WAN/LAN PLAN&DESIGN

GRADUATE PROJECT

Qian Li (Alison)

4/24/2008

WAN/LAN Planing&Design
Professor Ronald G. Fulle
0614.774.01
Due April 24, 2008

Purpose

The purpose of this project is to design and develop a network, then to test different "what-if" scenarios with varying topologies, traffic matrices, and configurations. Network I can use reporting features to compare the results of different scenarios, and thereby determine the most effective and least costly network designs to meet future demands. To accomplish this purpose I will create two baseline scenarios, both of them use the map of China. One is transparent in OCH layer, and the other is opaque in OCH layer. The networks must be robust, optimal design. The function of two scenarios is to implement communication through whole country area. They represent one worldwide big telecommunication company named QL Communication Corporation, Ltd. All these requirements decide my topologies and network performance. In the end of this project, I will compare two scenarios, and give the answer of which one is better.

Resources

This project was completed by using software SP Guru Transport Planner 14.0, Educational Version by OPNET Technologies, Inc.

Approach

Baseline Scenarios

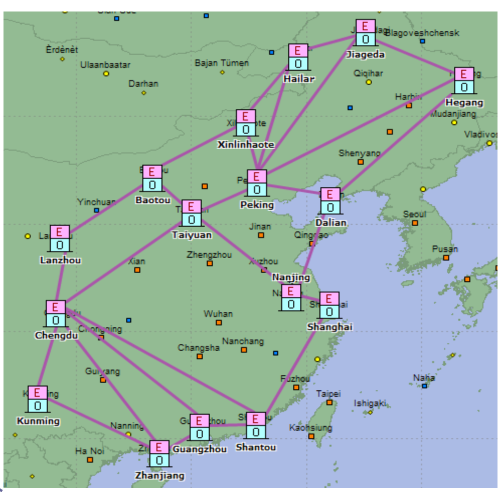
1. Create one new project with two scenarios

First step, I created two scenarios of my project, the topology is based on the Map of China, as our company provides nationwide communication of China.

Scenario 1—China (Transparent)

Name: Nationwide Communication of China

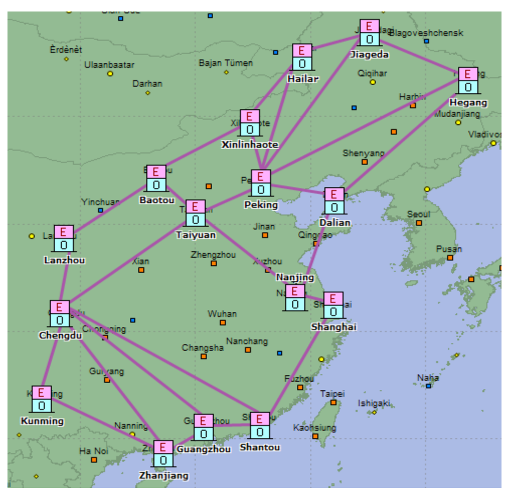
Network Topology:



Scenario 2— China (Opaque)

Name: Nationwide Communication of China

Network Topology:



2. Define the network topology

1. The topologies are same in my project:
   Nodes: 16
   Links: 26

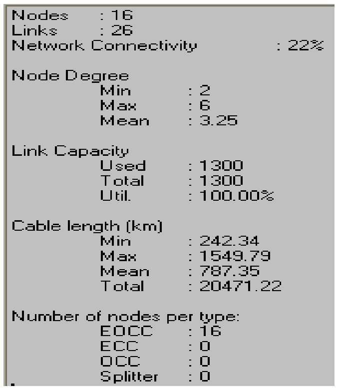


Fig 1- OTS layer topology

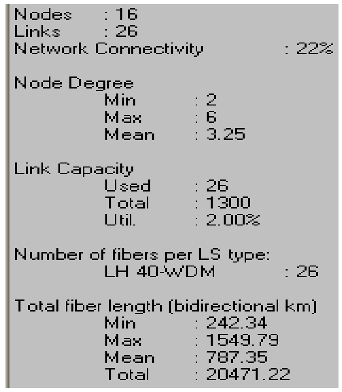


Fig 2- OMS layer topology

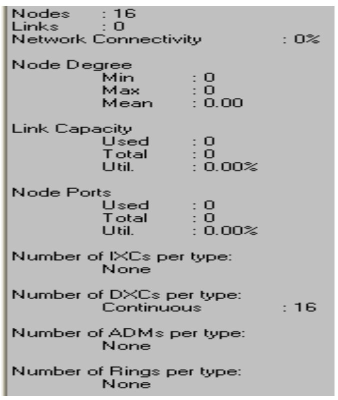


Fig4 - DCL layer topology

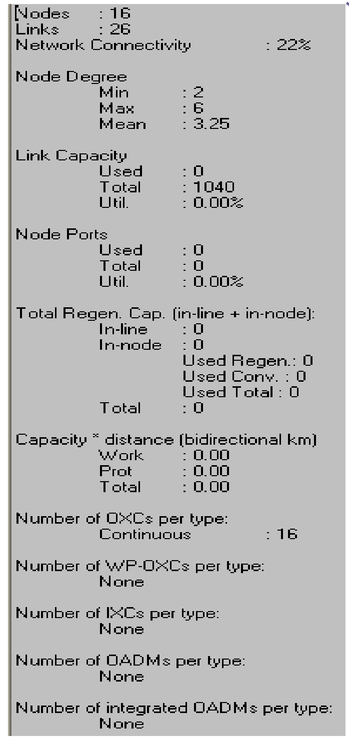


Fig3 - OCH layer topology

(Above figs are the layer topology details of scenario1, those are different from scenario2. At the end of the project, I will compare the result of two scenarios.)

3. Define the network properties:

In this part, I set properties such as transparency and opaque mode, node types.

1. I set specific properties for networks.
   Layer Details: there are 4 layers in my project, for each layer there are specific properties for links and devices based on different layer's function.

   Link design: bellowing is the result

Performed link design on Chengdu <-> Zhanjiang (1) (length = 1275.55):
2 Regeneration sites added at 500, and 1000 km;
10 OA sites added at 100, 200, 300, 400, 600, 700,
800, 900, 1100, and 1200 km;
Performed link design on Chengdu <-> Guangzhou (1) (length = 1278.64):
2 Regeneration sites added at 500, and 1000 km;
10 OA sites added at 100, 200, 300, 400, 600, 700,
800, 900, 1100, and 1200 km;
Performed link design on Chengdu <-> Shantou (1) (length = 1549.79):
2 Regeneration sites added at 600, and 1200 km;
13 OA sites added at 100, 200, 300, 400, 500, 700,
800, 900, 1000, 1100, 1300, 1400, and 1500 km;
Performed link design on Peking <-> Hailar (1) (length = 1001.45):
1 Regeneration sites added at 600 km;
9 OA sites added at 100, 200, 300, 400, 500, 700,
800, 900, and 1000 km;
Performed link design on Peking <-> Jiageda (1) (length = 1293.4):
2 Regeneration sites added at 500, and 1000 km;
10 OA sites added at 100, 200, 300, 400, 600, 700,
800, 900, 1100, and 1200 km;
Performed link design on Peking <-> Hegang (1) (length = 1342.05):
2 Regeneration sites added at 500, and 1000 km;
11 OA sites added at 100, 200, 300, 400, 600, 700,
800, 900, 1100, 1200, and 1300 km;
Performed link design on Taiyuan <-> Chengdu (1) (length = 1121.97):
1 Regeneration sites added at 600 km;
10 OA sites added at 100, 200, 300, 400, 500, 700,
800, 900, 1000, and 1100 km;
Performed link design on Taiyuan <-> Nanjing (1) (length = 881.756):
1 Regeneration sites added at 500 km;
7 OA sites added at 100, 200, 300, 400, 600, 700,
and 800 km;

Fig 5- link design result

Network

Designation	Fiber Pairs	Reg. Stations	OA Stations	Length	Delay	Designed	User Cost
[Baotou <-> Xinlinhaote (1)]	50	1	5	664.7 km	3.323 ms	Yes	0.00
[Chengdu <-> Guangzhou (1)]	50	2	10	1,278.6 km	6.393 ms	Yes	0.00
[Chengdu <-> Shantou (1)]	50	2	13	1,549.8 km	7.749 ms	Yes	0.00
[Chengdu <-> Zhanjiang (1)]	50	2	10	1,275.6 km	6.378 ms	Yes	0.00
[Dalian <-> Hegang (1)]	50	1	10	1,169.8 km	5.849 ms	Yes	0.00
[Guangzhou <-> Shantou (1)]	50	0	3	373.6 km	1.868 ms	Yes	0.00
[Hailar <-> Jiageda (1)]	50	0	3	367.6 km	1.838 ms	Yes	0.00
[Hegang <-> Jiageda (1)]	50	1	5	602.0 km	3.010 ms	Yes	0.00
[Kunming <-> Chengdu (1)]	50	1	5	677.1 km	3.386 ms	Yes	0.00
[Kunming <-> Zhanjiang (1)]	50	1	8	913.5 km	4.568 ms	Yes	0.00
[Lanzhou <-> Baotou (1)]	50	1	5	699.2 km	3.496 ms	Yes	0.00
[Lanzhou <-> Chengdu (1)]	50	0	5	585.8 km	2.929 ms	Yes	0.00
[Nanjing <-> Dalian (1)]	50	1	6	788.5 km	3.943 ms	Yes	0.00
[Peking <-> Dalian (1)]	50	0	4	429.7 km	2.148 ms	Yes	0.00
[Peking <-> Hailar (1)]	50	1	9	1,001.5 km	5.007 ms	Yes	0.00
[Peking <-> Hegang (1)]	50	2	11	1,342.0 km	6.710 ms	Yes	0.00
[Peking <-> Jiageda (1)]	50	2	10	1,293.4 km	6.467 ms	Yes	0.00
[Peking <-> Xinlinhaote (1)]	50	0	4	476.6 km	2.383 ms	Yes	0.00
[Shanghai <-> Nanjing (1)]	50	0	2	242.3 km	1.212 ms	Yes	0.00
[Shantou <-> Shanghai (1)]	50	1	9	1,046.0 km	5.230 ms	Yes	0.00
[Taiyuan <-> Baotou (1)]	50	0	3	352.3 km	1.762 ms	Yes	0.00
[Taiyuan <-> Chengdu (1)]	50	1	10	1,122.0 km	5.610 ms	Yes	0.00
[Taiyuan <-> Nanjing (1)]	50	1	7	881.8 km	4.409 ms	Yes	0.00
[Taiyuan <-> Peking (1)]	50	0	4	435.1 km	2.176 ms	Yes	0.00
[Xinlinhaote <-> Hailar (1)]	50	0	5	568.0 km	2.840 ms	Yes	0.00
[Zhanjiang <-> Guangzhou (1)]	50	0	3	334.7 km	1.673 ms	Yes	0.00

