2008

WAN/LAN Planning and Design

Getting to know OPNET Transport Planner

This Project has the main goal of making graduate students to learn about OPNET Transport Planner in a general sense from the designing standpoint. The strategy used to go about this was to create a simple scenario in which to practice and use as many attributes as possible from the OPNET Transport Planner suit.

Franklin Perez Coste
Rochester Institute of Technology
4/24/2008

Setting up the Scenario

For this Project, the idea is to get acquainted with a new designing tool: OPNET Transport Planner. Like with any new software, it is always best to start simple in order to understand the different options and have better control of the outcomes. My idea for this was to design a Core and Distribution Layer for a starting Internet Service Provider that would launch a new service with some capabilities that would allow the use of splitters between the Core and Distribution: The use of different wavelengths for different Distribution Centers. Here's the reason: It is much easier to combine traffic at splitters when they come at different wavelengths because that means no "collisions".

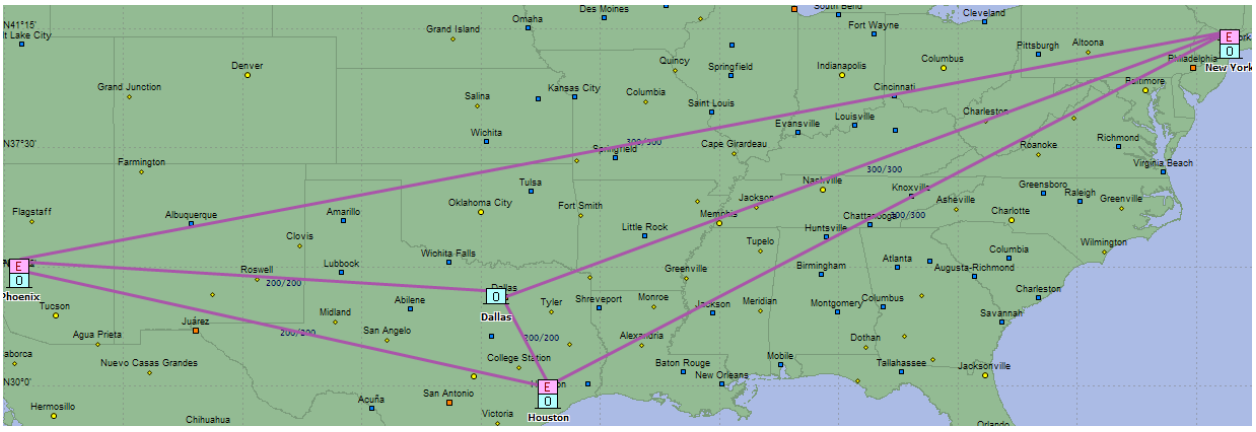
I worked with three scenarios, the first being a Core network with only four nodes which allowed me to play around with the tool and understand how everything works. The second and third scenarios deal with the Distribution Layer and in here I could apply some concepts and play with some more sophisticated components for my design.

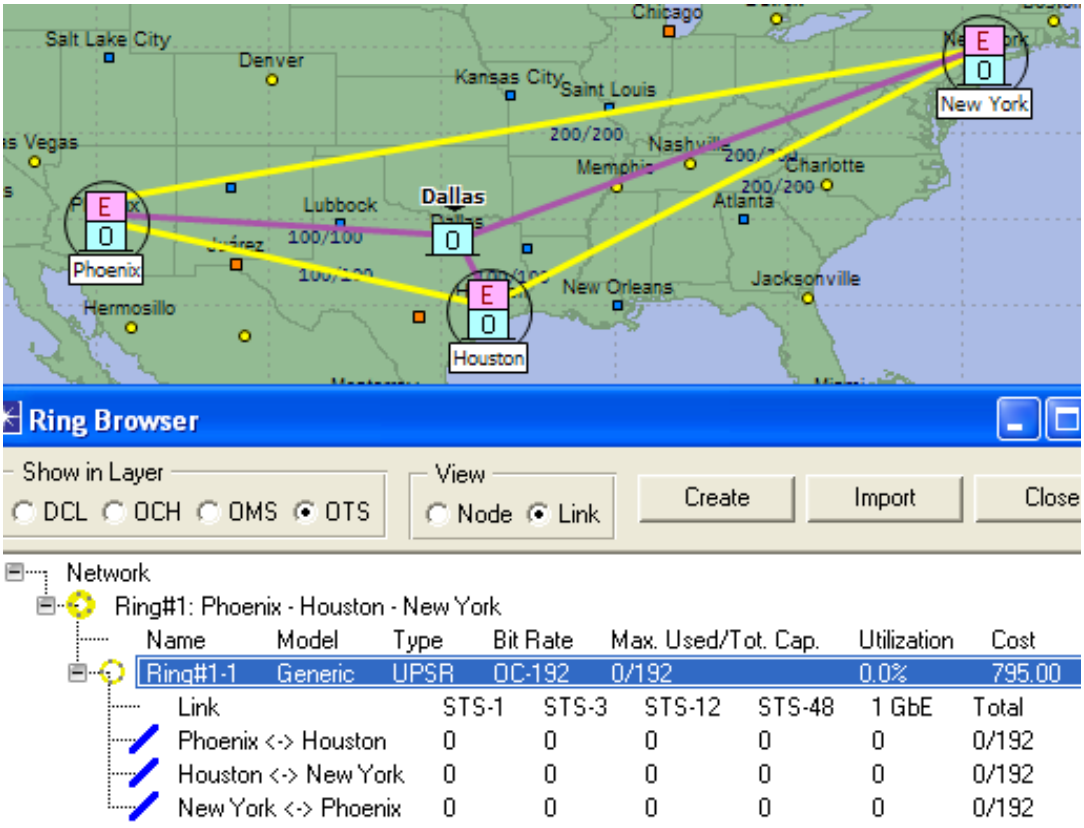
Now that I have introduced what I'm trying to do here and my general strategy, I would like to share with the reader some of my findings during the project. I will start with my scenario set-up, and quickly move on to how OPNET Transport Planner helped me as a designer get a perfect solution.

A starting Internet Service Provider is deploying a nation-wide network that is targeting some of the major cities in the United States launching a new service that only this ISP can provide to large corporations. They would like to design a network that will cover their Core and Distribution Layers that are robust and efficient. The Cost of the network should be moderate and the network itself should be scalable.

As a network designer, I chose to work with OPNET Transport Planner because it offers a very easy way to create and manage scenarios with different characteristics

and compare them according to different criteria. Let's have a look at our first topology: The Core Network.



