4 Network Evaluation

Failure Analysis

The Failure Analysis feature allows you to study the impact of equipment failures on the traffic routed in the network by specifying any sequence of equipment failures. SP Guru Transport Planner shows how the traffic reacts to these failures. Depending on the protection schemes applied, part of the traffic can be recovered and part of the traffic can be interrupted.

The following failures can be simulated:

- OTS layer: cable failure and node failure (node fails in all layers)
- OCH layer: OXC, IXC, OADM, and patch panel failure or complete node failure
- DCL layer: DXC failure, failing all ADMs, or complete node failure

Procedure 4-1 Performing Failure Analysis

1 Open the WDMGuru_Tutorial_Failure_Analysis project.

1.1 Select **File** > **Open...**.

1.2 Select the **WDMGuru_Tutorial_Failure_Analysis** project, then press **Open**.

➥ The example project is loaded, containing the scenario **scenario1**.

2 Inspect the routed traffic matrices.

2.1 Select **Design > Routing Results**.

2.2 Select the **DCL** layer and the traffic matrix **STS-1.** The selected traffic matrix has been accommodated in the network (using the ring sizing and grooming algorithm).

2.3 Select **OCH**. The OC-48 traffic matrix deploys 1+1 protection. The OCH_STS-1-1_Grooming traffic matrix is the outcome of the grooming algorithm, applied to the part of the STS-1 matrix that is not accommodated on the rings.

2.4 Close the **Routing Results** dialog box.

3 Perform failure analysis.

3.1 Select **Info > Failure Analysis**.

➥ The **Failure Analysis** dialog box appears.

Closing the dialog box exits the failure analysis mode.

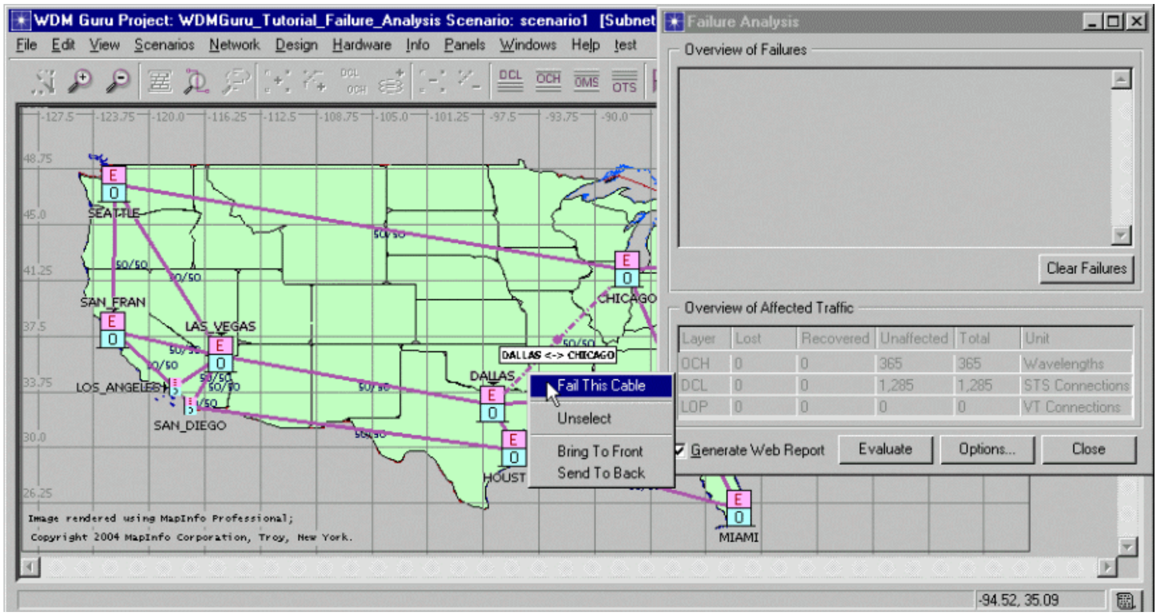
Note—When you are in failure analysis mode, no network design operations can be performed.

3.2 Select the OTS layer view using the **OTS** button on the toolbar.

3.3 Right-click on the link between **Dallas** and **Chicago**, then select **Fail This Cable**.

➥ The cable fails (indicated by a red cross).

Note that the cable failure has been added to the **Overview of Failures** section of the **Failure Analysis** dialog box.

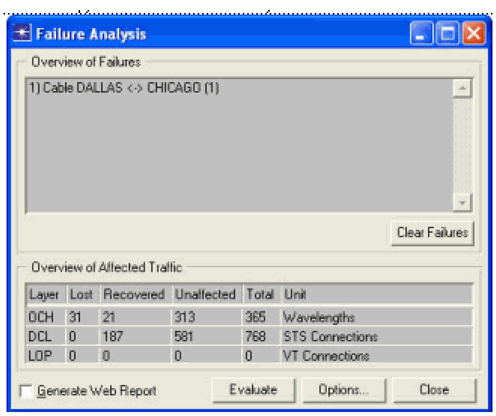


3.4 Uncheck **Generate Web Report** and click **Evaluate** in the **Failure Analysis** dialog box.

➥ The **Overview of Affected Traffic** section shows the impact of the cable failure on the traffic accommodated in the network.

In the OCH layer:

- 52 of the 365 optical channels that were routed are affected (21of these channels can be recovered, 31 are lost)
- 768 STS-1 units are routed in the DCL layer (187 units are affected but all can be recovered by the ring and mesh protection schemes)



3.5 Use the **OCH** button on the toolbar to view the OCH layer. The link between **Dallas** and **Chicago** is colored in orange, meaning that this link fails as a consequence of the cable failure in the OTS layer.

4 Inspect the impact of the cable failure.

4.1 Select **Network > Connection Browser** to inspect the impact of the failure on the traffic accommodated in the network.

CAUTION—Do not close the Failure Analysis dialog box. If you close the dialog box, you will exit the failure analysis mode.

