and choose Configure OADMs.

➥ The Configure OADMs dialog box appears and shows all fiber pairs that terminate in that node. This window shows only those fibers that are equipped (using the default line system in transparent mode) but do not carry any traffic. The fiber pairs are identified by the name of the "Opposite node" and the "Fiber index."

Figure 10-3 Configure OADMs Dialog Box



4 To introduce an OADM between two fibers, do the following:

4.1 Click on a fiber to select it. (This also highlights the fiber in the Project Editor window.)

4.2 While holding down the Control key, click on the second fiber and choose Add OADM.

After you add the required OADMs, you can view them in the OCH Node Browser. The Node Type field indicates whether OADMs are present in the node; for example, the field might read “OXC + OADMs”. The OADM subtree shows the total number of ports for all OADMs in that node and lists (as children) the individual OADMs and their port usage. To remove an OADM, right-click on an OADM and select Remove OADM. For more information, see OCH Node Browser on page TrP-4-15.

End of Procedure 10-1

Transparent Network Routing Procedure

The Routing and Dimensioning dialog boxes both contain a Transparent Routing Options button. After you prepare a transparent network, you can start a routing or dimensioning operation, then specify options specific to transparent networks. These options are described in Transparent Routing Options Dialog Box on page TrP-10-12.

For general information about routing and dimensioning, see Chapter 6 Routing on page TrP-6-1and Chapter 7 Dimensioning on page TrP-7-1.

Routing / Dimensioning Results for Transparent Networks

When a routing operation finishes, the Routing Results window shows the percentage of traffic that is accommodated in the network and the utilization of the tributary (for WP-OXCs), node, link, and regeneration resources. You can inspect these results at any time by choosing Design > Routing Results. For more information, see Routing Results on page TrP-6-16.

When a dimensioning operation finishes, the Dimensioning Results window reports on the link and node equipment added by the operation.

You can generate a spreadsheet report for transparent networks from the CSV Report Generation dialog box (Info > Export to Spreadsheet). For more information, see Transparent Routing Report on page TrP-15-32.

You can see details about the installed node equipment and utilization in the Node Browser (Network > Node Browser). For more information, see Node Browser on page TrP-4-14.

You can see details about connections, routes, wavelengths used and possible wavelength regenerators or converters in the Connection Browser (Network > Connection Browser). Mark the Show Wavelength Configurations field to inspect the wavelength assignment of the individual connections. For more information, see Connection Browser on page TrP-4-23.

Transparent Routing Options Dialog Box

The Transparent Routing Options dialog box (Figure 10-4 and Table 10-1 on page TrP-10-12) appears when you click the Transparent Routing Options button in either the Routing or the Dimensioning dialog box. Some options in this dialog box are available in both operations; others are available for routing or dimensioning operations only.

