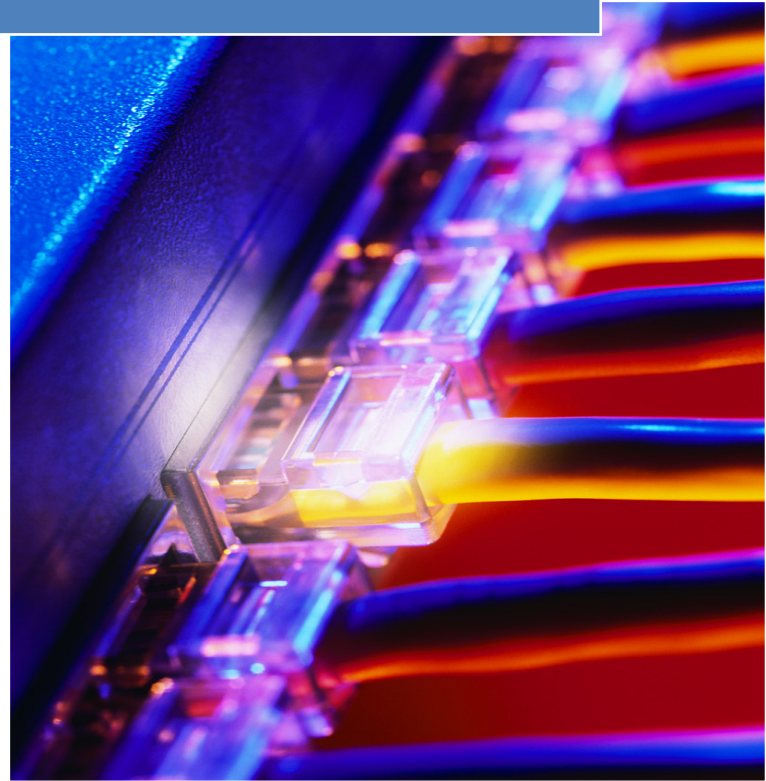


**WAN/LAN Planning and Design**

**Graduate Project**

**2009**

# 4Com New High Capacity Network



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5/7/2009

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# Fourth Generation Communications (4Com) New High Capacity Network

## About 4Com

4Com is a telecommunications company in the Dominican Republic that offers integrated services of Internet, digital television and voice to personal customers, as well as specialized services to businesses, institutions and other service providers, ensuring reliable service, high quality, accessible cost and highly secure infrastructure. The voice, data and video network is fully supported over IP technology; the last mile to the customer is primarily based on WiMax technology with point to point microwave access. The large volumes of information generate by the customers is routed through the internal fiber backbone.

4Com is actually offering its services in only seven of the main cities of the Dominican Republic, however its excellent service in these cities is highly appreciated by the customers, and this market acceptance has incentivized an exponential growth of the network bandwidth requirements. This growth and the fact that 4Com wants to keep providing an excellent service to the major population of the Dominican Republic are the main reasons for the upgrade/replace of the fiber backbone network. A secondary problem with the actual fiber backbone is that it does not have redundancy links in Puerto Plata. Puerto Plata is one of the most important nodes in the network because is one of the two points (the second one is Santo Domingo) of interconnection to the Internet network through the ARCOS submarine optic cable. Another problem is that the nodes in Santiago and Santo Domingo are articulations points in this network.

Figure 1 displays the actual fiber optic network of 4Com, as it could be seen in this figure there is only seven (7) point of service and two regenerators. It is also noticeable that the interconnection point in Puerto Plata has no link redundancy.



Figure 1 - 4Com Actual Network Topology

The proposed new network is displayed in figure 2, here ten new locations were added and two regenerators were changed for Electrical-Optical Cross Connections (EOCC). Also note that the links in Puerto Plata and Santo Domingo have various redundant links and that now there is not articulation point in this network.

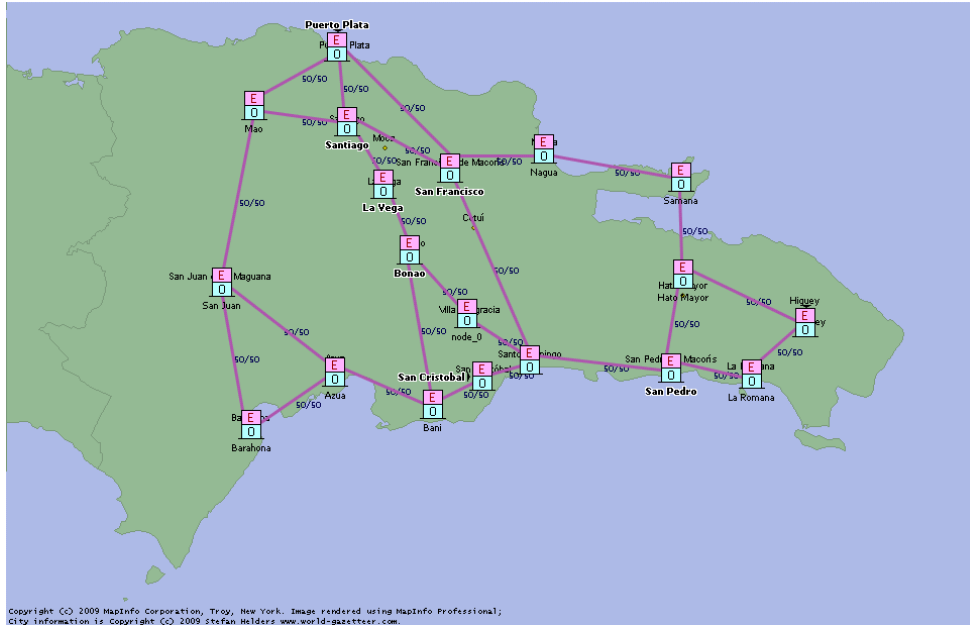


Figure 2 - 4Com Future Network

## Network Design

For the implementation of this project two different scenarios were implemented, the first scenario is the actual fiber backbone network with only nine (9) nodes that are used to distribute the bandwidth of the customers of the seven main cities: Santo Domingo, Santiago, San Cristobal, Puerto Plata, San Francisco, La Vega and San Pedro. In the second scenario 10 new nodes are added to the network: Mao, Barahona, San Juan, Nagua, Samaná, Higüey, La Romana, Hato Mayor, Azua and Baní. The topology in the second scenario is a partial mesh network designed to eliminate any articulation point and to have a more reliable routing path between nodes. The second scenario also solves the problem of the redundancy in the node of Puerto Plata.

For both scenarios the network is designed to meet a link utilization of 50% (as usual), the default settings for the parameters of dimensioning and grooming were selected. Also the parameters for availability (MTTR, MTBF, etc.) were left in default.