4.2 Select the **OCH** radio button under Traffic.

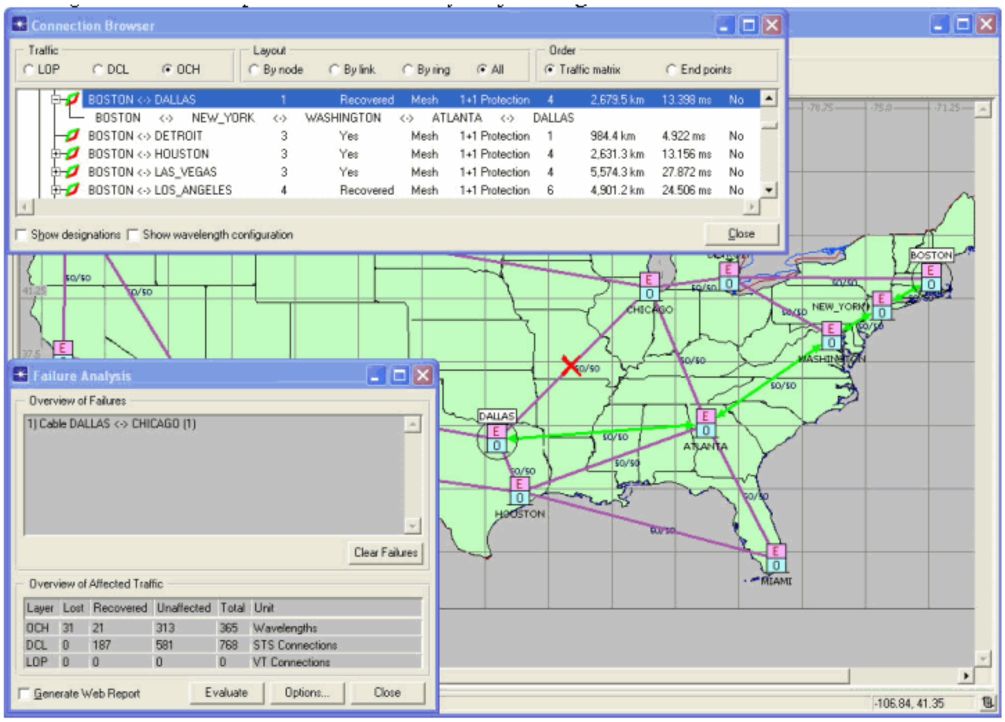
4.3 Click on the **+** sign to inspect the connections of the OC-48 traffic matrix.

➥ The connections are either unaffected (indicated as **Yes** in the **Routed** column) or rerouted using a backup path (indicated as **Recovered**).

Note that all connections affected by the cable failure can be recovered due to the 1+1 protection scheme deployed.

For example, check the connection between Boston and Dallas. The working path (Boston –> Detroit –> Chicago –> Dallas) is affected by the failing cable Dallas <-> Chicago. Therefore, the connection is recovered using its protecting path (Boston –> New York –> Washington –> Atlanta -> Dallas). This backup path is not affected by the failure. It is inherent to the 1+1 protection scheme that all connections affected by a single link failure can be recovered.

Note—The optical channels that were reported as failed in step 3.4 were not part of this OC-48 matrix, but were OCH connections that supported DCL traffic (from grooming) or DCL rings.



4.4 Select **DCL** in the connection browser.

4.5 Use the **+** icon to expand the STS-1 traffic matrix. Note that all its affected connections can be recovered using their back-up path.

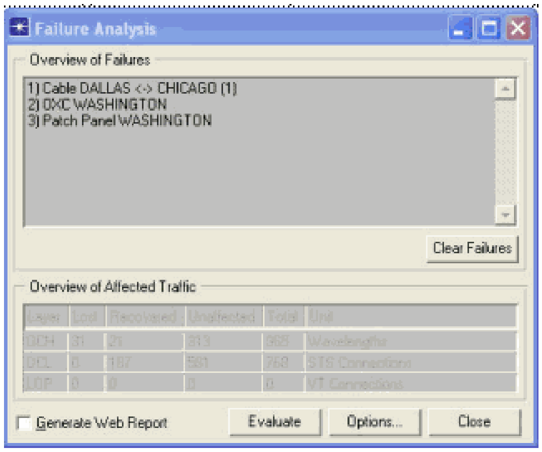
4.6 Close the connection browser (do not close the **Failure Analysis** dialog box).

5 Continue failure analysis.

5.1 Use the **OCH** button on the toolbar to view the OCH layer.

5.2 Right-click on the node **Washington**, then select **Fail This Node**.

➥ Both the OXC and the patch panel fail in this location.



5.3 In the **Failure Analysis** dialog box, check **Generate Web Report** and then click **Evaluate**.

If the Generate Web Report option is selected, the web browser launches automatically and shows a failure analysis report. This report contains information about the affected and recovered traffic for the current network simulation.

In the OCH layer 102 traffic units are affected now, of which only 12 units are recoverable. Traffic is also disrupted in the DCL layer.