Figure 10-4   Transparent Routing Options Dialog Box

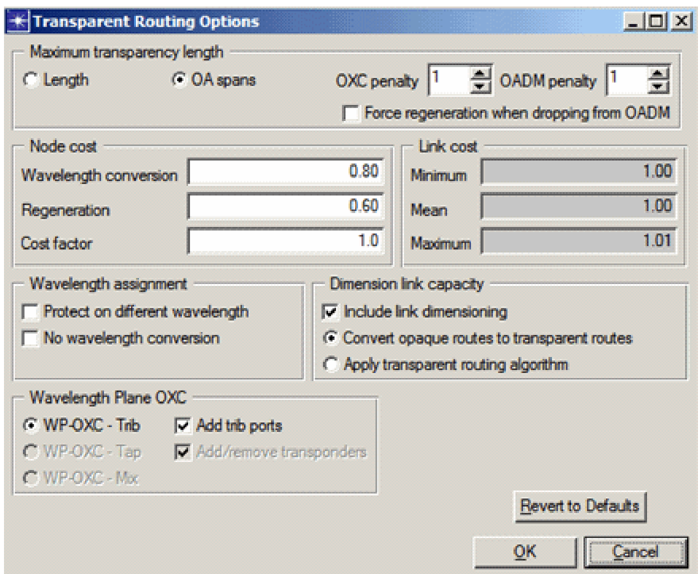


Table 10-1   Transparent Routing Options Dialog Box

Item	Description	Reference
Dimension Link Capacity	Include Link Dimensioning—Add the required link equipment in addition to adding the node equipment (dimensioning operations only) • Convert Opaque Routes to Transparent Routes—Perform link dimensioning based on the algorithm for opaque networks, which does not take the transparency length into account. Afterwards, calculate the required in-node regenerators and wavelength converters for these routes • Apply Transparent Routing Algorithm—Find optimal transparent routes using the algorithm described in Routing Algorithm on page TrP-10-6	Dimension Link Capacity on page TrP-10-16

Table 10-1 Transparent Routing Options Dialog Box (Continued)

Item	Description	Reference
Link & Node Cost	Link Costs: • Minimum/Maximum/Mean—Minimum, maximum and mean cost of all links in the network (not editable) Node costs: • Regen Cost—Initial signal regeneration cost (per node) when all capacity is available • Wavelength Conversion—Initial wavelength conversion cost (per node) when all capacity is available • Cost Factor—Multiplier for the WC/ WR cost as the utilization of these resources increases from 0 to 100 percent	Cost Parameters on page TrP-10-15
Maximum Transparency Length	• Length—Route and assign regenerators based on the maximum transparency length of the line system • OA Spans—Route and assign regenerators based on the maximum number of OA spans of the line system, taking into account the span penalties for intermediate OXCs and OADMs If OA spans are used to express the MTL, you can specify an additional OXC penalty and an OADM penalty. This specifies the number of additional OA spans counted for each transparent OXC or OADM passed. You can also force regeneration of signals that drop off the OADM.	Maximum Transparency Length on page TrP-10-14
Wavelength Assignment Options	Wavelength assignment and conversion options • Protect on Different Wavelength—If you have 1+1 protection enabled, you can specify the following constraint: for each connection, the working and protection path must enter and leave on a different wavelength, in both end nodes. • No Wavelength Conversion—Disables possible (implicit or explicit) wavelength conversion along the path in intermediate nodes.	Wavelength Assignment Options on page TrP-10-15
Revert to Defaults	After you change the Transparent Routing Options (by clicking OK), these settings are stored for the next transparent routing operation. If you click Revert to Defaults, the default settings are restored the next time you open this dialog box.	—

Table 10-1 Transparent Routing Options Dialog Box (Continued)

Item	Description	Reference
Wavelength Plane OXC Options	These options can be set only if there are WP-OXCs with integrated terminal multiplexers present in the network. For dimensioning operations, you can specify the default Wavelength Plane OXC type to be installed by the dimensioning action in nodes that are not yet initialized (greenfield nodes). Select WP-OXC—Trib, WP-OXC —Tap or WP-OXC—Mix. For routing operations, you can specify whether the routing action can install additional tributary ports and transponders if needed to accommodate additional connections in the network.	Dimension Link Capacity on page TrP-10-16
End of Table 10-1		

Maximum Transparency Length

The Using Line System Type field indicates the current default line system type used for OCH links.

The Transparency Length is the distance a signal can travel through the network without requiring regeneration. SP Guru Transport Planner calculates this length based on the transmission characteristics of the line system type, using the formula:

```
MTL = maximum_OA_span_length * maximum_#_OA_spans_without_regeneration
```

The maximum transparency length (MTL) is expressed in length units or in OA spans. If OA spans are used to express the MTL, you can specify an additional OXC penalty and an OADM penalty. This specifies the number of additional OA spans counted for each transparent OXC or OADM passed, as a measure of the extra degradation experienced by a signal when it passes through a transparent OXC or OADM.

If a node consists of OADMs and OXCs, both penalties are counted. To force regeneration of signals that are dropped from the OADM, select the “Force regeneration when dropping from OADM” option. If this option is selected, only pass-through signals of the OADM can be transparent.

Note—You cannot set the transparency length or the line system type in this dialog box. To change the line system type, use the Default WDM Line System for OCH Link setting in the Network Properties dialog box (Network > Network Properties).