The following are the network properties that are common for both scenarios:

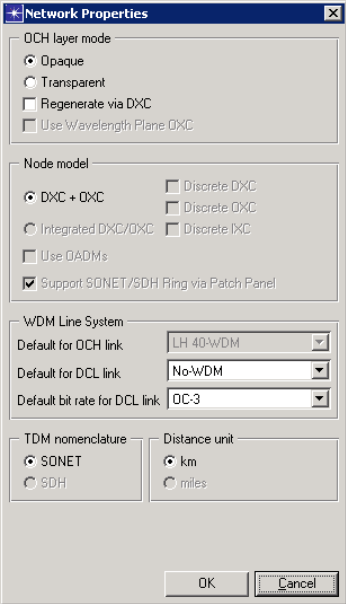


Figure 3 - Network Properties

In figure 3 the network properties for both scenarios is displayed, opaque OCH Layer Mode is used, and the Node Model is DXC + OXC. Here also the default WDM Line System for OCH and DCL Links are configured. The TDM Nomenclature is SONET and the distance unit is Kilometers.

# First Scenario Design

## Network Topology

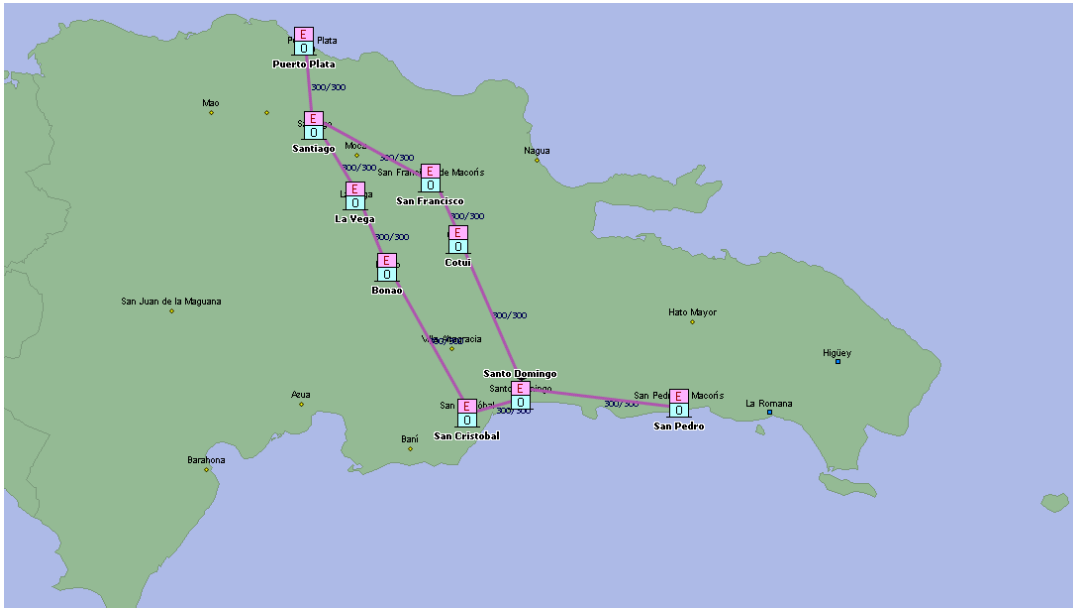


Figure 4 - Network Topology

## Traffic Matrix Editor

The figures 5 and 6 shows the OCH Traffic Matrix and the DCL Traffic Matrix respectively, for the OCH Traffic a random traffic of wavelengths from 1 to 10 is used. For the DCL Traffic a random traffic from 1 to 20 (STS-3) is used.

**Traffic Matrix Editor**

Layer:  LOP  DCL  OCH

Buttons: New, Delete, Random..., Uniform...

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

	Bonao	Cotui	La Vega	Puerto Plata	San Cristobal	San Francisco	San Pedro	Santiago	Santo Domingo
Bonao	-	4	8	3	4	6	5	5	8
Cotui	4	-	9	1	7	10	9	4	3
La Vega	8	9	-	10	10	2	2	4	7
Puerto Plata	3	1	10	-	1	3	8	8	3
San Cristobal	4	7	10	1	-	2	6	8	8
San Francisco	6	10	2	3	2	-	3	1	5
San Pedro	5	9	2	8	6	3	-	6	5
Santiago	5	4	4	8	8	1	6	-	1
Santo Domingo	8	3	7	3	8	5	5	1	-

This traffic matrix is set up, hence cannot be renamed, deleted, or modified.

Close

Figure 5 - OCH Matrix Editor

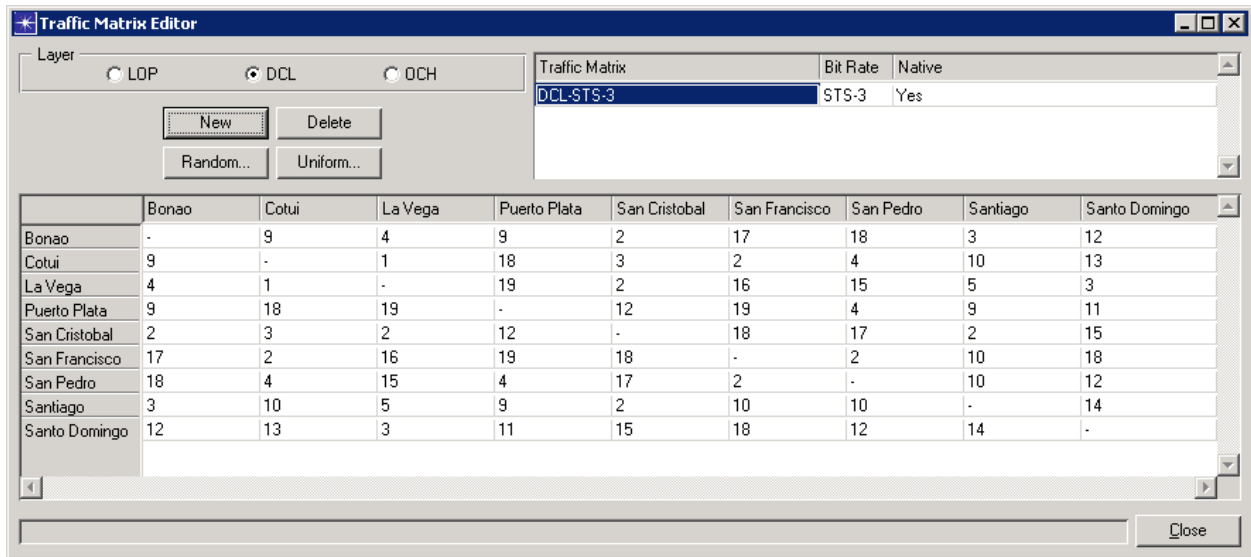


Figure 6 – DCL Matrix editor

### DCL Logical Layer Links

The figure 7 shows the DCL Logical Layer Links (the virtual links between nodes) for all nodes in this first scenario.