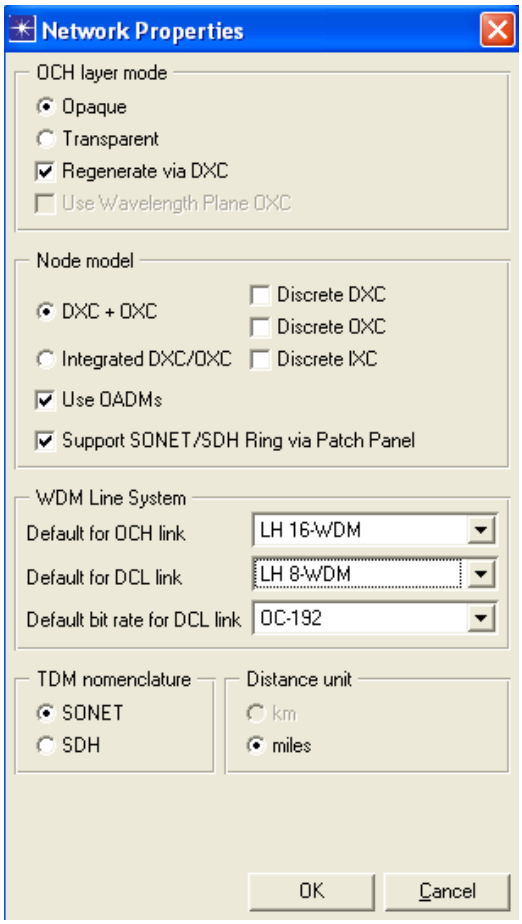


This Core network consists of three main nodes located at Phoenix, Houston and New York connected by direct links, as well as a central optical distribution device that will come handy in the deployment of our Distribution Network and serves as an excellent alternative path between the main sites in case of failure. There is a ring

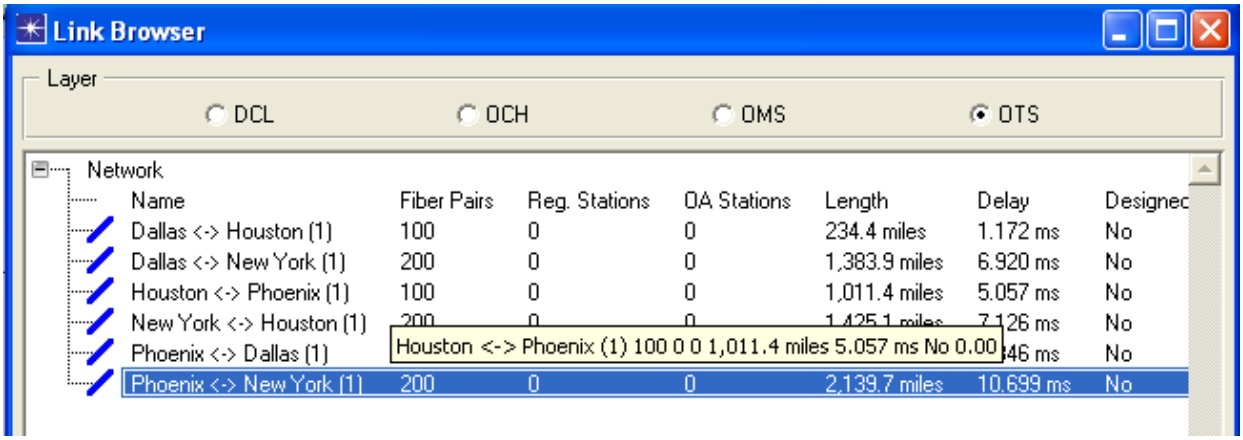
topology designed for the Core Network and with this added Optical star topology on top of it, we can technically loose up to two links to one of the main cities or all three links of the ring at once and the service will not be affected.

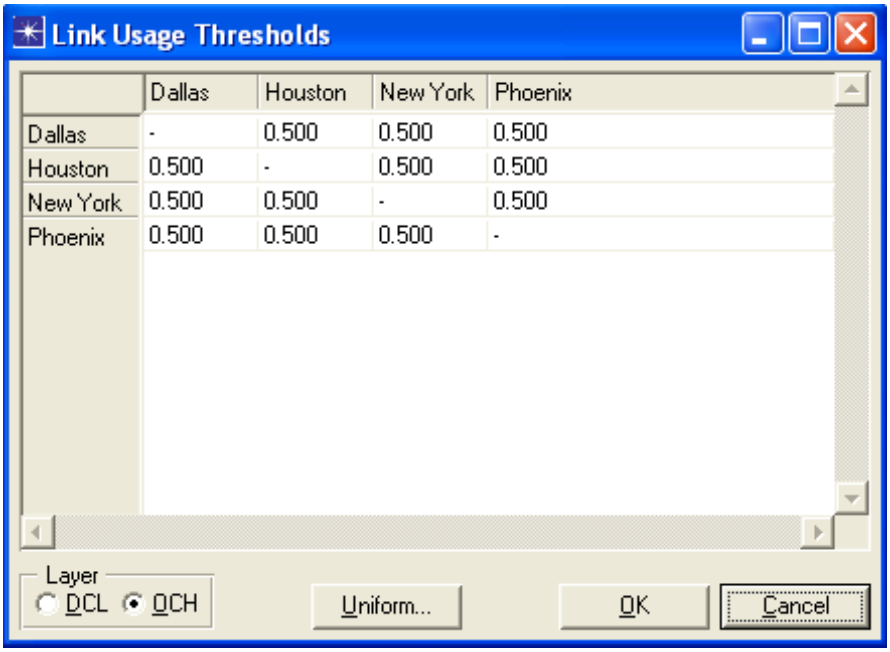
The first thing to do after setting up the nodes and connecting them is to set up the network properties. In here we can decide how our general Wave Division Multiplexing system will be configured and some other general properties such as the use of Optical Add and Drop Multiplexers, whether we are using SONET or SDH, kilometers or miles and the mode in which we would like our OCH layer to work (this layer has to do with the wavelengths in our system).

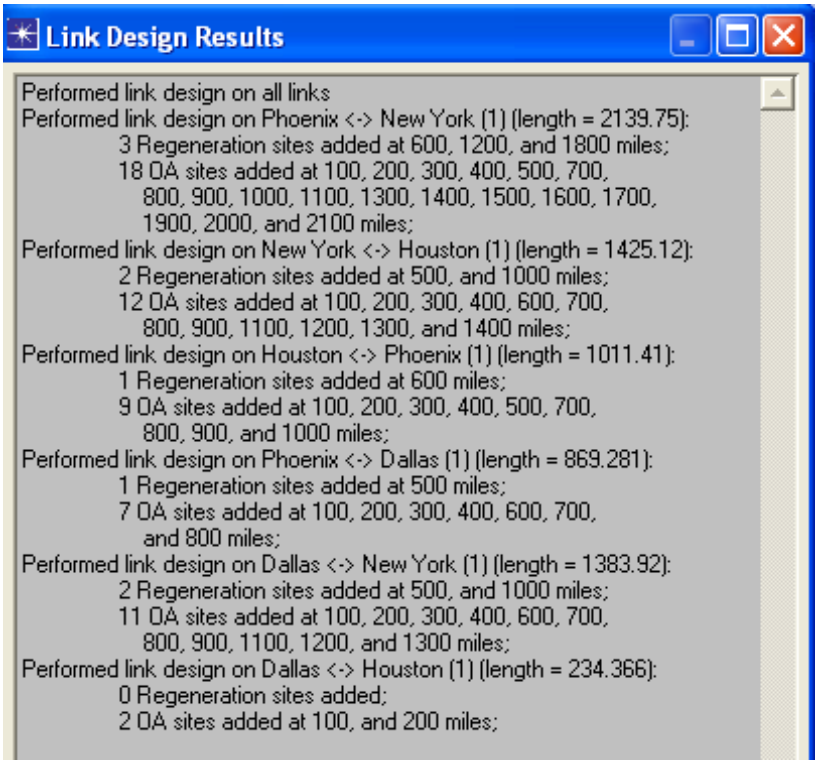
In the graph below we can appreciate the box that comes out prompting about the network properties we have just discussed and the option that I selected for this project.