Fig 6- OTS layer link browser

Network

Name	Fiber Pairs	Length	Delay	User Cost
Baotou <-> Xinlinhaote (1)	1/50	664.7 km	3.323 ms	1.00
Chengdu <-> Guangzhou (1)	1/50	1,278.6 km	6.393 ms	1.00
Chengdu <-> Shantou (1)	1/50	1,549.8 km	7.749 ms	1.00
Chengdu <-> Zhanjiang (1)	1/50	1,275.6 km	6.378 ms	1.00
Dalian <-> Hegang (1)	1/50	1,169.8 km	5.849 ms	1.00
Guangzhou <-> Shantou (1)	1/50	373.6 km	1.868 ms	1.00
Hailar <-> Jiageda (1)	1/50	367.6 km	1.838 ms	1.00
Hegang <-> Jiageda (1)	1/50	602.0 km	3.010 ms	1.00
Kunming <-> Chengdu (1)	1/50	677.1 km	3.386 ms	1.00
Kunming <-> Zhanjiang (1)	1/50	913.5 km	4.568 ms	1.00
Lanzhou <-> Baotou (1)	1/50	699.2 km	3.496 ms	1.00
Lanzhou <-> Chengdu (1)	1/50	585.8 km	2.929 ms	1.00
Nanjing <-> Dalian (1)	1/50	788.5 km	3.943 ms	1.00
Peking <-> Dalian (1)	1/50	429.7 km	2.148 ms	1.00
Peking <-> Hailar (1)	1/50	1,001.5 km	5.007 ms	1.00
Peking <-> Hegang (1)	1/50	1,342.0 km	6.710 ms	1.00
Peking <-> Jiageda (1)	1/50	1,293.4 km	6.467 ms	1.00
Peking <-> Xinlinhaote (1)	1/50	476.6 km	2.383 ms	1.00
Shanghai <-> Nanjing (1)	1/50	242.3 km	1.212 ms	1.00
Shantou <-> Shanghai (1)	1/50	1,046.0 km	5.230 ms	1.00
Taiyuan <-> Baotou (1)	1/50	352.3 km	1.762 ms	1.00
Taiyuan <-> Chengdu (1)	1/50	1,122.0 km	5.610 ms	1.00
Taiyuan <-> Nanjing (1)	1/50	881.8 km	4.409 ms	1.00
Taiyuan <-> Peking (1)	1/50	435.1 km	2.176 ms	1.00
Xinlinhaote <-> Hailar (1)	1/50	568.0 km	2.840 ms	1.00
Zhanjiang <-> Guangzhou (1)	1/50	334.7 km	1.673 ms	1.00

Fig 7- OMS layer link browser

Network

Name	Default LS Type	Wavelengths	Working	Protecting	Shared	User Cost		
Baotou <-> Xinlinhaote (1)	LH 40-WDM	0/40	0	0	0	1.00		
Designation	Line System Type	Bands	Band 1	Band 2	Band 3	Total	Length	Delay
[Baotou <-> Xinlinhaote (2)]	LH 40-WDM	3/3	0/8	0/8	0/24	0/40	664.7 km	3.323 ms
Chengdu <-> Guangzhou (1)	LH 40-WDM	0/40	0	0	0	1.00		
Designation	Line System Type	Bands	Band 1	Band 2	Band 3	Total	Length	Delay
[Chengdu <-> Guangzhou (2)]	LH 40-WDM	3/3	0/8	0/8	0/24	0/40	1,278.6 km	6.393 ms
Chengdu <-> Shantou (1)	LH 40-WDM	0/40	0	0	0	1.00		
Designation	Line System Type	Bands	Band 1	Band 2	Band 3	Total	Length	Delay
[Chengdu <-> Shantou (2)]	LH 40-WDM	3/3	0/8	0/8	0/24	0/40	1,549.8 km	7.749 ms
Chengdu <-> Zhanjiang (1)	LH 40-WDM	0/40	0	0	0	1.00		
Dalian <-> Hegang (1)	LH 40-WDM	0/40	0	0	0	1.00		
Guangzhou <-> Shantou (1)	LH 40-WDM	0/40	0	0	0	1.00		
Hailar <-> Jiageda (1)	LH 40-WDM	0/40	0	0	0	1.00		
Hegang <-> Jiageda (1)	LH 40-WDM	0/40	0	0	0	1.00		
Kunming <-> Chengdu (1)	LH 40-WDM	0/40	0	0	0	1.00		
Kunming <-> Zhanjiang (1)	LH 40-WDM	0/40	0	0	0	1.00		
Lanzhou <-> Baotou (1)	LH 40-WDM	0/40	0	0	0	1.00		
Lanzhou <-> Chengdu (1)	LH 40-WDM	0/40	0	0	0	1.00		
Nanjing <-> Dalian (1)	LH 40-WDM	0/40	0	0	0	1.00		
Peking <-> Dalian (1)	LH 40-WDM	0/40	0	0	0	1.00		
Peking <-> Hailar (1)	LH 40-WDM	0/40	0	0	0	1.00		
Peking <-> Hegang (1)	LH 40-WDM	0/40	0	0	0	1.00		
Peking <-> Jiageda (1)	LH 40-WDM	0/40	0	0	0	1.00		
Peking <-> Xinlinhaote (1)	LH 40-WDM	0/40	0	0	0	1.00		
Shanghai <-> Nanjing (1)	LH 40-WDM	0/40	0	0	0	1.00		
Shantou <-> Shanghai (1)	LH 40-WDM	0/40	0	0	0	1.00		
Taiyuan <-> Baotou (1)	LH 40-WDM	0/40	0	0	0	1.00		
Taiyuan <-> Chengdu (1)	LH 40-WDM	0/40	0	0	0	1.00		
Taiyuan <-> Nanjing (1)	LH 40-WDM	0/40	0	0	0	1.00		
Taiyuan <-> Peking (1)	LH 40-WDM	0/40	0	0	0	1.00		
Xinlinhaote <-> Hailar (1)	LH 40-WDM	0/40	0	0	0	1.00		
Zhanjiang <-> Guangzhou (1)	LH 40-WDM	0/40	0	0	0	1.00		

Fig 8- OCH layer link browser

I didn't specifically set DCL link. Later, when I dimension my project, DCL layer will be mesh topology.

Node Design:

Network

Node ID	Latitude	Longitude	Type
Baotou	40.56	109.95	EOCC
Chengdu	31.12	103.7	EOCC
Dalian	38.974	121.55	EOCC
Guangzhou	23.186	113.05	EOCC
Hailar	48.99	119.5	EOCC
Hegang	47.34	130.3	EOCC
Jiageda	50.725	123.86	EOCC
Kunming	25.13	102.5	EOCC
Lanzhou	36.378	103.96	EOCC
Nanjing	32.2	119.0	EOCC
Peking	40.2	116.8	EOCC
Shanghai	31.71	121.5	EOCC
Shantou	23.33	116.7	EOCC
Taiyuan	38.109	112.54	EOCC
Xinlinhaote	44.45	116.1	EOCC
Zhanjiang	21.383	110.45	EOCC

Fig 9- OTS layer node browser

Network

Node ID	Fiber Capacity
Baotou	0/150
Chengdu	0/300
Dalian	0/150
Guangzhou	0/150
Hailar	0/150
Hegang	0/150
Jiageda	0/150
Kunming	0/100
Lanzhou	0/100
Nanjing	0/150
Peking	0/300
Shanghai	0/100
Shantou	0/150
Taiyuan	0/200
Xinlinhaote	0/150
Zhanjiang	0/150

Fig 10- OMS layer node browser

Network

Node ID	Node Type	Trib Ports	Trunk Ports	Total Ports		
Baotou	OXC	0	0	0		
Type		Trib Ports	Trunk Ports	Total Ports	Transp. Units (SR)	Prot. Transp. Units (SR)
OXC Continuous		0	0	0	0	0
Chengdu	OXC	0	0	0		
Type		Trib Ports	Trunk Ports	Total Ports	Transp. Units (SR)	Prot. Transp. Units (SR)
OXC Continuous		0	0	0	0	0
Dalian	OXC	0	0	0		
Type		Trib Ports	Trunk Ports	Total Ports	Transp. Units (SR)	Prot. Transp. Units (SR)
OXC Continuous		0	0	0	0	0
Guangzhou	OXC	0	0	0		
Hailar	OXC	0	0	0		
Hegang	OXC	0	0	0		
Jiageda	OXC	0	0	0		
Kunming	OXC	0	0	0		
Lanzhou	OXC	0	0	0		
Nanjing	OXC	0	0	0		
Peking	OXC	0	0	0		
Shanghai	OXC	0	0	0		
Shantou	OXC	0	0	0		
Taiyuan	OXC	0	0	0		
Xinlinhaote	OXC	0	0	0		
Zhanjiang	OXC	0	0	0		

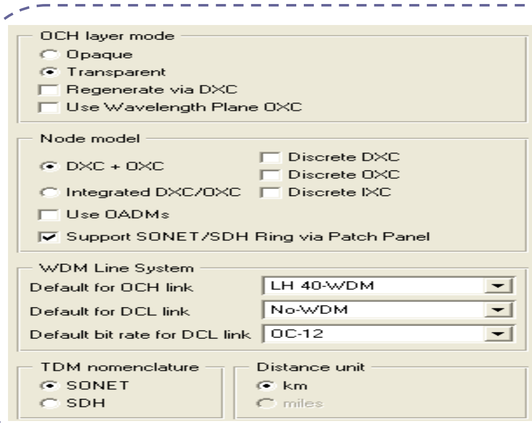
Fig 11- OCH layer node browser (before changing traffic)

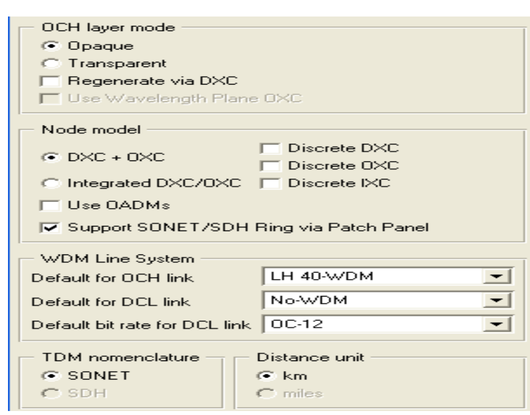
Network

Node ID	Node Type	Trib Ports	Trunk Ports	Total Ports	Grooming	Ring Interconnection
Baotou	DXC	0	0	0	Yes	ADM back-to-back
Type	Trib Ports	Trunk Ports	Total Ports	Terminal Mux	Mid-Stage Mux	
DXC Continuous	0	0	0/0	0	0	
Chengdu	DXC	0	0	0	Yes	ADM back-to-back
Type	Trib Ports	Trunk Ports	Total Ports	Terminal Mux	Mid-Stage Mux	
DXC Continuous	0	0	0/0	0	0	
Dalian	DXC	0	0	0	Yes	ADM back-to-back
Type	Trib Ports	Trunk Ports	Total Ports	Terminal Mux	Mid-Stage Mux	
DXC Continuous	0	0	0/0	0	0	
Guangzhou	DXC	0	0	0	Yes	ADM back-to-back
Hailar	DXC	0	0	0	Yes	ADM back-to-back
Hegang	DXC	0	0	0	Yes	ADM back-to-back
Jiageda	DXC	0	0	0	Yes	ADM back-to-back
Kunming	DXC	0	0	0	Yes	ADM back-to-back
Lanzhou	DXC	0	0	0	Yes	ADM back-to-back
Nanjing	DXC	0	0	0	Yes	ADM back-to-back
Peking	DXC	0	0	0	Yes	ADM back-to-back
Shanghai	DXC	0	0	0	Yes	ADM back-to-back
Shantou	DXC	0	0	0	Yes	ADM back-to-back
Taiyuan	DXC	0	0	0	Yes	ADM back-to-back
Xinlinhaote	DXC	0	0	0	Yes	ADM back-to-back
Zhanjiang	DXC	0	0	0	Yes	ADM back-to-back