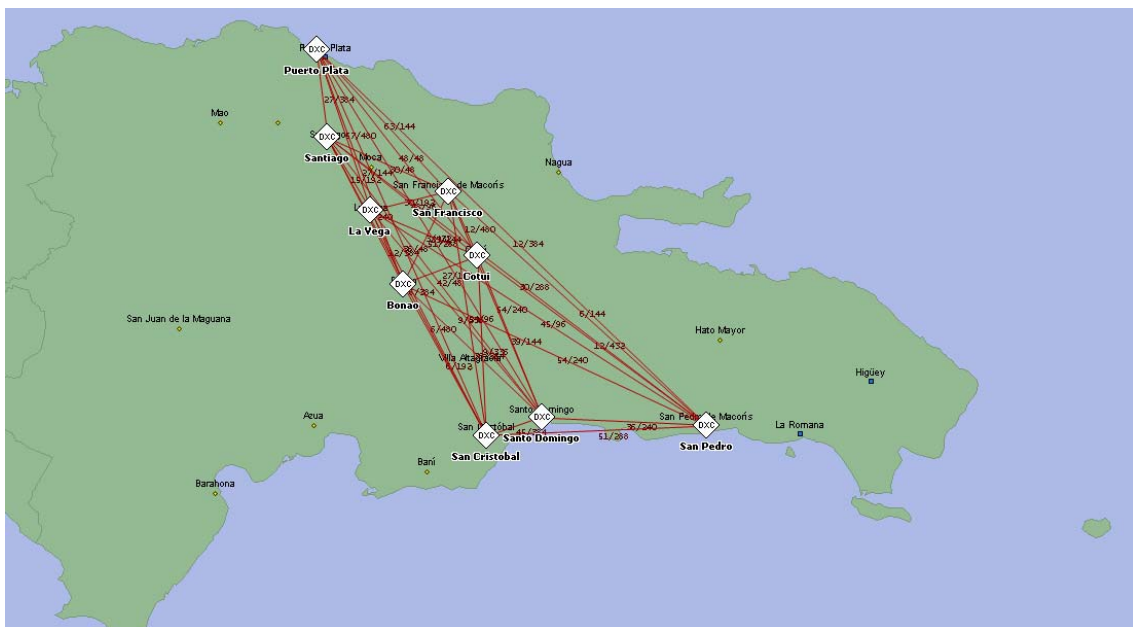
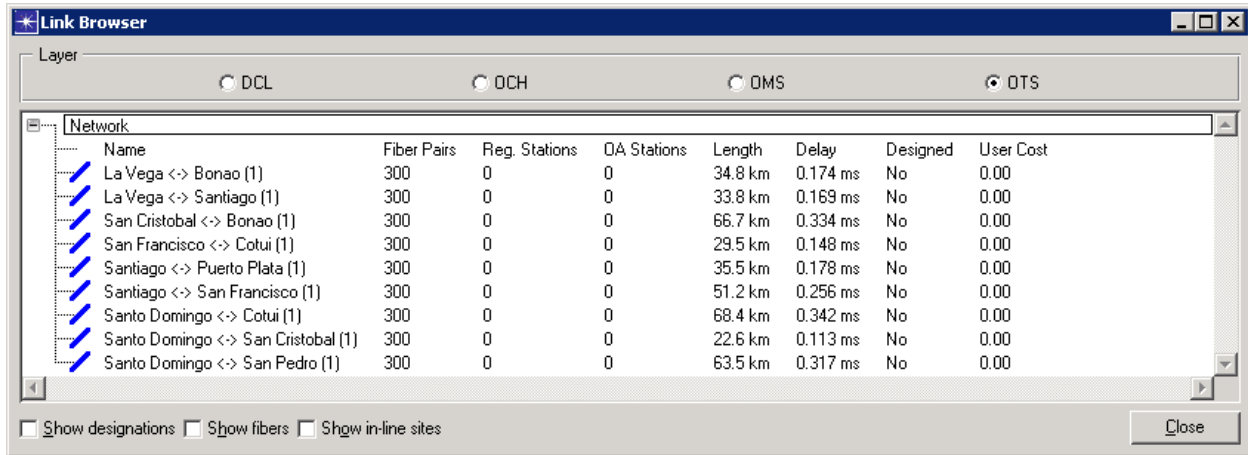


Figure 7 - DCL Logical Layer Links

## Links Configurations

In figure 8 the links for this scenario are displayed, here you can see that there is no need for regenerator or amplifier because of the short distances (the longest distance is 68.4 km) between links.

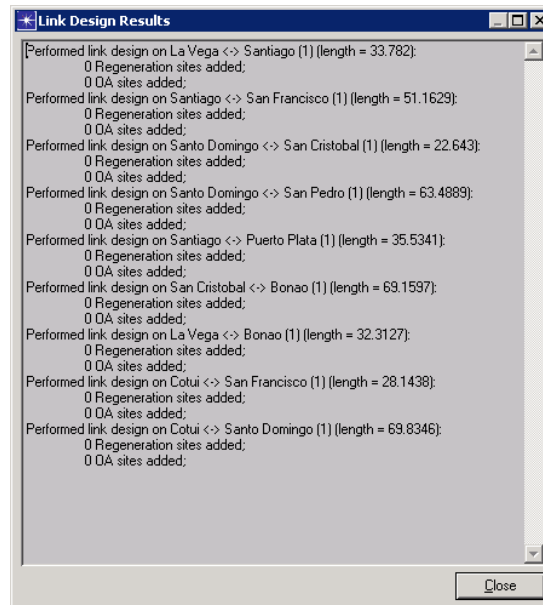


The screenshot shows a window titled "Link Browser" with a "Layer" section containing radio buttons for DCL, OCH, OMS, and OTS. Below this is a table with columns: Name, Fiber Pairs, Reg. Stations, OA Stations, Length, Delay, Designed, and User Cost. The table lists ten links between various locations, all with 300 fiber pairs, 0 regenerator stations, 0 OA stations, and a "Designed" status of "No".

Name	Fiber Pairs	Reg. Stations	OA Stations	Length	Delay	Designed	User Cost
La Vega <-> Bonao (1)	300	0	0	34.8 km	0.174 ms	No	0.00
La Vega <-> Santiago (1)	300	0	0	33.8 km	0.169 ms	No	0.00
San Cristobal <-> Bonao (1)	300	0	0	66.7 km	0.334 ms	No	0.00
San Francisco <-> Cotui (1)	300	0	0	29.5 km	0.148 ms	No	0.00
Santiago <-> Puerto Plata (1)	300	0	0	35.5 km	0.178 ms	No	0.00
Santiago <-> San Francisco (1)	300	0	0	51.2 km	0.256 ms	No	0.00
Santo Domingo <-> Cotui (1)	300	0	0	68.4 km	0.342 ms	No	0.00
Santo Domingo <-> San Cristobal (1)	300	0	0	22.6 km	0.113 ms	No	0.00
Santo Domingo <-> San Pedro (1)	300	0	0	63.5 km	0.317 ms	No	0.00

Figure 8 - Link browser

The link information can be observed also in the Link Design Report that is displayed in figure 9.



