Optimization of High Capacity Optical Transport Network using Riverbed SP GURU Transport Planner for Metropolitan Network

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***Abstract*—** Network optimization is inevitable to improve network carrying capacity and reliability of an ICT optical fiber network which capacity is otherwise limited. In this paper, a multilayer transport network capable of carrying high volumes of traffic utilizing SDH/DWDM technology is designed using SP Guru transport planner software. This network describes five network nodes in which the main service stations are located in five major cities (London, Birmingham, Glasgow, Edinburg and York) connected in a mesh topology. Different scenarios having provision for protected and unprotected Link mode in order to evaluate and compare the cost and effective option of protection to be used are described. Two criteria are set to determine the best scenario, namely the cost and survivability of the network. In this model, different scenario links and node are failed to determine the amount of links affected and maximum delay to reroute under faulty link or node condition (link protected mode). The result obtained comparing the cost and failure analysis in protected and unprotected mode scenarios showed that in protected mode under different failure conditions the system failed link was all recovered within and in the unprotected link mode unaffected ratio of about 85% was obtained. It was also shown that the cost of the network link and node is having a difference in cost margin of less than 6% between protected and unprotected scenario. This result is a deployable method in ICT fiber infrastructure in Nigeria as it provides a high carrying capacity for networks.

Key words — Optimization, Protection, Optical fiber, transport planner, metropolitan network.

INTRODUCTION

Due to the demand for high data transport there is need for optimizing the optical transport network (OTN) required to transfer high amount of data traffic at a reasonable cost and high reliability. In recent times, OTNs use SDH/DWDM technology in designing the optical transport network. OTN is an efficient way of multiplexing data into optical light paths. It was designed to provide support for optical networking using wavelength division multiplexing (WDM) technology (ITU, 2001). The need for OTN was due to high bandwidth requirement in the transport core (Zhang & Ansari, 2009). The first building block in the foundation of an OTN is the point to point WDM system which supports multiple data rate such as STM-4, STM-16 up to STM-64. In this study STM-16 was used. The system also supports different client layer technologies such as PDH, SDH ATM and IP, and allows implementation of an optical channel (OCh) (Falcao, 1998). The need for protection cannot be over emphasized with high capacity fiber cables and optical cross connects. Any fiber fault or cross-connect failure will be catastrophic hence a dedicated protection is used in the protected scenario of this model simulation.

In this study an optical transport network was modeled using riverbed SP Guru transport planner containing five major cities in the United Kingdom (London, Birmingham, Glasgow, Edinburg and York) as core stations. Using a mesh topology, three layers of the OTN network were modeled. Optical transmission section (OTS), optical Multiplexing Section (OMS), and Optical Channel (OCH) and by extension the network cost were simulated in the first part by comparing two scenarios, one in network link unprotected mode and then protected mode. In the second part of the study, different links and nodes were failed and the effects on network performance were observed to determine which fit best to be used based on network cost and survivability under faulty link(s) and node condition for this model network.

OPTICAL TRANSPORT NETWORK OVERVIEW

OTN is a protocol to transport network as defined by the ITU-T G.709. It was developed to solve the problem of SDH/SONET which was designed for only voice predominant service (ITU, 2001). The optical network was becoming larger and more complex and needed a standard that would allow scalability (Yadev, 2012), hence a new standard OTN was developed by ITU-T. The beauty of OTN is transparency and manageability. No matter what service is placed inside the OTN payload, the network will guarantee transparency even if it crosses multiple separate networks, unlike SONET and SDH which not only re-time the service but also strip off overhead information preventing end to end communication (Tomich, Vonahnen, & Sheehan, 2006). OTN can also support asynchronous data services such as Plesiochronous Digital Hierarchy (PDH), Ethernet, Gigabit Ethernet services and others (Nesset, 2015).