Fig 12- DCL layer node browser (before changing traffic)

I use default equipment properties, which are shown below:

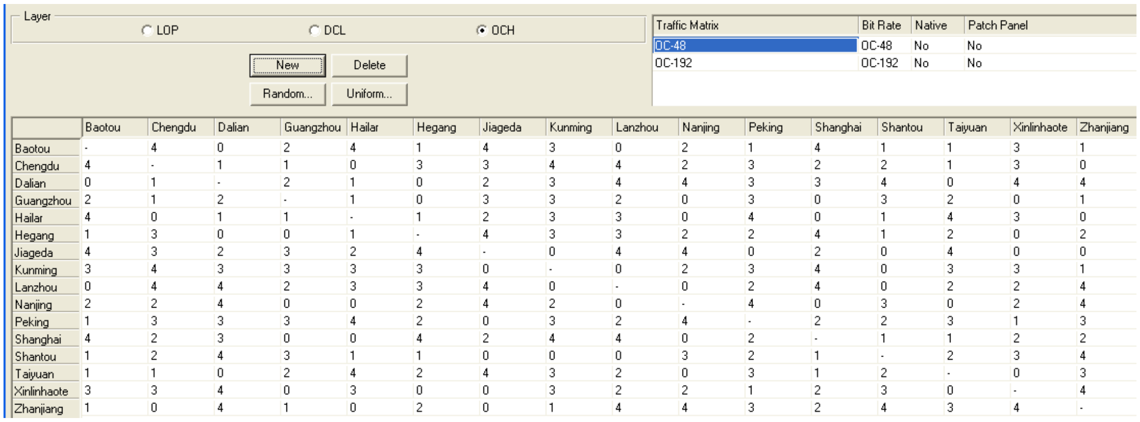




All these properties include cable costs, fiber costs, and optical channel costs, etc. And equipment properties are same in my two scenarios.

4. Creating traffic matrices

The final step is to create one or more traffic matrices and run the simulation.
Bellowing is a part of my traffic matrices:



Traffic Matrix	Bit Rate	Native	Patch Panel
OC-48	OC-48	No	No
OC-192	OC-192	No	No

	Baotou	Chengdu	Dalian	Guangzhou	Hailar	Hegang	Jiageda	Kunming	Lanzhou	Nanjing	Peking	Shanghai	Shantou	Taiyuan	Xinlinhaote	Zhanjiang
Baotou	-	4	0	2	4	1	4	3	0	2	1	4	1	1	3	1
Chengdu	4	-	1	1	0	3	3	4	4	2	3	2	2	1	3	0
Dalian	0	1	-	2	1	0	2	3	4	4	3	3	4	0	4	4
Guangzhou	2	1	2	-	1	0	3	3	2	0	3	0	3	2	0	1
Hailar	4	0	1	1	-	1	2	3	3	0	4	0	1	4	3	0
Hegang	1	3	0	0	1	-	4	3	3	2	2	4	1	2	0	2
Jiageda	4	3	2	3	2	4	-	0	4	4	0	2	0	4	0	0
Kunming	3	4	3	3	3	3	0	-	0	2	3	4	0	3	3	1
Lanzhou	0	4	4	2	3	3	4	0	-	0	2	4	0	2	2	4
Nanjing	2	2	4	0	0	2	4	2	0	-	4	0	3	0	2	4
Peking	1	3	3	3	4	2	0	3	2	4	-	2	2	3	1	3
Shanghai	4	2	3	0	0	4	2	4	4	0	2	-	1	1	2	2
Shantou	1	2	4	3	1	1	0	0	0	3	2	1	-	2	3	4
Taiyuan	1	1	0	2	4	2	4	3	2	0	3	1	2	-	0	3
Xinlinhaote	3	3	4	0	3	0	0	3	2	2	1	2	3	0	-	4
Zhanjiang	1	0	4	1	0	2	0	1	4	4	3	2	4	3	4	-

I created traffic matrices for OCH, and DCL layer.

5. Other network settings

1) Delay Setting: Propagation delay: 0.005000 ms/km
2) Link Availability: 1.00000000
3) Link Usage Thresholds: all 1.000

Analysis Results

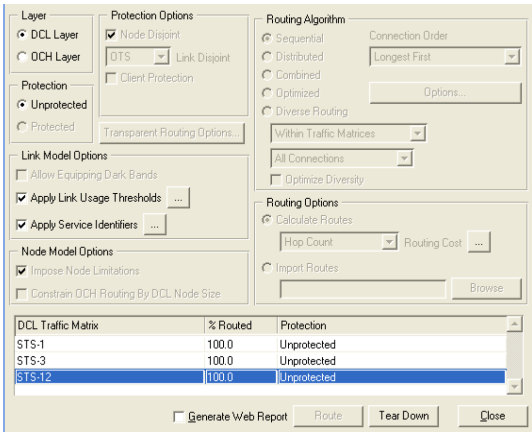
I analysis the network based on collected simulation results.

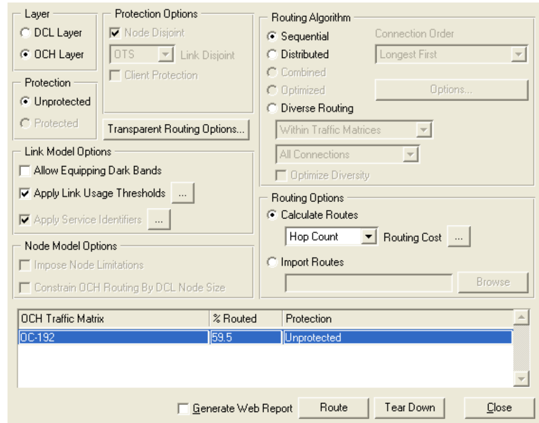
The main objectives of the range tests would be

a) Wavelength Usage
b) Evaluate Availability
c) Failure Analysis
d) Cost Analysis

1. Route DCL/OCH Traffic

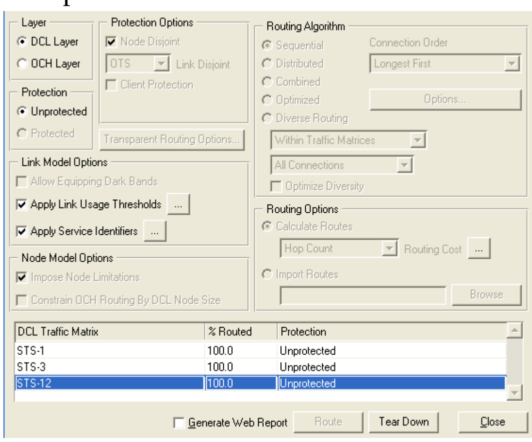
Opaque:

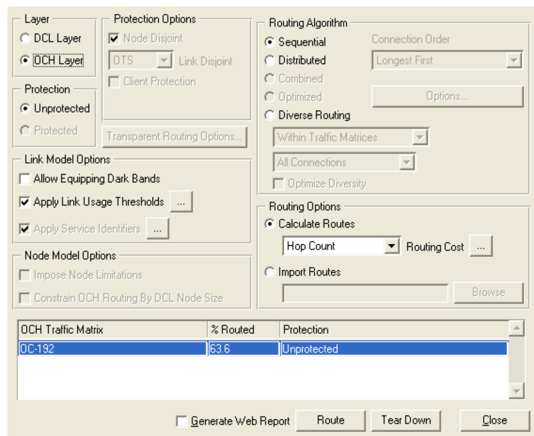




In DCL layer, traffics are 100% routed, in OCH layer are 59.5%.

Transparent:





In DCL layer, traffics are 100% routed, in OCH layer are 63.6%.

The result of my project:

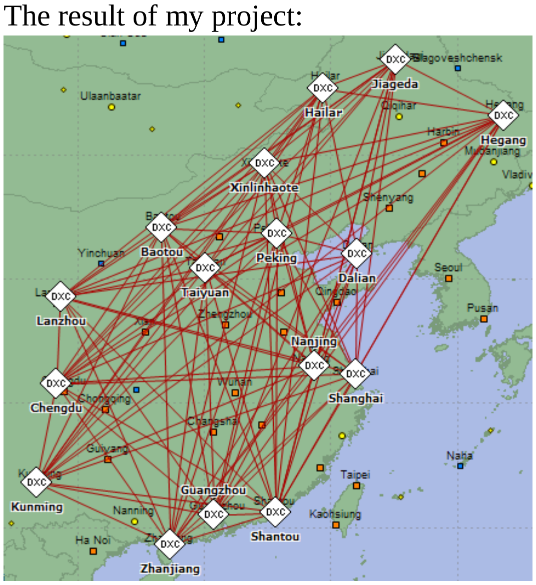


Fig 13- DCL layer logical link

2. Dimension DCL/OCH Layer

When you dimension a network at a network layer, SP Guru Transport Planner installs the required node and link equipment to support a traffic matrix at that layer. SP Guru Transport Planner performs upgrade dimensioning: it upgrades the network equipment to meet the new traffic demands, but retains existing equipment and traffic. The reason why I used dimension can be seen from following test: (I tested the network after I changed network topology to get lower OCH layer utilization.)

