

# **WAN/LAN PLANNING AND DESIGN**

**GRADUATE PROJECT**

**BY**

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**SUBMITTED ON: 04/24/2008**

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# GRADUATE PROJECT DESCRIPTION

**THE MISSION:** Indian Universities constitute one of the largest Higher Education Systems in the world. “With 265 universities and 13150 affiliated colleges it is a great challenge to ensure effective coordination and communication amongst 88 lakh students and 3.5 lakh teachers” [Source: Wikipedia], it is a great challenge to ensure effective coordination and communication. Fast changing curricula and frequent introduction of new subjects impose a great demand on the system in general. Indian Universities need to be given the required trust to enter the third millennium with a leading edge.

Technology is a driving force in contemporary education system. The Government of India has launched a series of ambitious programs to bring about a qualitative change in the academic infrastructure especially for higher education. Under this initiative, **AB Corp Consultancy group** is modernizing the university campuses with state-of-the-art campus wide networks and setting up its own nationwide communication network. The first of these series of programs will comprise of connecting all the IITs and IIMs together via a Nation-wide Terrestrial Backbone using Fiber Optic links.

**ABOUT AB Corp:** AB Corp is a statutory organization established by an act of Parliament. It serves as a vital link between the Union and State Governments and the institution of higher learning. With these programs initiated by the Government of India, AB Corp will be a boon to the higher education system in many ways:

1. AB Corp will become *a vehicle for distance learning* to facilitate spread of quality education all over the country.
2. AB Corp will be a tool to distribute education *material and journals* to remotest of areas.
3. AB Corp will be *a resource for researchers and scholars* for tapping most up-to-date information.
4. AB Corp will form *a medium for collaboration* among the teachers and students not only within the country but all over the world.
5. AB Corp will be an *Intranet for University Automation*.
6. AB Corp will *encompass entire University System* for most efficient utilization of precious network resources.
7. AB Corp will establish a *channel for Globalization* of Education and facilitate the universities in marketing their services and development.

## **ABOUT IITs & IIMs:**

“The **Indian Institutes of Technology (IITs)**, are a group of seven elite autonomous engineering and technology-oriented institutes of higher education established and declared as *Institutes of National Importance* by the Government of India. The IITs were created to train scientists and engineers, with the aim of developing a skilled workforce to support the economic and social development of India after independence in 1947.” [Source: Wikipedia]

“The **Indian Institutes of Management (IIMs)** are India's premier business schools that also conduct research and provide consultancy services in the field of management to various sectors of the Indian economy. They were created by the Indian Government with the aim of identifying the brightest intellectual talent available in the student community of India and training it in the best Management

Techniques available in the world, to ultimately create a pool of elite world class managers to manage and lead the various sections of the Indian economy.” [Source: Wikipedia]

The IITs and the IIMs are recognized as premier education institutions, comparable to the best in the world for teaching, research and interaction with industries. **These Institutes being Role Models must share knowledge and skills with other institutions to improve their quality and standards in technical and management education.**

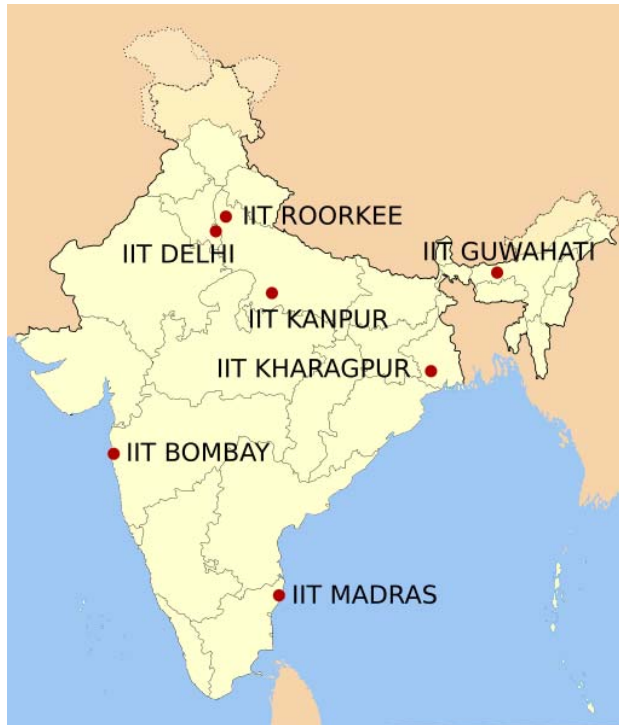


Fig.1 IITs in India [Source: Wikipedia]



Fig. 2 IIMs in India [Source: Wikipedia]

**ABOUT THE NETWORK:** As the beginning of a highly ambitious program to connect universities, the Network initially will be based on the Nation-wide terrestrial backbone using fiber links that connects each of the IITs and the IIMs with one another. As shown in the maps above, 7 of the IITs and 7 of the IIMs across India will be connected to each other using these fiber links.

The Network is based on open IP platform, employing state-of-the-art technologies like IP Multicast, TCP Spoofing and other Internet tools that provide interactive education on PC or TV, enabling on-line response to queries. Open systems architecture will ensure support for current and future applications. Users from Educational Institutions would enjoy high data rates while accessing Intranet and Internet resources.