THE MESH NETWORK

A mesh network topology (Figure 1) was used in this model to provide more routing path in the event of a failed node or link. To determine the number of port and node, the theoretical formula for mesh network was employed as in Forouzan & Fegan, (2007) since a fully connected network with n nodes, has n(n-1)/2 direct links.

$$\text{Number of links} = \frac{n(n-1)}{2}. \qquad (1)$$

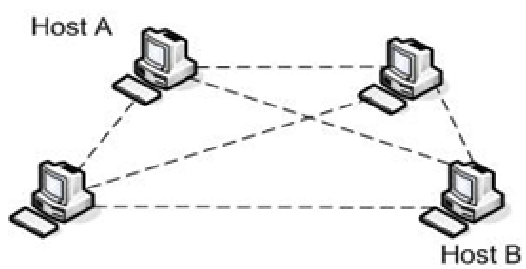


Figure 1: Mesh network topology

Equation (1) is used to obtain the number of required links for the topology. Each node has a dedicated connection to other nodes. In this case node (n) is 8 hence, 28 links were required.

The maximum input power (Pin_{max}) and power required at the receiver (Pr) for each link is determined by using

$$Pinmax(dB) = (\alpha L + \Pr dB) \text{ (Gumaste, \& Anthony, 2003)} \qquad (2)$$

and by extension

$$L = \frac{Pin - Pr}{\alpha} \qquad (3)$$

where the attenuation in dB/km is α

L is the maximum transmission distance.

Equation (2) and (3) were used by the simulation software to determine the number of repeaters, optical amplifiers over a particular length of link.

OTN USING WDM

Optical networks are designed using a layered approach, the higher layer are fully managed by electronic equipment. Different protocol can be stack over one another (IP over ATM, ATM over SDH, IP over SDH ATM over Ethernet and so on) (Doshi, Dravida, Harshavardhana, Hauser & Wang, 1999). The Wave division multiplexing (WDM) optical layer act as a common platform able to carry various kind of protocol combination. It is a circuit switching oriented multiprotocol transport level. Multiprotocol is the ability to transparently support upper layer application protocol stack. This technique enables network operator to extend transport capacity and reduce number of repeaters needed (FSAN, 2015). The WDM setup optical point to point circuit based on the request from the upper layer. The optical circuit is known as light path. Each path carries a digital stream. Electro-optical devices interface between the WDM and higher electronic layer and is transparently switched by each electro-optical device on its path which can be an optical cross connect (OXC) or an Add and Drop multiplexer (OADM) (Hill *et al*., 1993) as will be seen in section IV.

According to the ITU-T G.872 WDM is made up of four sub layers namely the optical channel sublayer (OCh), Optical multiplex section sublayer (OMS), the optical transmission section sublayer (OTS) and the physical media sublayer (optical fiber).

OCh takes care of all end to end networking function. OMS performs WDM multiplex of all the channel on a single fiber by a particular wavelength. The Optical Transmission section sublayer (OTS) manages and supervises the optical connection.

SIMULATION SETUP AND SCENARIO

The model was built using Riverbed SP Guru Transport planner. This software provides the design environment to simulate and perform analysis of the proposed model (Bharat T. & Doshi, 1998). The model was built based on mesh network topology and a station located in five major cities in the United Kingdom (London, Birmingham, Glasgow, Edinburgh and York). Also, three subnet were added in the neighboring area to the nearest station as shown in Figure 2.