Before dimension:

Layer	Number of Links	Link Utilization			Used Capacity	Total Capacity	Utilization (%)	Unit
		Between 100.0 and 90.0 %	Between 90.0 and 75.0 %	Between 75.0 and 0.0 %				
OTS	26	26	0	0	1,300	1,300	100.00	Fiber Pairs
OMS	26	0	0	26	57	1,300	4.38	Fiber Pairs
OCH	26	3	1	22	1,117	2,280	48.99	Wavelengths
DCL	115	0	5	110	4,625	38,880	11.90	STS-1 Units

After dimension:

Dimension OC-48

Traffic Matrix	Newly Routed Connections	Total Routed Connections	Demanded Connections	Percent Routed	Total Hops of Working Paths	Mean Hops of Working Paths
OC-48	322	322	322	100.0	818	2.540

Utilization

Variable	Value
OCH Used Link Capacity	818 wavelengths
OCH Equipped Link Capacity	2,280 wavelengths
OCH Link Utilization	35.88%
OCH Node Utilization	100.0%

Dimension OC-192

Traffic Matrix	Newly Routed Connections	Total Routed Connections	Demanded Connections	Percent Routed	Total Hops of Working Paths	Mean Hops of Working Paths
OC-192	122	122	122	100.0	297	2.434

Utilization

Variable	Value
OCH Used Link Capacity	297 wavelengths
OCH Equipped Link Capacity	2,280 wavelengths
OCH Link Utilization	13.03%

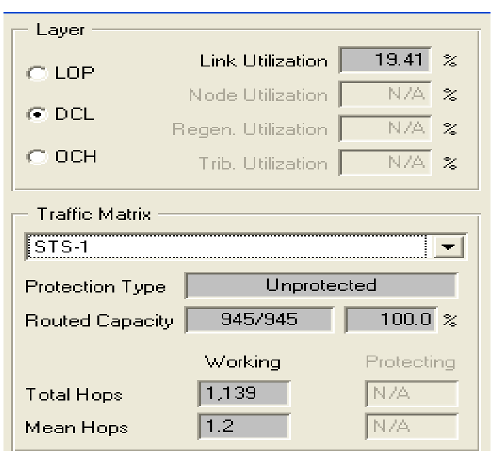
OCH Node Utilization	100.0%

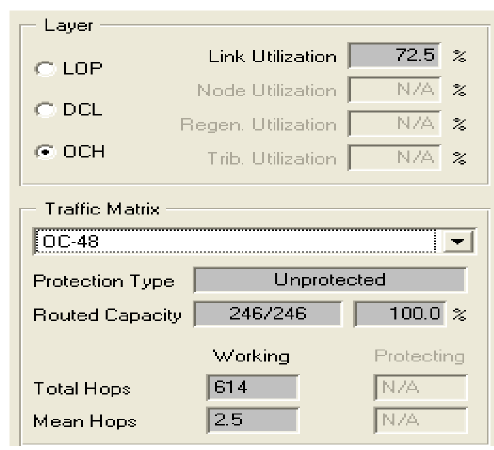
Link utilization is decreased, but dimension OC-48 is better. So I should use dimension in my network.

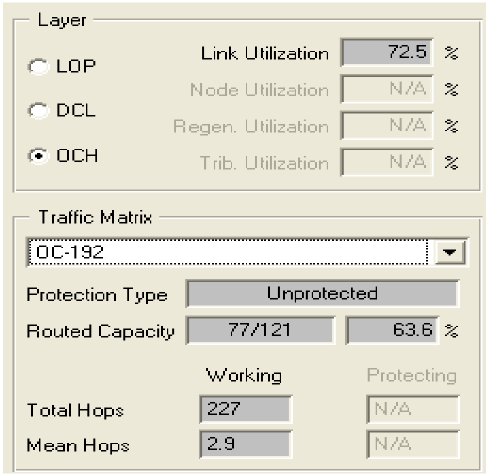
Layer	Number of Links	Link Utilization			Used Capacity	Total Capacity	Utilization (%)	Unit
		Between 100.0 and 90.0 %	Between 90.0 and 75.0 %	Between 75.0 and 0.0 %				
OTS	26	26	0	0	1,300	1,300	100.00	Fiber Pairs
OMS	26	0	0	26	57	1,300	4.38	Fiber Pairs
OCH	26	0	0	26	818	2,280	35.88	Wavelengths
DCL	105	11	10	84	5,241	15,456	33.91	STS-1 Units

DCL layer is well used.

3. Routing Results (from 3-9 are the results got before I made final changes, used to compare with my changing)
Opaque:

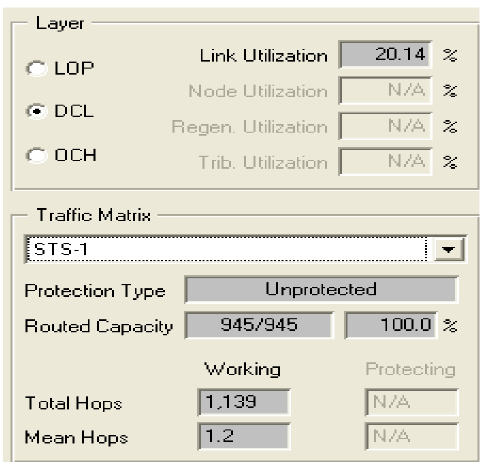


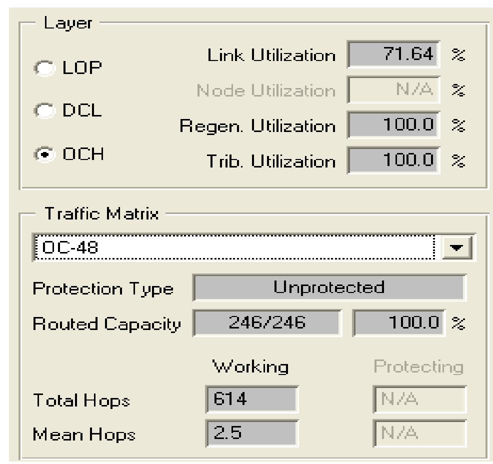


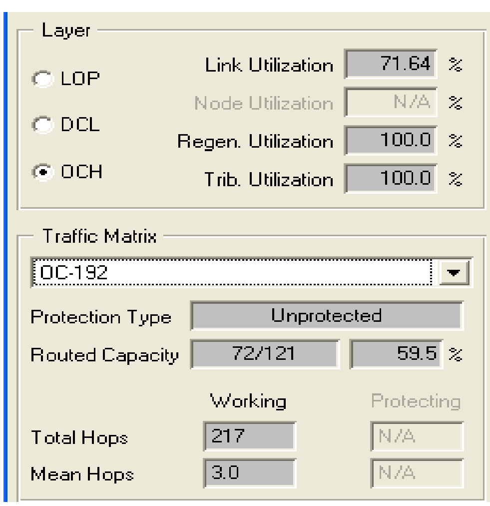


The capacity in DCL layer is 100%, but in OCH layer OC-192 is 63.6%. In OCH layer, system has higher link utilization.

Transparent:



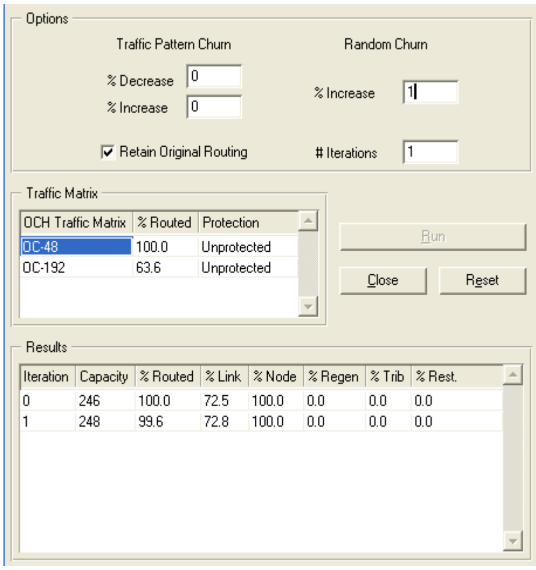


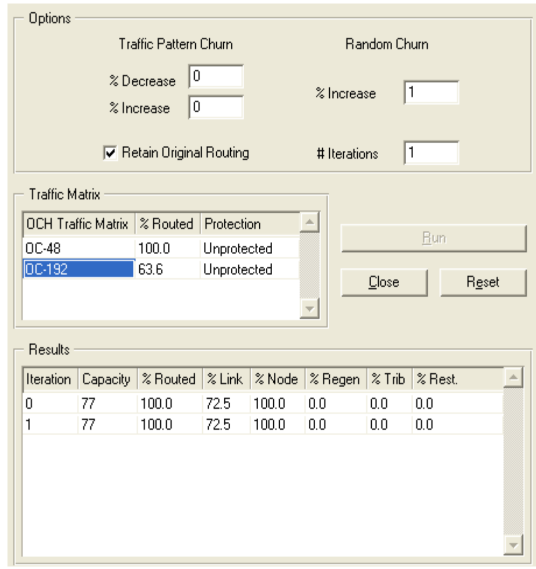


The capacity in DCL layer is 100%, but in OCH layer OC-192 is 59.5%. In OCH layer, system has higher link utilization.

4. Traffic Variation

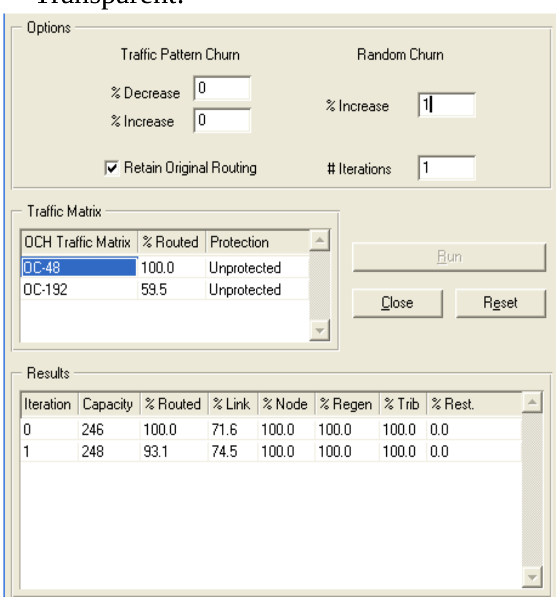
Opaque:

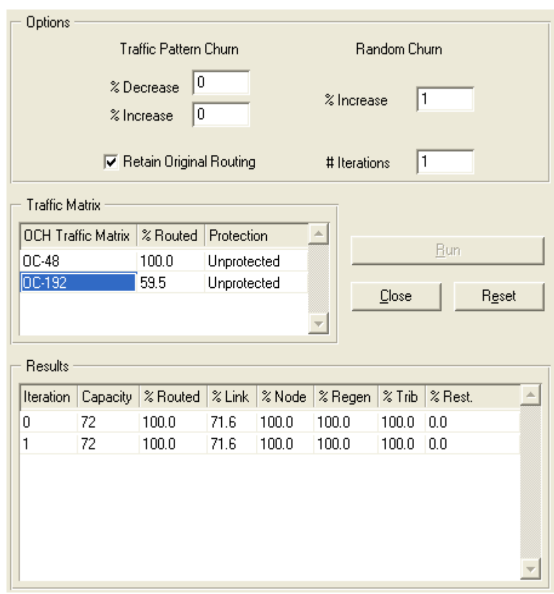




OC-192 performances better than OC-48 here.

Transparent:

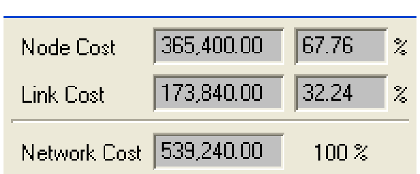




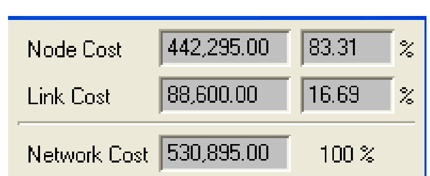
OC-192 performances better than OC-48 here.