## **STEPS:**

1. Create the Network Topology of Baseline Scenario

2. SCENARIO 1

- Traffic Matrix for DCL and OCH layers
- Observe DCL Logical Link Layers
- Input Regenerators and Amplifiers using Link Design
- Route using Automatic Routing Algorithm
- Observe the Routing Result
- Failure Analysis of Scenario 1
- Total cost of the Network

3. SCENARIO 2

- Increase Traffic on DCL and OCH layers by 100%
- Route using Automatic Routing Algorithm
- Observe the Routing Result
- Failure Analysis of Scenario 2
- Total cost of the Network

4. SCENARIO 3

- Create Scenario 3 using Manual Routing to achieve 100% routed traffic on DCL and OCH layers.
- Failure Analysis of the Network in this Scenario
- Total Network Cost
- Overview of Total Cost

5. COMPARISON and CONCLUSION

# 1. NETWORK TOPOLOGY

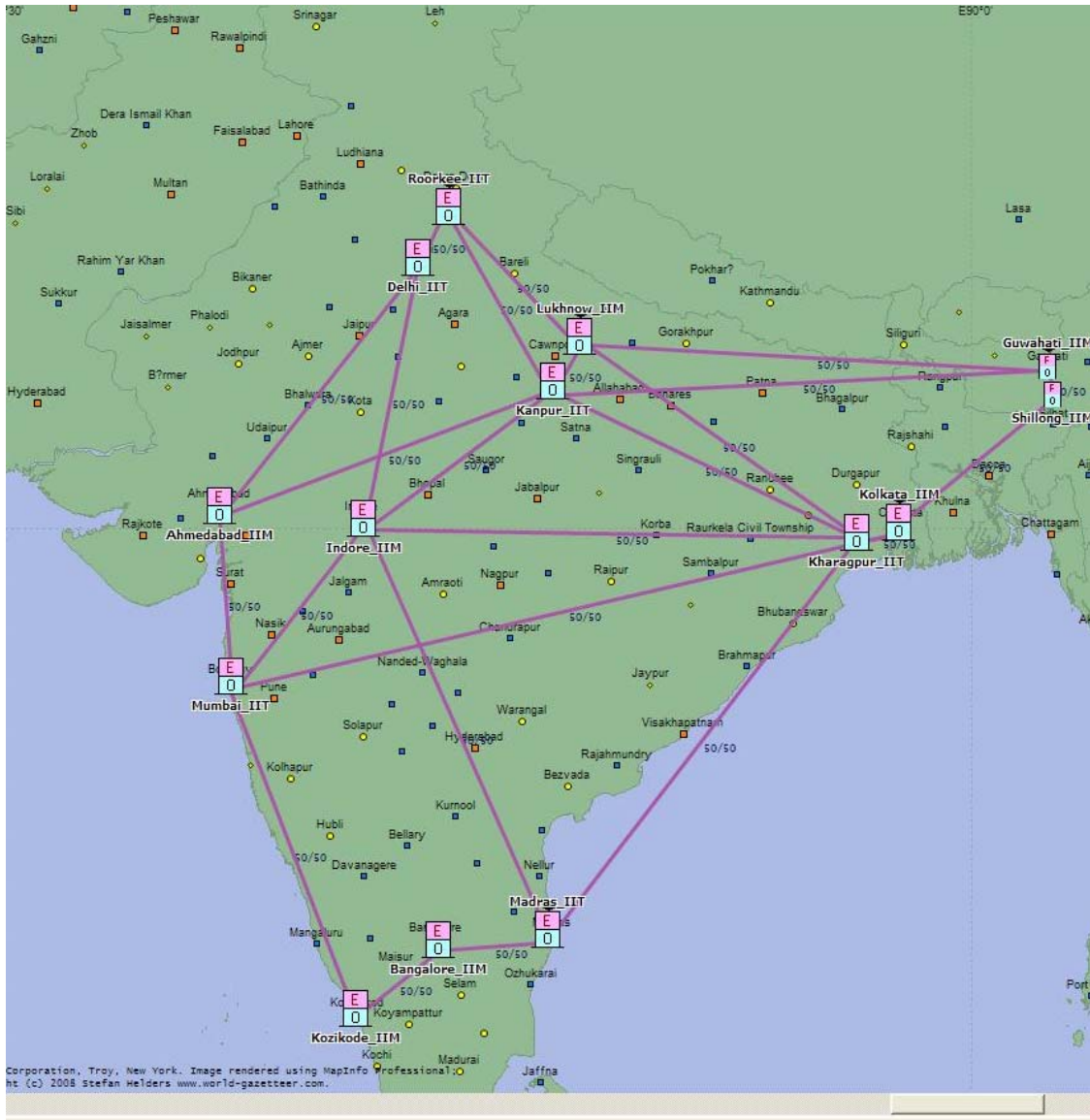


Fig. 1

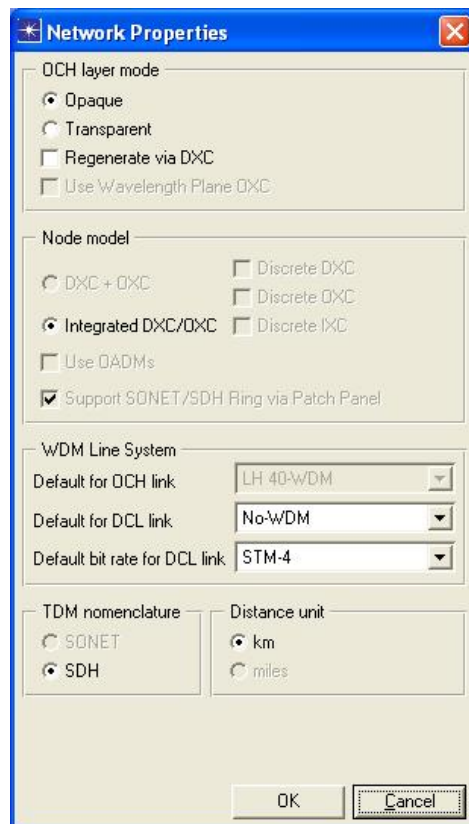
Figure 1 shows the Network Topology. The topology is not a fully Mesh Topology but has been optimized to function like a Mesh Topology by achieving the Routed Traffic of 100%.