The screenshot shows a window titled "Link Design Results" with a list of design reports for each link. Each report states the link name and length, followed by "0 Regeneration sites added;" and "0 OA sites added;".

```
Performed link design on La Vega <-> Santiago (1) (length = 33.782):  
0 Regeneration sites added;  
0 OA sites added;  
Performed link design on Santiago <-> San Francisco (1) (length = 51.1629):  
0 Regeneration sites added;  
0 OA sites added;  
Performed link design on Santo Domingo <-> San Cristobal (1) (length = 22.643):  
0 Regeneration sites added;  
0 OA sites added;  
Performed link design on Santo Domingo <-> San Pedro (1) (length = 63.4889):  
0 Regeneration sites added;  
0 OA sites added;  
Performed link design on Santiago <-> Puerto Plata (1) (length = 35.5341):  
0 Regeneration sites added;  
0 OA sites added;  
Performed link design on San Cristobal <-> Bonao (1) (length = 69.1597):  
0 Regeneration sites added;  
0 OA sites added;  
Performed link design on La Vega <-> Bonao (1) (length = 32.3127):  
0 Regeneration sites added;  
0 OA sites added;  
Performed link design on Cotui <-> San Francisco (1) (length = 28.1438):  
0 Regeneration sites added;  
0 OA sites added;  
Performed link design on Cotui <-> Santo Domingo (1) (length = 69.8346):  
0 Regeneration sites added;  
0 OA sites added;
```

Figure 9 - Link Design Report

## Routing Results

The routing results for OCH is shown in figure 10, in figure 11 the routing results for DCL is also displayed. Observe that in both routing results the routed traffic capacity is 100%, thus no dimensioning

was needed. Also observe that the link utilization in both results is a lot smaller than the threshold limit of 50%.

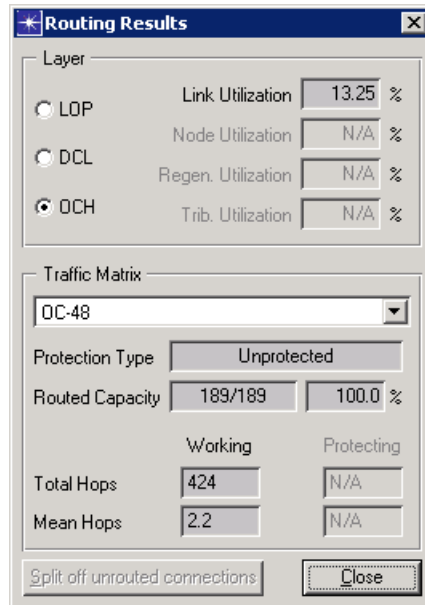


Figure 10 - OCH Routing Results

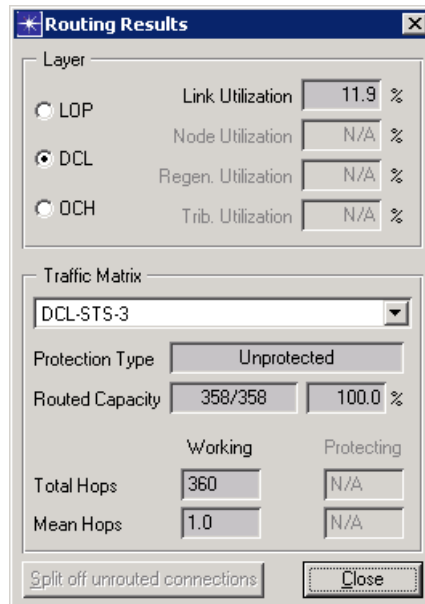


Figure 11 - DCL Routing Results

## Failure Analysis

A failure analysis is implemented to determine the reliability of the network; in this scenario a fail in the links for Santiago/Puerto Plata and Santo Domingo/San Pedro was introduced. In the results of the failure analysis we can see that 73 wavelengths are lost, also it is important to note that the entire network losses communication with Puerto Plata, this is an important issue because Puerto Plata provides connection to Internet through the ARCOS submarine optic cable.

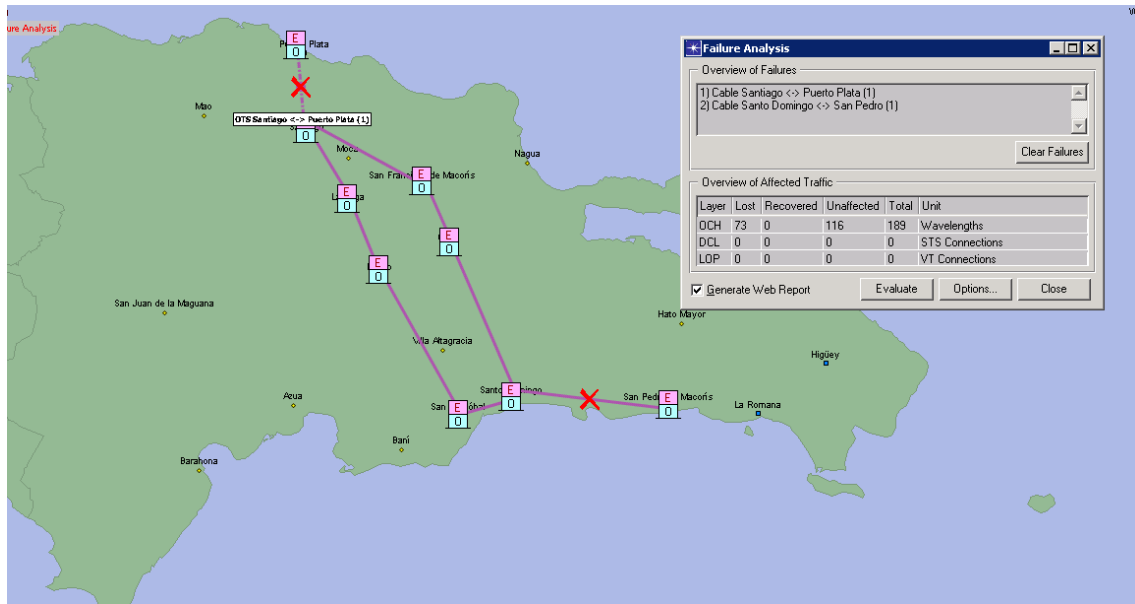


Figure 12 - Failure Analysis

## Network Cost

The figure 13 displays the Total Network Cost; observe that the node cost represents more than 80% of the total network cost.

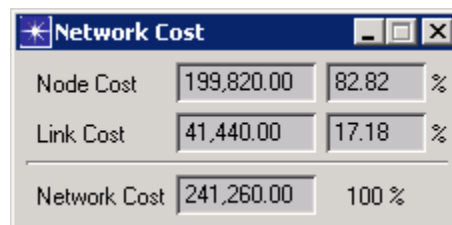


Figure 13 - Network Cost

## Traffic Variation

A random growth of 20% of traffic was added to the entire network to appreciate the performance of the network under these conditions. In figure 14 we can see that the increase in the total traffic by 20%

only produce a network utilization of 15.7%, less than two percent more than the original traffic; this data indicates that this network could support this grow without facing problems.