5. Network Cost

Opaque:



Transparent:



6. Link Utilization per Layer

Opaque:

Layer	Number of Links	Link Utilization			Used Capacity	Total Capacity	Utilization (%)	Unit
		Between 100.0 and 90.0 %	Between 90.0 and 75.0 %	Between 75.0 and 0.0 %				
OTS	26	26	0	0	1,300	1,300	100.00	Fiber Pairs
OMS	26	0	0	26	29	1,300	2.23	Fiber Pairs
OCH	26	10	3	13	841	1,160	72.50	Wavelengths
DCL	106	0	0	106	0	26,592	0.00	STS-1 Units

Transparent:

Layer	Number of Links	Link Utilization			Used Capacity	Total Capacity	Utilization (%)	Unit
		Between 100.0 and 90.0 %	Between 90.0 and 75.0 %	Between 75.0 and 0.0 %				
OTS	26	26	0	0	1,300	1,300	100.00	Fiber Pairs
OMS	26	0	0	26	29	1,300	2.23	Fiber Pairs
OCH	26	10	3	13	831	1,160	71.64	Wavelengths
DCL	106	0	0	106	0	25,632	0.00	STS-1 Units

7. Wavelength Usage

Opaque:

Wavelength	Used	Total
1	29	29
2	29	29
3	29	29
4	29	29
5	29	29
6	29	29
7	29	29
8	29	29
9	29	29
10	29	29
11	29	29
12	28	29
13	27	29
14	27	29
15	27	29
16	26	29
17	25	29
18	22	29
19	21	29
20	19	29
21	19	29
22	18	29
23	18	29
24	17	29
25	17	29
26	17	29
27	16	29
28	16	29
29	16	29
30	16	29
31	15	29
32	15	29
33	15	29
34	13	29
35	13	29
36	13	29
37	13	29
38	11	29
39	11	29
40	11	29
41	0	0

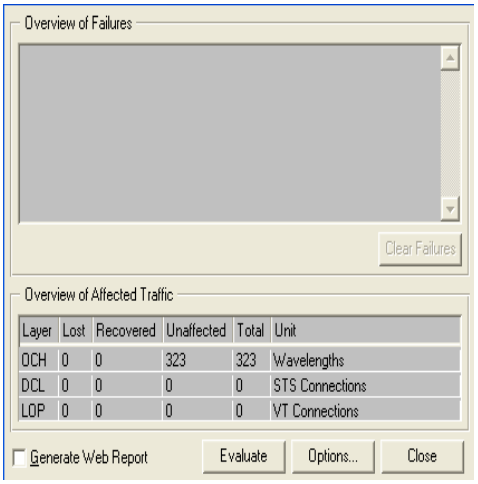
Transparent:

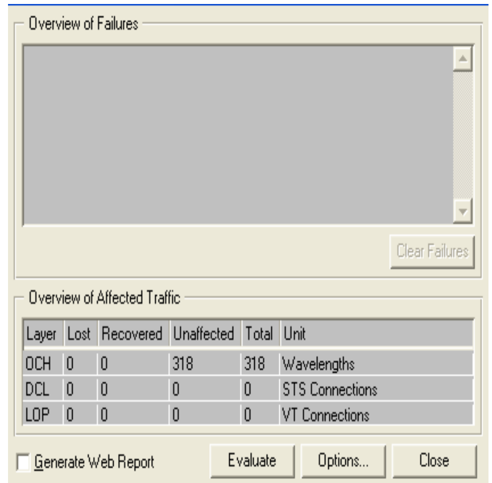
Wavelength	Used	Total
1	29	29
2	29	29
3	29	29
4	29	29
5	29	29
6	28	29
7	28	29
8	26	29
9	26	29
10	26	29
11	26	29
12	26	29
13	27	29
14	28	29
15	27	29
16	27	29
17	25	29
18	23	29
19	21	29
20	20	29
21	18	29
22	18	29
23	17	29
24	17	29
25	16	29
26	17	29
27	17	29
28	16	29
29	17	29
30	16	29
31	16	29
32	16	29
33	14	29
34	14	29
35	13	29
36	13	29
37	14	29
38	11	29
39	11	29
40	11	29
41	0	0

In wavelength usage aspect, two scenarios are almost same.

8. Evaluate Availability
This report is too big; I will show it to Professor later by myself.

9. Failure Analysis
Opaque: Transparent:





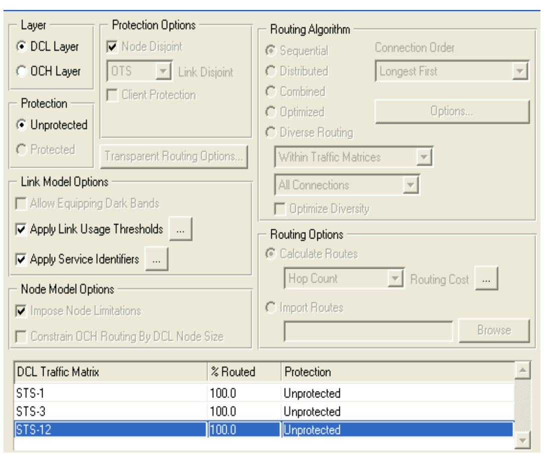
The result shows there is no lost in my scenarios.

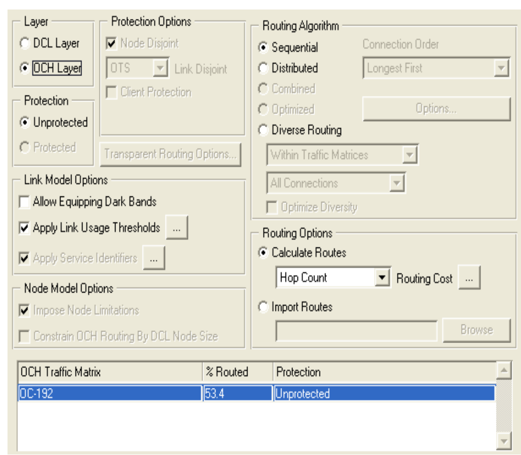
Growth of 20% Traffic Simulation

In this part, I will increase my traffic up to 20% of previous simulation.

1. Route DCL/OCH Traffic (from 1-8 are the results got before I made final changes, used to compare with my changing)

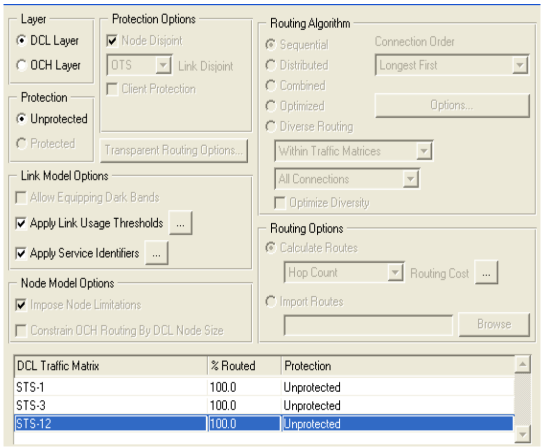
Opaque:

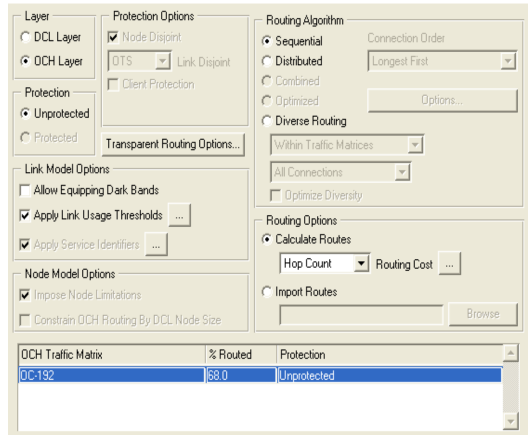




In DCL layer, traffics are 100% routed, in OCH layer are 53.4%.

Transparent:

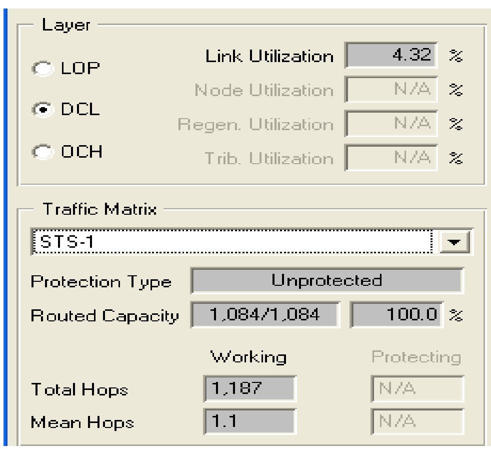


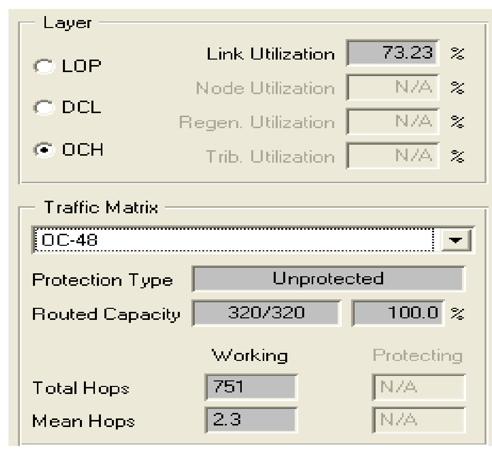


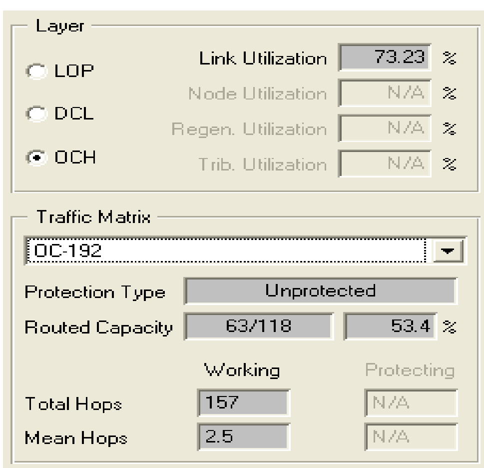
In DCL layer, traffics are 100% routed, in OCH layer are 68%.

2. Routing Results

Opaque:

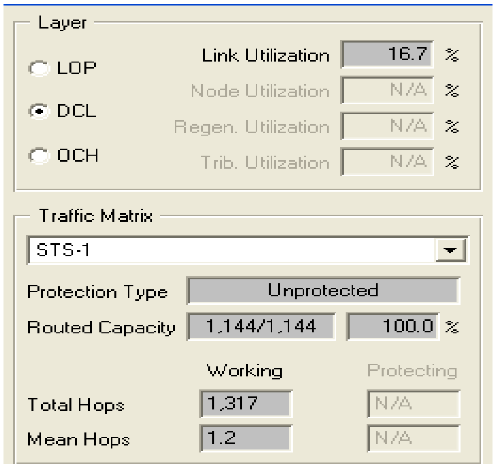


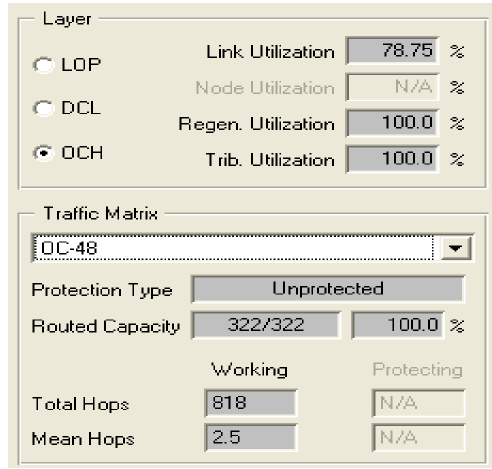


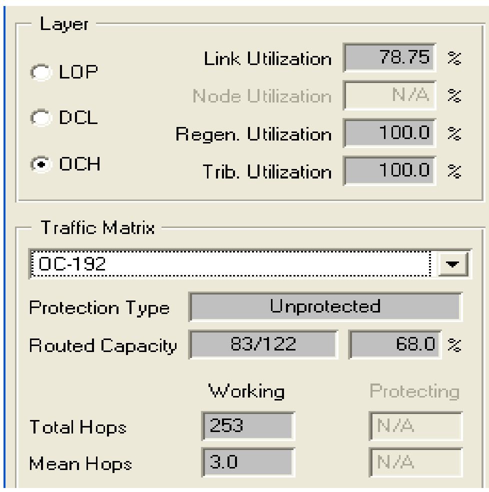


The capacity in DCL layer is 100%, but in OCH layer OC-192 is 53.4%. In OCH layer, system has higher link utilization.

