Graduate Project

OPNET Transport Planner

Network Planning and Design

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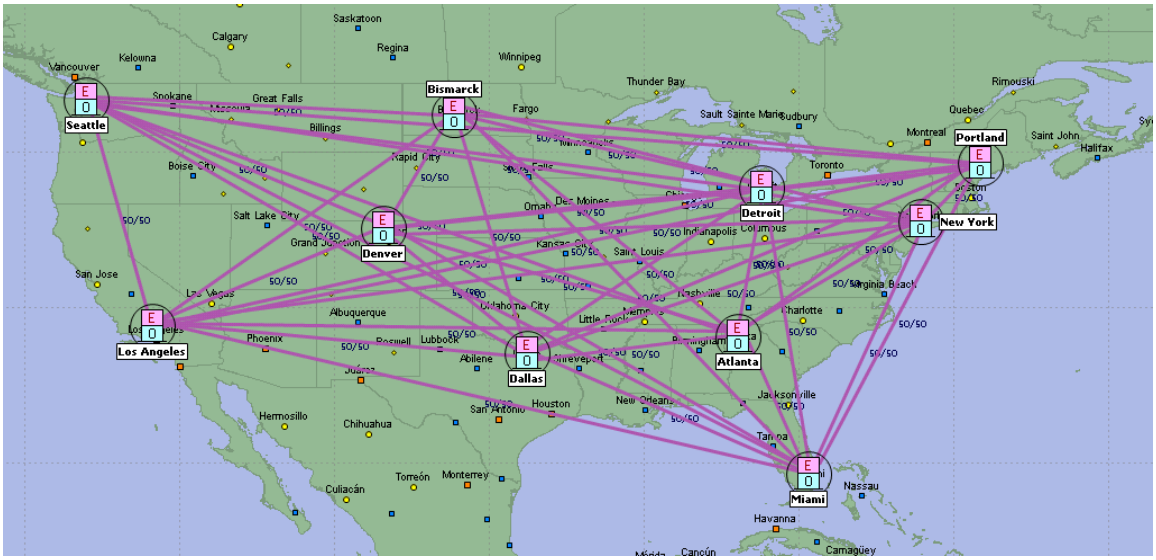
Overview

The purpose of this project is to gain some insight on how to use OPNET transport planner to design and simulate optical networks at a basic level. It provides an introductory understanding of using the various tools within the program to provide network data.

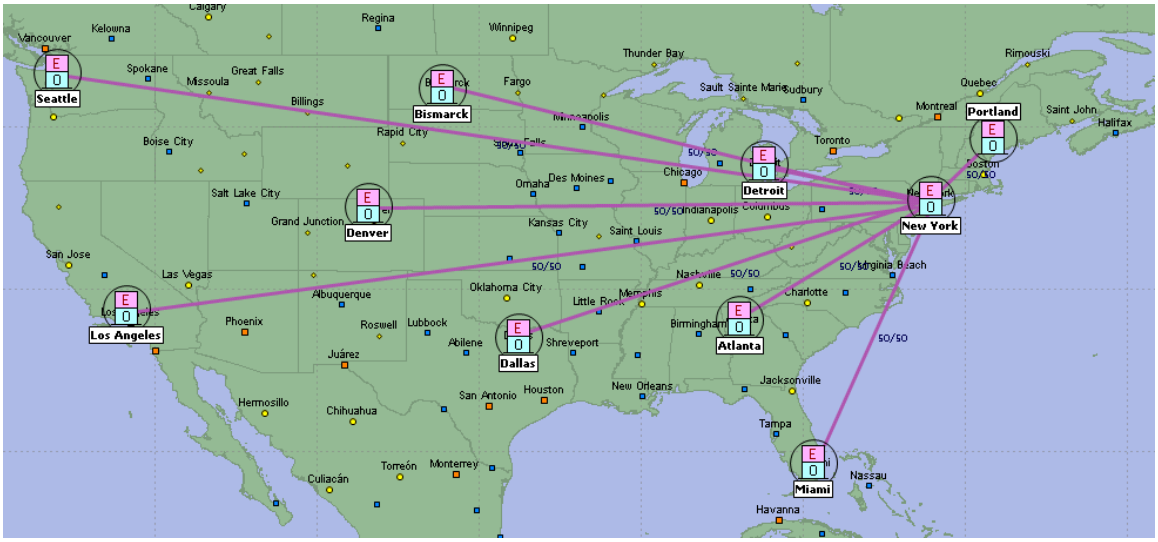
The best method of learning OPNET is to play with it and see how it reacts to well known topologies and how to implement well known topologies in the WAN.

The topologies used in this project are a fully meshed network, a star network, and a ring network. These topologies are seen below:

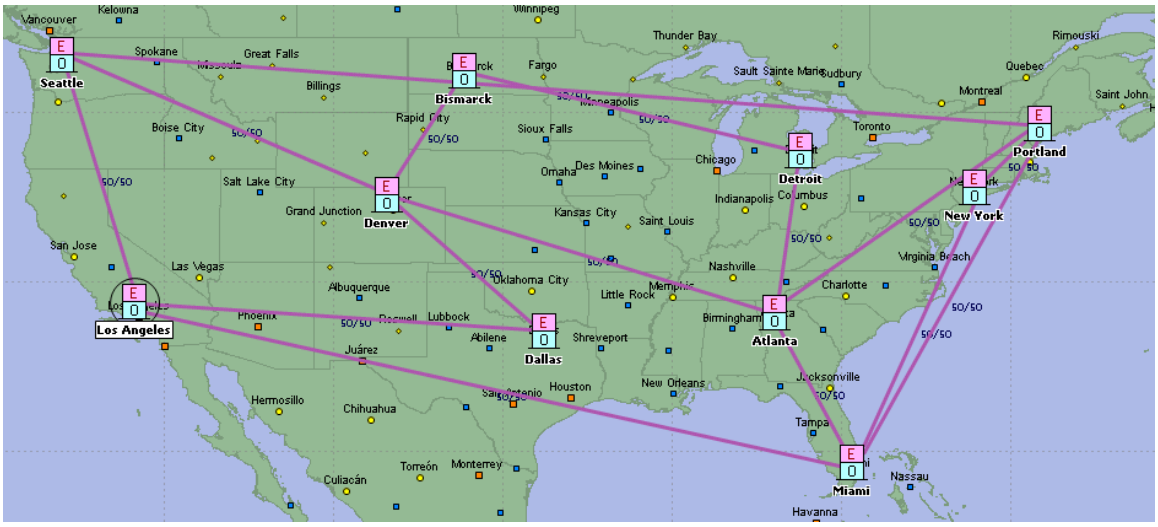
FULL MESH



STAR



MULTIPLE RINGS

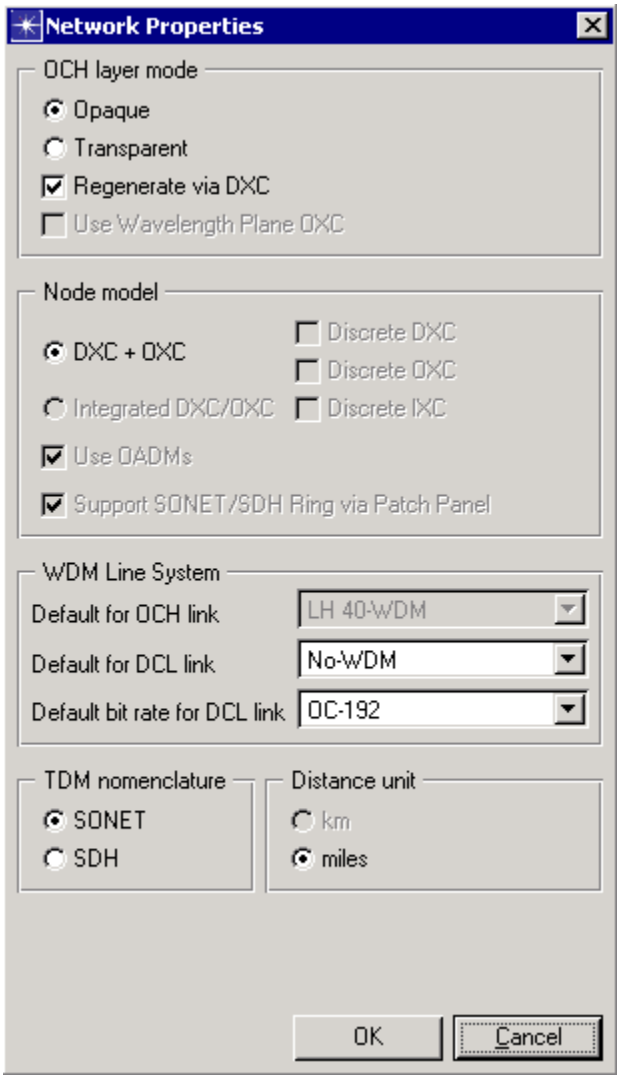


The goal of this project in addition to learning about OPNET is to demonstrate the differences between these three network topologies using cost analysis, failure analysis, growth analysis, and usage analysis.