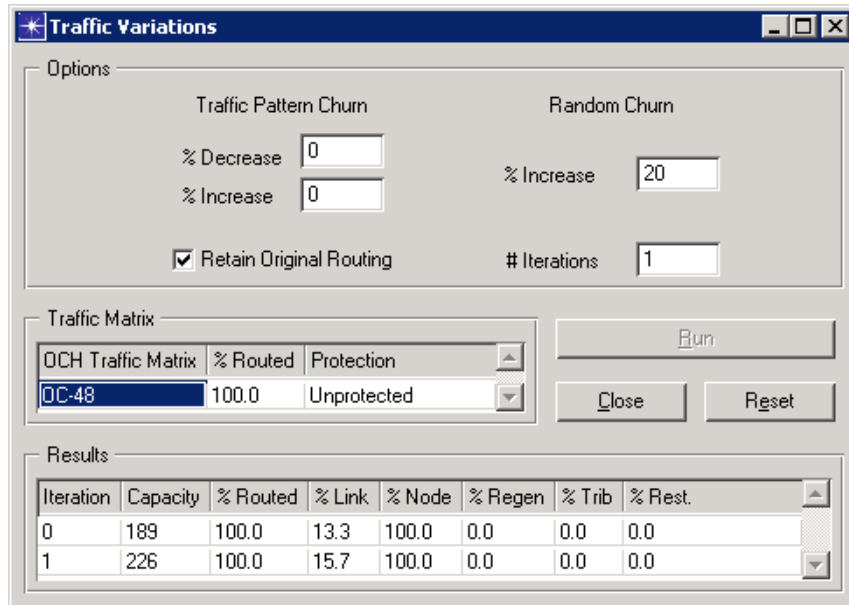


Figure 14 - Traffic Variation (a growth of 20% of the traffic)

## Second Scenario Design

### Network Topology

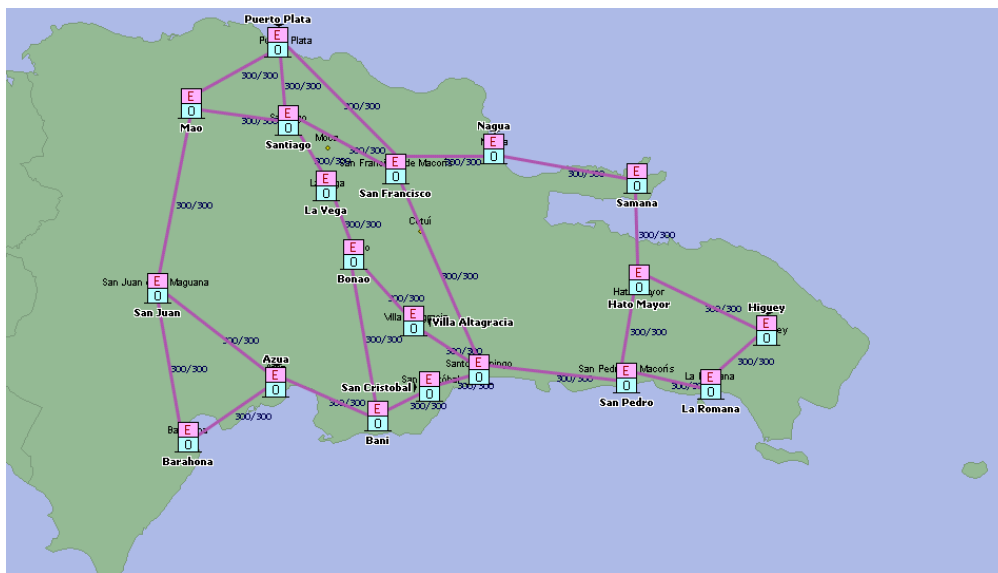


Figure 15 - Network Topology

## Traffic Matrix Editor

The figures 16 and 17 show the OCH Traffic Matrix and the DCL Traffic Matrix respectively, for the OCH Traffic a random traffic of wavelengths from 1 to 10 is used. For the DCL Traffic a random traffic from 1 to 20 (STS-3) is used.

The screenshot shows the Traffic Matrix Editor window with the OCH layer selected. The Traffic Matrix table is as follows:

	Azua	Bani	Barahona	Bonao	Hato Mayor	Higüey	La Romana	La Vega	Mao	Nagua	Puerto Plata	Samana	San Cristobal	San Francisco	San Juan	San Pedro	Santiago	Santo Domingo	Villa Altigracia
Azua	-	2	0	2	2	6	4	5	2	6	5	3	4	9	7	3	9	7	0
Bani	2	-	7	2	1	10	10	7	7	0	9	7	9	5	5	1	5	7	3
Barahona	0	7	-	1	1	8	3	7	3	7	1	2	3	5	0	0	5	7	2
Bonao	2	2	1	-	6	7	1	2	4	2	1	0	1	6	6	2	0	2	6
Hato Mayor	2	1	1	6	-	1	3	4	5	0	8	1	1	0	5	6	1	6	0
Higüey	6	10	8	7	1	-	9	9	7	5	0	10	10	3	0	0	4	7	6
La Romana	4	10	3	1	3	9	-	7	7	8	3	9	1	7	4	1	5	6	2
La Vega	5	7	7	2	4	9	7	-	5	0	9	6	7	10	4	5	6	10	6
Mao	2	7	3	4	5	7	7	5	-	6	9	9	6	9	2	3	5	10	10
Nagua	6	0	7	2	0	5	8	0	6	-	2	2	9	3	10	3	5	4	9
Puerto Plata	5	9	1	1	8	0	3	9	9	2	-	8	10	9	7	5	6	6	9
Samana	3	7	2	0	1	10	9	6	9	2	8	-	0	2	8	6	8	7	5
San Cristobal	4	9	3	1	1	10	1	7	6	9	10	0	-	4	6	8	7	0	7
San Francisco	9	5	5	6	0	3	7	10	9	3	9	2	4	-	7	3	10	6	7
San Juan	7	5	0	6	5	0	4	4	2	10	7	8	6	7	-	9	9	1	3
San Pedro	3	1	0	2	6	0	1	5	3	3	5	6	8	3	9	-	7	9	2
Santiago	9	5	5	0	1	4	5	6	5	5	6	8	7	10	9	7	-	6	5
Santo Domingo	7	7	7	2	6	7	6	10	10	4	6	7	0	6	1	9	6	-	7
Villa Altigracia	0	3	2	6	0	6	2	6	10	9	9	5	7	7	3	2	5	7	-

Figure 16 – OCH Traffic Matrix

The screenshot shows the Traffic Matrix Editor window with the DCL layer selected. The Traffic Matrix table is as follows:

	Azua	Bani	Barahona	Bonao	Hato Mayor	Higüey	La Romana	La Vega	Mao	Nagua	Puerto Plata	Samana	San Cristobal	San Francisco	San Juan	San Pedro	Santiago	Santo Domingo	Villa Altigracia
Azua	-	4	3	12	6	8	9	18	4	3	8	12	15	3	6	16	17	1	2
Bani	4	-	16	12	15	13	10	17	20	4	15	4	17	6	19	20	9	11	6
Barahona	3	16	-	16	19	4	19	1	11	11	15	13	17	11	10	17	12	5	9
Bonao	12	12	16	-	6	18	19	3	17	2	18	1	18	3	19	18	12	9	3
Hato Mayor	6	15	19	6	-	7	7	7	6	8	17	17	3	10	13	13	19	10	5
Higüey	8	13	4	18	7	-	4	19	10	1	17	13	17	18	10	17	16	13	16
La Romana	9	10	19	19	7	4	-	14	5	4	17	11	11	3	17	19	20	13	1
La Vega	18	17	1	3	7	19	14	-	9	6	14	8	16	18	11	14	8	11	10
Mao	4	20	11	17	6	10	5	9	-	1	8	8	10	5	4	3	20	17	7
Nagua	3	4	11	2	8	1	4	6	1	-	4	13	18	15	16	14	13	15	7
Puerto Plata	8	15	15	18	17	17	17	14	8	4	-	14	4	13	7	11	8	5	2
Samana	12	4	13	1	17	13	11	8	8	13	14	-	1	12	13	11	12	20	18
San Cristobal	15	17	17	18	3	17	11	16	10	18	4	1	-	2	4	1	5	3	18
San Francisco	3	6	11	3	10	18	3	18	5	15	13	12	2	-	12	7	11	9	1
San Juan	6	19	10	19	13	10	17	11	4	16	7	13	4	12	-	6	3	13	1
San Pedro	16	20	17	18	13	17	19	14	3	14	11	11	1	7	6	-	9	7	4
Santiago	17	9	12	12	19	16	20	8	20	13	8	12	5	11	3	9	-	2	13
Santo Domingo	1	11	5	9	10	13	13	11	17	15	5	20	3	9	13	7	2	-	15
Villa Altigracia	2	6	9	3	5	16	1	10	7	7	2	18	18	1	1	4	13	15	-