6 Inspect the impact of the equipment failures.

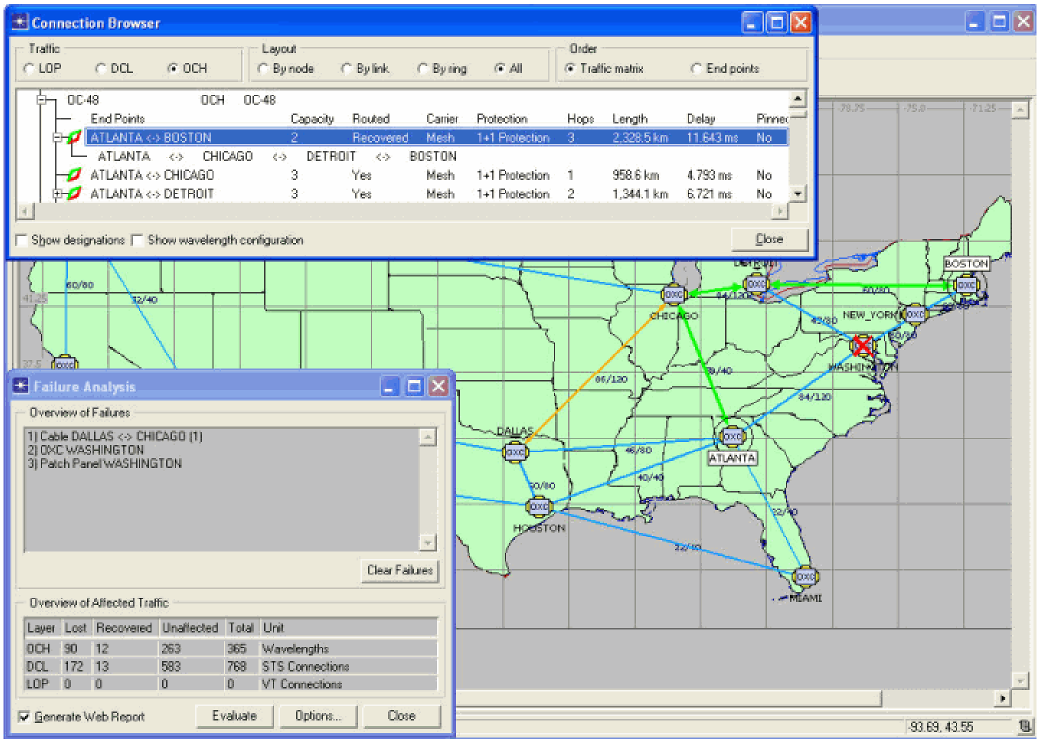
6.1 Select **Network > Connection Browser** to inspect the impact of the failures on the traffic accommodated in the network.

CAUTION—Do not close the Failure Analysis dialog box. If you close the dialog box, you will exit the failure analysis mode.

6.2 Select **OCH**.

6.3 Click on the **+** sign to inspect the connections of the OC-48 traffic matrix.

Some affected connections are not recovered (indicated by **Lost** in the **Routed** column). This is due to the two failures in the network. Note that a node failure results in losing all connections entering the network in that node, while transit connections could be recovered. So, each connection entering the network in Washington is lost, while the connection Atlanta <-> Boston, for example, is recovered.



6.4 Select **DCL** in the connection browser. Inspect the **STS-1** traffic matrix. Some of its connections are also lost.

6.5 Close the connection browser (do not close the **Failure Analysis** dialog box).

7 Repair the cable failure.

7.1 Use the **OTS** button on the toolbar to view the OTS layer.

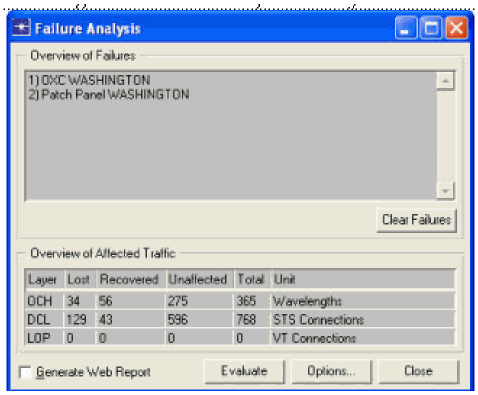
7.2 Right-click on the failing cable between **Dallas** and **Chicago**, then select **Repair This Cable**.

➥ This removes the cable failure. The red cross on the link is removed and the failure no longer appears in the **Overview of Failures** section in the **Failure Analysis** dialog box.

7.3 In the **Failure Analysis** dialog box, uncheck **Generate Web Report** and click **Evaluate**.

➥ In the OCH layer, 90 optical channels are affected, 34 optical channels are disrupted. Also, traffic is lost in the DCL layer.

7.4 Compare this result with the result in step 3 of this procedure. The single node failure **Washington** has a more severe impact on the traffic accommodated in the network than the single cable failure **Dallas <-> Chicago**. Note that the 1+1 protection scheme cannot recover traffic towards a failing node.



7.5 Close the **Failure Analysis** dialog box.

➥ This clears all user-defined failures and ends the failure analysis.

8 Generate a failure analysis report

8.1 Go to **Info > Export to Web Report > Failure Analysis Report...**.

➥ The **Generate Failure Analysis Report** dialog box allows you to define the options to create a failure analysis web report.

Keep in mind that this web report shows information about different network scenarios, while the report generated during a failure analysis operation (see step 5.3) shows information about the current scenario only.

8.2 Check **Cables** (Elements To Fail).

➥ This means that only cable failures are simulated for the web report.

8.3 Check **Single** (Element Failure Combination), implying only single (cable) failures are simulated.

8.4 Press **OK** to generate the failure analysis report.

➥ The web report is automatically opened.

8.5 Select **Overview** in the Failure Analysis Report file.

➥ This section gives an overview of the total, affected, recovered and lost traffic per layer and per failure scenario.

Layer	OCH				DCL				LOP			
Unit	Wavelengths				STS Connections				VT Connections			
Traffic	Lost	Recovered	Unaffected	Total	Lost	Recovered	Unaffected	Total	Lost	Recovered	Unaffected	Total
Cable ATLANTA <-> MIAMI (1)	3	12	350	365	0	71	697	768	0	0	0	0
Cable ATLANTA <-> WASHINGTON (1)	8	37	320	365	0	90	678	768	0	0	0	0
Cable CHICAGO <-> ATLANTA (1)	7	7	351	365	0	51	717	768	0	0	0	0
Cable CHICAGO <-> DETROIT (1)	8	39	318	365	0	233	535	768	0	0	0	0
Cable DALLAS <-> ATLANTA (1)	4	14	347	365	0	37	731	768	0	0	0	0
Cable DALLAS <-> CHICAGO (1)	31	21	313	365	0	187	581	768	0	0	0	0
Cable DALLAS <-> HOUSTON (1)	6	19	340	365	0	110	658	768	0	0	0	0
Cable DETROIT <-> BOSTON (1)	5	27	333	365	0	122	646	768	0	0	0	0
Cable DETROIT <-> WASHINGTON (1)	6	3	356	365	0	78	690	768	0	0	0	0

8.6 Verify the cable failure **Dallas <-> Chicago** in the **Overview traffic per failure scenario** table. 52 of the 365 optical channels are affected by this cable failure, of which 21 channels can be recovered.