Next we take a look at the design properties of our links. We need to set up the links and decide how many fiber pairs we need on each link. We can use the Link Browser to inspect the different layers of our design and change some link properties such as how many fiber pairs we have on each link in the OTS level. We can also define the link usage threshold to 50%, in order to comply with the most general rule about link utilization. Finally, we design the links to all this requirements and obtain a detailed box where OPNET shows how many Regenerators and Optical Amplifiers will be needed to cover the distance with fiber optic from point-to-point. The three graphs below show the process of setting up the properties of the links.



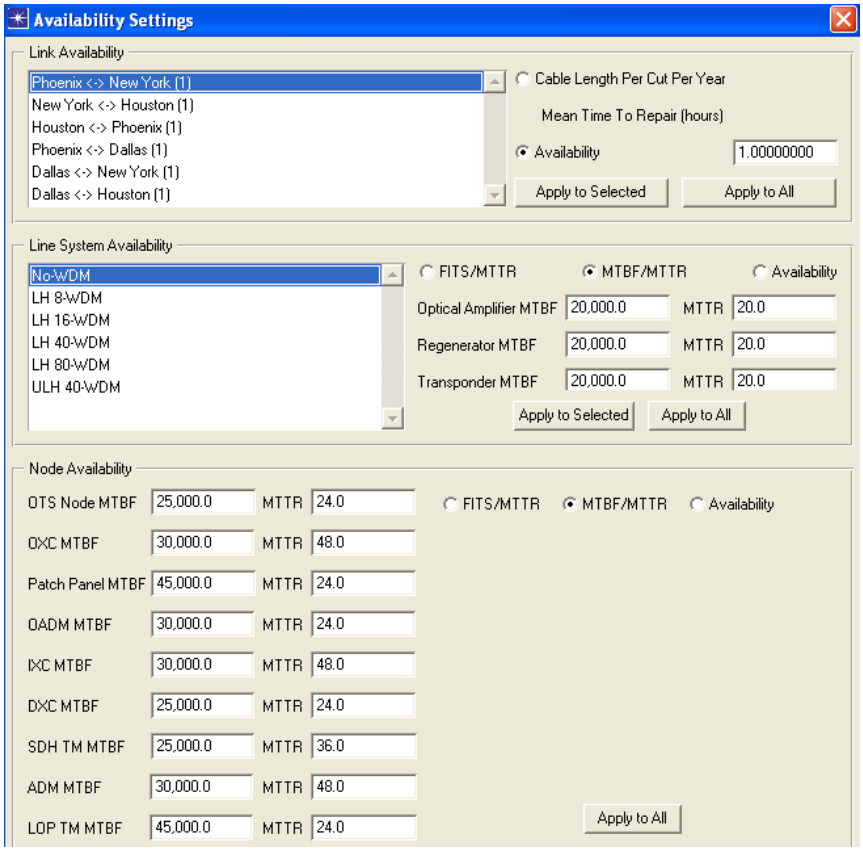


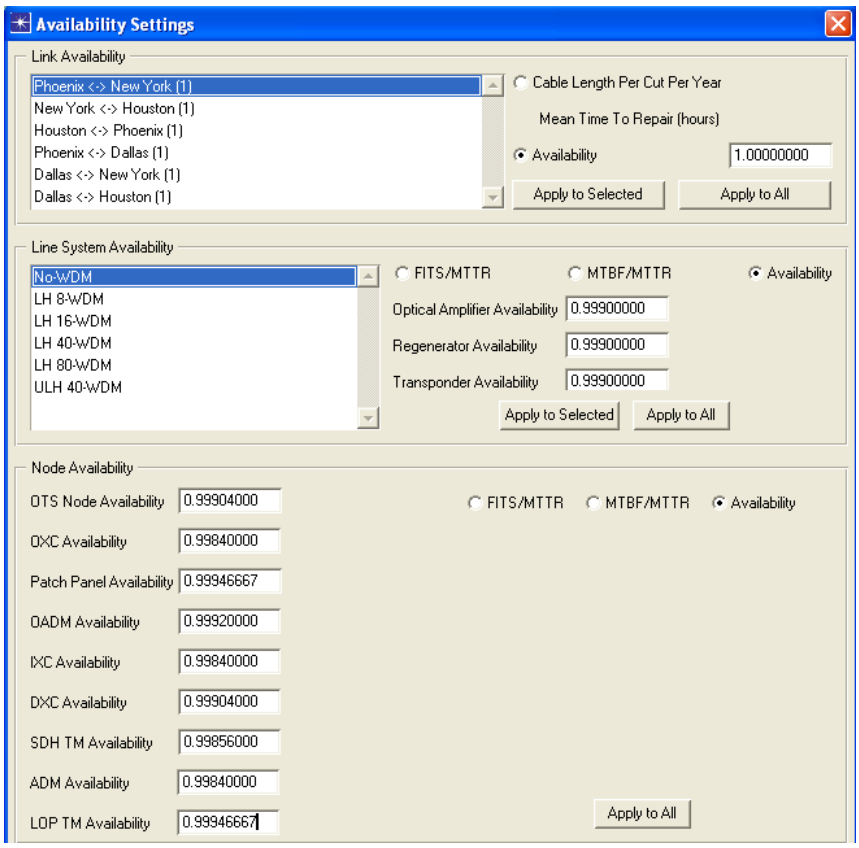


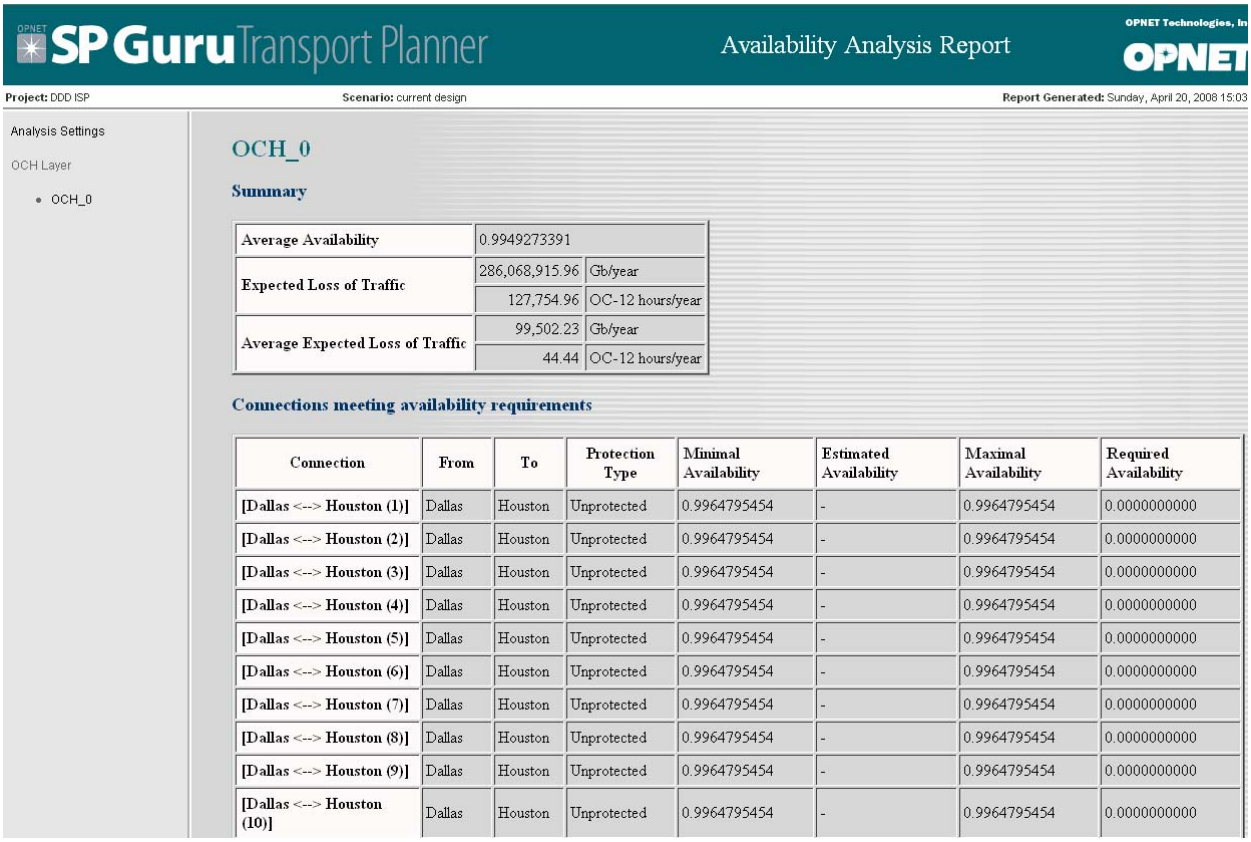
We can also set up the availability of our network either by fixing a value or manipulating the Mean Time to Repair (MTTR) and the Mean Time Between Failures (MTBF), as shown in the graphs below. This will help the designer plan the MTTR and MTBF according to the organization's guidelines or requirements, and thus be able to recommend some values for it.

Reports about availability can be created on a web format, as well as many other reports regarding failure analysis and routing. These reports are self explanatory and we only provide one example in this document given the large amount of space that each screenshot takes.

In this report, a summary of the overall availability and the expected loss of traffic are displayed at the top. After this, a detailed analysis appears broken down to the specific links themselves.


Availability Settings
Link Availability
Phoenix <-> New York (1)
New York <-> Houston (1)
Houston <-> Phoenix (1)
Phoenix <-> Dallas (1)
Dallas <-> New York (1)
Dallas <-> Houston (1)
Cable Length Per Cut Per Year
Mean Time To Repair (hours)
Availability
1.00000000
Apply to Selected
Apply to All