Common Settings:

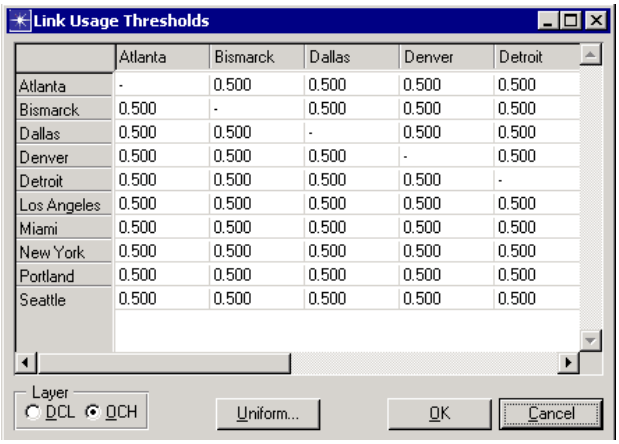
In order for the comparison between topologies to be as fair as possible, all the initial settings and conditions had to be the same.

This screenshot illustrates the network properties common to all three scenarios:

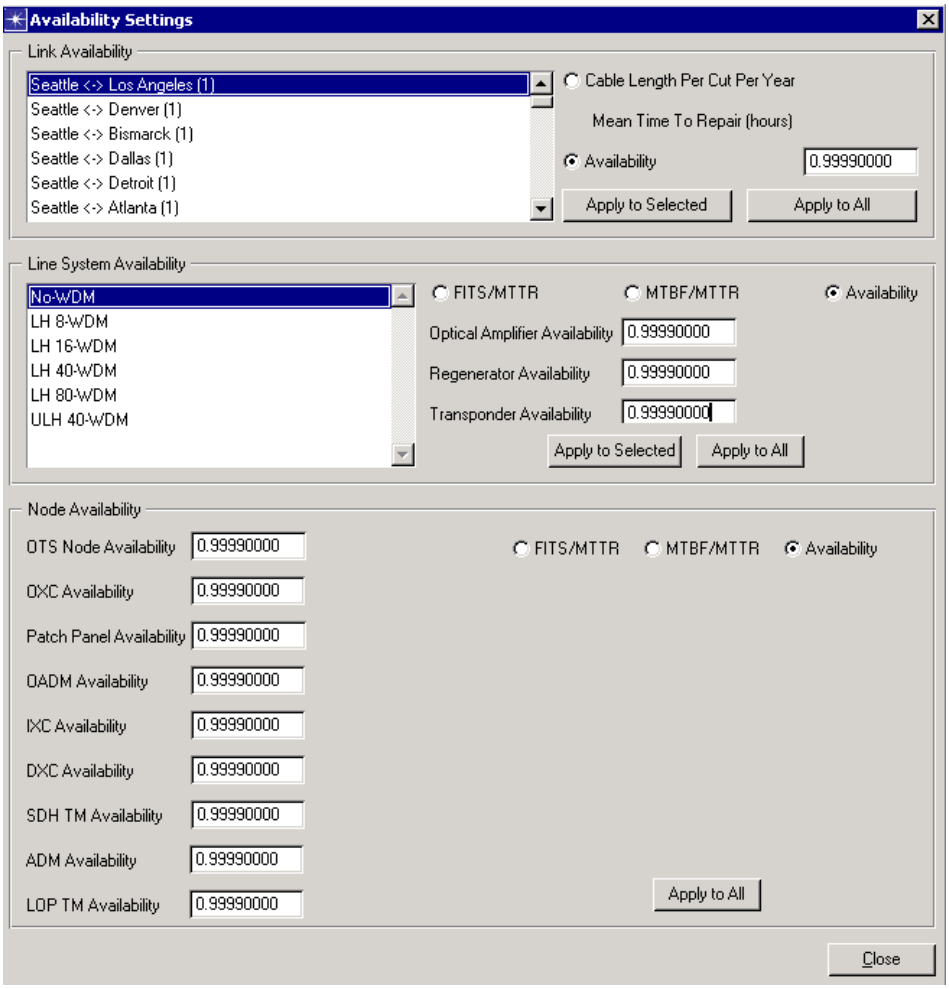


For simplicity and because these are solely optical networks, It made sense to use Optical Add Drop Multiplexers to facilitate the traffic on the fiber. SONET is more widely accepted than SDH. OC-192 seemed like a more likely bit rate used in WANs though it is probably much larger now.

This screenshot illustrates the Link Usage Thresholds which cap the utilization of each link to the standard of 50%.



All Availabilities for each topology were set to a standard of .9999 shown here:



Random traffic was created on the networks using the Traffic Matrix Editor with a threshold of 1-5.

Traffic Matrix Editor

Layer: LOP / DCL / OCH

Traffic Matrix	Bit Rate	Native	Patch Panel
OCH_0	OC-48	Yes	No

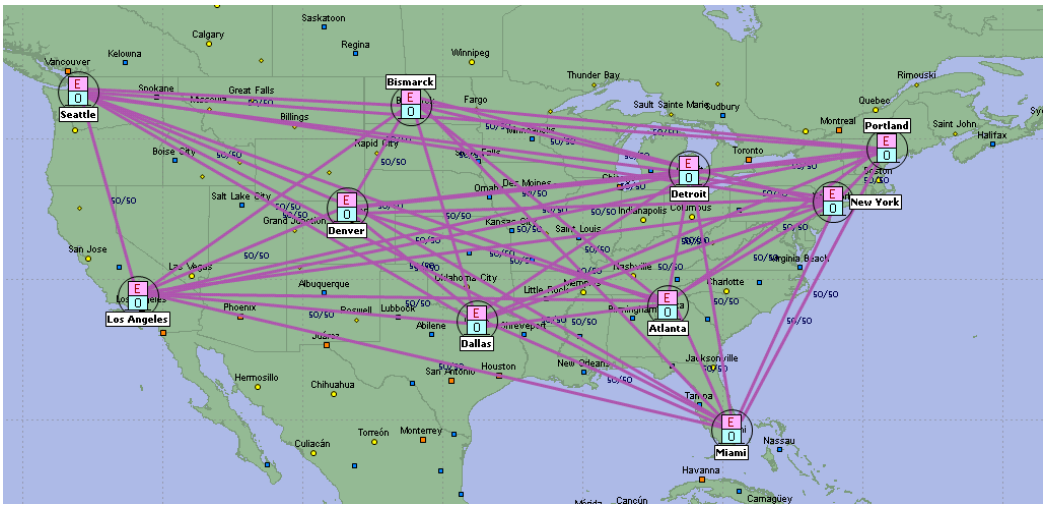
New | Delete | Random... | Uniform...

	Atlanta	Bismarck	Dallas	Denver	Detroit	Los Angeles	Miami	New Yo
Atlanta	-	5	1	3	5	2	5	4
Bismarck	5	-	2	5	2	2	4	2
Dallas	1	2	-	1	4	4	5	5
Denver	3	5	1	-	3	3	2	4
Detroit	5	2	4	3	-	2	1	3
Los Angeles	2	2	4	3	2	-	5	4
Miami	5	4	5	2	1	5	-	1
New York	4	2	5	4	3	4	1	-
Portland	1	2	3	1	4	4	5	2
Seattle	3	2	4	3	5	5	5	1