Transparent:



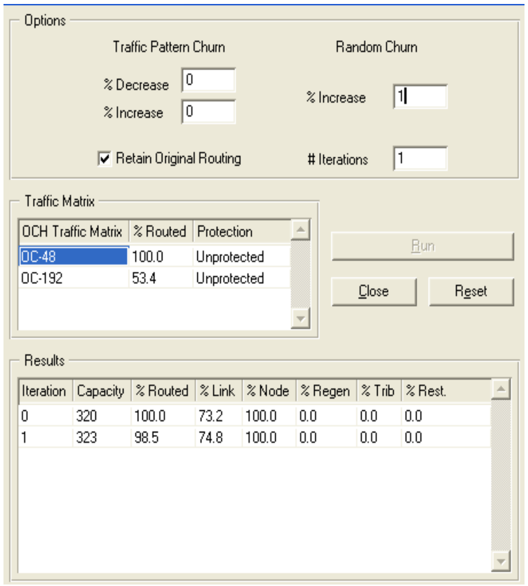


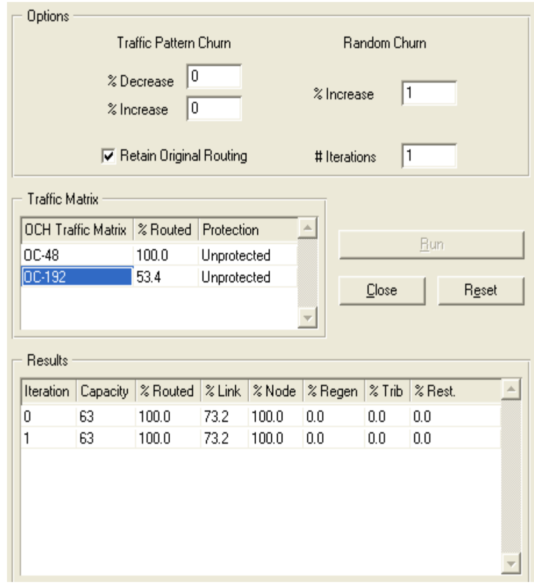


The capacity in DCL layer is 100%, but in OCH layer OC-192 is 68%. In OCH layer, system has higher link utilization.

3. Traffic Variation

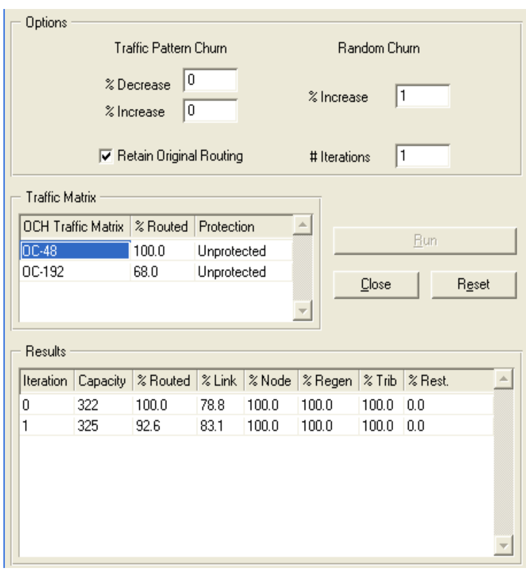
Opaque:

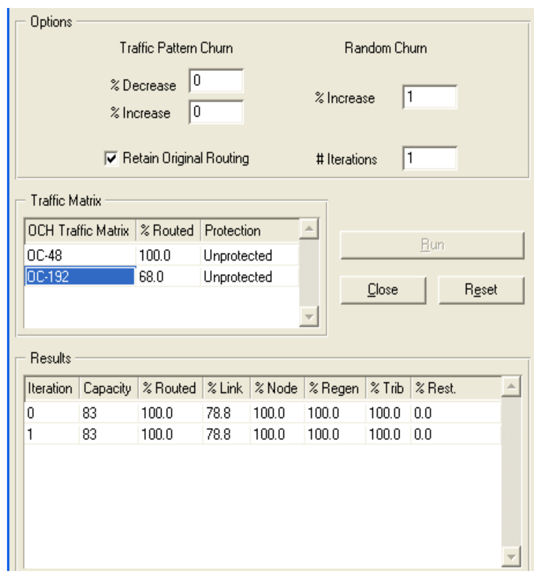




OC-192 performances better than OC-48 here.

Transparent:

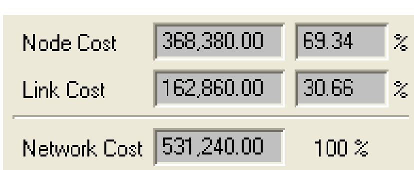




OC-192 performances better than OC-48 here.

4. Network Cost

Opaque:



Transparent:

5. Link Utilization per Layer

Opaque:

Layer	Number of Links	Link Utilization			Used Capacity	Total Capacity	Utilization (%)	Unit
		Between 100.0 and 90.0 %	Between 90.0 and 75.0 %	Between 75.0 and 0.0 %				
OTS	26	26	0	0	1,300	1,300	100.00	Fiber Pairs
OMS	26	0	0	26	31	1,300	2.38	Fiber Pairs
OCH	26	9	3	14	908	1,240	73.23	Wavelengths
DCL	110	0	0	110	0	27,456	0.00	STS-1 Units

Transparent

Layer	Number of Links	Link Utilization			Used Capacity	Total Capacity	Utilization (%)	Unit
		Between 100.0 and 90.0 %	Between 90.0 and 75.0 %	Between 75.0 and 0.0 %				
OTS	26	26	0	0	1,300	1,300	100.00	Fiber Pairs
OMS	26	0	0	26	34	1,300	2.62	Fiber Pairs
OCH	26	12	5	9	1,071	1,360	78.75	Wavelengths
DCL	111	0	0	111	0	31,392	0.00	STS-1 Units

6. Wavelength Usage
Opaque:

Wavelength	Used	Total
1	31	31
2	31	31
3	31	31
4	31	31
5	31	31
6	31	31
7	30	31
8	30	31
9	30	31
10	29	31
11	28	31
12	28	31
13	28	31
14	28	31
15	28	31
16	27	31
17	27	31
18	25	31
19	24	31
20	24	31
21	23	31
22	21	31
23	20	31
24	20	31
25	20	31
26	20	31
27	19	31
28	18	31
29	18	31
30	16	31
31	16	31
32	16	31
33	16	31
34	14	31
35	14	31
36	14	31
37	14	31
38	13	31
39	13	31
40	11	31
41	0	0

Transparent:

Wavelength	Used	Total
1	34	34
2	33	34
3	32	34
4	33	34
5	34	34
6	33	34
7	32	34
8	33	34
9	33	34
10	32	34
11	31	34
12	31	34
13	30	34
14	30	34
15	30	34
16	30	34
17	30	34
18	30	34
19	29	34
20	28	34
21	27	34
22	27	34
23	26	34
24	26	34
25	26	34
26	26	34
27	26	34
28	26	34
29	26	34
30	25	34
31	23	34
32	22	34
33	21	34
34	20	34
35	19	34
36	18	34
37	17	34
38	16	34
39	13	34
40	13	34
41	0	0

In wavelength usage aspect, two scenarios are almost same.

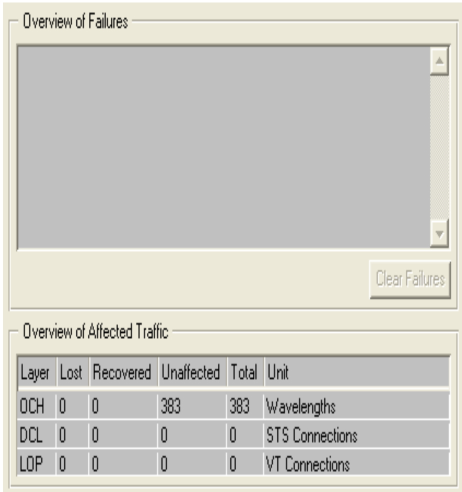
7. Evaluate Availability

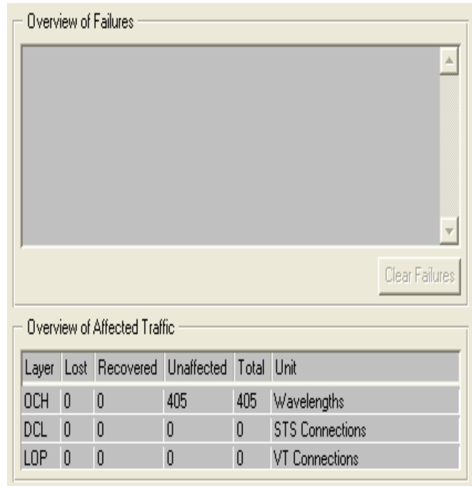
This report is too big; I will show it to Professor later by myself.

8. Failure Analysis

Opaque:

Transparent:





The result shows there is no lost in my scenarios.

If I fail some links in my network (use one scenario to test):

Layer	Lost	Recovered	Unaffected	Total	Unit
OCH	45	0	399	444	**Wavelengths**
DCL	157	0	1,691	1,848	**STS Connections**
LOP	0	0	0	0	**VT Connections**

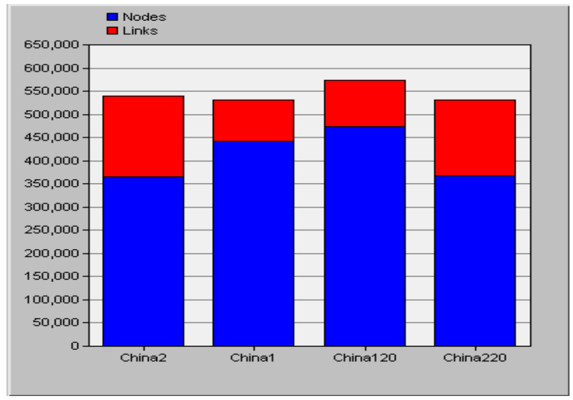
So, that means my network now is good, with all the links there is no lost.