Figure 17 – DCL Traffic Matrix



Link Browser

Layer:  DCL  OCH  DMS  OTS

Network

Name	Fiber Pairs	Reg. Stations	OA Stations	Length	Delay	Designed	User Cost
Azua <-> Bani (1)	300	0	0	46.3 km	0.232 ms	Yes	0.00
Bani <-> Bonao (1)	300	0	0	73.8 km	0.369 ms	Yes	0.00
Bani <-> San Cristobal (1)	300	0	0	26.0 km	0.130 ms	Yes	0.00
Barahona <-> Azua (1)	300	0	0	45.1 km	0.225 ms	Yes	0.00
Barahona <-> San Juan (1)	300	0	0	68.7 km	0.344 ms	Yes	0.00
Bonao <-> La Vega (1)	300	0	0	33.2 km	0.166 ms	Yes	0.00
Bonao <-> Villa Altigracia (1)	300	0	0	39.8 km	0.199 ms	Yes	0.00
Hato Mayor <-> Higüey (1)	300	0	0	59.5 km	0.298 ms	Yes	0.00
Hato Mayor <-> Samana (1)	300	0	0	46.1 km	0.230 ms	Yes	0.00
Higüey <-> La Romana (1)	300	0	0	34.2 km	0.171 ms	Yes	0.00
La Romana <-> San Pedro (1)	300	0	0	36.4 km	0.182 ms	Yes	0.00
La Vega <-> Santiago (1)	300	0	0	33.8 km	0.169 ms	Yes	0.00
Mao <-> Puerto Plata (1)	300	0	0	46.4 km	0.232 ms	Yes	0.00
Mao <-> San Juan (1)	300	0	0	84.8 km	0.424 ms	Yes	0.00
Mao <-> Santiago (1)	300	0	0	42.1 km	0.211 ms	Yes	0.00
Nagua <-> Samana (1)	300	0	0	63.1 km	0.316 ms	Yes	0.00
San Francisco <-> Nagua (1)	300	0	0	42.8 km	0.214 ms	Yes	0.00
San Francisco <-> Puerto Plata (1)	300	0	0	76.3 km	0.381 ms	Yes	0.00
San Francisco <-> Santo Domingo (1)	300	0	0	97.1 km	0.485 ms	Yes	0.00
San Juan <-> Azua (1)	300	0	0	66.3 km	0.331 ms	Yes	0.00
San Pedro <-> Hato Mayor (1)	300	0	0	44.5 km	0.223 ms	Yes	0.00
Santiago <-> Puerto Plata (1)	300	0	0	35.5 km	0.178 ms	Yes	0.00
Santiago <-> San Francisco (1)	300	0	0	51.2 km	0.256 ms	Yes	0.00
Santo Domingo <-> San Cristobal (1)	300	0	0	22.6 km	0.113 ms	Yes	0.00
Santo Domingo <-> San Pedro (1)	300	0	0	63.5 km	0.317 ms	Yes	0.00
Villa Altigracia <-> Santo Domingo (1)	300	0	0	35.8 km	0.179 ms	Yes	0.00

Show designations  Show fibers  Show in-line sites

Close

Figure 19 - Link Brower Traffic

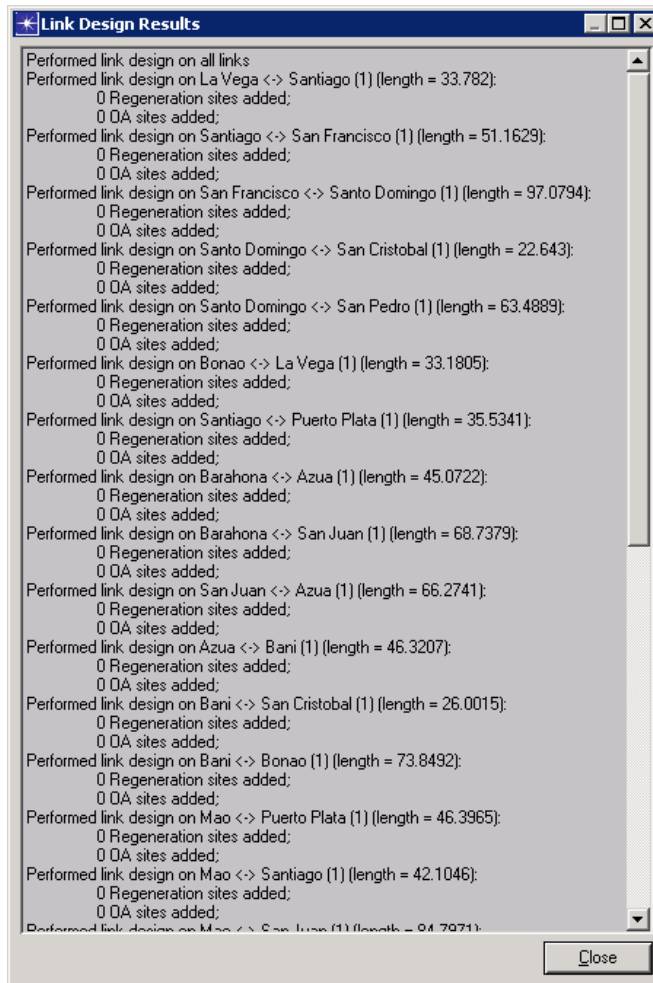


Figure 20 - Link Design Report

### Routing Results

The routing results for OCH is shown in figure 21, in figure 22 the routing results for DCL is also displayed. Observe that in both routing results the routed traffic capacity is 100%, thus no dimensioning was needed. Also observe that the link utilization in both results is a lot smaller than the threshold limit of 50%.