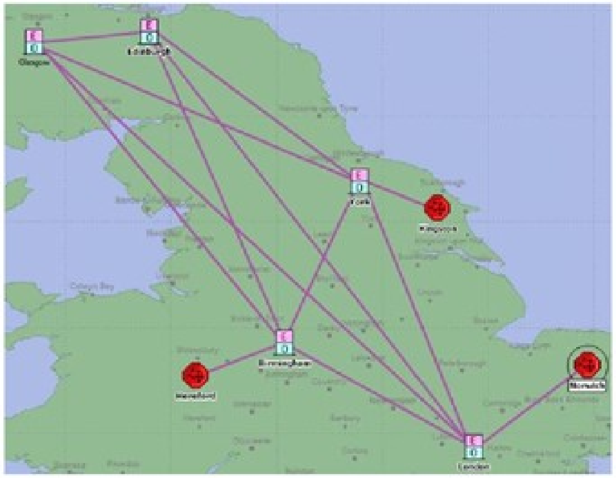


Figure 2: The network topology

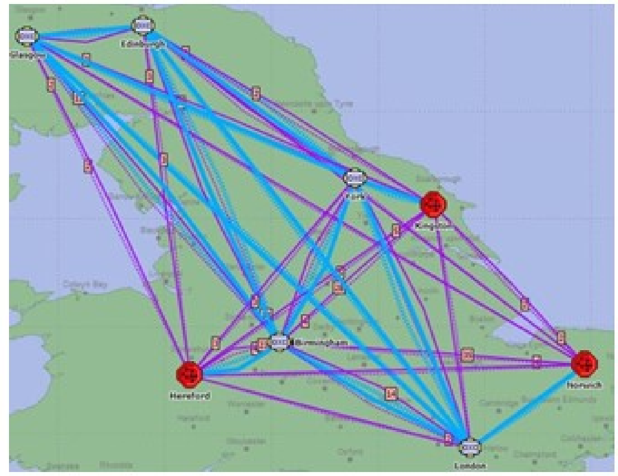


Figure 3: The network topology showing route in OCh and OTS

As depicted in Figures 2 and 3 the darker grey links denote the OTS layer while the lighter grey links in Figure 2 depict the OCh layer. The numbers on the links denote the number of links in the bundle between the point to point links and the OXC representing in station location.

The following parameters are used for the model shown above:

Table 1: Table of parameters

Attribute	Value
Traffic matrix	Optical Channel (OCh)
OCh bit rate	STM-16 (2.5Gb/s)
OCh support link type	OCH SDH, Patch panel Yes
TDM Nomenclature	SDH
OCh Layer mode	Opaque
Node model	OXC, DXC, ODU XC
LS type	LH 40-WDM
DCL bit rate	STM-4
Fiber pair Equip	LH 40-WDM per pair
Protection	Dedicated (1+1)
Distance Unit	Km
Map	United Kingdom
Routing	OCh, Asymmetrically
OXC, ODU XC	Type 1
Topology Parent	Mesh
Topology subnet	Ring
Stations	Electrical Optical Cross Connect(EOCC)

Topologies

The choice of topology in this model is mesh. It is specified with the use of a connectivity matrix without capacity constraint, leaving the core module to optimize routing along all paths where capacities are available (Bharat T. & Doshi, 1998). It is desirable because of its robust survivability in the presence of faulty links or nodes, and as mentioned in section I, a failure in the OTS layer can be catastrophic.

Protection

During network design protection is necessary to provide redundancy in case of faulty link or node. Protection can be dedicated path 1+1 or 1:1 this type of protection is resource consuming in mesh network. In the case of dedicated path 1:1 low priority traffic can be transferred on this path in the absence of failure but this required an addition of end to end signaling which will in turn introduce more delay. In this model, a dedicated protection path 1+1 is used although more resource is required but less delay when fault occurs and also another scenario with unprotected mode is experimented so as to evaluate its effect on the cost and failure analysis.

Traffic Matrix

The traffic matrix used is based on the OCh layer. The matrix is configured given more links priority to larger cities such as London, Birmingham, Glasgow, and Edinburgh depending on the size of the city. Because of the volume of traffic that may be required in places where the population is relatively small to the other city, less links are allocated to avoid over provisioning the network node and waste of resources and increase cost. The matrix can also be done by given random value, but this will lead to a node being either over provisioned or under provisioned.

SIMULATION RESULTS AND DISCUSION

Network cost

This is the cost of nodes and links used in the network.