Conclusion

In this project, I created two scenarios for my primary traffic, and then I increased my traffic to 20% and duplicated two scenarios to see how the system handles increasing traffic. From above simulation results, we can see that transparent transport network is better than opaque. The concept behind my conclusion is: In opaque transport networks, about 60 to 80 percent of the network installation cost goes to the line cards and transponders that convert the electrical signals to optical signals. To reduce this cost, transparent networks regenerate signals within nodes and move regeneration away from the WDM links—specifically the long-reach transponders that terminate channels within these links. Instead, regeneration occurs within nodes selectively.

Scenario Comparison

	China2	China1	China120	China220
Nodes	365,400.00	442,295.00	473,035.00	368,380.00
Links	173,840.00	88,600.00	99,555.00	162,860.00
Total	539,240.00	530,895.00	572,590.00	531,240.00



Network cost

	China2	China1	China120	China220
# Nodes	16	16	16	16
Min. Degree	2	2	2	2
Max. Degree	6	6	6	6
Mean Degree	3.3	3.3	3.3	3.3
Connectivity %	21.67	21.67	21.67	21.67
# Links	26	26	26	26
Used Capacity	841	831	1,071	908
Total Capacity	1,160	1,160	1,360	1,240
Utilization %	72.5	71.64	78.75	73.23
Capacity * Distance - Working	651,245.3	639,466.2	805,858.1	698,653.7
Capacity * Distance - Protecting	0.0	0.0	0.0	0.0
Capacity * Distance - Total	651,245.3	639,466.2	805,858.1	698,653.7
# Patch Panel Nodes	0	0	0	0
# OADM Nodes	0	0	0	0

OCH layer topology

	China2	China1	China120	China220
# Nodes	16	16	16	16
Min. Degree	12	12	12	12
Max. Degree	15	15	15	15
Mean Degree	13.3	13.3	13.9	13.8
Connectivity %	88.33	88.33	92.5	91.67
# Links	106	106	111	110
Used Capacity	0	0	0	0
Total Capacity	26,592	25,632	31,392	27,456
Utilization %	0.0	0.0	0.0	0.0
# Terminal Multiplexer Nodes	0	0	0	0
# Rings	0	0	0	0

DCL layer topology

Link Analysis

Opaque

Network

Name	Fiber Pairs	Length	Delay	User Cost
Baotou < [illegible]	[illegible]	[illegible]7 km	3.323 ms	1.00
Chengdu <-> Guangzhou (1)	1/50	1,278.6 km	6.393 ms	1.00
Chengdu <-> Shantou (1)	1/50	1,549.8 km	7.749 ms	1.00
Chengdu <-> Zhanjiang (1)	1/50	1,275.6 km	6.378 ms	1.00
Dalian <-> Hegang (1)	1/50	1,169.8 km	5.849 ms	1.00
Guangzhou <-> Shantou (1)	1/50	373.6 km	1.868 ms	1.00
Hailar <-> Jiageda (1)	1/50	367.6 km	1.838 ms	1.00
Hegang <-> Jiageda (1)	1/50	602.0 km	3.010 ms	1.00
Kunming <-> Chengdu (1)	1/50	677.1 km	3.386 ms	1.00
Kunming <-> Zhanjiang (1)	1/50	913.5 km	4.568 ms	1.00
Lanzhou <-> Baotou (1)	2/50	699.2 km	3.496 ms	1.00
Lanzhou <-> Chengdu (1)	1/50	585.8 km	2.929 ms	1.00
Nanjing <-> Dalian (1)	1/50	788.5 km	3.943 ms	1.00
Peking <-> Dalian (1)	1/50	429.7 km	2.148 ms	1.00
Peking <-> Hailar (1)	1/50	1,001.5 km	5.007 ms	1.00
Peking <-> Hegang (1)	1/50	1,342.0 km	6.710 ms	1.00
Peking <-> Jiageda (1)	1/50	1,293.4 km	6.467 ms	1.00
Peking <-> Xinlinhaote (1)	1/50	476.6 km	2.383 ms	1.00
Shanghai <-> Nanjing (1)	1/50	242.3 km	1.212 ms	1.00
Shantou <-> Shanghai (1)	1/50	1,046.0 km	5.230 ms	1.00
Taiyuan <-> Baotou (1)	1/50	352.3 km	1.762 ms	1.00
Taiyuan <-> Chengdu (1)	2/50	1,122.0 km	5.610 ms	1.00
Taiyuan <-> Nanjing (1)	1/50	881.8 km	4.409 ms	1.00
Taiyuan <-> Peking (1)	2/50	435.1 km	2.176 ms	1.00
Xinlinhaote <-> Hailar (1)	1/50	568.0 km	2.840 ms	1.00
Zhanjiang <-> Guangzhou (1)	1/50	334.7 km	1.673 ms	1.00

Name Fiber Pairs Length Delay User Cost

Before increasing

Network

Name	Fiber Pairs	Length	Delay	User Cost
Baotou <-> Xinlinhaote (1)	1/50	664.7 km	3.323 ms	1.00
Chengdu <-> Guangzhou (1)	1/50	1,278.6 km	6.393 ms	1.00
Chengdu <-> Shantou (1)	1/50	1,549.8 km	7.749 ms	1.00
Chengdu <-> Zhanjiang (1)	1/50	1,275.6 km	6.378 ms	1.00
Dalian <-> Hegang (1)	1/50	1,169.8 km	5.849 ms	1.00
Guangzhou <-> Shantou (1)	1/50	373.6 km	1.868 ms	1.00
Hailar <-> Jiageda (1)	1/50	367.6 km	1.838 ms	1.00
Hegang <-> Jiageda (1)	1/50	602.0 km	3.010 ms	1.00
Kunming <-> Chengdu (1)	1/50	677.1 km	3.386 ms	1.00
Kunming <-> Zhanjiang (1)	1/50	913.5 km	4.568 ms	1.00
Lanzhou <-> Baotou (1)	2/50	699.2 km	3.496 ms	1.00
Lanzhou <-> Chengdu (1)	1/50	585.8 km	2.929 ms	1.00
Nanjing <-> Dalian (1)	1/50	788.5 km	3.943 ms	1.00
Peking <-> Dalian (1)	2/50	429.7 km	2.148 ms	1.00
Peking <-> Hailar (1)	1/50	1,001.5 km	5.007 ms	1.00
Peking <-> Hegang (1)	1/50	1,342.0 km	6.710 ms	1.00
Peking <-> Jiageda (1)	1/50	1,293.4 km	6.467 ms	1.00
Peking <-> Xinlinhaote (1)	1/50	476.6 km	2.383 ms	1.00
Shanghai <-> Nanjing (1)	1/50	242.3 km	1.212 ms	1.00
Shantou <-> Shanghai (1)	1/50	1,046.0 km	5.230 ms	1.00
Taiyuan <-> Baotou (1)	1/50	352.3 km	1.762 ms	1.00
Taiyuan <-> Chengdu (1)	2/50	1,122.0 km	5.610 ms	1.00
Taiyuan <-> Nanjing (1)	1/50	881.8 km	4.409 ms	1.00
Taiyuan <-> Peking (1)	3/50	435.1 km	2.176 ms	1.00
Xinlinhaote <-> Hailar (1)	1/50	568.0 km	2.840 ms	1.00
Zhanjiang <-> Guangzhou (1)	1/50	334.7 km	1.673 ms	1.00

After increasing

Transparent

Network

Name	Fiber Pairs	Length	Delay	User Cost
Baotou <-> Xinlinhaote (1)	1/50	664.7 km	3.323 ms	1.00
Chengdu <-> Guangzhou (1)	1/50	1,278.6 km	6.393 ms	1.00
Chengdu <-> Shantou (1)	1/50	1,549.8 km	7.749 ms	1.00
Chengdu <-> Zhanjiang (1)	1/50	1,275.6 km	6.378 ms	1.00
Dalian <-> Hegang (1)	1/50	1,169.8 km	5.849 ms	1.00
Guangzhou <-> Shantou (1)	1/50	373.6 km	1.868 ms	1.00
Hailar <-> Jiageda (1)	1/50	367.6 km	1.838 ms	1.00
Hegang <-> Jiageda (1)	1/50	602.0 km	3.010 ms	1.00
Kunming <-> Chengdu (1)	1/50	677.1 km	3.386 ms	1.00
Kunming <-> Zhanjiang (1)	1/50	913.5 km	4.568 ms	1.00
Lanzhou <-> Baotou (1)	2/50	699.2 km	3.496 ms	1.00
Lanzhou <-> Chengdu (1)	2/50	585.8 km	2.929 ms	1.00
Nanjing <-> Dalian (1)	2/50	788.5 km	3.943 ms	1.00
Peking <-> Dalian (1)	2/50	429.7 km	2.148 ms	1.00
Peking <-> Hailar (1)	1/50	1,001.5 km	5.007 ms	1.00
Peking <-> Hegang (1)	1/50	1,342.0 km	6.710 ms	1.00
Peking <-> Jiageda (1)	1/50	1,293.4 km	6.467 ms	1.00
Peking <-> Xinlinhaote (1)	1/50	476.6 km	2.383 ms	1.00
Shanghai <-> Nanjing (1)	2/50	242.3 km	1.212 ms	1.00
Shantou <-> Shanghai (1)	1/50	1,046.0 km	5.230 ms	1.00
Taiyuan <-> Baotou (1)	1/50	352.3 km	1.762 ms	1.00
Taiyuan <-> Chengdu (1)	2/50	1,122.0 km	5.610 ms	1.00
Taiyuan <-> Nanjing (1)	1/50	881.8 km	4.409 ms	1.00
Taiyuan <-> Peking (1)	3/50	435.1 km	2.176 ms	1.00
Xinlinhaote <-> Hailar (1)	1/50	568.0 km	2.840 ms	1.00
Zhanjiang <-> Guangzhou (1)	1/50	334.7 km	1.673 ms	1.00

Before increasing

Network

Name	Fiber Pairs	Length	Delay	User Cost
Baotou <-> Xinlinhaote (1)	1/50	664.7 km	3.323 ms	1.00
Chengdu <-> Guangzhou (1)	1/50	1,278.6 km	6.393 ms	1.00
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Taiyuan <-> Nanjing (1)	1/50	881.8 km	4.409 ms	1.00
Taiyuan <-> Peking (1)	3/50	435.1 km	2.176 ms	1.00
Xinlinhaote <-> Hailar (1)	1/50	568.0 km	2.840 ms	1.00
Zhanjiang <-> Guangzhou (1)	1/50	334.7 km	1.673 ms	1.00

After increasing

From above graphs we can see that, at core links, I put more fiber pairs to give protection to the traffic. Even though it will increase cost, but it increases capacity.

In order to increase OCH capacity, I dimensioned the network. After I dimensioned network, in DCL layer the topology changes to mesh topology, which means SP Guru Transport Planner installing the required node and link equipment to support a traffic matrix at that layer in order to let my system performance well.

I used STS-1, 3, 12 to support my data services in a more capacity-efficient way over SONET/SDH, such as one STS-1 can support 1Gb/s traffic.