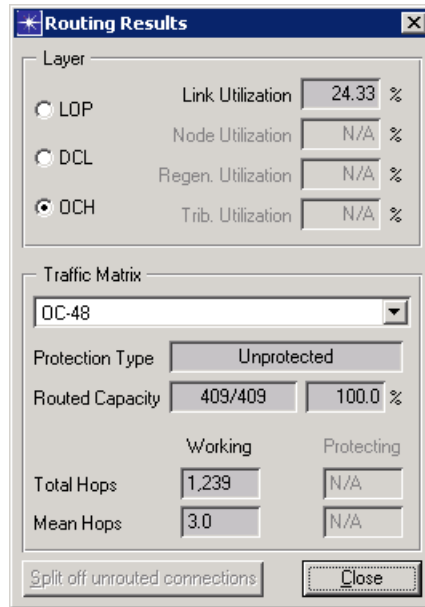


Figure 21 - OCH Routing Results

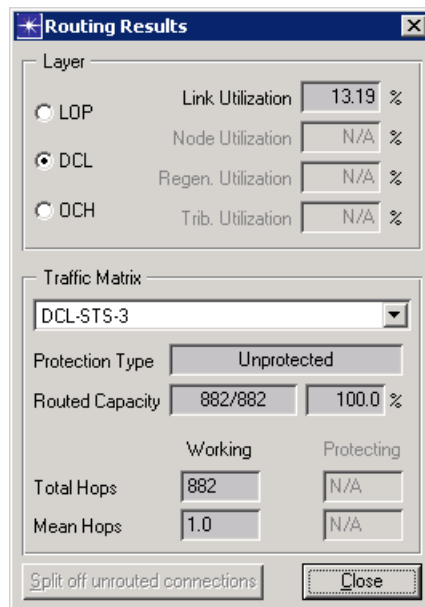


Figure 22 - DCL Routing Results

### Failure Analysis

A failure analysis is implemented to determine the reliability of this second network; in this scenario the same fail in the links for Santiago/Puerto Plata and Santo Domingo/San Pedro is introduced. In the results of the failure analysis we can see that 225 wavelengths and 581 STS connections are lost, but in

this scenario the network do not drop the communication with Puerto Plata and the network keep working after this failure.

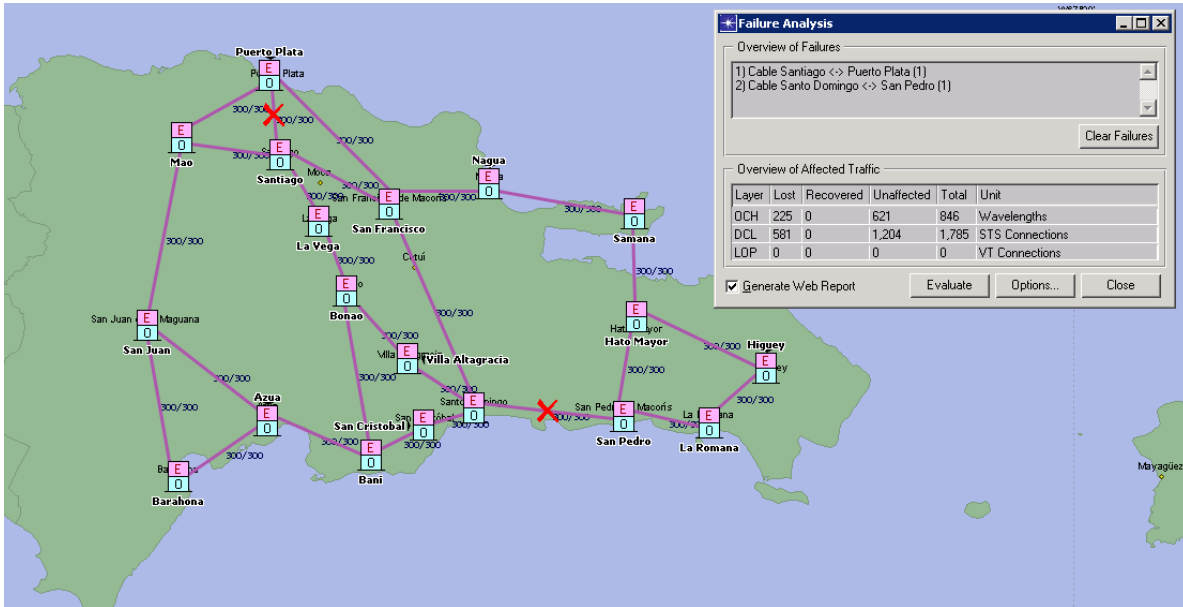


Figure 23 - Failure Analysis

### Network Cost

The figure 24 displays the Total Network Cost; observe that in this second scenario the node cost represents a little bit more than 72% of the total network cost.

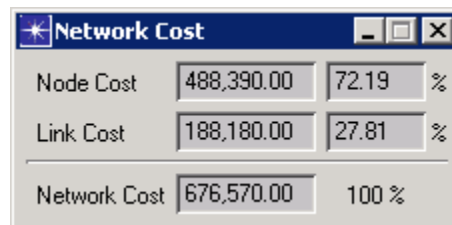


Figure 24 - Total Network Cost

### Traffic Variation

A random growth of 20% of traffic was also added to the entire network in this scenario to appreciate the performance of the network under these conditions. In figure 25 we can see that the increase in the total traffic by 20% only produce a network utilization of 28.9%, a little bit more than four percent more

than the original traffic; this data indicates that this network could support this grow without facing problems.

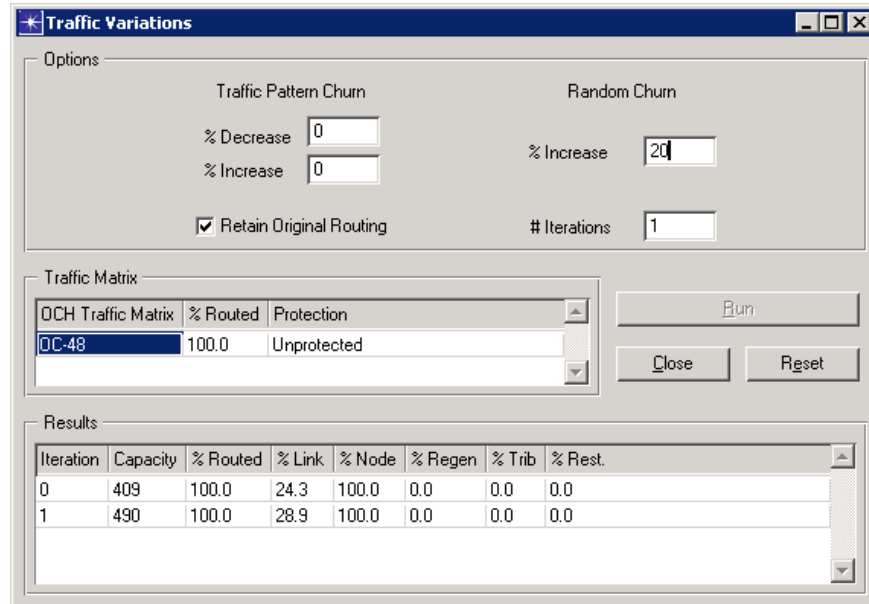


Figure 25 - Traffic Variation (a growth of 20% of the traffic)

## Networks Comparison

In figures 26, 27 and 28 we can see that the cost for the second scenario is bigger, as expected; cause of the increase in the number of nodes and links; but this increase is also reflected in the total capacity of the network as indicated in figures 29 and 30 where OCH and DCL total capacity are shown respectively.