Line System Availability
No-WDM
LH 8-WDM
LH 16-WDM
LH 40-WDM
LH 80-WDM
ULH 40-WDM
FITS/MTTR
MTBF/MTTR
Availability
Optical Amplifier MTBF
20,000.0
MTTR
20.0
Regenerator MTBF
20,000.0
MTTR
20.0
Transponder MTBF
20,000.0
MTTR
20.0
Apply to Selected
Apply to All
Node Availability
OTS Node MTBF
25,000.0
MTTR
24.0
FITS/MTTR
MTBF/MTTR
Availability
OXC MTBF
30,000.0
MTTR
48.0
Patch Panel MTBF
45,000.0
MTTR
24.0
OADM MTBF
30,000.0
MTTR
24.0
IXC MTBF
30,000.0
MTTR
48.0
DXC MTBF
25,000.0
MTTR
24.0
SDH TM MTBF
25,000.0
MTTR
36.0
ADM MTBF
30,000.0
MTTR
48.0
LOP TM MTBF
45,000.0
MTTR
24.0
Apply to All


Availability Settings
Link Availability
Phoenix <-> New York (1)
New York <-> Houston (1)
Houston <-> Phoenix (1)
Phoenix <-> Dallas (1)
Dallas <-> New York (1)
Dallas <-> Houston (1)
Cable Length Per Cut Per Year
Mean Time To Repair (hours)
Availability
1.00000000
Apply to Selected
Apply to All
Line System Availability
No-WDM
LH 8-WDM
LH 16-WDM
LH 40-WDM
LH 80-WDM
ULH 40-WDM
FITS/MTTR
MTBF/MTTR
Availability
Optical Amplifier Availability
0.99900000
Regenerator Availability
0.99900000
Transponder Availability
0.99900000
Apply to Selected
Apply to All
Node Availability
OTS Node Availability
0.99904000
FITS/MTTR
MTBF/MTTR
Availability
OXC Availability
0.99840000
Patch Panel Availability
0.99946667
OADM Availability
0.99920000
IXC Availability
0.99840000
DXC Availability
0.99904000
SDH TM Availability
0.99856000
ADM Availability
0.99840000
LOP TM Availability
0.99946667
Apply to All



SP Guru Transport Planner — Availability Analysis Report — OPNET Technologies, In

Project: DDD ISP | Scenario: current design | Report Generated: Sunday, April 20, 2008 15:03

Analysis Settings

OCH Layer

- OCH_0

OCH_0

Summary

Average Availability	0.9949273391	
Expected Loss of Traffic	286,068,915.96	Gb/year
	127,754.96	OC-12 hours/year
Average Expected Loss of Traffic	99,502.23	Gb/year
	44.44	OC-12 hours/year

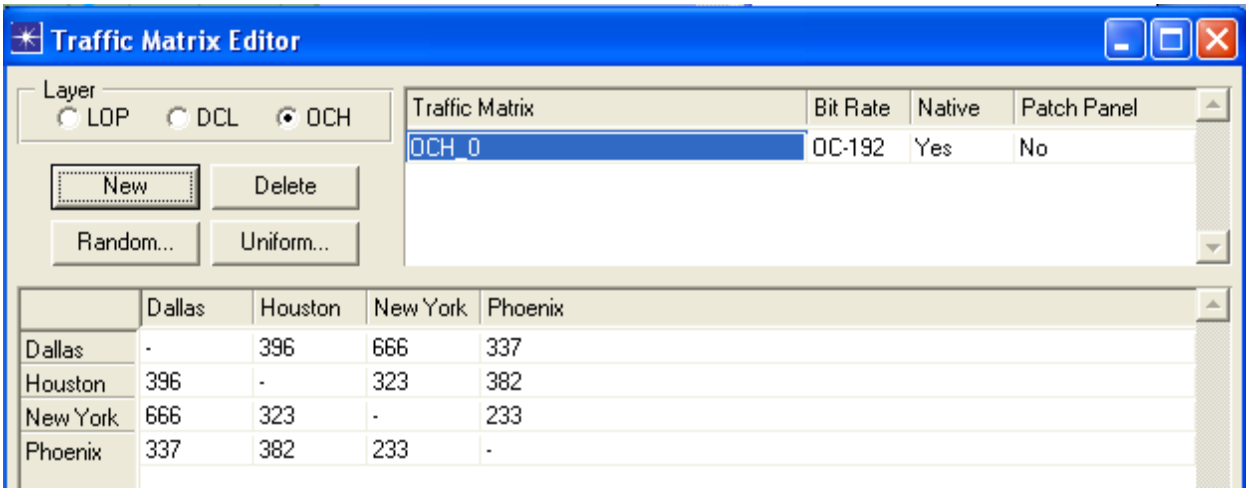
Connections meeting availability requirements