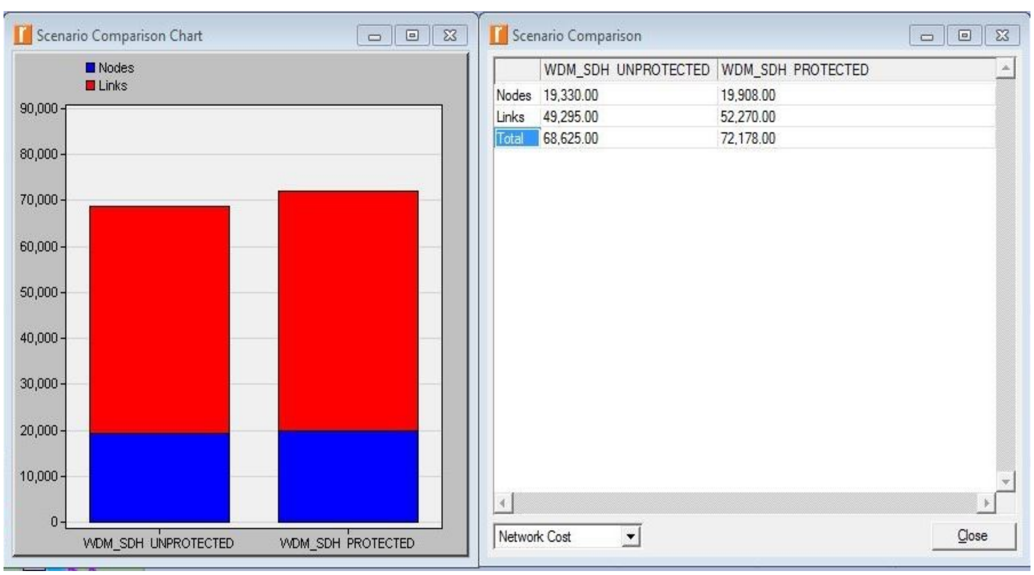


Figure 4: Network cost

Table 2: Network Cost

Attribute	Unprotected	Protected
Node	19,330.00	19,908.00
Links	49,295.00	52,270.00
Total	68,625.00	72,178.00

Considering Table 2 and Figure 3 it can be deduced that the difference in cost in the protected and unprotected mode is £3553. So in terms of cost it can be observed that the unprotected is cheaper. However, the protected mode will be recommended because the cost difference is less than 5.1% which can be compensated for or paid back by enhanced network reliability and efficiency.

Node cost

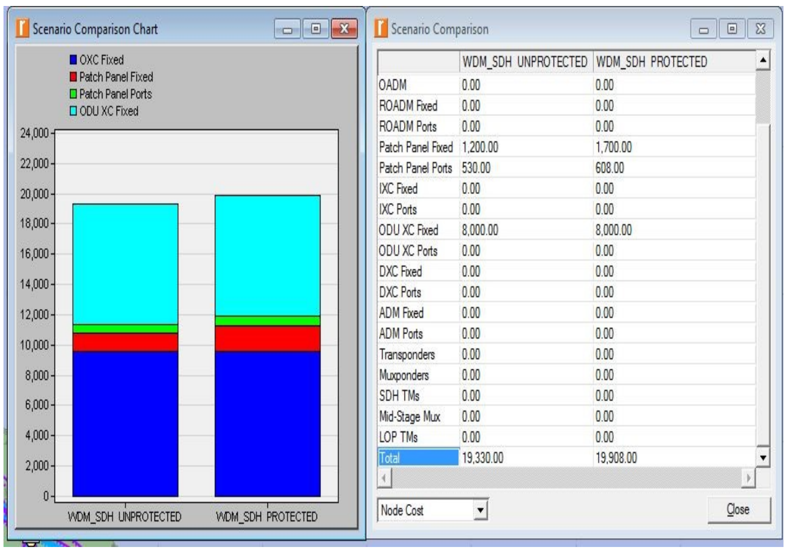


Figure 5: Node cost

Table 3: Node Cost

Attribute	Unprotected	Protected
Patch panel fixed	1,200.00	1,700.00
ODU XC fixed	8,000.00	8,000.00
Patch panel port	530.00	608.00
Total	19,330.00	19,908.00

It can be deduced from Table 3 and Figure 4 that the protected mode is relatively in cost higher and the difference is £578 which can be seen as less than 3% increase in cost, but comparable with the cost of total failure of link. So the protected mode is preferred.