**Routing** (both in DCL and OCH layers) tries to accommodate in the network as much traffic as possible using only the existing infrastructure. Link capacities are fixed and if there is insufficient capacity, part of the traffic remains unrouted.

**Dimensioning** adds additional resources (if needed) to accommodate all traffic in the OCH layer. Resources are added while respecting a specified objective (minimum cost, shortest path, etc). Dimensioning of the DCL layer is called **Grooming**.

In our case, Dimensioning will not be required but is still done. The Dimensioning results are attached. Since in both of our Scenarios we have 100% Routed Traffic, we do not need Dimensioning and Grooming.

## NETWORK PROPERTIES



Network for Scenario 1 has been created using the above Network Properties. Integrated DXC/OXC directs the use of a single integrated electrical switch that implements both DXC (Digital Cross Connect) and OXC (Optical Cross Connect) functions. This integrated switch interfaces with SONET/SDH line cards and with DWDM line systems.

Defaults for DCL link line systems and bit rates can also be set here.

## 2. SCENARIO 1

Traffic Matrix Editor for OCH: Random Traffic of wavelengths from 1 to 4 has been used in this Scenario.

	Ahmedabad_IIM	Bangalore_IIM	Delhi_IIT	Guwahati_IIM	Indore_IIM	Kanpur_IIT
Ahmedabad_IIM	-	1	1	3	4	1
Bangalore_IIM	1	-	4	2	3	3
Delhi_IIT	1	4	-	4	1	3
Guwahati_IIM	3	2	4	-	2	3
Indore_IIM	4	3	1	2	-	4
Kanpur_IIT	1	3	3	3	4	-
Kharagpur_IIT	2	2	4	1	2	4
Kolkata_IIM	3	3	4	1	1	4
Kozikode_IIM	4	2	2	3	2	4
Lukhnow_IIM	4	2	1	3	3	2
Madras_IIT	1	3	4	2	2	4
Mumbai_IIT	3	2	4	1	1	4
Roorkee_IIT	1	2	1	3	4	4
Shillong_IIM	2	3	1	3	4	1

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

Fig. 2 OCH Traffic Matrix Editor

	Ahmedabad_IIM	Bangalore_IIM	Delhi_IIT	Guwahati_IIM	Indore_IIM	Kanpur_IIT
Ahmedabad_IIM	-	4	1	2	4	2
Bangalore_IIM	4	-	4	2	2	2
Delhi_IIT	1	4	-	2	2	3
Guwahati_IIM	2	2	2	-	3	3
Indore_IIM	4	2	2	3	-	2
Kanpur_IIT	2	2	3	3	2	-
Kharagpur_IIT	4	1	1	4	1	3
Kolkata_IIM	3	3	2	1	4	3
Kozikode_IIM	1	3	1	4	1	3
Lukhnow_IIM	3	4	1	4	4	1
Madras_IIT	1	4	3	2	3	4
Mumbai_IIT	4	3	3	1	1	1
Roorkee_IIT	1	4	4	3	2	2
Shillong_IIM	2	2	4	3	2	4

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

Fig. 3 DCL Traffic Matrix Editor

## DCL Logical Layer Links

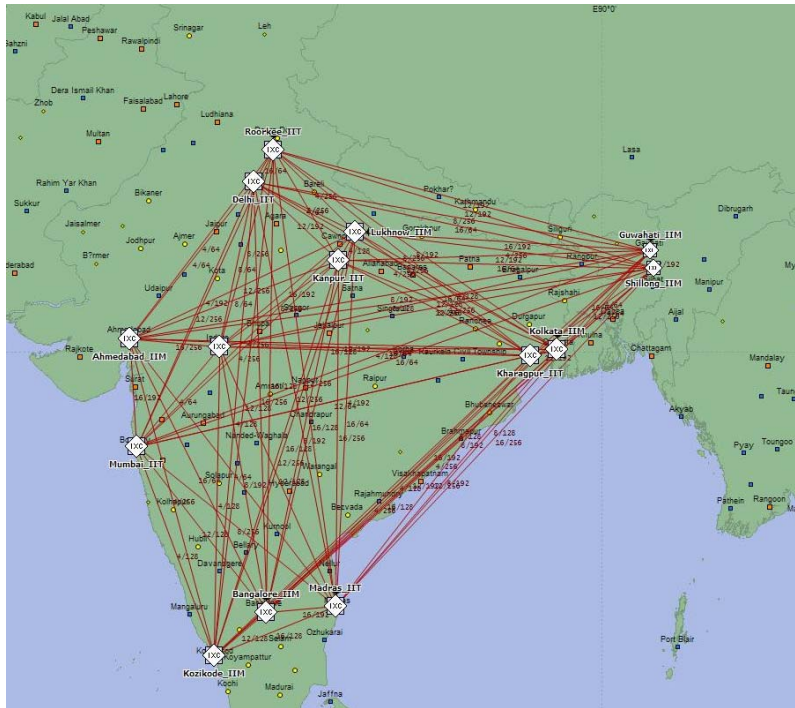


Fig. 4 DCL logical links

Above figure shows the DCL logical links that get created after OCH traffic routing using Automatic Routing algorithm.