I used routing in DCL/OCH layer. The capacity in DCL layer is 100%, but in OCH layer OC-192 is lower than 100%. In OCH layer, system has higher link utilization. It should be lower than 50% in system. When I checked utilization report, some links are 100% used. The way to get lower utilization is to add fiber pairs or use higher capacity links.

On the other hand, when I compare different layer utilization, OTS has the highest and OMS has the lowest. That's because in OMS layer some core traffic links use more than 1 fiber pairs which can reduce link utilization. In DCL layer, I used mesh topology, which also can reduce link utilization. But here it is not necessary.

After I increased traffic, systems used more links, which introduced a little bit lower link utilization than before. So, that means in my system, how it handles increasing traffic is through using more links. When look at network cost between before increasing traffic and after increasing, we can find out that: the cost in Opaque network is almost the same, but in Transparent network it increased. The reason is easy to be understood. The advantage of Transparent network is that regeneration occurs within nodes selectively. It can reduce the cost. Before increasing traffic, it's obvious that cost in Transparent network is lower than Opaque network, which also means at the beginning the cost in Opaque network was already high. After increasing 20% traffic, regeneration still occurs in Opaque network, and the traffic doesn't reach to the threshold to increase nodes and links usage because my traffic is not high; however, in Transparent network, the increasing traffic will introduce more regeneration, can more cost of network. That's why the network cost increased after increasing 20% traffic.

On the other aspect, Regeneration in an intermediate node gives a connection additional flexibility, because it enables the connection to switch wavelengths when it passes through the node. In a transparent network, each signal is regenerated every MTL kilometers. This also shows Transparent network has better characteristics than Opaque network.

Changing

After I found out the problems, I changed my network by adding and deleting fiber pairs. I added fiber pairs in high traffic places. I used Transparent network and traffic after increasing scenarios to try my changing. I want to reduce my link utilization in OCH layer to 50%, and well use DCL layer links.

Optimized Result:

Before increasing traffic

Layer	Number of Links	Link Utilization			Used Capacity	Total Capacity	Utilization (%)	Unit
		Between 100.0 and 90.0 %	Between 90.0 and 75.0 %	Between 75.0 and 0.0 %				
OTS	26	26	0	0	1,300	1,300	100.00	Fiber Pairs
OMS	26	0	0	26	58	1,300	4.46	Fiber Pairs
OCH	26	0	0	26	900	2,320	38.79	Wavelengths
DCL	111	0	2	109	4,365	35,040	12.46	STS-1 Units

The highest utilization in OCH layer is close to 50%, and the utilization is reduced to 38.79%. DCL layer is used now.

Network

Name	Fiber Pairs	Length	Delay	User Cost
Baotou <-> Xinlinhaote (1)	3/50	664.7 km	3.323 ms	1.00
Chengdu <-> Guangzhou (1)	2/50	1,278.6 km	6.393 ms	1.00
Chengdu <-> Shantou (1)	3/50	1,549.8 km	7.749 ms	1.00
Chengdu <-> Zhanjiang (1)	2/50	1,275.6 km	6.378 ms	1.00
Dalian <-> Hegang (1)	1/50	1,169.8 km	5.849 ms	1.00
Guangzhou <-> Shantou (1)	1/50	373.6 km	1.868 ms	1.00
Hailar <-> Jiageda (1)	1/50	367.6 km	1.838 ms	1.00
Hegang <-> Jiageda (1)	1/50	602.0 km	3.010 ms	1.00
Kunming <-> Chengdu (1)	2/50	677.1 km	3.386 ms	1.00
Kunming <-> Zhanjiang (1)	1/50	913.5 km	4.568 ms	1.00
Lanzhou <-> Baotou (1)	4/50	699.2 km	3.496 ms	1.00
Lanzhou <-> Chengdu (1)	3/50	585.8 km	2.929 ms	1.00
Nanjing <-> Dalian (1)	2/50	788.5 km	3.943 ms	1.00
Peking <-> Dalian (1)	4/50	429.7 km	2.148 ms	1.00
Peking <-> Hailar (1)	2/50	1,001.5 km	5.007 ms	1.00
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Peking <-> Jiageda (1)	1/50	1,293.4 km	6.467 ms	1.00
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Shanghai <-> Nanjing (1)	2/50	242.3 km	1.212 ms	1.00
Shantou <-> Shanghai (1)	2/50	1,046.0 km	5.230 ms	1.00
Taiyuan <-> Baotou (1)	4/50	352.3 km	1.762 ms	1.00
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Taiyuan <-> Nanjing (1)	2/50	881.8 km	4.409 ms	1.00
Taiyuan <-> Peking (1)	4/50	435.1 km	2.176 ms	1.00
Xinlinhaote <-> Hailar (1)	2/50	568.0 km	2.840 ms	1.00
Zhanjiang <-> Guangzhou (1)	1/50	334.7 km	1.673 ms	1.00

After increasing traffic

Layer	**Number of Links**	**Link Utilization**			**Used Capacity**	**Total Capacity**	**Utilization (%)**	**Unit**
		Between 100.0 and 90.0 %	**Between 90.0 and 75.0 %**	**Between 75.0 and 0.0 %**				
OTS	26	26	0	0	1,300	1,300	100.00	Fiber Pairs
OMS	26	0	0	26	57	1,300	4.38	Fiber Pairs
OCH	26	1	2	23	1,115	2,280	48.90	Wavelengths
DCL	115	0	5	110	4,625	38,880	11.90	STS-1 Units

The highest utilization in OCH layer is close to 50%, and the utilization is reduced to 48.90%.
After using dimension:

Layer	**Number of Links**	**Link Utilization**			**Used Capacity**	**Total Capacity**	**Utilization (%)**	**Unit**
		Between 100.0 and 90.0 %	**Between 90.0 and 75.0 %**	**Between 75.0 and 0.0 %**				
OTS	26	26	0	0	1,300	1,300	100.00	Fiber Pairs
OMS	26	0	0	26	57	1,300	4.38	Fiber Pairs
OCH	26	0	0	26	818	2,280	35.88	Wavelengths
DCL	105	11	10	84	5,241	15,456	33.91	STS-1 Units

Network

Name	Fiber Pairs	Length	Delay	User Cost
Baotou <-> Xinlinhaote (1)	3/50	664.7 km	3.323 ms	1.00
Chengdu <-> Guangzhou (1)	2/50	1,278.6 km	6.393 ms	1.00
Chengdu <-> Shantou (1)	3/50	1,549.8 km	7.749 ms	1.00
Chengdu <-> Zhanjiang (1)	2/50	1,275.6 km	6.378 ms	1.00
Dalian <-> Hegang (1)	1/50	1,169.8 km	5.849 ms	1.00
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Hailar <-> Jiageda (1)	1/50	367.6 km	1.838 ms	1.00
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Kunming <-> Chengdu (1)	2/50	677.1 km	3.386 ms	1.00
Kunming <-> Zhanjiang (1)	1/50	913.5 km	4.568 ms	1.00
Lanzhou <-> Baotou (1)	4/50	699.2 km	3.496 ms	1.00
Lanzhou <-> Chengdu (1)	3/50	585.8 km	2.929 ms	1.00
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Taiyuan <-> Nanjing (1)	2/50	881.8 km	4.409 ms	1.00
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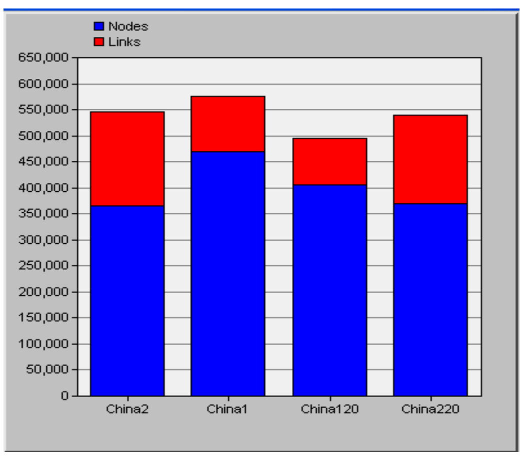
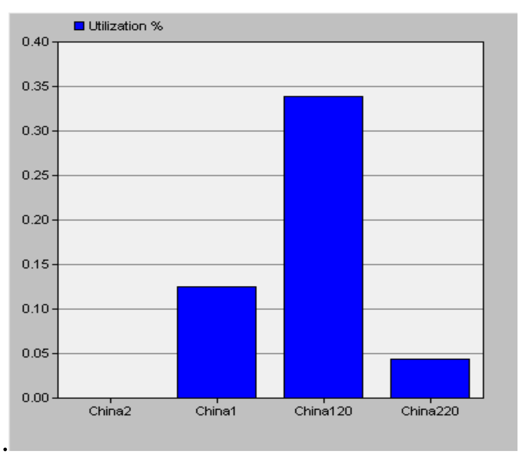
Xinlinhaote <-> Hailar (1)	2/50	568.0 km	2.840 ms	1.00
Zhanjiang <-> Guangzhou (1)	1/50	334.7 km	1.673 ms	1.00

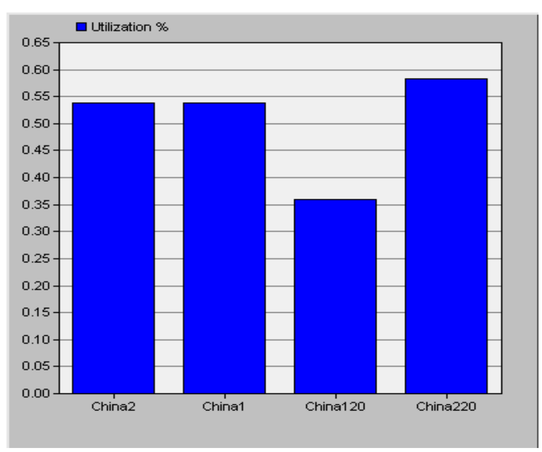
Network cost

I made changes in Transparent network and also the scenario after increasing traffic, the cost is reduced in both



	China2	China1	China120	China220
Nodes	365,400.00	468,395.00	406,475.00	369,464.00
Links	181,315.00	107,400.00	88,230.00	169,560.00
Total	546,715.00	575,795.00	494,705.00	539,024.00





DCL layer utilization

OCH layer utilization

So, my concept of changing my topology is right. The OCH layer link utilization is reduced after I change my network. And DCL layer is in use now. The cost of Transparent network is also reduced in high traffic when compare with Opaque network.

Accounting to the simulation results and graphs, we can safely draw the conclusion that Transparent network is better than Opaque network, especially in large traffic network. All these advantages can be found in link utilization, and cost.

In the progress of my project, I first set traffic and network topology. After simulation, I changed network and traffic, and then get the better solution and further conclusion.

Improvements

All experiments could have been improved in several ways. First of all, the durations should have been longer so we could observe the long-term effects of sending data in the ways tested in this project. In addition, since this is only a simulation, these ‘nodes’ are working from a predetermined script. In order to get the best results, the experiment should be performed using real nodes and a real connection.

For the simulation of traffic in busy network, in reality, there might be some different factors. And results may vary slightly due to different node placement. We should pay attention to the macroscopical change in implementation.