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Creating Reliability In Optical Network By Installation And Implementation Of Self Healing Optical Network.

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Abstract: *The ever increasing request for data haulage,has called for survivability and adequate planning /implementation of Network frame architecture for protection of data .Against the background of multi or double link failure in the optical domain of wave length division multiplex,mesh networks using new Algorithm called IMPROVED SHARED-PATH PROTECTION (ISPP) is introduced to enable the challenges of failures be overcome.*
*This work views and develops two algorithmic methods of addressing this issue the first phase is to generate a set of promising paths and the second is to take holistically a heuristic ILP(Integer Linear Programming) analysis based on simulated allocation and annealing which can select paths, thus reducing the network deployment cost.Results obtained indicated that the promising path generator supplied sets of non-failure for Nominal network design task than the sets of protected Network designwhich fairs well **in alternate routing** task.The utilization of heuristic ILP optimization tools showed a good reduction in overall cost of ducts and nodes installation.*

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I. INTRODUCTION:

The increasing demand for broadband backbone has led to concerted efforton studies, analysis, planning, installationand maintenance of optic fiber network. Poor network planning operations,has led to failures, such as call-droppings, interferences, partial or total loss of data and others as always complained by network users (Mukherjee, 1997). This analysis is focused on protecting the network from link or path failures and blocking probabilities of optical network system. The work will improve on the removal of link failures by providing the necessary ,nodes, links, switches, primary paths, backup paths and disjointed links. This will necessitate theintrduction of wavelength division multiplex (various values to different links) and propose an algorithm to archieve the ideal network protection (Maier, 2002). It must be realized that wave length division multiplex has a characteristics of inherent dispersion which must be taking into consideration the implementation network expansion. A simulation of the dynamic network environment will be applied to automatically switch from one path to the other when any path fails. Nodes will be developed and analysed with corresponding links. Primary and Back-up paths will be developed to share mixed wavelength links. Similarly, some mixed backup links can be transformed into primary links during bottleneck situations. The basis of this arrangement is for easy sharing of resources by network links to prevent failures and then improve the overall performance operations of the network (Fredrick, 2013).Here the technic of frequency re-use applies.

It is very critical in network operations when links fail due to congestions or break I link, hence the high demand of the numerous services make it imperative that the network must be expanded. In order to expand the network for proper and smooth usage, procedures must be followed which are either to replace the existing core by increasing the bandwidth which implies that the old core has to be aboundoned and replaced with new core of higher bandwidth (Somani, 2003). This has the disadvantage of high cost. The second and better option is the provision of facilities to expand the link/path without incuring the cost of replacing with new cores. To achieve this, the paths and links are created with the incoperation of wavelengths of various values and optical carrier group of various values. This is Synchronous Optical Network (SONET) and Synchronous

Digital Hirachy (SDH) families Subramaniam, 2000).It is a clear fact that at any point in time when failure is experienced in the network link or path and there is no alternative route or redundant backup facilities , heavy traffic are lost. As the size of optical networks keep enlarging, the probability of multi-link failures become much higher.. The simple reason is that the national network is based on single-link (BUS TOPOLOGY) operation or primary route; for instance, from Porthacourt to Enugu, Enugu to Onitsha- to Lagos without planning for automated switch over in the invent of link and interchangable failure in operations.

In this design the algorithm is such that each request is directed to a primary path and towards disjointed links(backup link) (Sridharan and Somani, 2005). This ensures that if one link fails on the primary path and another failure occurs on the first backup path then there is still an available backup path to transmit the traffic. The simple plan of the proposed system is to allow two backup paths to share same wavelength (Ramaswami, 2002)

In optical communication networks, an optical coupler enables signals in optical fibers or integrated optical circuits (IOCs) to be selectively coupled from one path to another or one circuit to another(Ramamurthy, 2003). The Optical Switchis a unit that actually switches light between two adjacent waveguides, which also performs switching by exploiting nonlinear material properties to propagate light. Any generic fiber optic data link, transport and provide the optical data through the fiber optic components based systems only. Generally, a fiber optic data link divides into three basic operations:

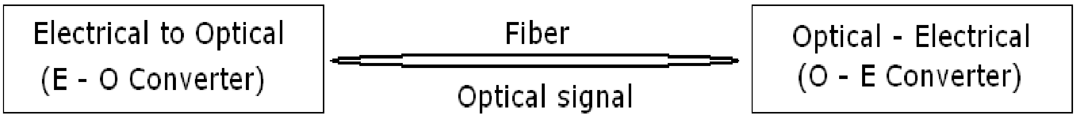


***Fig. 1.2:** A block diagram of an E – O – E optical communication link*

Primarily, an optic fibre communication system is made up of a transmitting device that converts an electrical energy into light signal, an optical fibre cable that carries the signal, (Jozsa and Orincsay, 2013) and the receiver that converts the light signal backinto electrical signal as shown in the block diagram

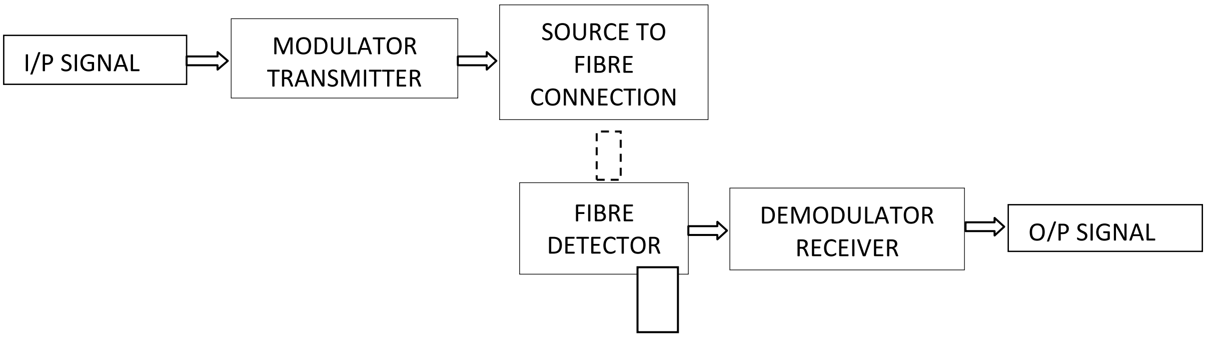


Fig 1.2 Block diagram of opticfiber network

The requisite conversion must be achieved in such a way, that original electrical signal remains at the input and output port. However this needs the networks to go through the process of conversion from and vice versa. Therefore to avoid this conversion that wastes much power consumption and slows the speed of signals, there is the need of inserting all optical components which do not have any need of conversions (Yen, 2007). Optical couplers are important components, which are very much required in optical networks or communication links for their day to day operations and various applications. With the advent of multimedia and scientific computing, there is an exponential growth in bandwidth demand raised by many users possessing the internet connections, this has great impact for their use particularly in military and in academic communities (Ramasubramanian, 2014).

Therefore WDM technology based all-optical mesh networks have been in use to adjust the Internet's ever growing bandwidth demand, as the mesh-in-nature Internet backbones are proven to be much capable in terms of efficiency and reliability (Wen, 2004). In telecom applications, an optical coupler can be used for selective coupling from one circuit to another in optical fibers or integrated optical circuits (IOCs

The capability of transmitting large amounts of information over long distances at nearly the speed of light and without any significant loss of data or interference has made optical fibers perfect choice to use in modern communication systems. In O–E–O devices, the conversion of optical to electrical and vice versa requires extra power and generates unavoidable extra heat, which put great impact on the device cost, if the conversion has to take place quickly or many times. Besides, it is almost impossible for electronic conversion circuitry to keep pace with very high speed optical data transfer, creating a bottleneck situation and thus decreasing the overall efficiency of optical links and communication channels (Harjani, 2016). The guidance of the signals in all – optical domain improves the efficiency of a communication system exponentially.

The risk of system or network failure in Optical networks, survivability is a very critical because the networks are prone to failures. The fibre link failures may lead to heavy traffic being dropped or lost,hence the purpose of this is to prevent network outages and strive to improve the turn –around -timeas well.