Link Browser							
Layer							
DCL							
Network							
Name	Fiber Pair	Reg Stations	OA Stations	Length	Delay	Designed	User Cost
Ahmedabad_IM ↔ Delhi_IT (1)	50	1	6	787.0 km	3.935 ms	Yes	0.00
Bangalore_IM ↔ Madras_IT (1)	50	0	2	276.6 km	1.383 ms	Yes	0.00
Delhi_IT ↔ Roorkee_IT (1)	50	0	1	146.0 km	0.730 ms	Yes	0.00
Guwahati_IM ↔ Kanpur_IT (1)	50	1	10	1,147.2 km	5.736 ms	Yes	0.00
Guwahati_IM ↔ Lucknow_IM (1)	50	1	9	1,082.9 km	5.414 ms	Yes	0.00
Indore_IM ↔ Delhi_IT (1)	50	1	5	695.4 km	3.427 ms	Yes	0.00
Indore_IM ↔ Kanpur_IT (1)	50	0	5	567.7 km	2.839 ms	Yes	0.00
Kanpur_IT ↔ Ahmedabad_IM (1)	50	1	7	842.8 km	4.214 ms	Yes	0.00
Kanpur_IT ↔ Roorkee_IT (1)	50	0	5	507.8 km	2.539 ms	Yes	0.00
Kharagpur_IT ↔ Indore_IM (1)	50	1	10	1,174.6 km	5.874 ms	Yes	0.00
Kharagpur_IT ↔ Kanpur_IT (1)	50	1	7	814.7 km	4.073 ms	Yes	0.00
Kharagpur_IT ↔ Kolkata_IM (1)	50	0	1	103.0 km	0.515 ms	Yes	0.00
Kharagpur_IT ↔ Lucknow_IM (1)	50	1	7	822.4 km	4.112 ms	Yes	0.00
Kharagpur_IT ↔ Madras_IT (1)	50	2	10	1,273.5 km	6.368 ms	Yes	0.00
Kolkata_IM ↔ Mumbai_IT (1)	50	2	14	1,655.4 km	8.277 ms	Yes	0.00
Kolkata_IM ↔ Shillong_IM (1)	50	0	4	491.6 km	2.458 ms	Yes	0.00
Kozikode_IM ↔ Bangalore_IM (1)	50	0	2	273.0 km	1.365 ms	Yes	0.00
Kozikode_IM ↔ Mumbai_IT (1)	50	1	8	908.1 km	4.540 ms	Yes	0.00
Lucknow_IM ↔ Kanpur_IT (1)	50	0	1	129.2 km	0.646 ms	Yes	0.00
Madras_IT ↔ Indore_IM (1)	50	1	10	1,152.0 km	5.760 ms	Yes	0.00
Mumbai_IT ↔ Ahmedabad_IM (1)	50	0	4	442.8 km	2.214 ms	Yes	0.00
Mumbai_IT ↔ Indore_IM (1)	50	0	5	517.0 km	2.585 ms	Yes	0.00
Roorkee_IT ↔ Lucknow_IM (1)	50	0	4	447.3 km	2.236 ms	Yes	0.00
Shillong_IM ↔ Guwahati_IM (1)	50	0	0	73.3 km	0.367 ms	Yes	0.00