Close

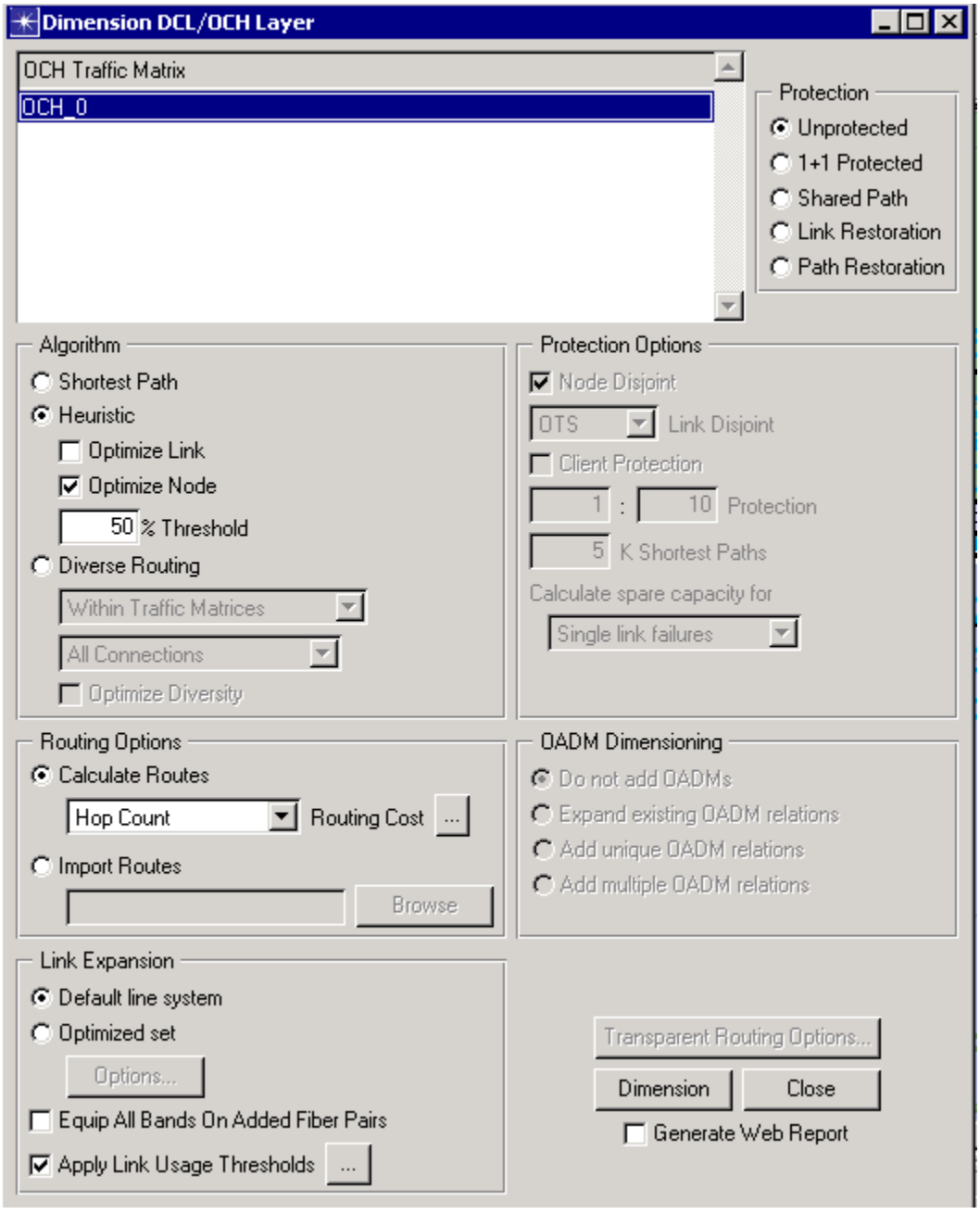
Individual Topology Settings

FULL MESH



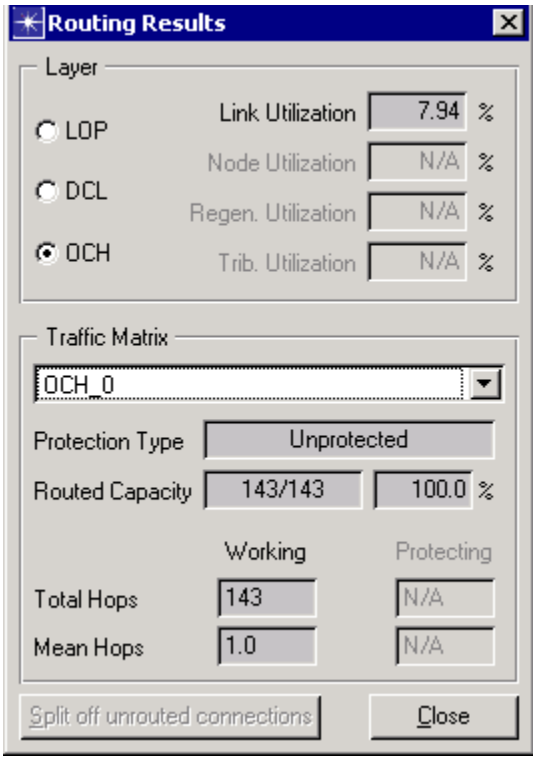
The fully meshed network took the most time to set up due to the vast amount of lines required to implement a full mesh network. As impractical as it is, the fully mesh network provided a good comparison level for other topologies.

The settings used to dimension this network are shown below:



Note the 50% threshold and lack of optimization of links. This creates a raw state, the most basic of basic mesh networks.

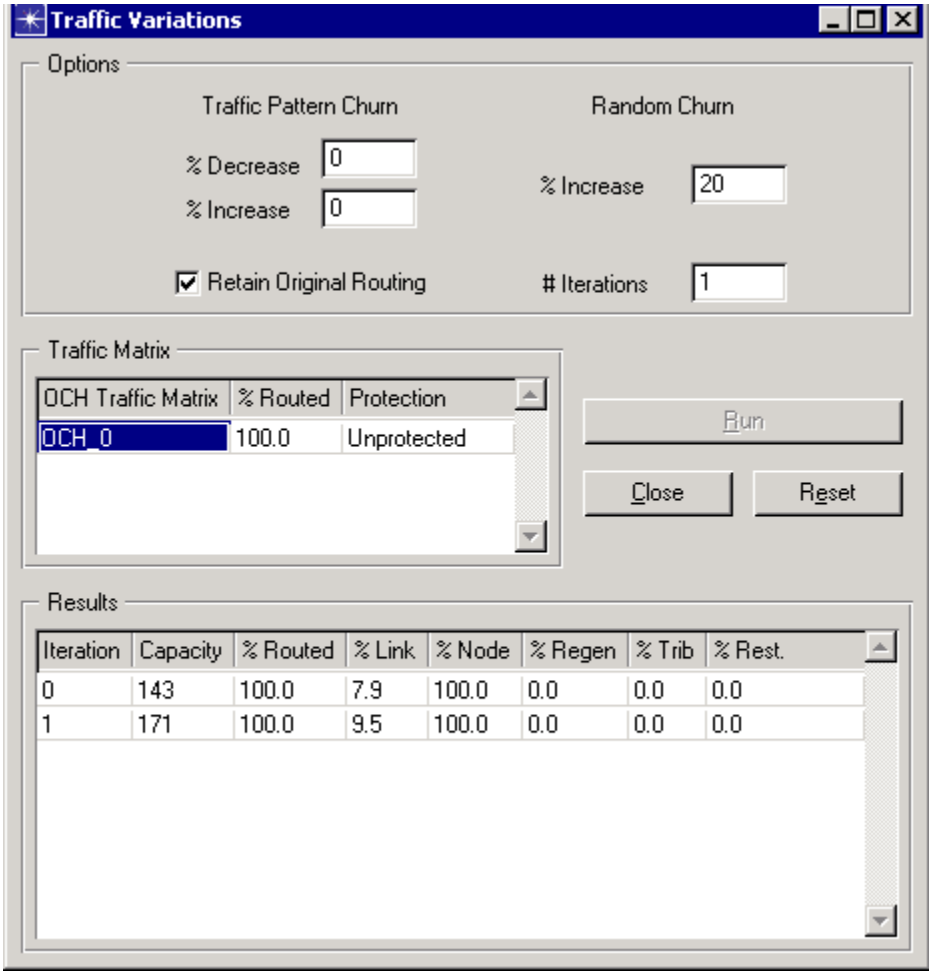
With traffic applied to the network, OPNET provides the following routing results table:



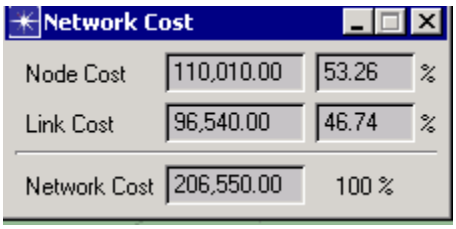
Note the highly underutilization of the links at only 7.94% which is to be expected given the number of lines traffic can travel on. Also note the mean number of hops as only 1 since each location has a direct connection to every other location.

Even with a **20% increase** in traffic, the link utilization only increases to 9.5% and is still 100% routed:

Note this is accomplished by using the built in Traffic Variation Tool in OPNET that allows users to temporarily alter traffic patterns.



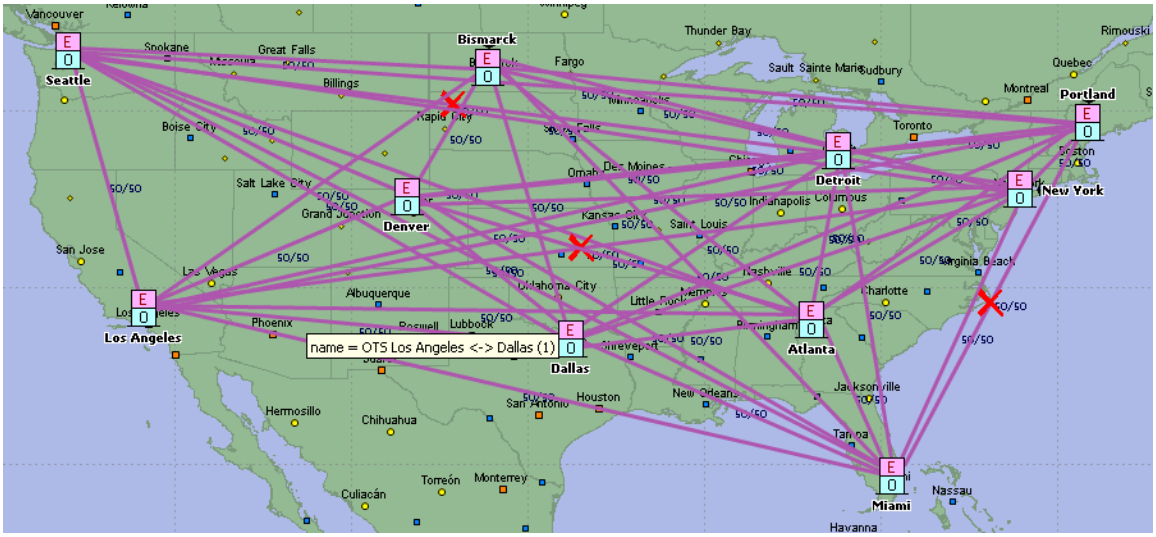
The Cost analysis of the Meshed Network returns these values:

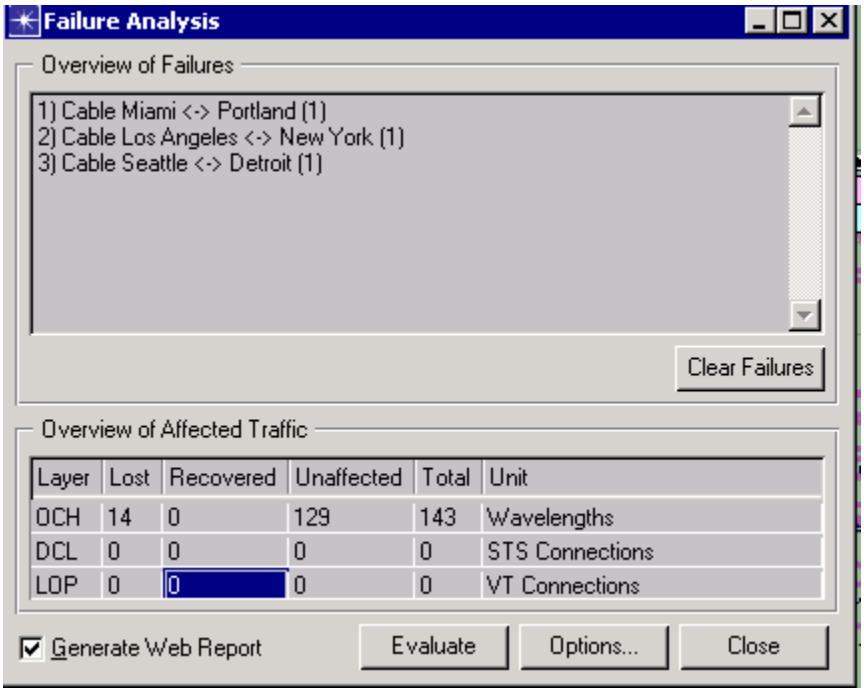


206,550.00 using the default equipment values in OPNET and only using optical equipment in the OCH/OTS layers.

Failure Analysis of this network was conducted in 2 phases. Phase 1 failed links and phase 2 failed a node. The results are shown below:

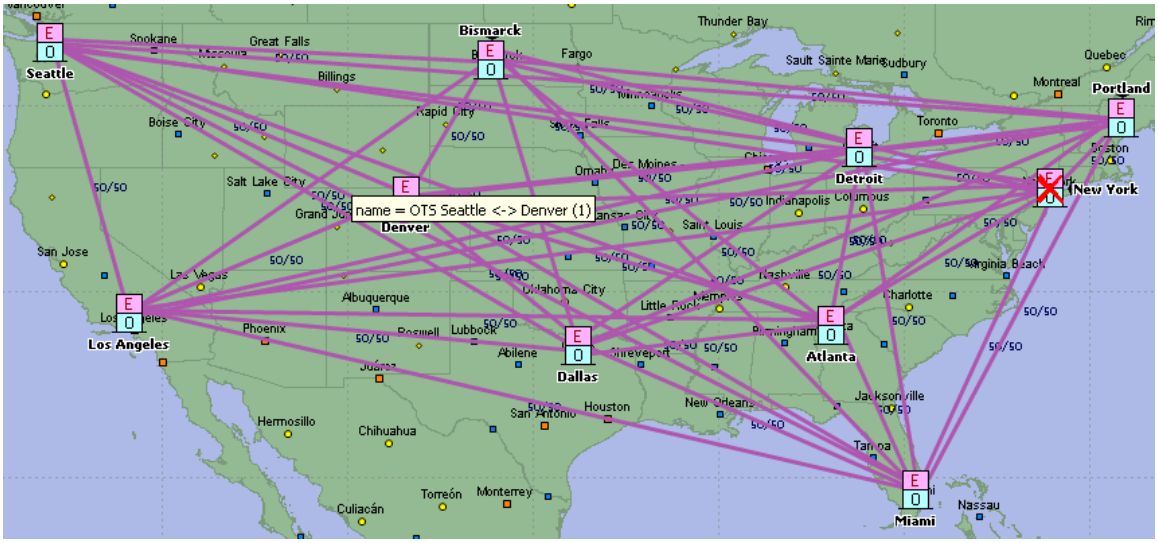
Failure Analysis Phase 1 Links:

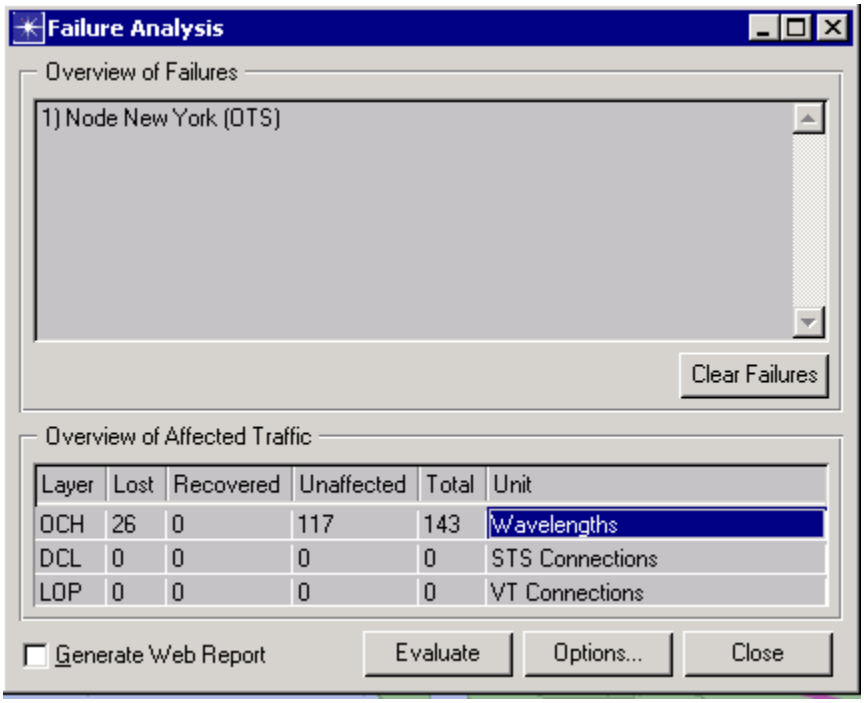




14 wavelengths were lost when 3 links failed. This equates to 9.8% loss.

Failure Analysis Phase 2 Nodes:

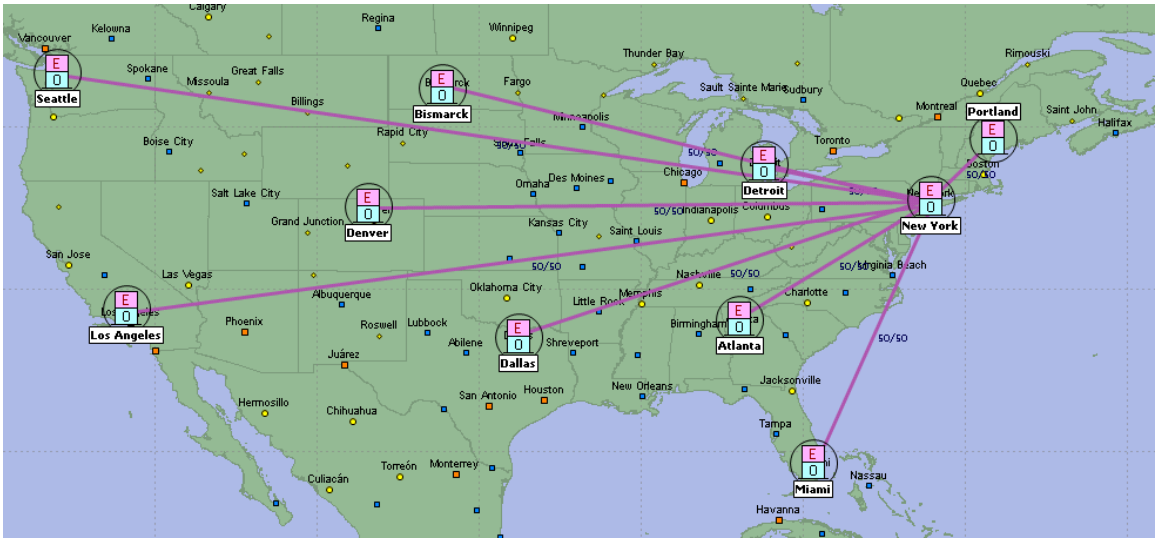




26 wavelengths were lost when the New York node failed. This equates to 18% loss.