In the DCL layer, 187 of the 768 STS-1 units are affected, but all of them can be recovered. Note that these results are the same as obtained in step 3.

8.7 Select **Cable Dallas <-> Chicago** at the left side of the report.

More details about the impact of this cable failure on the network traffic are displayed. Verify the traffic matrix **OC-48**. Note that all affected connections of this traffic matrix can be recovered. For example, the connection **Boston <-> Dallas** is recovered along the following path: BOSTON -> NEW_YORK -> WASHINGTON -> ATLANTA -> DALLAS. Verify that the same result was obtained in step 4.

From	To	Length (km)	Delay (ms)	Designation	Bit Rate	Capacity	From	To	Carrier	Route
BOSTON	DALLAS	2,679.5	13.398		OC-48	1	BOSTON	DALLAS	Mesh	BOSTON NEW_YORK WASHINGTON ATLANTA DALLAS
BOSTON	LOS_ANGELES	4,901.2	24.506		OC-48	1	BOSTON	LOS_ANGELES	Mesh	BOSTON NEW_YORK WASHINGTON ATLANTA HOUSTON SAN_DIEGO LOS_ANGELES
BOSTON	LOS_ANGELES	4,901.2	24.506		OC-48	1	BOSTON	LOS_ANGELES	Mesh	BOSTON NEW_YORK WASHINGTON ATLANTA HOUSTON SAN_DIEGO LOS_ANGELES
BOSTON	LOS_ANGELES	4,901.2	24.506		OC-48	1	BOSTON	LOS_ANGELES	Mesh	BOSTON NEW_YORK WASHINGTON ATLANTA HOUSTON SAN_DIEGO LOS_ANGELES
BOSTON	LOS_ANGELES	4,901.2	24.506		OC-48	1	BOSTON	LOS_ANGELES	Mesh	BOSTON NEW_YORK WASHINGTON ATLANTA HOUSTON SAN_DIEGO LOS_ANGELES

8.8 Close the **Failure Analysis Report** file.

8.9 Close the **Generate Failure Analysis Report** dialog box.

9 Close the project

9.1 Select **File** > **Close**.

9.2 Select **Don't Save** in the **Close Confirm** dialog box.

End of Procedure 4-1

Availability Analysis

The availability analysis feature allows you to calculate the service availability of traffic routed in the network. It takes into account the failure rate of network devices and the protection types deployed in the network. You can use the calculated service availability values to verify if service level agreements (for example, 99.99 percent network availability) can be met.

Procedure 4-2 Evaluating Recovery Strategies

1 Open the **WDMGuru_Tutorial_Scenarios** project.

1.1 Select **File** > **Open...**.

1.2 Select the **WDMGuru_Tutorial_Scenarios** project, then press **Open**.

➥ This project contains 4 scenarios for an example US network. Each scenario contains a design of the OCH layer for the traffic matrix called **OC-48**. Each of these scenarios uses a different protection strategy. The initially loaded scenario is called **USA_Unprotected**. In this scenario all traffic has been routed along a single unprotected path.

Note—If the **USA_Unprotected** scenario is not the default scenario, select Scenarios > Switch to Scenario and choose **USA_Unprotected**.

2 Define the equipment failure rates.

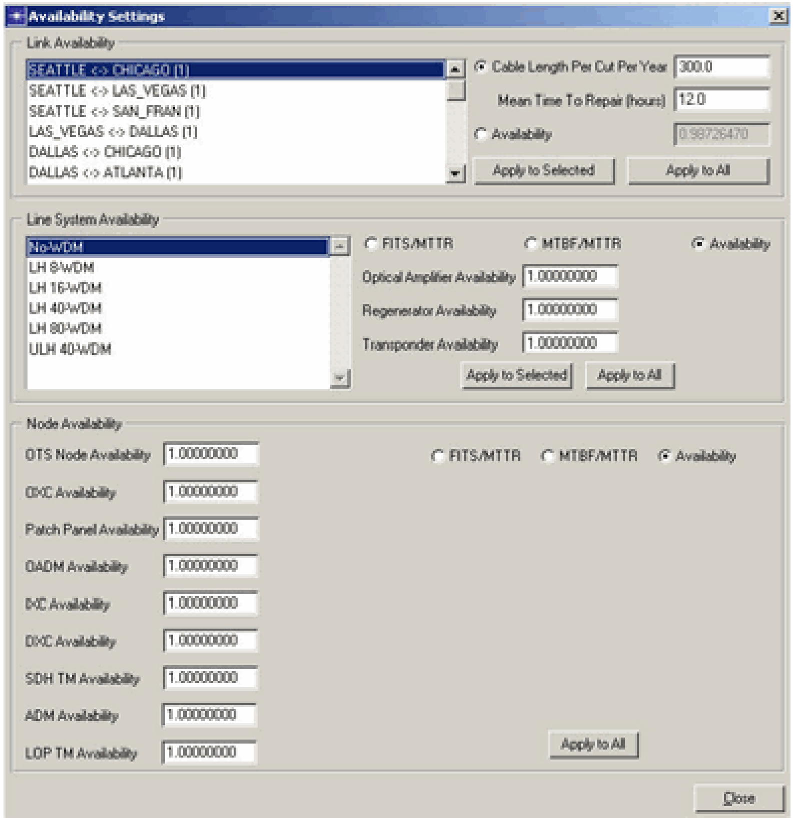
2.1 Select **Network > Availability Settings**. This dialog box allows you to specify the failure rate for different equipment types. Only link failures are considered in this example.