Fig. 5 Link Browser indicating the number of Regenerators and Amplifiers



# FAILURE ANALYSIS

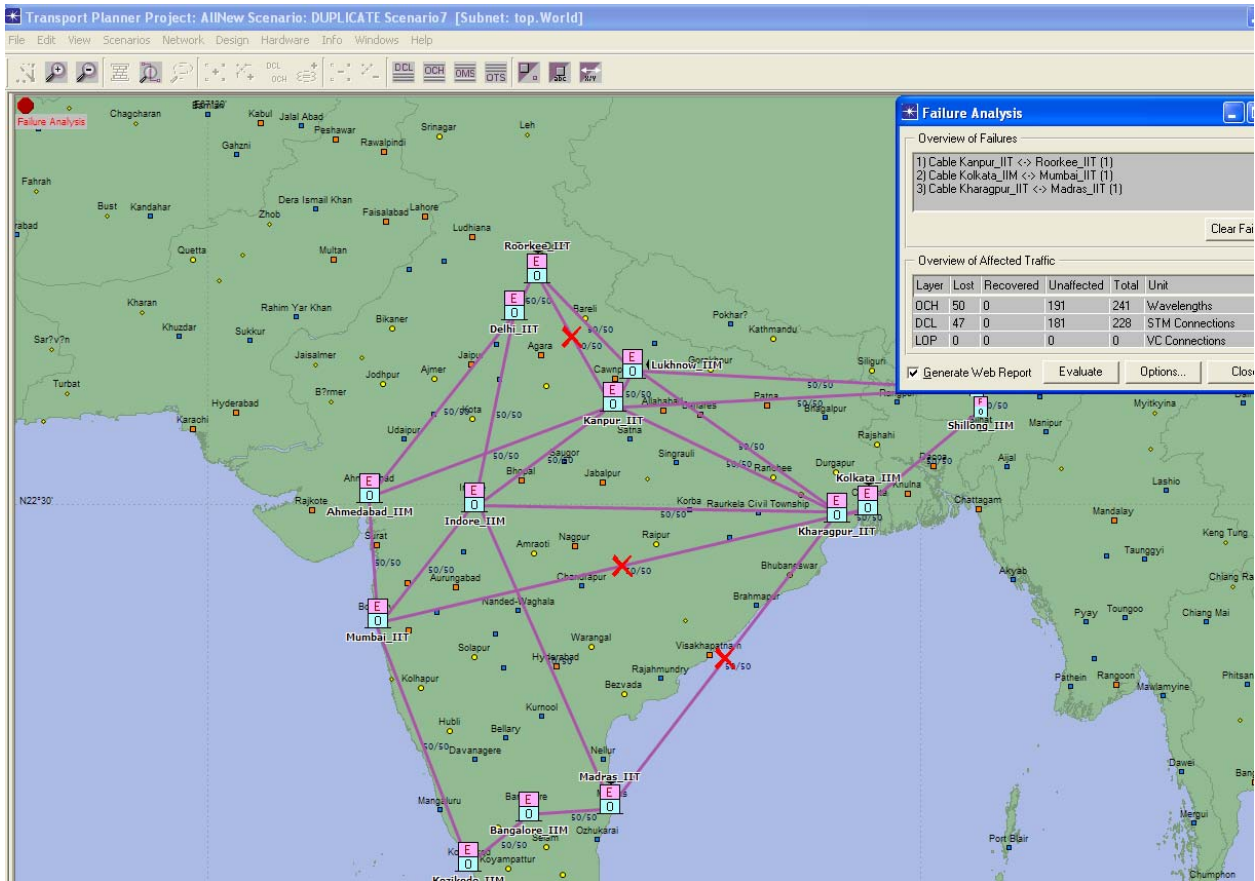


Fig. 8 Failure Analysis

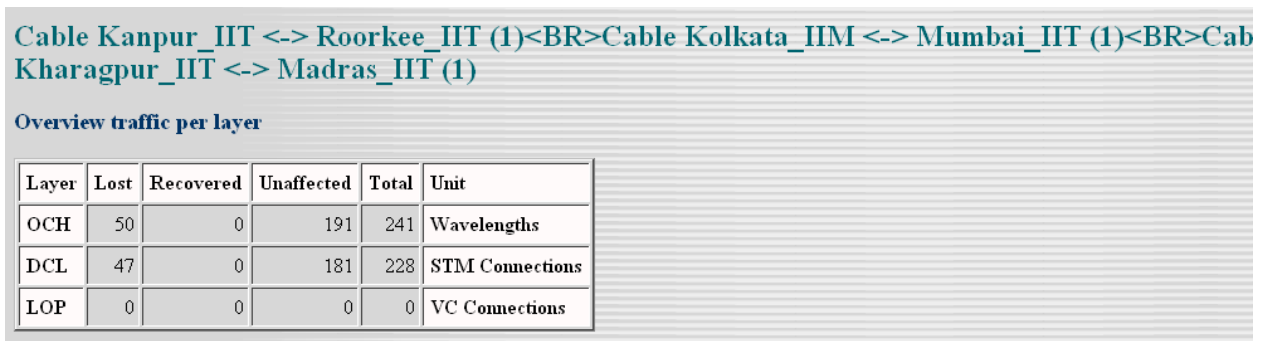


Fig. 9 Failure Analysis between the 3 nodes shown

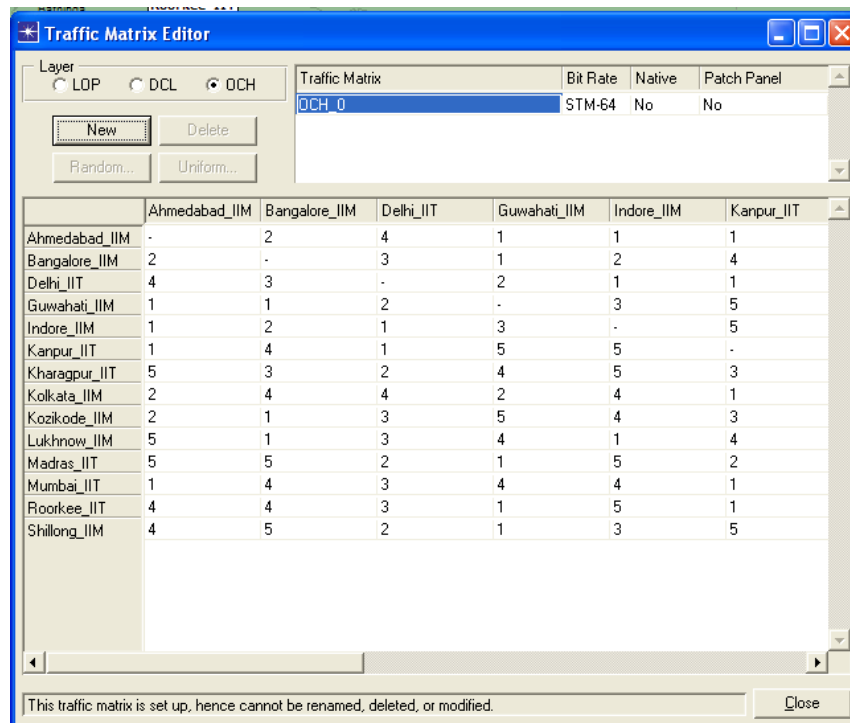
## TOTAL NETWORK COST

Category		Cost	Total
Link Cost	Cable	0.00	178,675.00
	Fiber	19,275.00	
	Channel	159,400.00	
	SDH Equipment	0.00	
Node Cost	Electrical	151,540.00	151,540.00
	Optical	0.00	
<b>Total Network Cost</b>			<b>330,215.00</b>

Fig. 10 Total Network Cost

## 3. SCENARIO 2

TRAFFIC MATRIX EDITOR: OCH and DCL Traffic have been increased by 100%. The range is from 1 to 5 now of the number of wavelengths in use.



The screenshot shows the Traffic Matrix Editor window with the following components:

- Layer:** LOP, DCL, OCH (selected)
- Traffic Matrix:** OCH\_0, Bit Rate: STM-64, Native: No, Patch Panel: No
- Buttons:** New, Delete, Random..., Uniform...
- Traffic Matrix Table:**

	Ahmedabad_IIT	Bangalore_IIT	Delhi_IIT	Guwahati_IIT	Indore_IIT	Kanpur_IIT
Ahmedabad_IIT	-	2	4	1	1	1
Bangalore_IIT	2	-	3	1	2	4
Delhi_IIT	4	3	-	2	1	1
Guwahati_IIT	1	1	2	-	3	5
Indore_IIT	1	2	1	3	-	5
Kanpur_IIT	1	4	1	5	5	-
Kharagpur_IIT	5	3	2	4	5	3
Kolkata_IIT	2	4	4	2	4	1
Kozikode_IIT	2	1	3	5	4	3
Lukhnow_IIT	5	1	3	4	1	4
Madras_IIT	5	5	2	1	5	2
Mumbai_IIT	1	4	3	4	4	1
Roorkee_IIT	4	4	3	1	5	1
Shillong_IIT	4	5	2	1	3	5