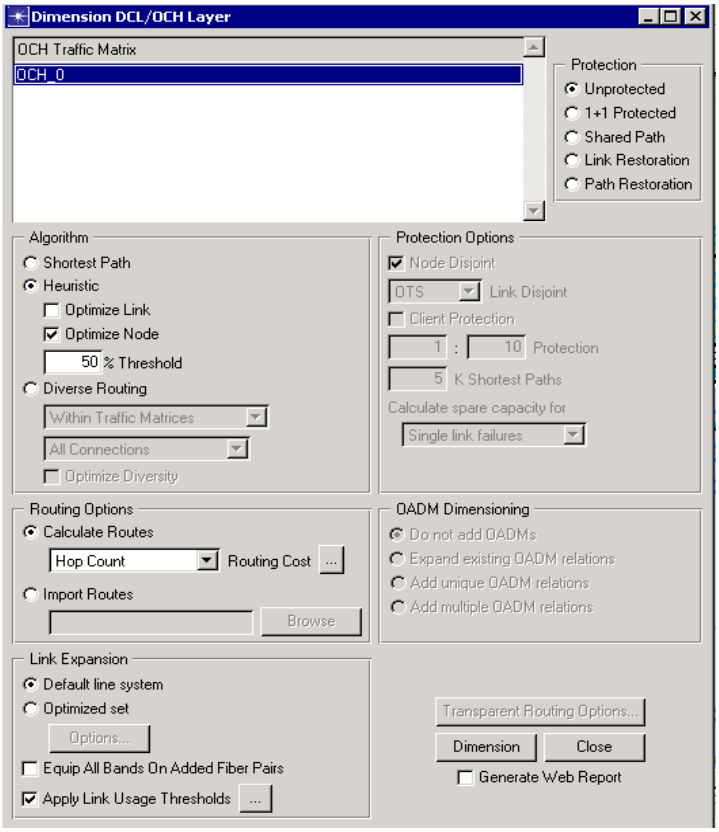
Due to amount of paths available in fully meshed network, failures did not greatly affect the network.

STAR



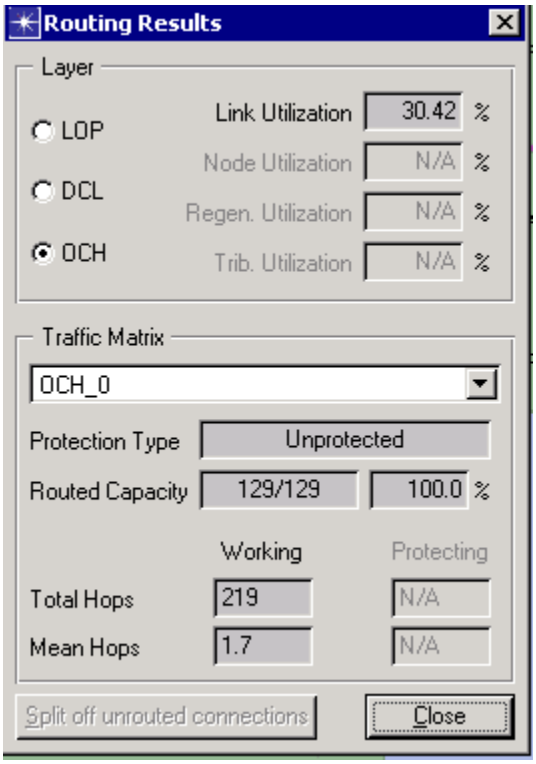
In this topology, New York is acting as the center of the star network and holds very high importance. Failure of this node would bring down the entire network as portrayed in the failure analysis later.

The settings used to dimension this network are shown below:



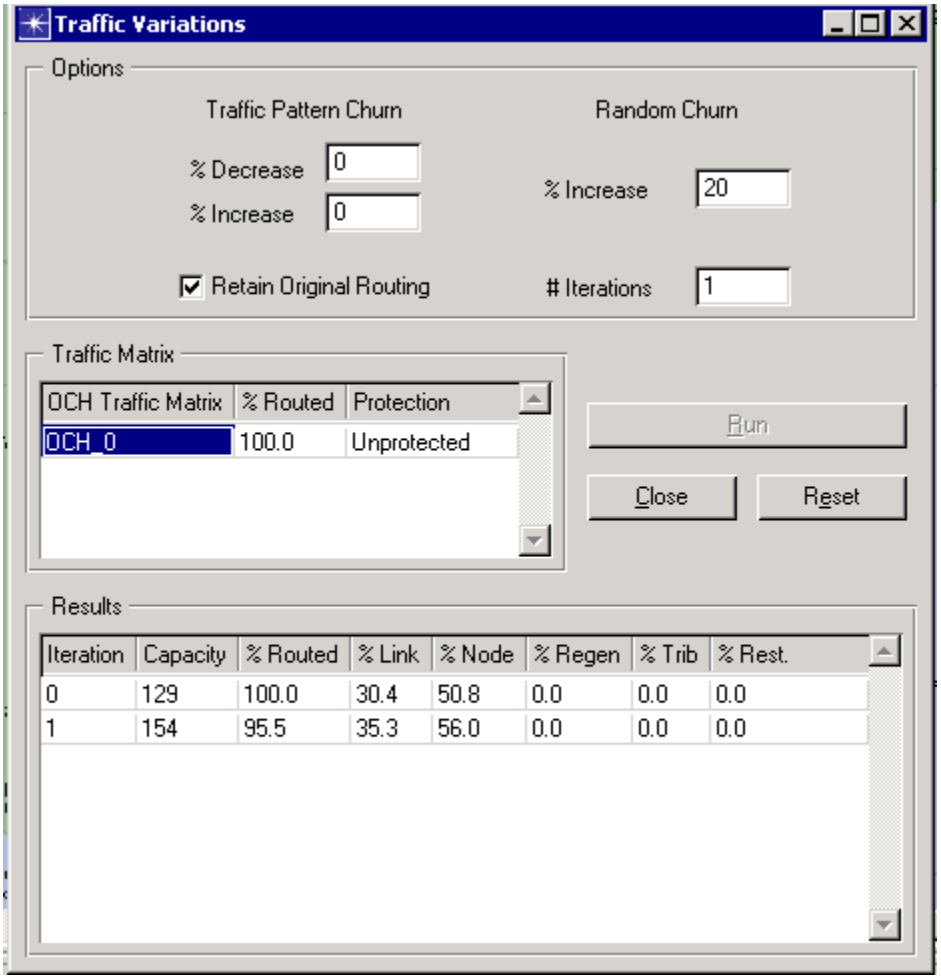
Note: 50% Threshold still applies. All settings are same as previous topologies but OPNET comes up with a different routing results.

With traffic applied to the network, OPNET provides the following routing results table:

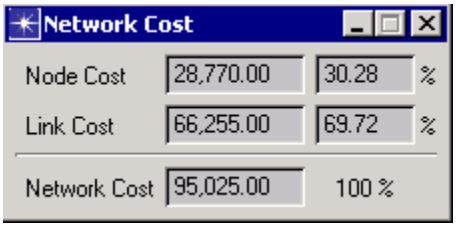


Note the higher utilization of the links at 30.42%. This value is expected to be higher than a Full Mesh since there are far less routes for the traffic to flow. Also note the mean number of hops is 1.7 which would equate to most of the traffic having to travel through another location which in this case is New York.

With a **20% increase** in traffic, the link utilization increases to 35.3% and is still 100% routed: This value may not be able to handle failures as well as lower utilized links.



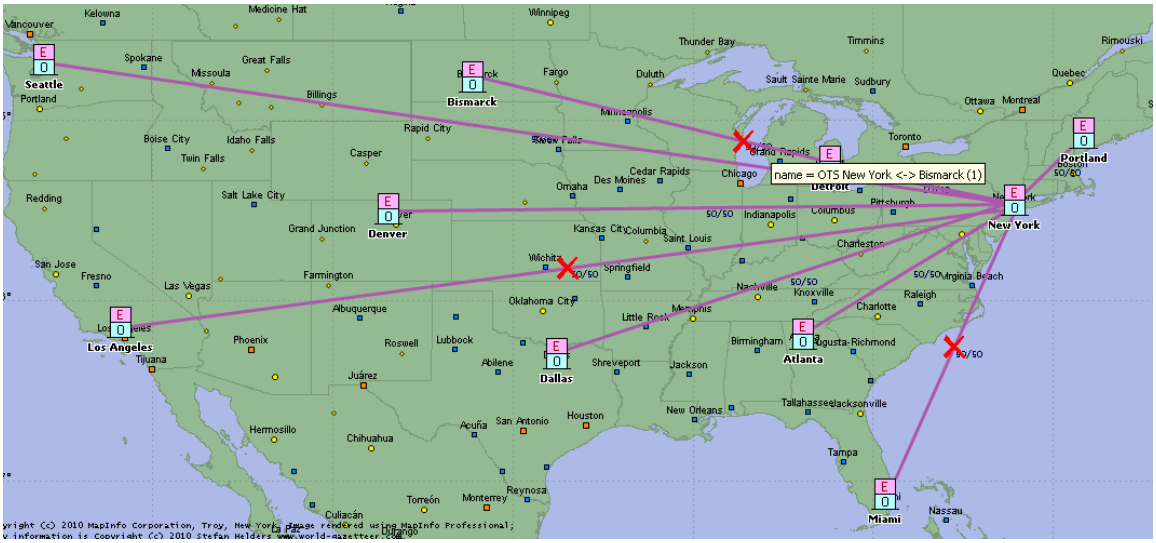
The Cost analysis of the Star Network returns these values:

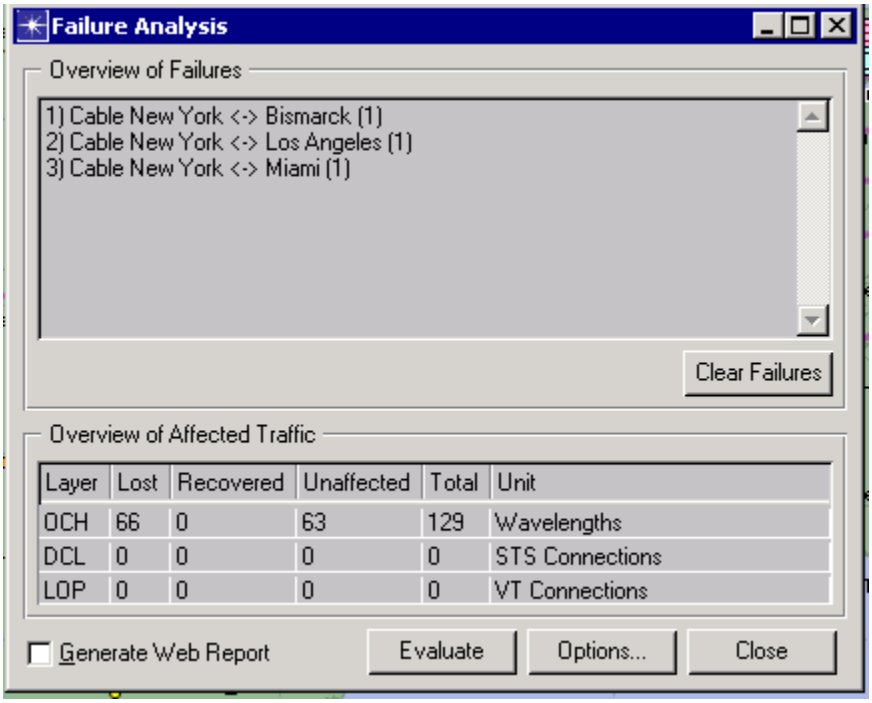


95,025.00 using the default equipment values in OPNET and only using optical equipment in the OCH/OTS layers. This is significantly cheaper than the fully meshed network.

Failure Analysis of this network was conducted in 2 phases. Phase 1 failed links and phase 2 failed a node. The results are shown below:

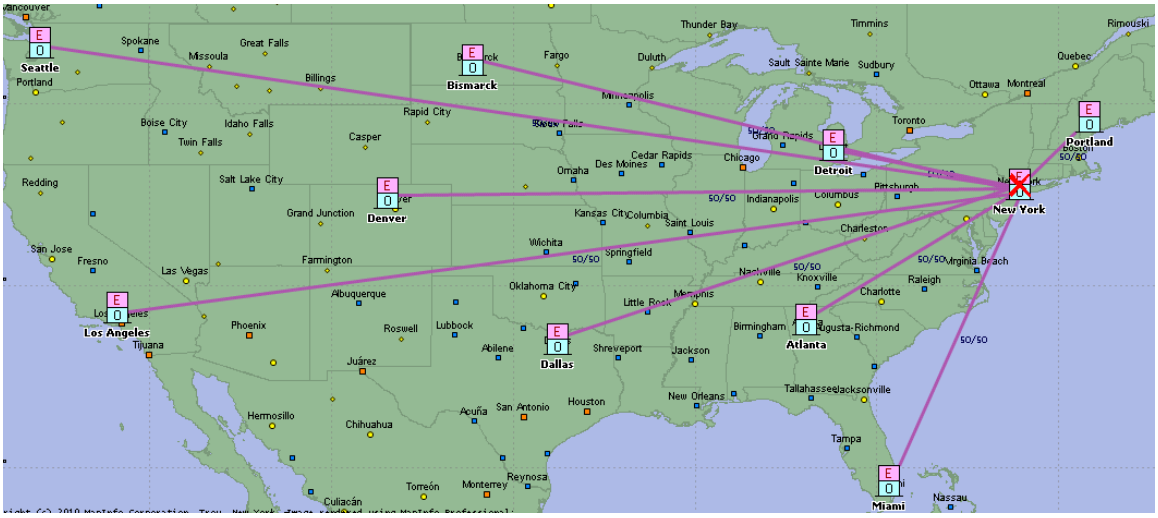
Failure Analysis Phase 1 Links:

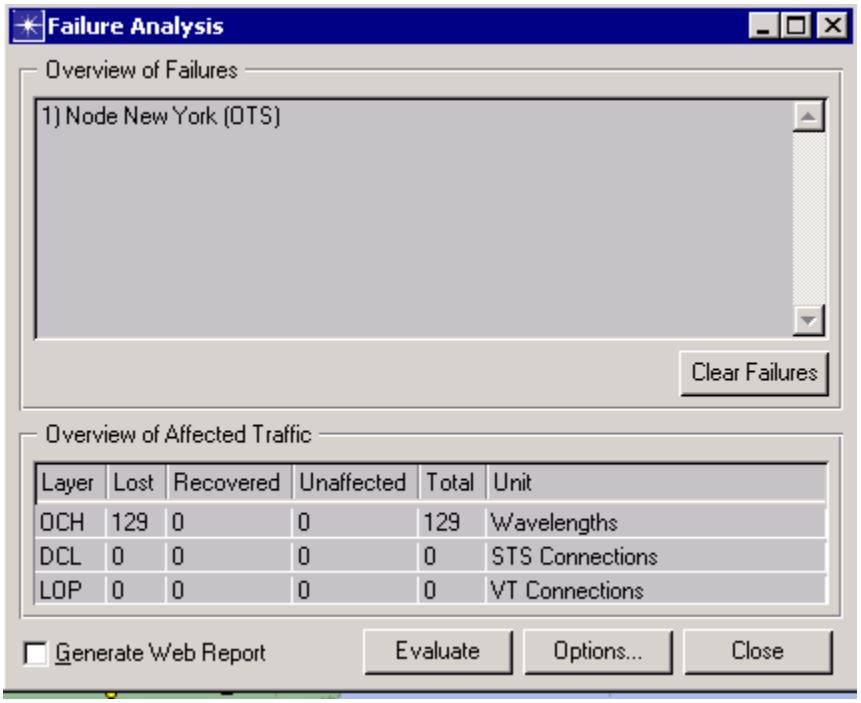




66 out of 129 wavelengths were lost when 3 links failed. That's more than 50% loss.

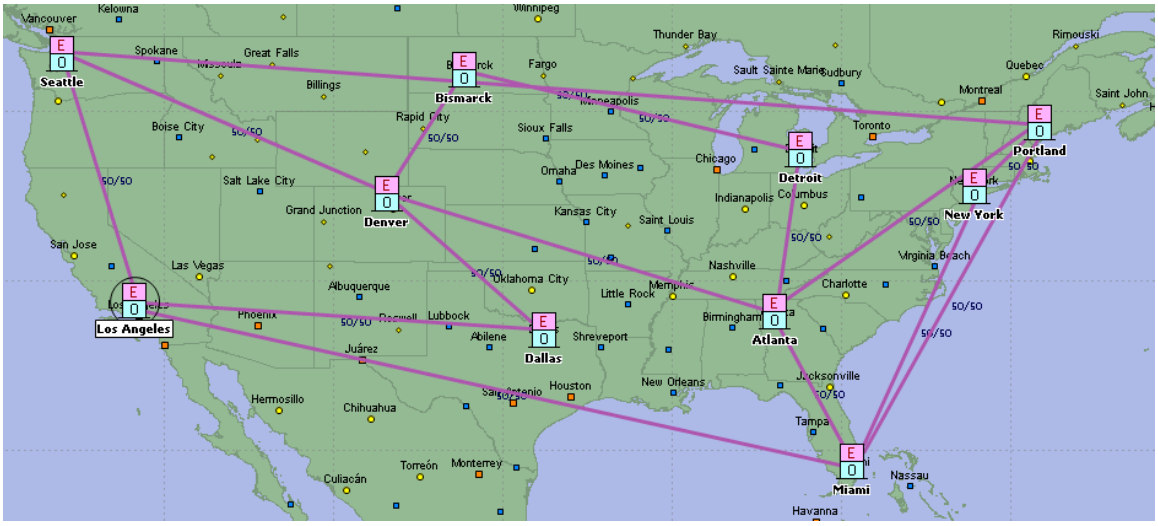
Failure Analysis Phase 2 Nodes:



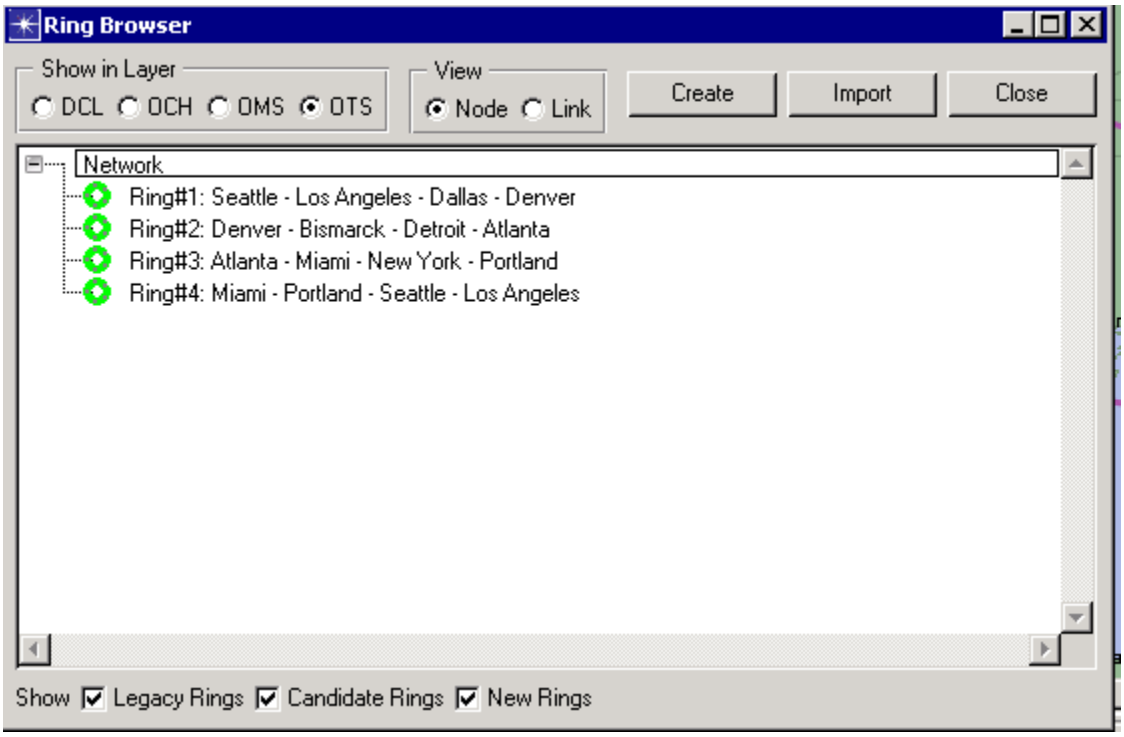


129 out of the 129 wavelengths were lost when the New York node failed. This is 100% loss and shows the danger of using a Star Network. The Central Node is absolutely critical and must not fail.

MULTIPLE RINGS

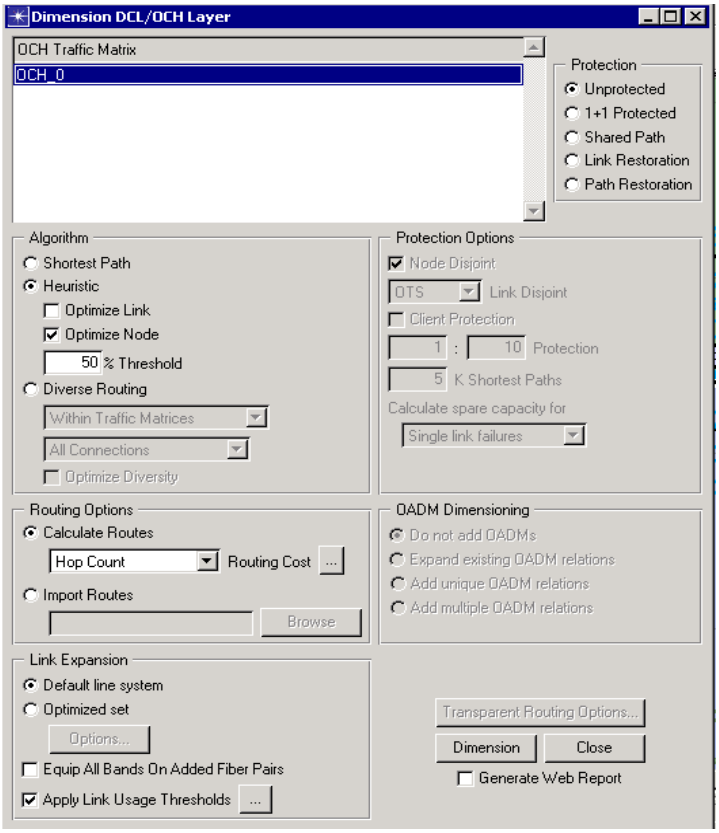


In this topology, there are four optical rings that interconnect the cities. These rings are shown in the ring browser:



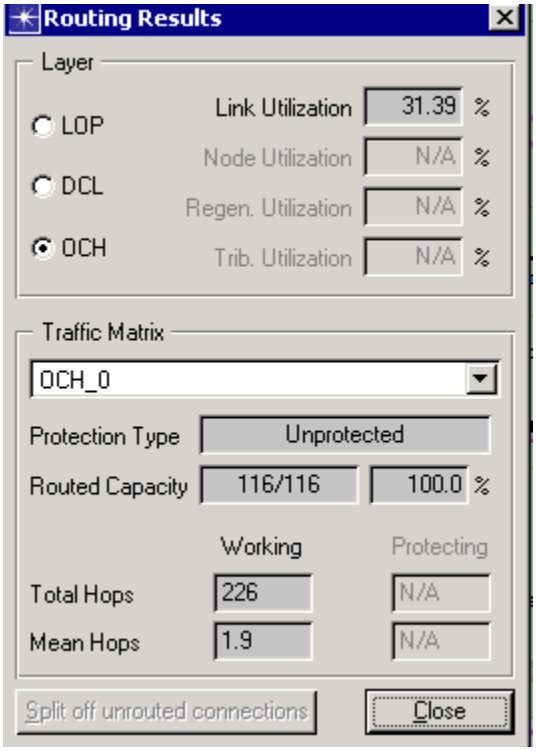
Each Ring number shows which cities form each ring.

The settings used to dimension this network are shown below:



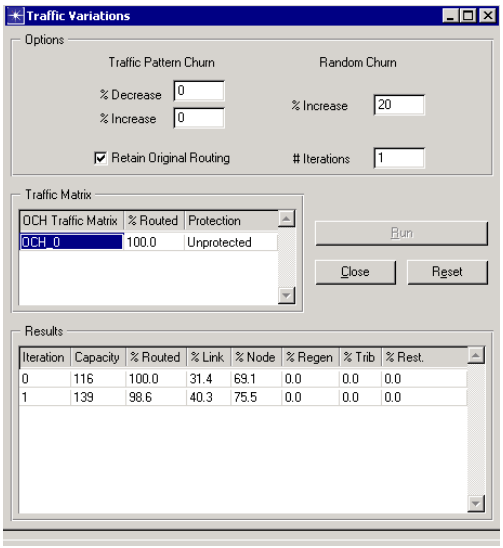
Note: 50% Threshold still applies. All settings are same as previous topologies but, once again, OPNET comes up with different routing results due to the different topology.

With traffic applied to the network, OPNET provides the following routing results table:

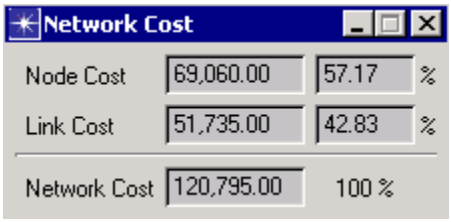


Note the higher utilization of the links at 31.39%. This value is expected to be higher than a Full Mesh and star because there traffic may have to traverse through a few rings to get where it needs to go. This also accounts for the increases mean hop count.

With a **20% increase** in traffic, the link utilization increases to 40.3% and is now 98.6% routed: The links cannot handle the higher traffic loads in this ring topology.