2.2 Select **Cable Length Per Cut Per Year** in the **Link Availability** section and set the value to **300** kilometers. This means that per 300 km of cable on cable cut is expected each year.

2.3 Set the **Mean Time To Repair** to **12** hours. Press **Apply to All** to apply this failure rate to all physical links in the network.

The failures rates of line system devices (e.g. Optical Amplifier) and nodes devices (e.g. OXC) can be specified as Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR), as availability (value between 0 and 1) or as Failures In Time (one FIT stands for one failure per 10e9 hours). In this example we only consider cable cuts, implying the availability of line system and node equipment is set to 1.

2.4 Close the **Availability Settings** dialog box.



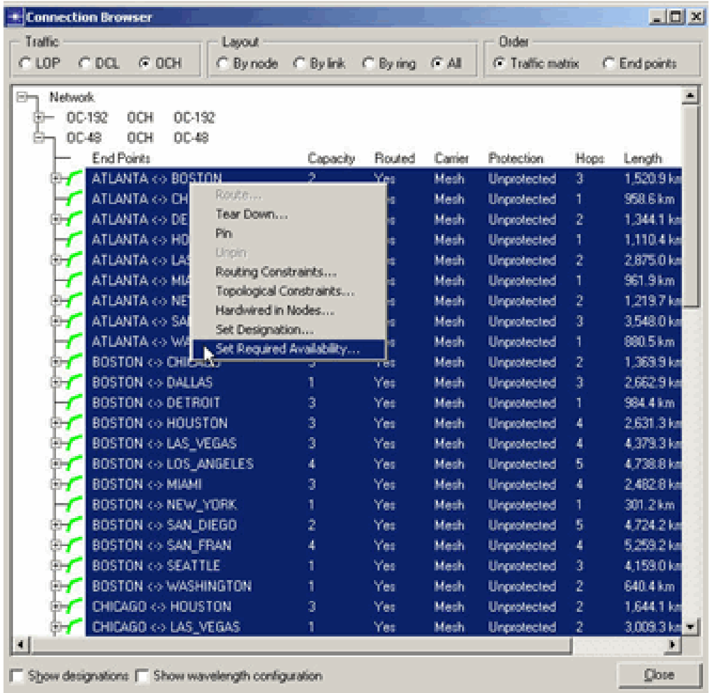
3 Set the required availability for the connections of the OC-48 traffic matrix.

3.1 Select **Network > Connection Browser**.

3.2 Select **OCH** ("Traffic), **All** ("Layout") and **Traffic Matrix** ("Order).

3.3 Expand the **OC-48** traffic matrix (using the "**+**" sign) to view all connections of this traffic matrix.

3.4 Select all connections of this traffic matrix and right-click on **Set Required Availability**.



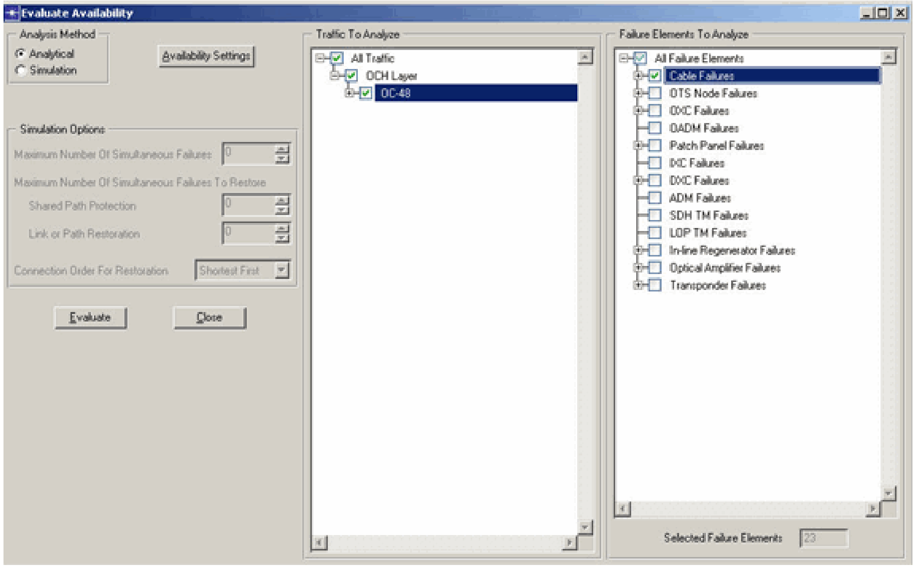
➥ The **Enter Required Availability** dialog box appears.

3.5 Fill in **0.99** as required availability. Click **OK** to set the required availability for each of the selected connections.

3.6 Close the **Connection Browser**.

4 Calculate the service availability (**USA_Unprotected** scenario).

4.1 Select **Info > Evaluate Availability** to calculate the availability of connections accommodated in the network.



4.2 Select **Analytical** as **Analysis Method**. For unprotected and 1+1 protected traffic this method gives exact results.

4.3 Expand **All Traffic** and **OCH Layer** (using the "**+**" sign) in the **Traffic To Analyze** section. Mark the **OC-48** traffic matrix. This implies that the availability algorithm calculates the availability for all routed connections of this traffic matrix.

4.4 Expand **All Failure Elements** (using the "**+**" sign) in the **Failure Elements To Analyze** section. All failure elements are displayed per failure type. Mark **Cable Failures**. This implies that only cable failures are taken into account to calculate the availability of the selected connections. Note that the number of selected failure elements amounts to **23** (as displayed in the lower right corner of the dialog box) because 23 physical links are present in the network.

4.5 Click **Evaluate** to calculate the service availability for the selected traffic taking into account the selected failure elements.

4.6 The **Availability Analysis** web report pops up. The first section of this report gives an overview of the analysis parameters set by the user. It shows that the analytical method was used and that only cable failures have been selected for this evaluation.