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

Fig. 11 OCH Traffic Matrix Editor

## DCL TRAFFIC MATRIX EDITOR

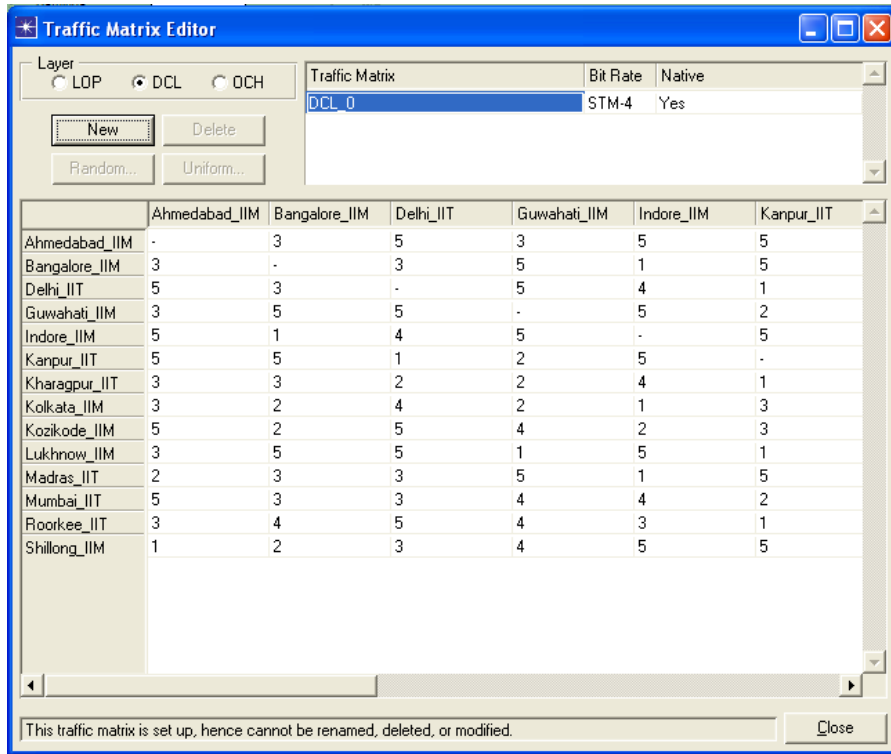


Fig. 12 DCL Traffic

## Routing Results

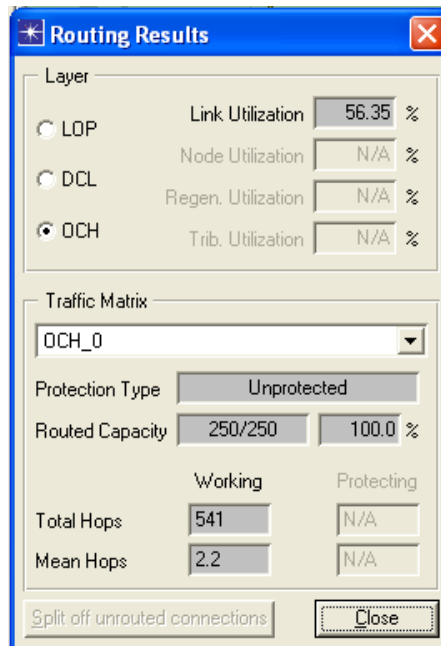


Fig. 13 Routing Results

# FAILURE ANALYSIS

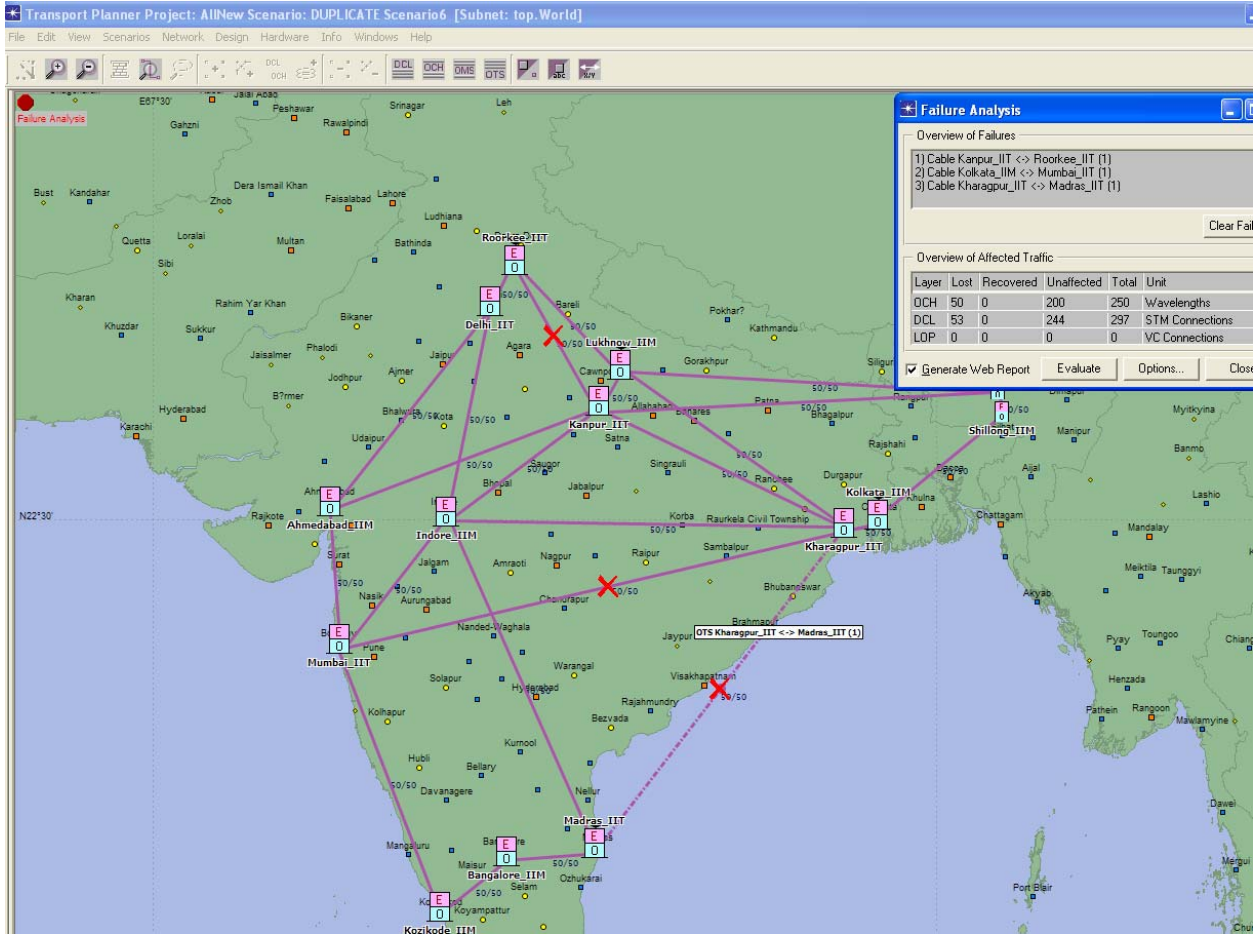


Fig. 14 Failure Analysis

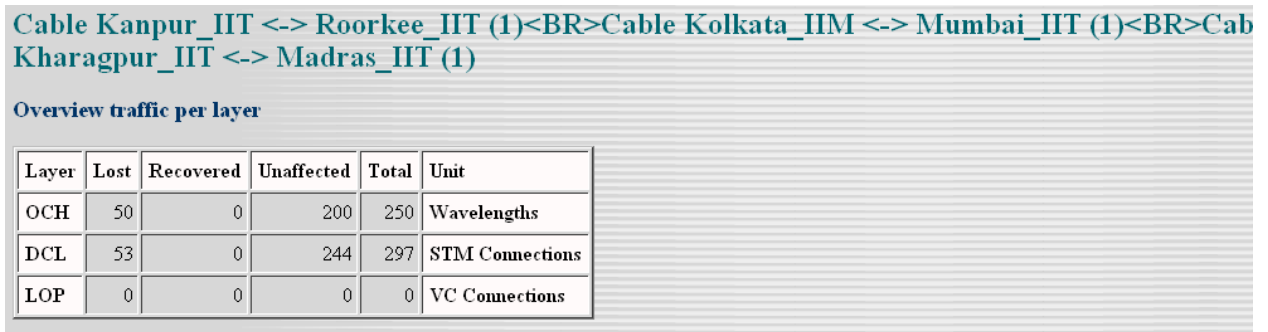


Fig. 15 Failure Analysis of the same 3 nodes

## TOTAL NETWORK COST

Category		Cost	Total
Link Cost	Cable	0.00	188,475.00
	Fiber	19,275.00	
	Channel	169,200.00	
	SDH Equipment	0.00	
Node Cost	Electrical	152,305.00	152,305.00
	Optical	0.00	
Total Network Cost			340,780.00

Fig. 16 Total Network Cost

## 4. SCENARIO 3

### Failure Analysis

**Overview traffic per layer**

Layer	Lost	Recovered	Unaffected	Total	Unit
OCH	0	4	87	91	Wavelengths
DCL	0	0	91	91	STM Connections
LOP	0	0	0	0	VC Connections