Connection	From	To	Protection Type	Minimal Availability	Estimated Availability	Maximal Availability	Required Availability
[Dallas <--> Houston (1)]	Dallas	Houston	Unprotected	0.9964795454	-	0.9964795454	0.0000000000
[Dallas <--> Houston (2)]	Dallas	Houston	Unprotected	0.9964795454	-	0.9964795454	0.0000000000
[Dallas <--> Houston (3)]	Dallas	Houston	Unprotected	0.9964795454	-	0.9964795454	0.0000000000
[Dallas <--> Houston (4)]	Dallas	Houston	Unprotected	0.9964795454	-	0.9964795454	0.0000000000
[Dallas <--> Houston (5)]	Dallas	Houston	Unprotected	0.9964795454	-	0.9964795454	0.0000000000
[Dallas <--> Houston (6)]	Dallas	Houston	Unprotected	0.9964795454	-	0.9964795454	0.0000000000
[Dallas <--> Houston (7)]	Dallas	Houston	Unprotected	0.9964795454	-	0.9964795454	0.0000000000
[Dallas <--> Houston (8)]	Dallas	Houston	Unprotected	0.9964795454	-	0.9964795454	0.0000000000
[Dallas <--> Houston (9)]	Dallas	Houston	Unprotected	0.9964795454	-	0.9964795454	0.0000000000
[Dallas <--> Houston (10)]	Dallas	Houston	Unprotected	0.9964795454	-	0.9964795454	0.0000000000

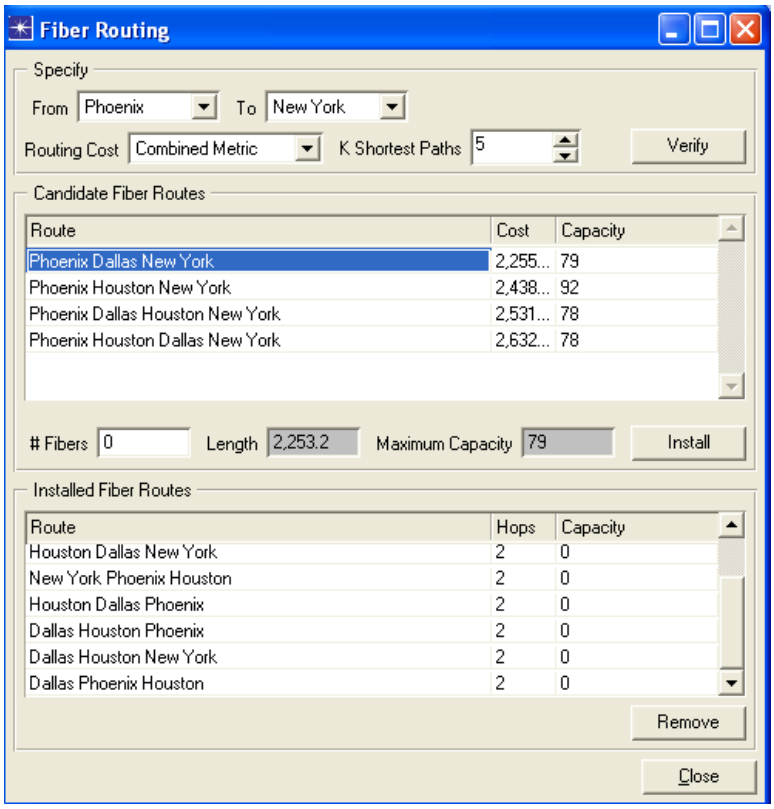
Another special tool of OPNET Transport Planner that we can easily take advantage of and has proven to be very useful in my designs is the Traffic Matrix. Whether we decide to do it randomly or manually, this tool offers a unique way of loading up the network with traffic in the Electrical environment (DCL Layer), and Optical Realm (OCH Layer).

In the graph below, we see an example of the Traffic Matrix, where the different links or cities are listed and we can decide what amount of traffic should the design tool allocate to each and every one of them.

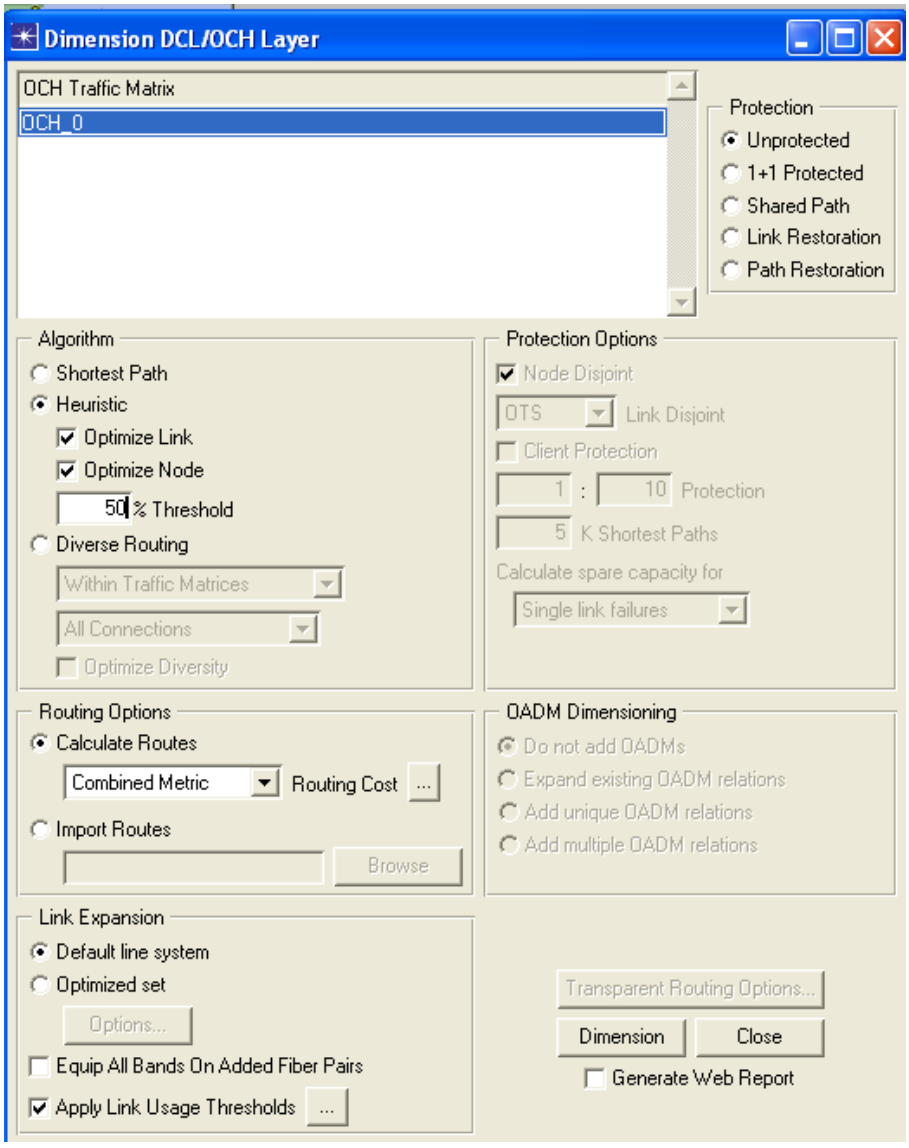
Keep in mind that the DCL and OCH Layers need to be attuned in the sense that the DCL or electrical traffic must be less than or equal to the capacity of the links in the OCH Layer (Optical Layer) for all the traffic in the electrical environment must be routed through the Optical Layer.