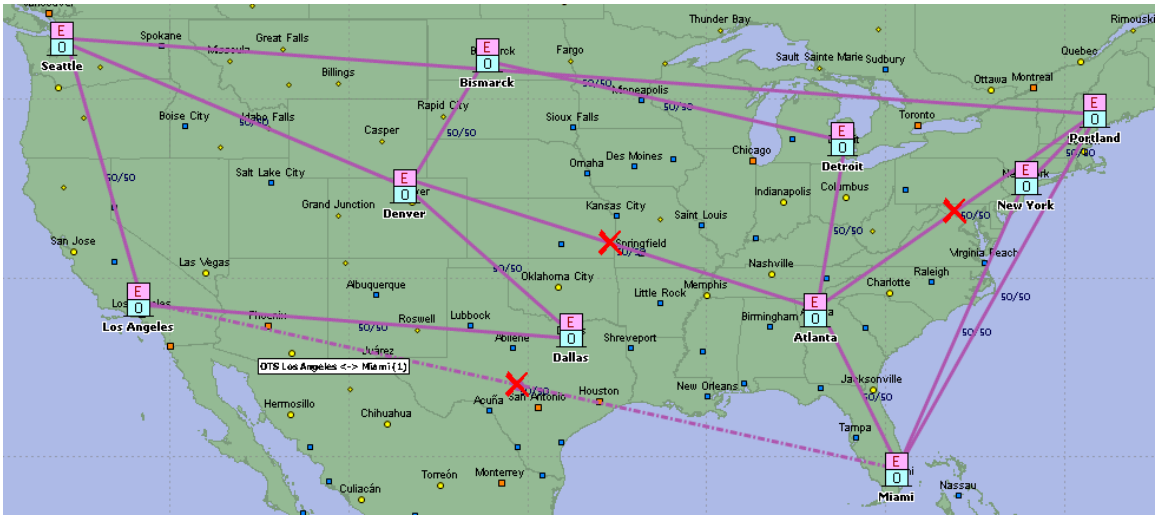
The Cost analysis of the Star Network returns these values:

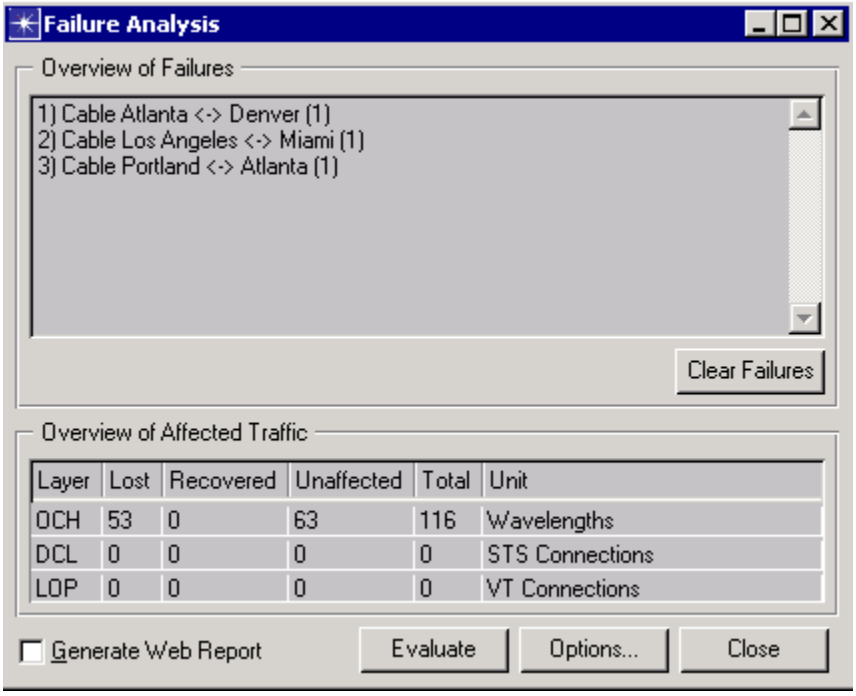


$120,795.00 using the default equipment values in OPNET and only using optical equipment in the OCH/OTS layers. This puts it between the Full Mesh and the Star Network.

Failure Analysis of this network was conducted in 2 phases. Phase 1 failed links and phase 2 failed a node. The results are shown below:

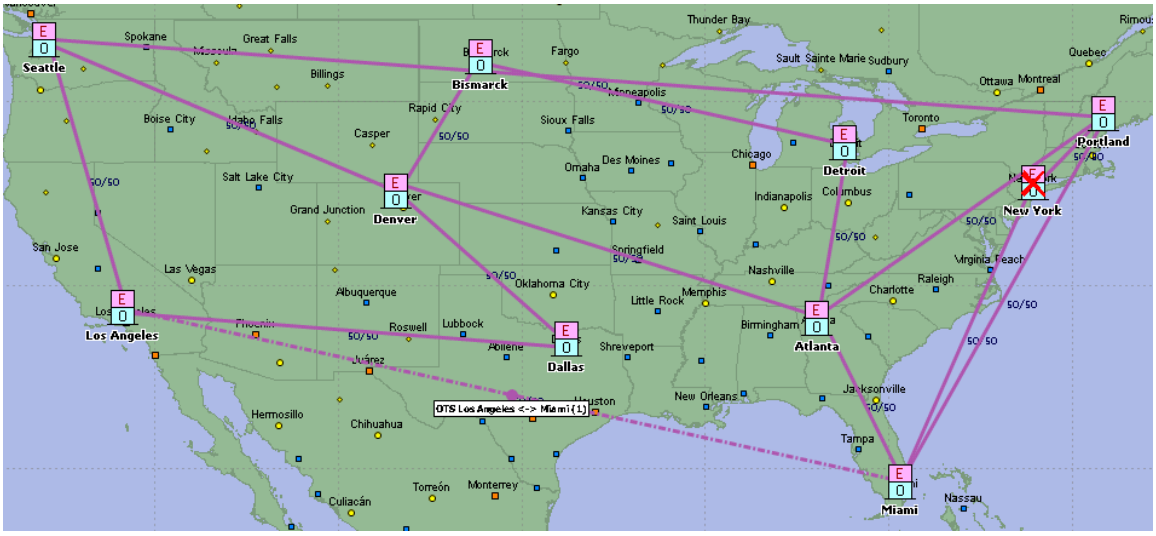
Failure Analysis Phase 1 Links:

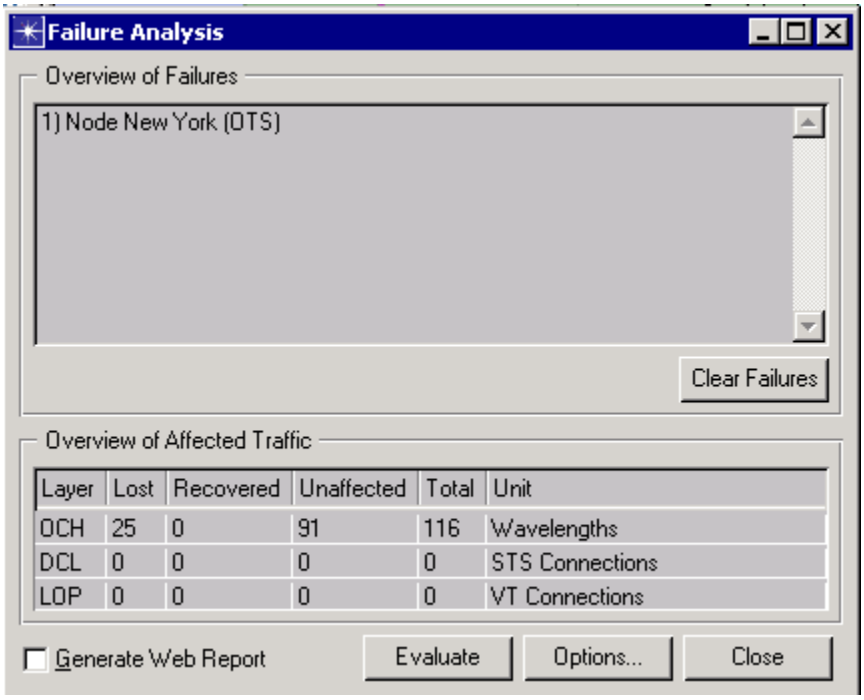




53 out of 116 wavelengths were lost when 3 links failed. That is nearly 46% loss. This may seem high compared to the full mesh but this network does have fewer wavelengths and is overall a smaller network handling the same amount of traffic as the full mesh.

Failure Analysis Phase 2 Nodes:





25 out of the 116 wavelengths were lost when the New York node failed. This is 21.56% loss which is reasonable considering New York is part of 2 rings.

Final Comparison

OPNET has shown that the FULL MESH topology has the smallest utilization, can deal with best with failures, but has the highest cost by far of the other two networks. Because of the cost, A FULL MESH is always impractical and wasteful as seen here since each link is only 7% utilized; a far cry from an efficient 50% utilization. The STAR Topology had the least cost, and utilization of around 30% which is quite good and on par with the RING topology. However, OPNET failure analysis tool made the danger of a STAR topology very clear in failing the central node which brought the whole network to its knees. It may be wise to use some of the money saved from implementing a STAR topology to fortify the central node against failures. The RING topology was toughest to set up in OPNET. OPNET likes to layer rings or add rings as backup and not as a main communication link. However, it still provided good data. The RING Network was slightly more expensive than the STAR and it had similar Utilization around 35%

which is a good place to be since pushing the traffic up to a utilization of over 40% started to exhibit problems in the ring. The RING Network did ok in failure analysis. Failing 3 links on this network essentially failed 3 out of 4 rings so the results were not all that farfetched. In hindsight, it might have made more sense to use larger fiber in both the STAR and RING topologies to account for the sheer size of the FULL MESH topology.

Even though the results were expected and typical, it was a great exercise in using OPNET to come up with these results since it becomes easier to tell if everything has been set correctly and provisioned correctly if one know what to expect. OPNET is a powerful and handy tool and it is very clear that so much more can be done with the software. This project only scrapes the surface of what is possible.