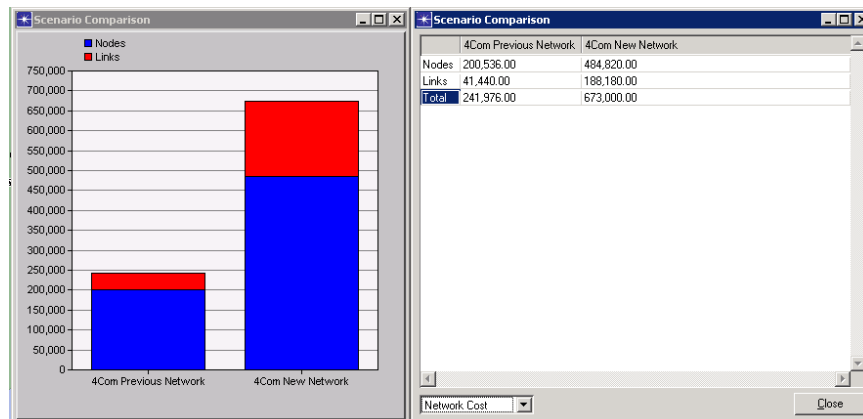


Figure 26 - Network Cost

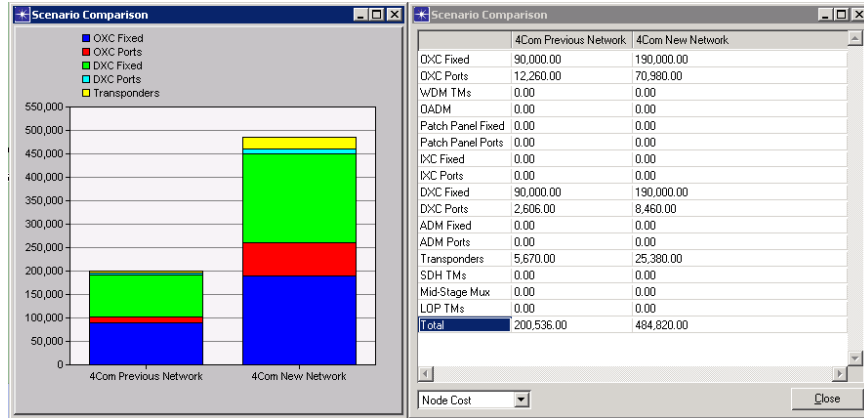


Figure 27 - Node Cost

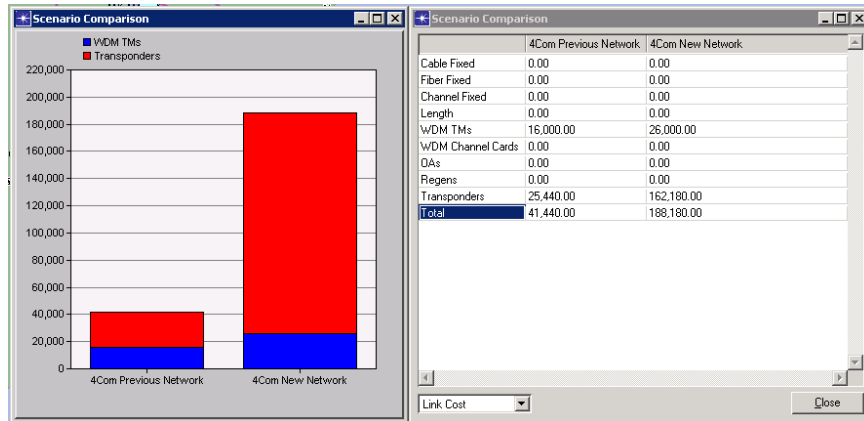


Figure 28 - Link Cost

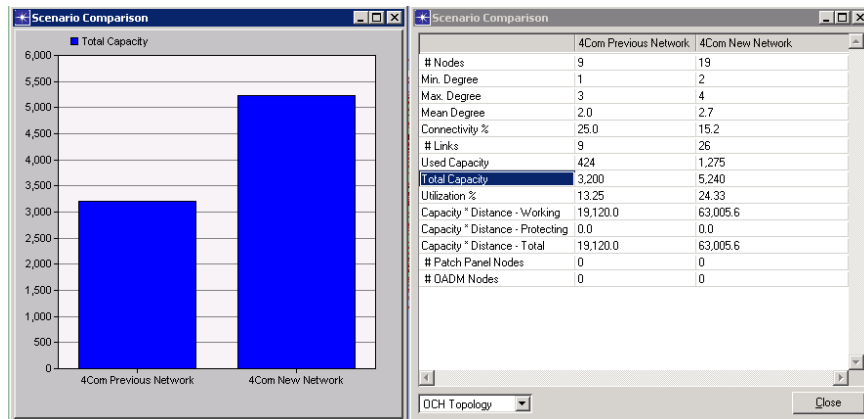


Figure 29 - OCH Total Capacity

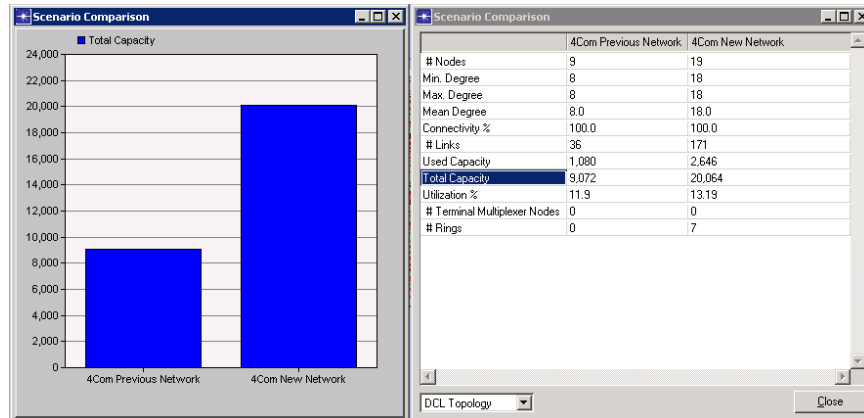


Figure 30 - DCL Total Capacity

## Conclusions

The implementation of a new backbone fiber network is a real need for 4Com, especially after the imminent growth of the bandwidth requirements by the new customers. This growth in the bandwidth requirements and the fact that 4Com wants to expand its services to ten (10) new cities are more than enough justification to implement the new network. However, there is another reason to implement this new network that is to make it more reliable; the reliability problem of the actual network can be easily noted by observing the failure analysis for both scenarios, where the fragility of the optical network of the first scenario is highlighted. Damage in some points and/or nodes of the first scenario could divide the entire network and in the case of Puerto Plata city isolate the access to a high bandwidth access point to the Internet. The fact that the second scenario is a partially meshed network, where no articulation point is present, ensures a more reliable backbone network to support the high capacity demand for the customers of 4Com.

The cost analysis for both scenarios shows how more expensive the implementation of the second scenario is compared to the first (see figures 26, 27 and 28). However, this extra cost is justified by the expected growth in the amount of customers in the new cities where 4Com will offer its services.

Finally to mention that 4Com was worried about if the new network could support any future growth and to test this, a 20% of traffic was added to the expected traffic in the new scenario to see the behavior of the network. The results of this test indicate that the new network could handle this type of growth without inconvenience (see figure 25).