Analysis Settings

Analysis Method	Analytical	
Selected Failure Elements	Cable Failures	[SEATTLE <-> CHICAGO (1)]
		[SEATTLE <-> LAS_VEGAS (1)]
		[SEATTLE <-> SAN_FRAN (1)]
		[LAS_VEGAS <-> DALLAS (1)]
		[DALLAS <-> CHICAGO (1)]
		[DALLAS <-> ATLANTA (1)]
		[HOUSTON <-> ATLANTA (1)]
		[ATLANTA <-> MIAMI (1)]
		[HOUSTON <-> MIAMI (1)]
		[ATLANTA <-> WASHINGTON (1)]
		[DETROIT <-> WASHINGTON (1)]
		[CHICAGO <-> DETROIT (1)]
		[DETROIT <-> BOSTON (1)]
		[WASHINGTON <-> NEW_YORK (1)]
		[NEW_YORK <-> BOSTON (1)]
		[SAN_FRAN <-> LAS_VEGAS (1)]
		[HOUSTON <-> SAN_DIEGO (1)]
		[LOS_ANGELES <-> SAN_FRAN (1)]
		[LOS_ANGELES <-> LAS_VEGAS (1)]
		[SAN_DIEGO <-> LAS_VEGAS (1)]
		[LOS_ANGELES <-> SAN_DIEGO (1)]
		[DALLAS <-> HOUSTON (1)]
		[CHICAGO <-> ATLANTA (1)]

4.7 Select **OC-48** in the upper left corner of the report. The displayed section gives an overview of the availability of this traffic matrix. The first table ("**Summary**") shows the average availability and the expected loss of traffic for the entire traffic matrix. The average availability amounts to 0.988147 and the expected loss of traffic (ELT) amounts to 15,990.15 hours per year. The ELT is the total amount of traffic the network is expected to lose yearly due to the (cable) failures affecting the connections. The Average Expected Loss of Traffic represents the average ELT per connection.

OC-48

Summary

Average Availability	0.9881470179	
Expected Loss of Traffic	143,220,548.75	Gb/year
	15,990.15	OC-48 hours/year
Average Expected Loss of Traffic	930,003.56	Gb/year
	103.83	OC-48 hours/year

The second table ("**Connections meeting availability requirements**") gives an overview of the connections of which the calculated value for the availability is higher than or equal to their required availability. Per routed connection, the source and destination node are shown, as is the protection type, the minimal and maximal availability and the required availability. Note that because the calculation of the availability is exact, the values for the minimal availability and the maximal availability are identical for each connection.

Connections meeting availability requirements

Connection	From	To	Protection Type	Minimal Availability	Estimated Availability	Maximal Availability	Required Availability
[ATLANTA=BOSTON#0|OC-48]	ATLANTA	BOSTON	Unprotected	0.9930690520	-	0.9930690520	0.9900000000
[ATLANTA=BOSTON#1|OC-48]	ATLANTA	BOSTON	Unprotected	0.9930690520	-	0.9930690520	0.9900000000
[ATLANTA=CHICAGO#0|OC-48]	ATLANTA	CHICAGO	Unprotected	0.9956228904	-	0.9956228904	0.9900000000
[ATLANTA=CHICAGO#1|OC-48]	ATLANTA	CHICAGO	Unprotected	0.9956228904	-	0.9956228904	0.9900000000
[ATLANTA=CHICAGO#2|OC-48]	ATLANTA	CHICAGO	Unprotected	0.9956228904	-	0.9956228904	0.9900000000
[ATLANTA=DETROIT#0|OC-48]	ATLANTA	DETROIT	Unprotected	0.9938700759	-	0.9938700759	0.9900000000
[ATLANTA=DETROIT#1|OC-48]	ATLANTA	DETROIT	Unprotected	0.9938700759	-	0.9938700759	0.9900000000
[ATLANTA=DETROIT#2|OC-48]	ATLANTA	DETROIT	Unprotected	0.9938700759	-	0.9938700759	0.9900000000
[ATLANTA=HOUSTON#0|OC-48]	ATLANTA	HOUSTON	Unprotected	0.9949298630	-	0.9949298630	0.9900000000
[ATLANTA=HOUSTON#1|OC-48]	ATLANTA	HOUSTON	Unprotected	0.9949298630	-	0.9949298630	0.9900000000
[ATLANTA=HOUSTON#2|OC-48]	ATLANTA	HOUSTON	Unprotected	0.9949298630	-	0.9949298630	0.9900000000
[ATLANTA=MIAMI|OC-48]	ATLANTA	MIAMI	Unprotected	0.9956076256	-	0.9956076256	0.9900000000

The last table ("**Connections failing to meet availability requirements**") gives an overview of the connections of which the availability is lower than their required availability. Because the connections are deployed without protection, a lot of connections are failing to meet their availability requirement.