Fig. 17 Failure Analysis

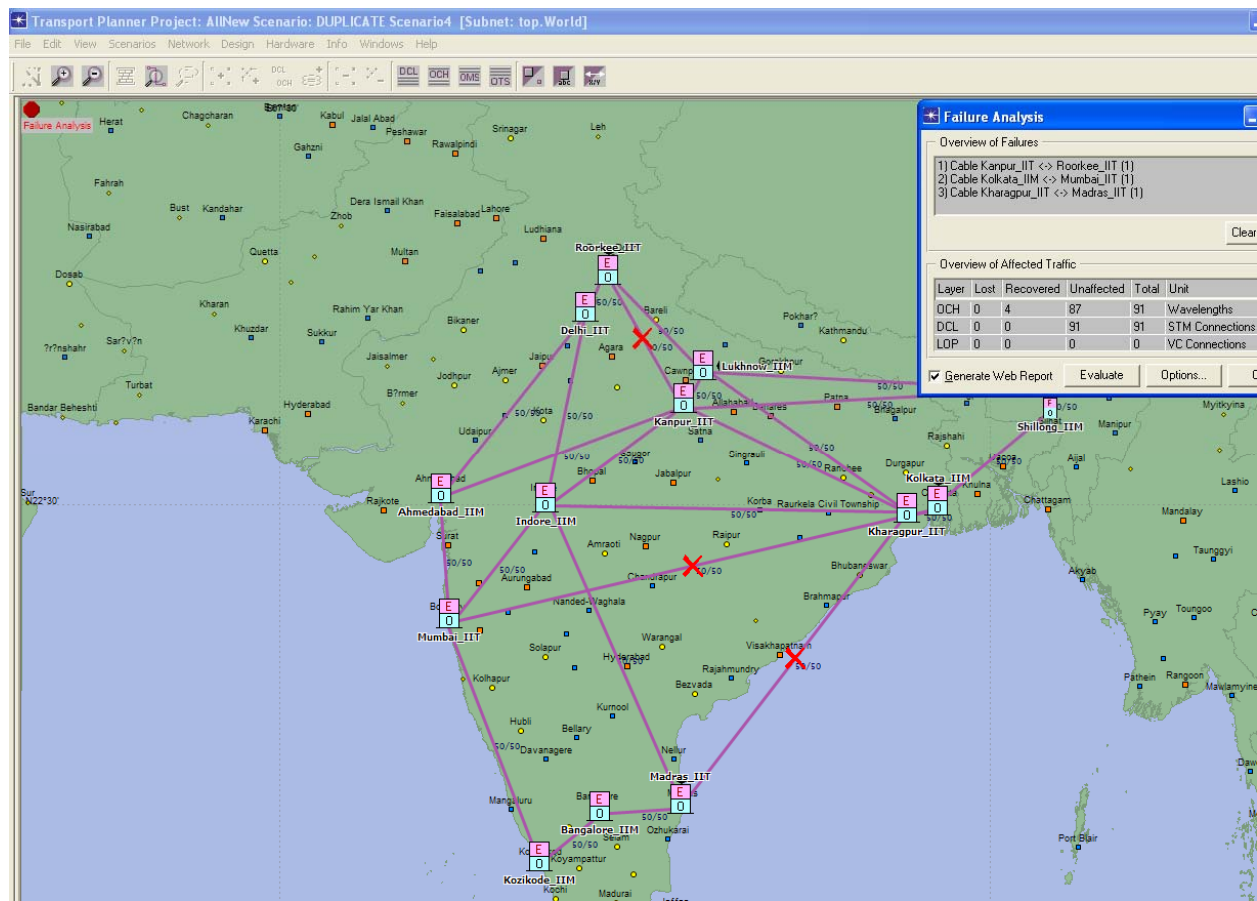
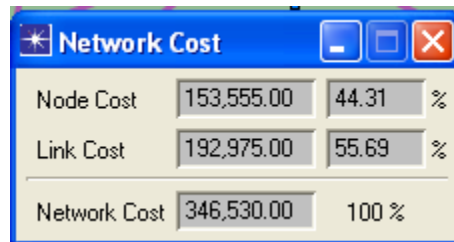


Fig. 18 Failure Analysis

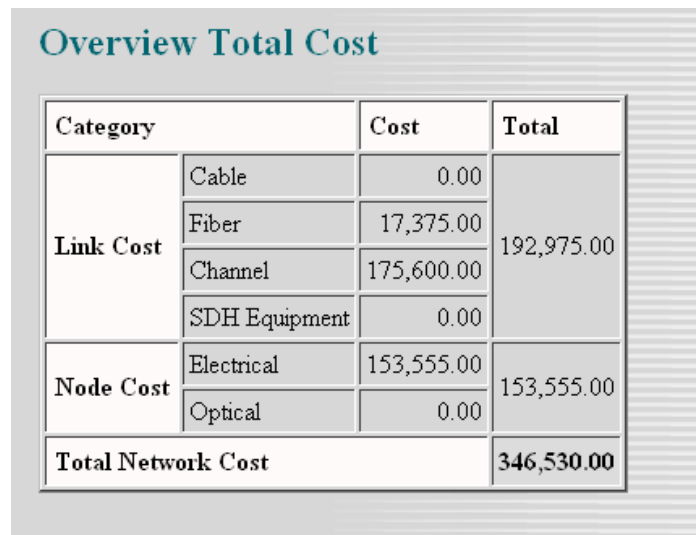
## TOTAL NETWORK COST



A screenshot of a software window titled "Network Cost". The window has a blue title bar with standard Windows window controls (minimize, maximize, close). The main content area is white and contains three rows of data. Each row has a label on the left, a numerical value in a text box, and a percentage in a text box. The first row is "Node Cost" with a value of 153,555.00 and 44.31%. The second row is "Link Cost" with a value of 192,975.00 and 55.69%. The third row is "Network Cost" with a value of 346,530.00 and 100%.

Category	Cost	Percentage
Node Cost	153,555.00	44.31 %
Link Cost	192,975.00	55.69 %
Network Cost	346,530.00	100 %

Fig. 19 Total Network Cost



A screenshot of a table titled "Overview Total Cost". The table has three columns: "Category", "Cost", and "Total". The "Category" column is split into "Link Cost" and "Node Cost". The "Link Cost" category is further divided into "Cable", "Fiber", "Channel", and "SDH Equipment". The "Node Cost" category is divided into "Electrical" and "Optical". The "Total" column shows the sum of costs for each category. The overall total network cost is 346,530.00.

Category	Cost	Total
Link Cost	Cable	0.00
	Fiber	17,375.00
	Channel	175,600.00
	SDH Equipment	0.00
Node Cost	Electrical	153,555.00
	Optical	0.00
Total Network Cost		346,530.00

Fig. 20 Total Network Cost Overview

## **5. CONCLUSIONS**

Above analysis, Figures and Results show that Scenario 3 which was manually routed unlike the Scenarios 1 and 2 has a higher network cost (See Figure 10, Figure 16, Figure 20). This is because now there are fixed routes for each node to the other node in the Network. Also, the network now is protected and hence each node will have an additional backup route to every other node to cater to link failures.

Looking at the Failure Analysis, Figure 9 and Figure 15 show that Scenario 1 has a slightly better performance as compared to Scenario 2. This is because in Scenario 2, the Traffic was slightly increased. Hence this resulted in loss of traffic as the number of links and routes are still the same. This performance is greatly improved in Scenario 3 as there are fixed routes for each node to every other node in the network. Hence traffic lost is a few as compared to the other Scenarios (Figure 17).