Link cost

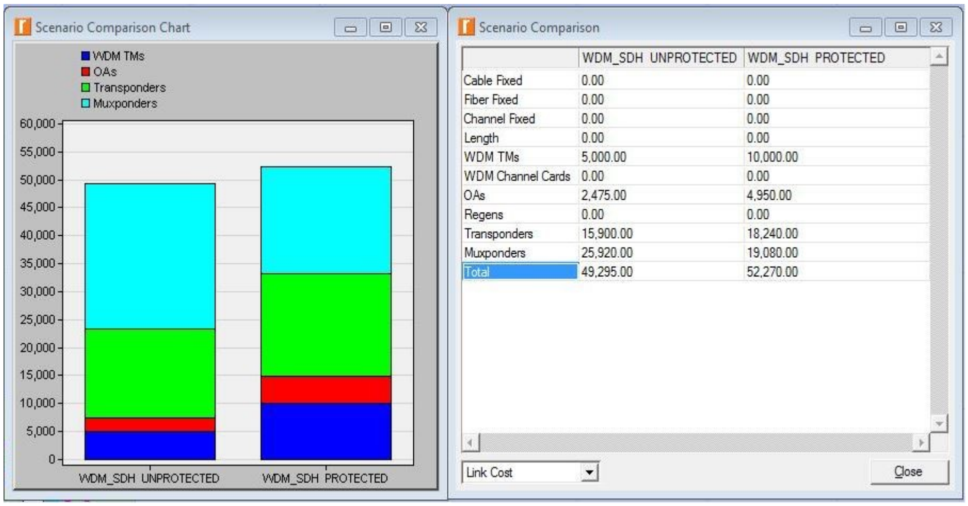


Figure 6: Link cost

Table 4: Node Cost

Attribute	Unprotected	Protected
WDM TMs	5,000.00	10,000.00
OAs	2,475.00	4,950.00
Transponders	15,900.00	18,240.00
Muxponders	25,920.00	19,080.00
Total	49,295.00	52,270.00

It can be inferred from Figure 6 and Table 4 that the link cost difference between the protected mode and unprotected is £2975. It can be drawn that the unprotected mode is cheaper and is less than 6% but compared with cost of restoring a faulty network. The protected link cost is recommended.

Topology information OCh

OCh Toplogy

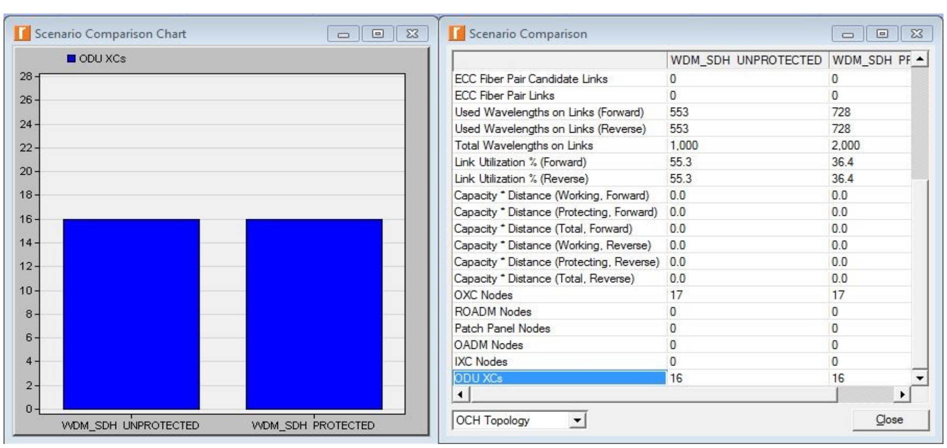


Figure 7: OCh Topology information

It can be deduced from Figure 6 that the information provided by the OCh topology as expected more wavelength is used on links in protected mode 728 (protected) to 553(unprotected), in which the total wavelength is observed to be twice that of unprotected mode, The link utilization for unprotected mode is more (55.3%) than the protected mode (36.4%). This low link utilization in the protected mode is due to reserved link resources to be used in the advent of a failure. Also same amount of OXC and ODU XC is used.