Connections failing to meet availability requirements

Connection	From	To	Protection Type	Minimal Availability	Estimated Availability	Maximal Availability	Required Availability
[ATLANTA=LAS_VEGAS#0|OC-48]	ATLANTA	LAS_VEGAS	Unprotected	0.9869135643	-	0.9869135643	0.9900000000
[ATLANTA=LAS_VEGAS#1|OC-48]	ATLANTA	LAS_VEGAS	Unprotected	0.9869135643	-	0.9869135643	0.9900000000
[ATLANTA=SAN_FRAN|OC-48]	ATLANTA	SAN_FRAN	Unprotected	0.9838807519	-	0.9838807519	0.9900000000
[BOSTON=DALLAS|OC-48]	BOSTON	DALLAS	Unprotected	0.9878854376	-	0.9878854376	0.9900000000
[BOSTON=HOUSTON#0|OC-48]	BOSTON	HOUSTON	Unprotected	0.9880340558	-	0.9880340558	0.9900000000
[BOSTON=HOUSTON#1|OC-48]	BOSTON	HOUSTON	Unprotected	0.9880340558	-	0.9880340558	0.9900000000
[BOSTON=HOUSTON#2|OC-48]	BOSTON	HOUSTON	Unprotected	0.9880340558	-	0.9880340558	0.9900000000
[BOSTON=LAS_VEGAS#0|OC-48]	BOSTON	LAS_VEGAS	Unprotected	0.9801430321	-	0.9801430321	0.9900000000
[BOSTON=LAS_VEGAS#1|OC-48]	BOSTON	LAS_VEGAS	Unprotected	0.9801430321	-	0.9801430321	0.9900000000
[BOSTON=LAS_VEGAS#2|OC-48]	BOSTON	LAS_VEGAS	Unprotected	0.9801430321	-	0.9801430321	0.9900000000
[BOSTON=LOS_ANGELES#0|OC-48]	BOSTON	LOS_ANGELES	Unprotected	0.9785340848	-	0.9785340848	0.9900000000
[BOSTON=LOS_ANGELES#1|OC-48]	BOSTON	LOS_ANGELES	Unprotected	0.9785340848	-	0.9785340848	0.9900000000
[BOSTON=LOS_ANGELES#2|OC-48]	BOSTON	LOS_ANGELES	Unprotected	0.9785340848	-	0.9785340848	0.9900000000
[BOSTON=LOS_ANGELES#3|OC-48]	BOSTON	LOS_ANGELES	Unprotected	0.9785340848	-	0.9785340848	0.9900000000
[BOSTON=MIAMI#0|OC-48]	BOSTON	MIAMI	Unprotected	0.9887071208	-	0.9887071208	0.9900000000

4.8 Close the **Availability Analysis Report** and the **Evaluate Availability** dialog box.

5 Switch to the **USA_Dedicated_Protected** scenario.

5.1 Select **Scenarios > Switch To Scenario > USA_Dedicated_Protected**. In this scenario, all traffic is routed using the 1+1 protection scheme. For each connection, both a working and dedicated protection path is reserved. The signal is simultaneously transmitted along both paths. Upon a failure on the working path, the destination selects the protection path. Note that the failure rates in this scenario are identical to those set in the **USA_Unprotected** scenario. Verify this in the **Network > Availability Settings** dialog box. Also, the required availability has been set to 0.99 for each connection of the traffic matrix OC-48. This can be verified by right-clicking on a connection in the **Network > Connection Browser** and selecting **Set Required Availability**.

6 Calculate the service availability (**USA_Dedicated_Protected** scenario).

6.1 Select **Info > Evaluate Availability.**

6.2 Select **Analytical** as **Analysis Method**.

6.3 Expand **All Traffic** and **OCH Layer** (using the "+" sign) in the **Traffic To Analyze** section. Mark the **OC-48** traffic matrix. This implies that all routed connections of this traffic matrix are selected for the availability calculation.

6.4 Expand **All Failure Elements** (using the "**+**" sign) in the **Failure Elements To Analyze** section. All failure elements are displayed per failure type. Mark **Cable Failures**.

6.5 Click **Evaluate** to calculate the service availability for the selected traffic taking into account the selected failure elements.

6.6 The **Availability Analysis** web report pops up.

6.7 Select **OC-48** in the upper left corner of the report. The **Summary** table shows that the average availability for this traffic matrix amounts to 0.999776 and the expected loss of traffic (ELT) amounts to 302.36 hours per year. Note that this latter value is much lower than for traffic accommodated without protection. So, due to using the 1+1 protection scheme, the achieved service availability is substantially higher. Also, all connections are now meeting their required availability.

OC-48

Summary

Average Availability	0.9997758715	
Expected Loss of Traffic	2,708,163.19	Gb/year
	302.36	OC-48 hours/year
Average Expected Loss of Traffic	17,585.48	Gb/year
	1.96	OC-48 hours/year

6.8 Close the **Availability Analysis Report** and the **Evaluate Availability** dialog box.

7 Switch to the **USA_Shared_path** scenario.

7.1 Select **Scenarios > Switch To Scenario > USA_Shared_path**. In this scenario, the routing of working and protecting path is similar to dedicated protection, but the protection path is only activated upon a failure. This allows sharing protection resources between connections that are not considered to fail simultaneously. Note that the equipment failure rates and the required availabilities for the OC-48 connections are identical to those set in the **USA_Unprotected** scenario.

8 Calculate the service availability (**USA_Shared_path** scenario).

8.1 Select **Info > Evaluate Availability**.

8.2 Select **Simulation** as **Analysis Method**. The simulation method simulates different failure scenarios and inspects the impact of the failures on the traffic accommodated in the network. This method results in more precise values for the availability, if shared path protection or restoration is deployed in the network. The analytical method, on the other hand, does not take into account those protection schemes. It treats traffic with shared path protection or restoration as unprotected traffic. This results in a sub-border for the availability.

8.3 Expand **All Traffic** and **OCH Layer** (using the "**+**" sign) in the **Traffic To Analyze** section. Mark the **OC-48** traffic matrix.

8.4 Expand **All Failure Elements** (using the "**+**" sign) in the **Failure Elements To Analyze** section. Mark **Cable Failures**.

8.5 For the simulation method, some extra parameters are needed because the availability is calculated by simulating different failure scenarios. Therefore, you must specify to which level of detail you want to simulate the failures.