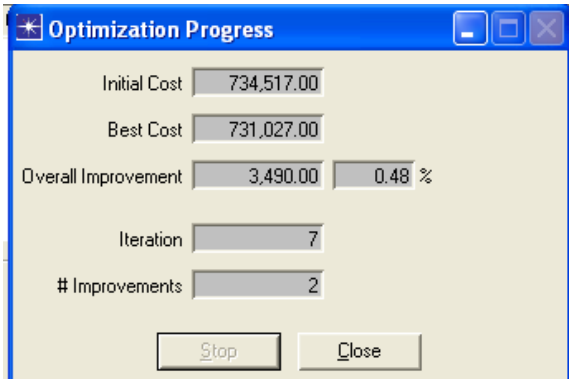


Next, we can decide how the traffic is routed through the fiber network by selecting paths to reach every destination. With this tool, we can verify all the paths that are available for a specific destination from the destination we have selected and choose the metrics under which to evaluate the paths. We then can select the best path according to the metrics that we have chosen. In the graph below we see the interface to do this process.



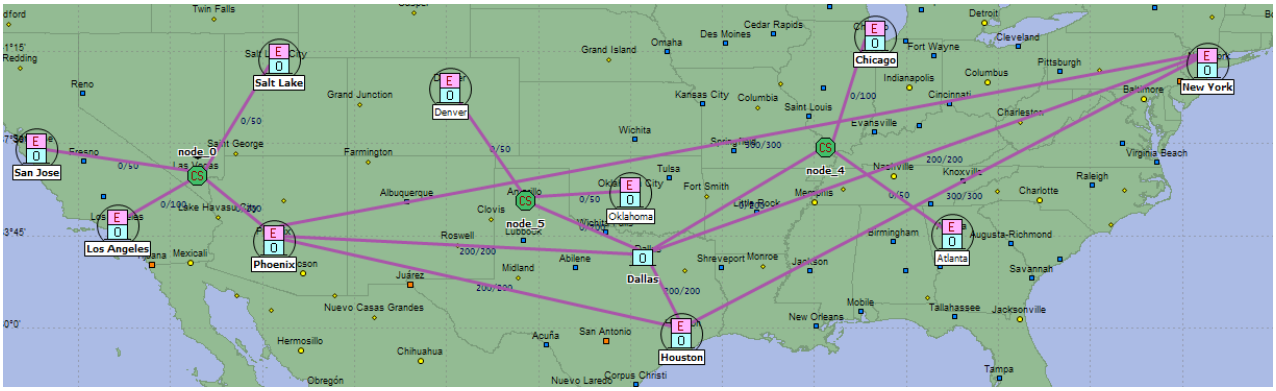
Another set of properties that we can use in the OPNET tool is the optimization and dimensioning capabilities that help us optimize our design and better dimension it at the DCL Layer, which translates into an improvement to the overall cost of the network we are designing. In the graph below we see the choices we can make towards protection and the optimization algorithm that we want the program to follow. The routing is also taken care here by evaluating paths according to the metric used (in this case a Combined Metric).





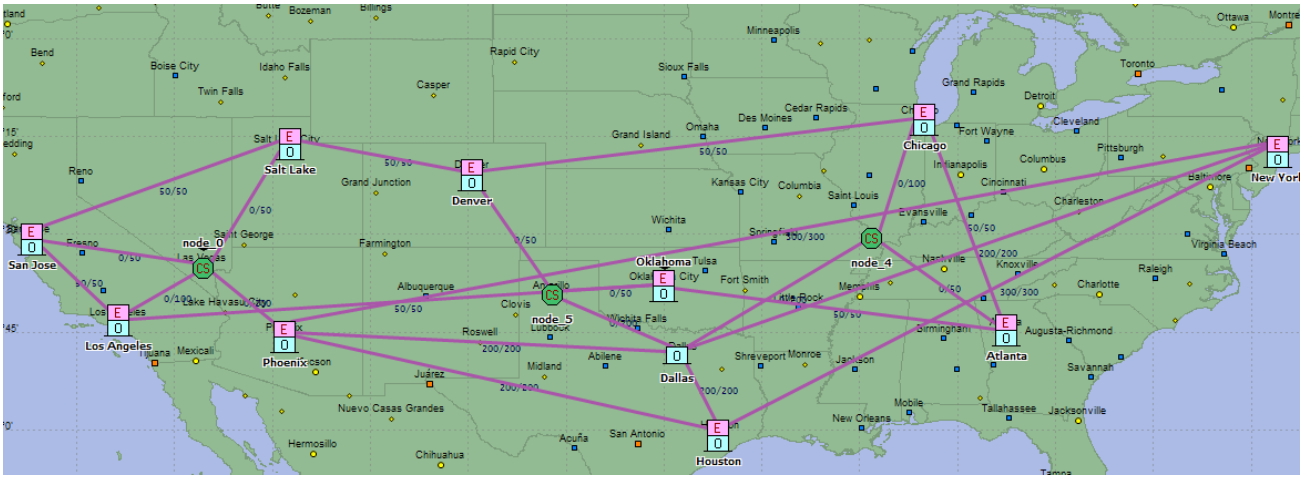
Well, after all this, we can say that we have used quite a handful of options and tools within the program that allows us to effectively design a scenario. Now we can move on too the analysis of our other two scenarios and finally use the comparison tool to see how we did.

Our second scenario basically consists on the implementation of our distribution network. We split the fiber links between the main points at the Core Layer to all the Distribution Layer Equipment. For example: Phoenix will serve directly Salt Lake City, San Jose and Los Angeles by the means of a splitter that will take the signal coming from Phoenix and equally divide it between the different cities. The same processes were performed to this design in order to dimension it and equip it with the right network properties, capabilities, WDM, availability settings, etc. But we won't go through all that because we already have done so with our Core Network scenario.