Table 5: OCh topology information

Attribute	Unprotected	Protected
Used wavelength on links	553	728
Total wavelength on links	1000	2000
Link utilization	55.3%	36.4%
OXC node	17	17
ODU XC node	16	16

Topology information OMS

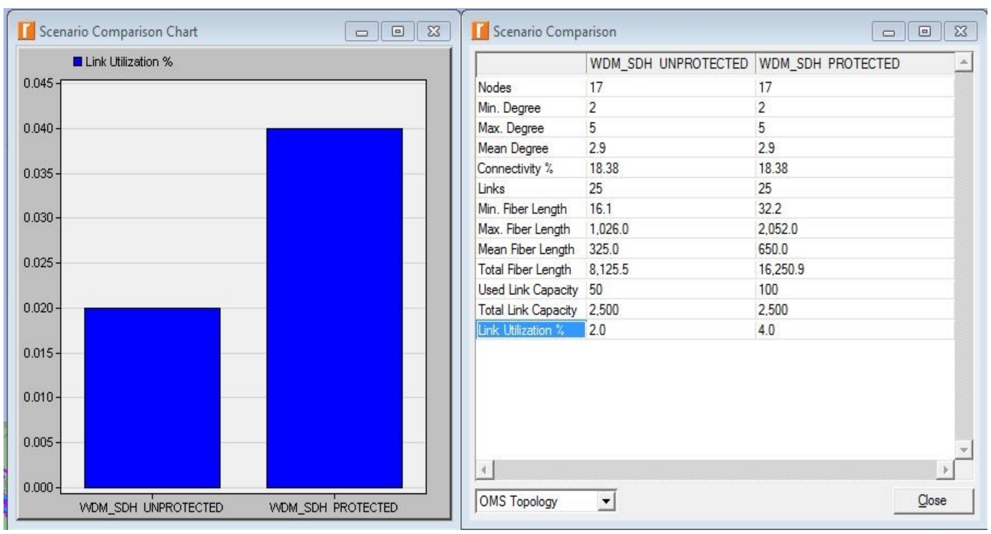


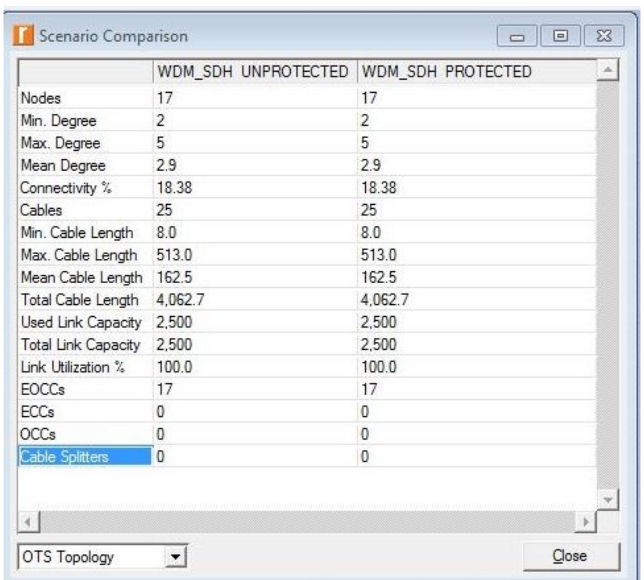
Figure 8: OMS Topology information

Considering Figure 8 and Table 6 it can be observed that the fiber link, fiber length, used link capacity and link utilization of the protected mode topology is twice the value of the unprotected mode. This is due to the resources required by the protected mode while other attributes remain the same on both protected and unprotected mode of the topology.