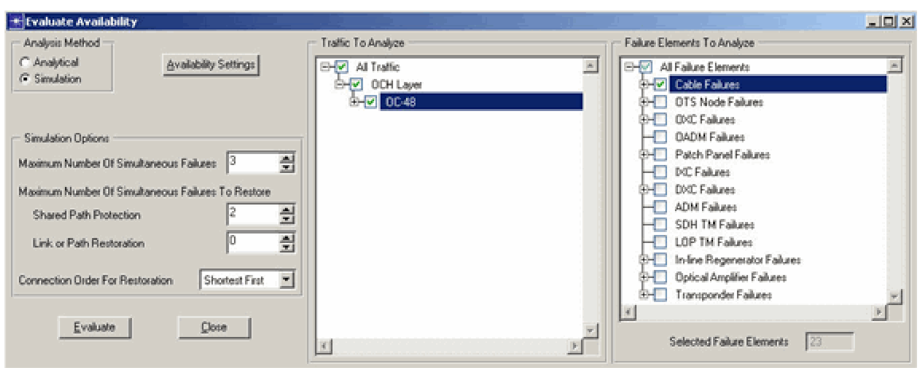
8.6 Select **3** as **Maximum Number Of Simultaneous Failures**. This implies that only failure scenarios with less than 4 simultaneous failures are simulated to calculate the service availability. Thus, scenarios with 4 to 23 failures are neglected. This saves calculation time, but it also implies that the calculated value for the service availability will be less exact. However, due to the fact that the probability of those neglected higher-order failure scenarios is rather low, this estimation is justified.

8.7 Select **2** as **Maximum Number Of Simultaneous Failures To Restore** for **Shared Path Protection**. This implies that in failure scenarios with less than 3 failures, the shared path protection scheme is applied to try to restore the connections. However, in scenarios with 3 simultaneous failures, shared path protection is not used. In those scenarios, the routed connections are treated as unprotected connections. This saves calculation time, but results in a less exact value for the availability.

8.8 Select **0** as **Maximum Number Of Simultaneous Failures To Restore** for **Link or Path Restoration**. This parameter limits the failure scenarios in which the link or path protection scheme is applied (analogously to the previous parameter for shared path protection). As no selected connections are accommodated in the network with link or path restoration, this parameter is not important for this simulation.

8.9 Select **Shortest First** as **Connection Order For Restoration**.

8.10 Click **Evaluate** to calculate the service availability for the selected traffic taking into account the selected failure elements. Note that the simulation method is more time-consuming than the analytical method.



8.11 After the calculation has finished, the **Availability Analysis** web report pops up. Note that now also the simulation options are displayed in the **Analysis Settings** section.

8.12 Select **OC-48** in the upper left corner of the report. The **Summary** table shows that the average availability for this traffic matrix amounts to 0.99971 and the expected loss of traffic (ELT) amounts to 395.21 hours per year. Note that both values are now approximate values, because the simulation method was chosen. The average availability for shared path protection is lower than for 1+1 protected routing. Due to sharing protection resources, particular higher-order failure scenarios affect more connections in the shared mode as opposed to connections in the dedicated protection mode.

OC-48

Summary

Average Availability	0.9997070470	
Expected Loss of Traffic	3,539,774.82	Gb/year
	395.21	OC-48 hours/year
Average Expected Loss of Traffic	22,985.55	Gb/year
	2.57	OC-48 hours/year

8.13 Close the **Availability Analysis Report** and the **Evaluate Availability** dialog box.

9 Switch to the **USA_Path_Restoration** scenario.

9.1 Select **Scenarios > Switch To Scenario > USA_Path_Restoration**. In this scenario, traffic is routed along a working path and the protection resources are again shared between disjoint working paths. The main difference with shared path protection is that the recovery path is not fixed, but depends on the failing network elements. The restoration algorithm reserves sufficient protection resources to meet the design criterion, here being able to restore all traffic in case a single link fails. Note that the equipment failure rates and the required availabilities for the OC-48 connections are identical to those set in the **USA_Unprotected** scenario.

10 Calculate the service availability (**USA_Path_Restoration** scenario).

10.1 Select **Info > Evaluate Availability**.

10.2 Select **Simulation** as **Analysis Method**.

10.3 Expand **All Traffic** and **OCH Layer** (using the "**+**" sign) in the **Traffic To Analyze** section. Mark the **OC-48** traffic matrix.

10.4 Expand **All Failure Elements** (using the "**+**" sign) in the **Failure Elements To Analyze** section. Mark **Cable Failures**.

10.5 Select **3** as **Maximum Number Of Simultaneous Failures**.

10.6 Select **0** as **Maximum Number Of Simultaneous Failures To Restore for Shared Path Protection**. As no selected connections are accommodated in the network with shared path protection, this parameter is not important for this simulation.

10.7 Select **2** as **Maximum Number Of Simultaneous Failures To Restore for Link or Path Restoration**. This implies that in failure scenarios with less than 3 failures, the link or path restoration scheme is considered to restore the connections. However, in scenarios with 3 simultaneous failures, link or path restoration is not used. In those scenarios, the routed connections are treated as unprotected connections.

10.8 Select **Shortest First as Connection Order For Restoration**.

10.9 Click **Evaluate** to calculate the service availability for the selected traffic taking into account the selected failure elements.

➥ After the calculation has finished, the **Availability Analysis** web report pops up.

10.10 Select **OC-48** (in the upper left corner of the report). The **Summary** table shows that average availability for this traffic matrix amounts to 0.99961 and the expected loss of traffic (ELT) amounts to 514.34 hours per year. This (approximate) value for the ELT is higher than for shared path protection.

OC-48

Summary

Average Availability	0.9996187391	
Expected Loss of Traffic	4,606,806.05	Gb/year
	514.34	OC-48 hours/year
Average Expected Loss of Traffic	29,914.32	Gb/year
	3.34	OC-48 hours/year

Comparing the results for the different protection schemes, it appears that the 1+1 protection scheme leads to the lowest expected loss of traffic and to highest service availability for the selected traffic matrix OC-48. This is not always the case. Which protection scheme leads to the highest service availability for a certain traffic matrix depends on the network topology, the traffic matrix itself, and the selected failure elements and their failure rates.

10.11 Close the **Availability Analysis Report** and the **Evaluate Availability** dialog box.

11 Close the project

11.1 Select **File > Close**.

11.2 Select **Don't Save** in the **Close Confirm** dialog box.

End of Procedure 4-2