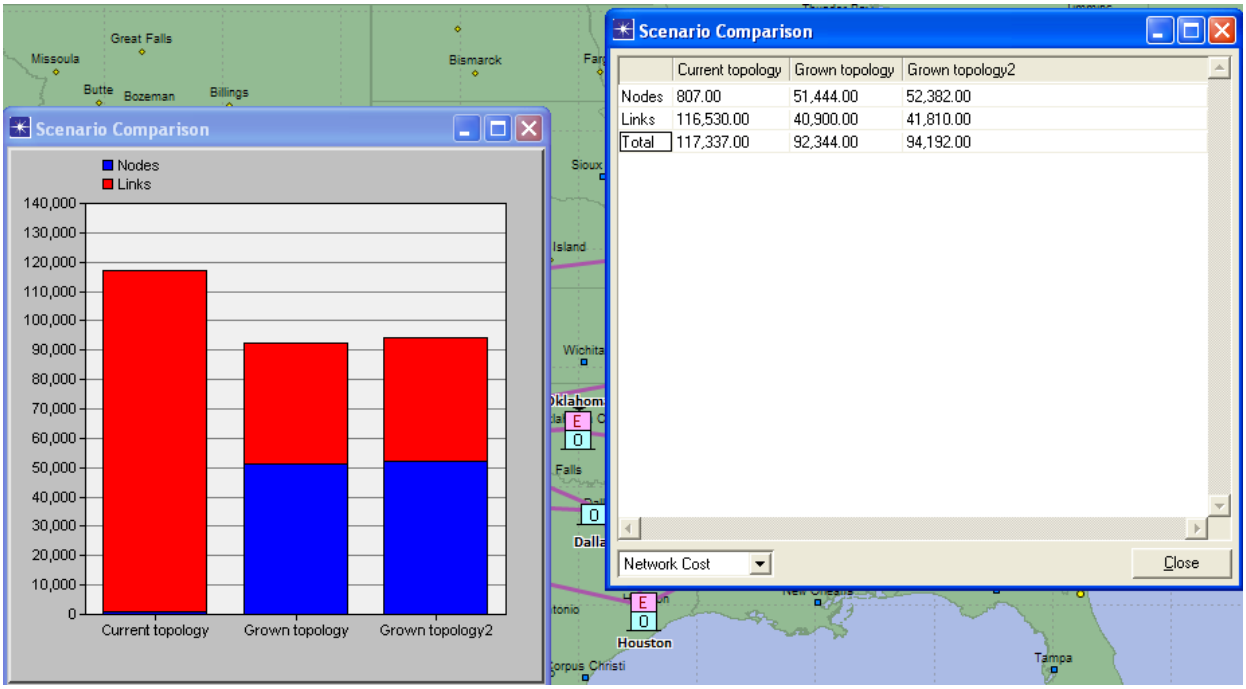
The last scenario is basically the same as the Distribution Layer Scenario, but with an added ring to the topology. This ring will connect all the distribution

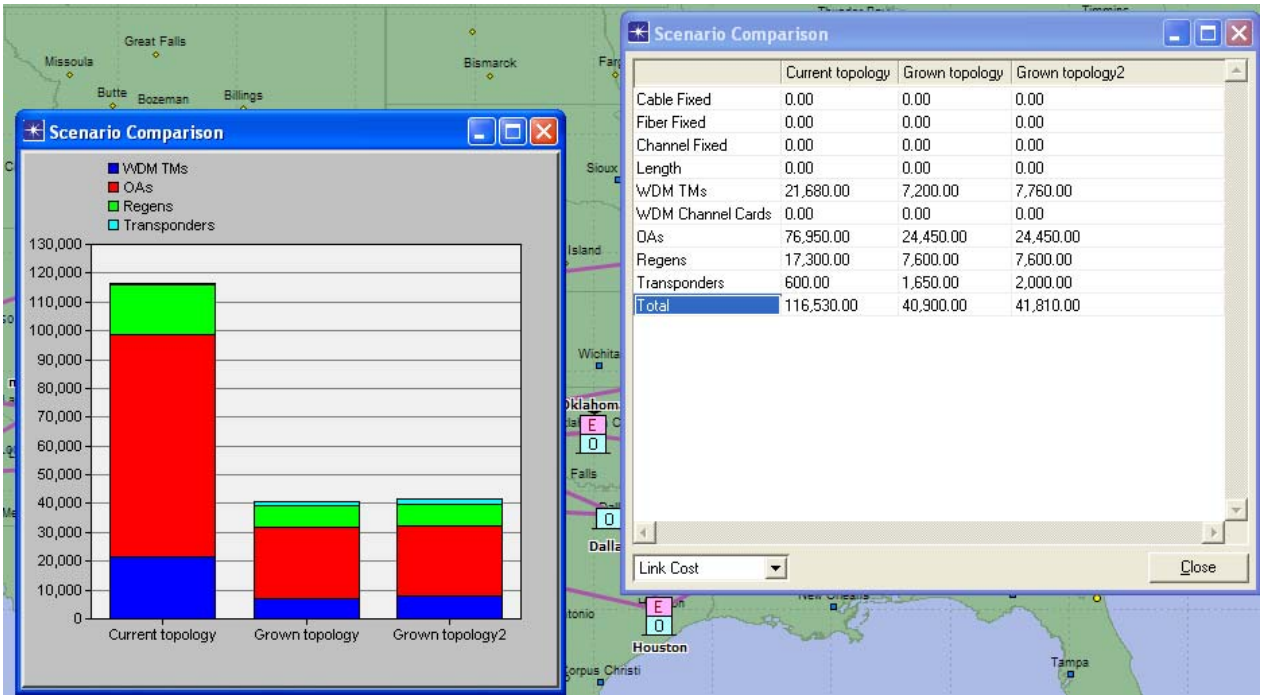
components in the network, providing more efficiency and connectivity throughout the design. One thing that we should mention here is that the Core network is not designed to serve customers. In the real world, we would probably have distribution layer equipment in the cities were the Core network is deployed, but for the sake of simplicity we have decided to leave that out of the picture. Below is the final scenario containing two rings.