Table 6: OMS topology information

Attribute	Unprotected	Protected
Nodes	17	17
Mini. Degree	2	2
Max. Degree	5	5
Mean Degree	2.9	2.9
Connectivity	18.38%	18.38%
Links	25	25
Min. Fiber Link	16.1	32.2
Max Fiber Length	1,026.0	2,052.0
Mean Fiber Length	325.0	650.0
Total Fiber length	8,125.5	16,250.9
Used Link Capacity	50	100
Total Link Capacity	2,500	2,500
Link Utilization %	2.0	4.0

Topology information OTS


Scenario Comparison

	WDM_SDH UNPROTECTED	WDM_SDH PROTECTED
Nodes	17	17
Min. Degree	2	2
Max. Degree	5	5
Mean Degree	2.9	2.9
Connectivity %	18.38	18.38
Cables	25	25
Min. Cable Length	8.0	8.0
Max. Cable Length	513.0	513.0
Mean Cable Length	162.5	162.5
Total Cable Length	4,062.7	4,062.7
Used Link Capacity	2,500	2,500
Total Link Capacity	2,500	2,500
Link Utilization %	100.0	100.0
EOCCs	17	17
ECCs	0	0
OCCs	0	0
Cable Splitters	0	0

OTS Topology

Close

Figure 9: OTS Topology information

It can be deduced that the same value of resources is used both in the protected mode scenario and unprotected mode.

Failure Analysis

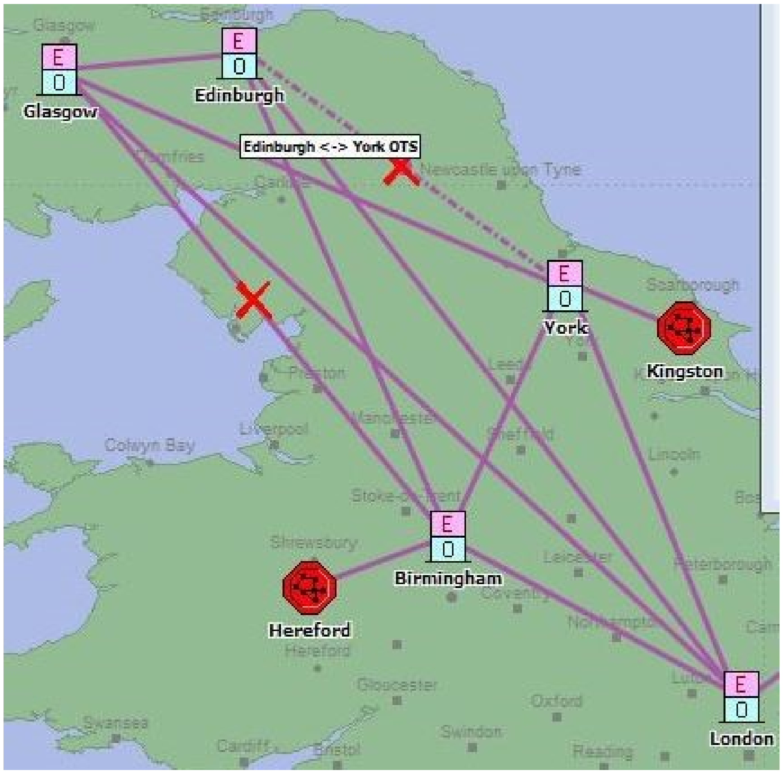


Figure 10: Failure scenario

The result of the effect of failed linked is shown in Table 7.