Cost Parameters

An important factor for the transparent routing algorithm is the ratio between the link cost and the cost for wavelength regeneration or conversion (WR/WC). For more information, see Routing Algorithm on page TrP-6-8.

The two primary "Node Cost" options determine how the algorithm weighs these competing costs. If you select "Hop Count" as the Routing Cost option (in the Dimension DCL/OCH Layer or the Route DCL/OCH Traffic dialog box), the WC Cost and Regen Cost are relative to the link costs. If the Regen Cost is more than 1, SP Guru Transport Planner prefers an additional hop over a wavelength regeneration in a one-hop shorter path. If Regen Cost is less than 1, SP Guru Transport Planner prefers regeneration.

If you select "Real Cost" as the Routing Cost option, SP Guru Transport Planner determines the shortest path by calculating the cost on each link—specifically, the cost of routing one channel on a link—based on the cost values specified in the network properties (described in Network Properties on page TrP-3-23). The Min, Max, and Mean non-editable fields indicate the current link costs. In this case, you enter the WC Cost and Regen.Cost parameters as absolute costs. For more information on the routing costs, see Routing Algorithm on page TrP-6-8.

The Cost Factor increases the cost of using regenerators as the regenerator utilization in the nodes increases. Thus, a factor of 2 means that the cost increases by a factor of 2, from the minimum (0%) to the maximum (100%) utilization.

Wavelength Assignment Options

If you run a dimensioning action that uses 1+1 protection, the "Protect on Different Wavelength" option determines that the working and protection paths of each connection enter and leave the end nodes on a different wavelength.

If selected, the "No Wavelength Conversion" option prevents implicit or explicit wavelength conversion in an intermediate node.

Note—Enabling these options might result in additional unroutable connections.

Dimension Link Capacity

If the “Include Link Dimensioning” option is selected, SP Guru Transport Planner adds (if needed) link capacity as well as in-node regeneration capacity to the network. Additional link capacity is added by equipping one ore more fiber pairs with the default WDM line system on that link. There are two link-dimensioning options:

- Convert Opaque Routes to Transparent Routes—With this option selected, SP Guru Transport Planner uses the same dimensioning algorithm as in opaque mode to determine the paths of the connections. Next, it assigns the required regenerators and wavelength converters to each path. Hence this algorithm performs routing and wavelength assignment in two separate steps. In the case of shared path protection and link or path restoration, this link-dimensioning option is the only one available.
- Apply Transparent Routing Algorithm—With this option selected, SP Guru Transport Planner applies the transparent routing algorithm that trades the routing cost for WR/WC cost. Hence this algorithm performs routing and wavelength assignment in one integrated step. For more details about the algorithm used, see Routing Algorithm on page TrP-6-8.

The “Apply Transparent Routing Algorithm” option might find better routes that require fewer regenerators or wavelength converters for some connections than the “Convert Opaque Routes to Transparent Routes” option. However, the trade-off is that “Convert Opaque Routes to Transparent Routes” option might be able to accommodate more connections in the network.

Wavelength-Plane OXC Options

These options are available if you are working with WP-OXCs.

If you are performing a dimensioning operation, you can specify the default Wavelength Plane OXC type. This is the OXC type installed by the dimensioning operation in greenfield nodes (that is, nodes that do not have a OXC type assigned). You can set the default WP-OXC type to Trib, Tap, or Mix. This determines how new OXC ports, added during the network design, are utilized. For more information, see WP-OXC Architectures on page TrP-2-27.

If you are running a routing operation, an important setting for WP-OXCs is the “Add trib ports” checkbox. This option enables you to use unused fiber ports on a WP-OXC as tributary ports, and thereby add extra add/drop capacity in a node.

If “Add/remove transponders” is selected, SP Guru Transport Planner installs new transponders at the tributary side over the ones that already exist. If this option is not selected, the routed traffic must reuse the installed transponders of a previous network design action. In the case of a wavelength-independent terminal multiplexer, these are tunable transponders; otherwise they are fixed-wavelength transponders.

Note—If the “Add/remove transponders” options is enabled, tearing down the traffic will also remove the transponders.