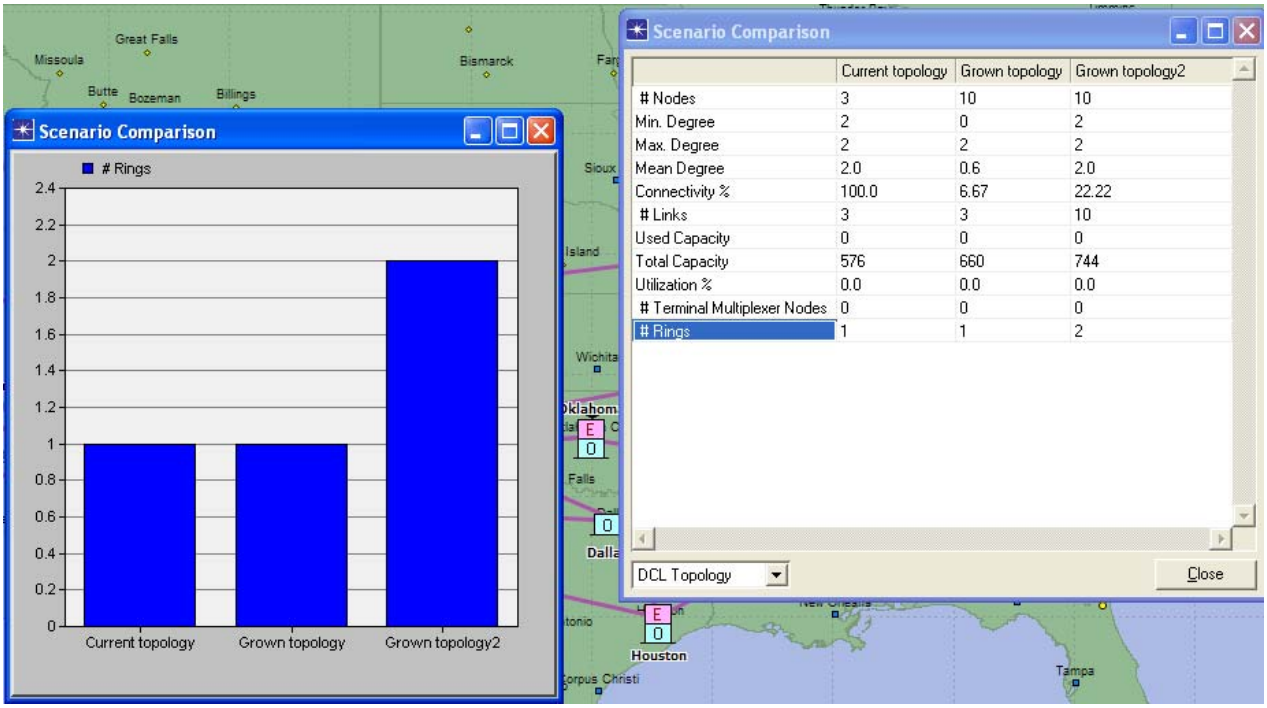


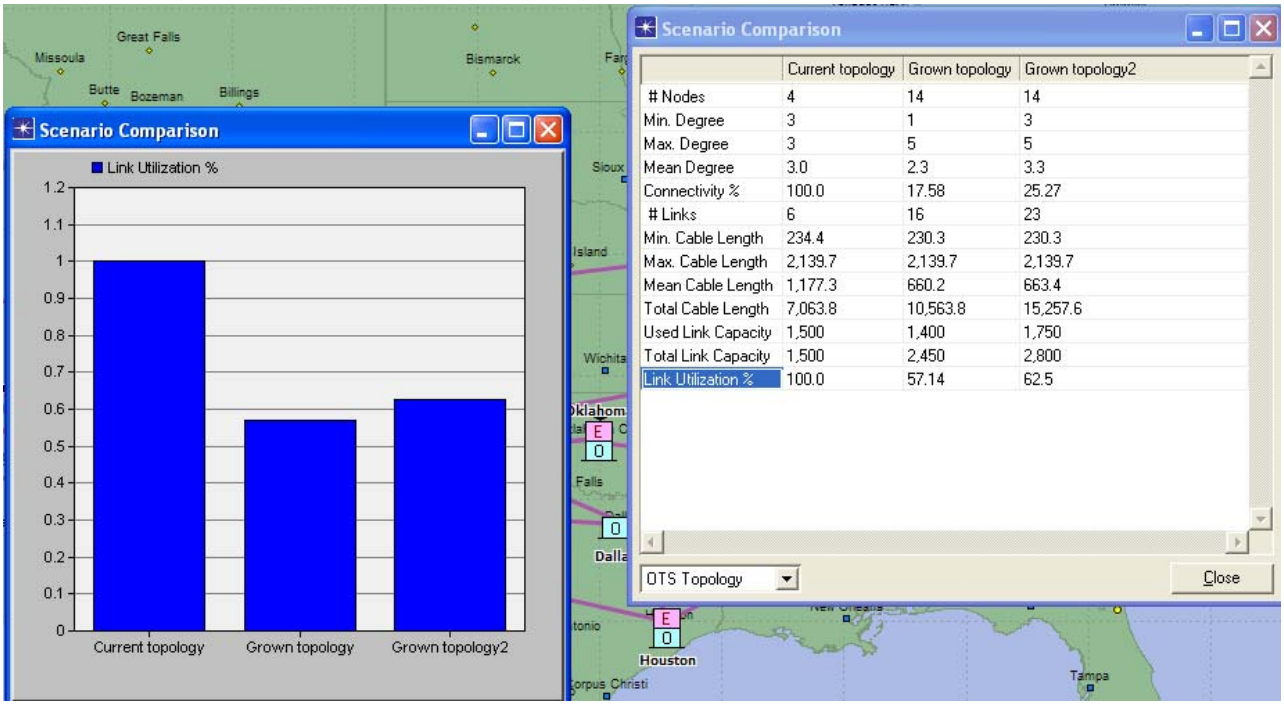
Finally, we get to compare these scenarios using the "Compare Scenario" tool from the OPNET Transport Planner. This allows us to evaluate the three scenarios from the point of view of cost, connectivity, links utilization on the different layers and more. Let's see what the results were when we used the compare scenarios function.

I won't go in depth into each and every category of the comparing function because our objective has only been to get to know the tool and use it in a hypothetical project created by ourselves in order to explore what the OPNET can do. I will say that OPNET Transport Planner is a great tool that allows a designer to have great power over the outcome and it is a great first step to go through when designing any kind of Optical Network. I did learn a lot from this experience and I will continue to learn as my Graduate Final Project will most likely have some elements of this and other Optical Systems Simulators and Programs.


Scenario Comparison
Nodes
Links
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Current topology
Grown topology
Grown topology2
Scenario Comparison
Current topology
Grown topology
Grown topology2
Nodes 807.00 51,444.00 52,382.00
Links 116,530.00 40,900.00 41,810.00
Total 117,337.00 92,344.00 94,192.00
Network Cost
Close
Great Falls
Missoula
Butte
Bozeman
Billings
Bismarck
Sioux
Island
Wichita
Falls
Houston
Tampa


Scenario Comparison
WDM TMs
OAs
Regens
Transponders
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Current topology
Grown topology
Grown topology2
Scenario Comparison
Current topology
Grown topology
Grown topology2
Cable Fixed 0.00 0.00 0.00
Fiber Fixed 0.00 0.00 0.00
Channel Fixed 0.00 0.00 0.00
Length 0.00 0.00 0.00
WDM TMs 21,680.00 7,200.00 7,760.00
WDM Channel Cards 0.00 0.00 0.00
OAs 76,950.00 24,450.00 24,450.00
Regens 17,300.00 7,600.00 7,600.00
Transponders 600.00 1,650.00 2,000.00
Total 116,530.00 40,900.00 41,810.00
Link Cost
Close
Great Falls
Missoula
Butte
Bozeman
Billings
Bismarck
Sioux
Island
Wichita
Falls
Houston
Tampa


Scenario Comparison
Rings
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Current topology
Grown topology
Grown topology2
Scenario Comparison
Current topology
Grown topology
Grown topology2
Nodes 3 10 10
Min. Degree 2 0 2
Max. Degree 2 2 2
Mean Degree 2.0 0.6 2.0
Connectivity % 100.0 6.67 22.22
Links 3 3 10
Used Capacity 0 0 0
Total Capacity 576 660 744
Utilization % 0.0 0.0 0.0
Terminal Multiplexer Nodes 0 0 0
Rings 1 1 2
DCL Topology
Close
Great Falls
Missoula
Butte
Bozeman
Billings
Bismarck
Houston
Tampa


Scenario Comparison
Link Utilization %
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Current topology
Grown topology
Grown topology2
Scenario Comparison
Current topology
Grown topology
Grown topology2
Nodes 4 14 14
Min. Degree 3 1 3
Max. Degree 3 5 5
Mean Degree 3.0 2.3 3.3
Connectivity % 100.0 17.58 25.27
Links 6 16 23
Min. Cable Length 234.4 230.3 230.3
Max. Cable Length 2,139.7 2,139.7 2,139.7
Mean Cable Length 1,177.3 660.2 663.4
Total Cable Length 7,063.8 10,563.8 15,257.6
Used Link Capacity 1,500 1,400 1,750
Total Link Capacity 1,500 2,450 2,800
Link Utilization % 100.0 57.14 62.5
OTS Topology
Close
Great Falls
Missoula
Butte
Bozeman
Billings
Bismarck
Houston
Tampa