Table 7: Result of failure analysis of unprotected links

Links (OCh)	Lost	Unaffected	Total wavelength	% lost
Birmingham<->London	29	259	288	10
Birmingham<->York	26	262	288	9
Edinburgh<->Birmingham	21	267	288	7.2
Edinburgh<->York	10	278	288	3.5
Glasgow<->Birmingham	18	270	288	6.3
Glasgow <->London	17	271	288	5.9
Glasgow <->York	10	278	288	3.5
London <->Edinburgh	21	267	288	7.2
York<->London	29	259	288	10
Edinburgh<->Glasgow	29	259	288	10

Table 8: Result when two links failed simultaneously

Links	lost	Unaffected	Total wavelength	% lost
Glasgow<->Birmingham, Birmingham<->York	44	244	288	15.3

Table 9: Result of failure analysis of protected links

Links (OCh)	Recovered	Unaffected	Total wavelength	Delay (ms)
Birmingham<->London	14	198	212	4
Birmingham<->York	8	204	212	2.7
Edinburgh<->Birmingham	14	198	212	3.2
Edinburgh<->York	8	204	212	3.8
Glasgow<->Birmingham	12	200	212	2.03
Glasgow <->London	16	196	212	2.8
Glasgow <->York	8	204	212	1.35
London <->Edinburgh	16	196	212	2.5
York<->London	8	204	212	3.4
Edinburgh<->Glasgow	14	198	212	3.2

It can be deduced from Table 7 that the percentage lost ranges between 10-3.5% in unprotected mode, as shown in Figure 11.

In another case when two links are failed simultaneously, the results are as presented in Table 8. It can be inferred that the number of lost link increase further as the links fail.

Regarding the protected links, it can be deduced from Table 9 that all link lost were recovered in the network and the worst delay time range was between 4ms - 1.35ms. Comparing the lost link in Tables 7 and 9 it can be deduced that the number links lost was higher.

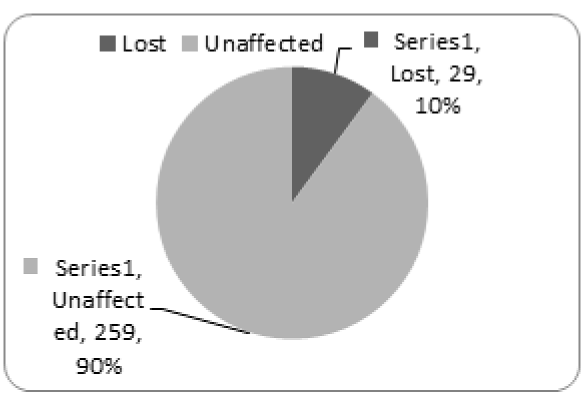


Figure 11: Failure analysis of unprotected link

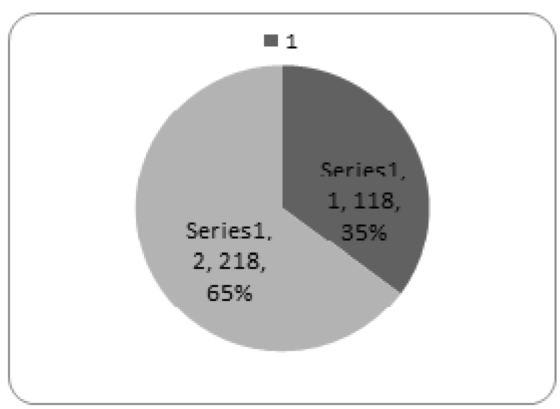


Figure 12: Result of lost link Versus Recovered link

CONCLUSION

In this study a network was modeled using SP Guru transport planner. The cost of the network was obtained in both protected and unprotected link mode scenario and it was observed that the network cost of unprotected was cheaper, and it had a link loss ranging within 15-10%. On the other hand, it was observed that the protected link mode was more expensive by a value of 5.1 %, which when compared with the cost of restoring the lost link in unprotected mode, was negligible. Considering the failure analysis obtained, the protected mode scenario recovered all its links (within the range of 4ms - 1.35ms). Hence it can be inferred that the protected link mode is more promising for effective deployment when considering cost and survivability of the modeled network.

This study has investigated a better and cost effective method of executing a communication network in metropolitan environments in the UK. The procedure can be replicated for fiber infrastructure in communication systems in Nigeria to achieve similar results. Given the terrain of communication network in Nigeria which is in the developmental stages, the deployment of such a system is a welcome idea that can improve the system.

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