II. METHOD AND SYSTEM IMPLEMENTATION:

The method adopted is simply Benchmark (CASE STUDY),Typically of Boolean Algebra improved by W.V.Quine, In its simple implementation to enable us obtain the SELF-HEALING effect ,for clarity lets design the simple synchronous sequential circuit for the binary sequence 0101 . Our usual bus topology of ABCD location

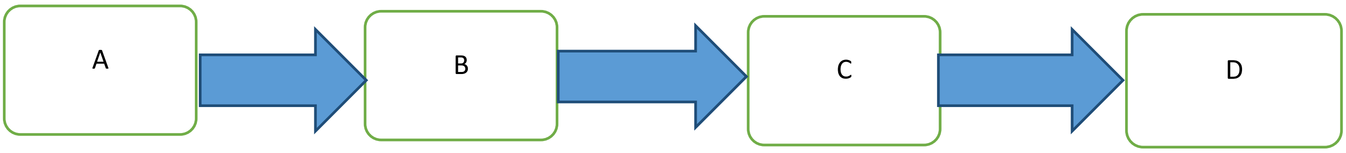


Fig 2.SCHEMATIC OF TRANSMISSION LINK FROM POINT A – D

The sketch above is searching for 0101 sequence avoiding break in transmission as well as overlapping. Analysis –when digit “1” is received at B ,there will be no movement that’s a failure,receving digit “0” then there is a through-put proceed to C. Receiving “00” indicates overlapping of signals,hence return to the first step,that is back to “0” At location C (node C),’0’ is being searched for but 011 is found,it means digit ‘1” is received then return to A for re-routing.

In summary at A ,if the input is “0” move tp B else find back-up, however if at A input is digit ‘1” re-route.

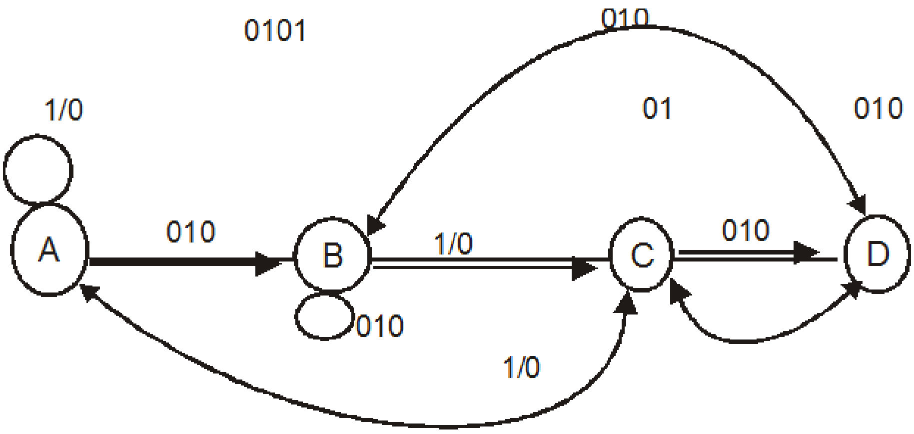


Fig 2.2 Back up diagram for self-healing.

Table 2.1

STATE TABLE

Y1Y2 \ X	0	1
00A	B,0	A0
01B	B,0	C,0
11 C	D,0	A,0
10D	B,0	C1

TRANSITION TABLE

Y1Y2 \ X	0	1
00	01/0	00/0
101	01/0	11/0
11	10/0	00/0
10	01/0	11/1

Having analysis the above and taking cognizance of our focus we proceed as follows:
Assuming the link for transmission is labelled xand y respectively and there is a break in the link, if the cut of links x and j see fig 2.3, leads to the failures of p_0 and p_1,the primary wavelength-link w_0 on link k used by p_1 can be released, so that w_0 is now free and it can be re-used by b_1^2. Then, the redundtant backup wavelength-link w_2 can be saved. Since w_0 can be used (or shared) by primary path p_1 and backup path b_1^2, it can be changed to the mixed wavelength-link. Based on the same principle, the primary wavelength-link w_1 on link j also can be changed to the mixed wavelength-link and can be shared *by* b_1^1, and then the redundant backup wavelength-link w_3 also can be saved (Ramamurthy, et al, 2003). In this project, the protection algorithm allowing the primary and backup paths to share the mixed wavelength-link is to be improved in shared-path protection (SPP), (Guo and Yu, 2014).

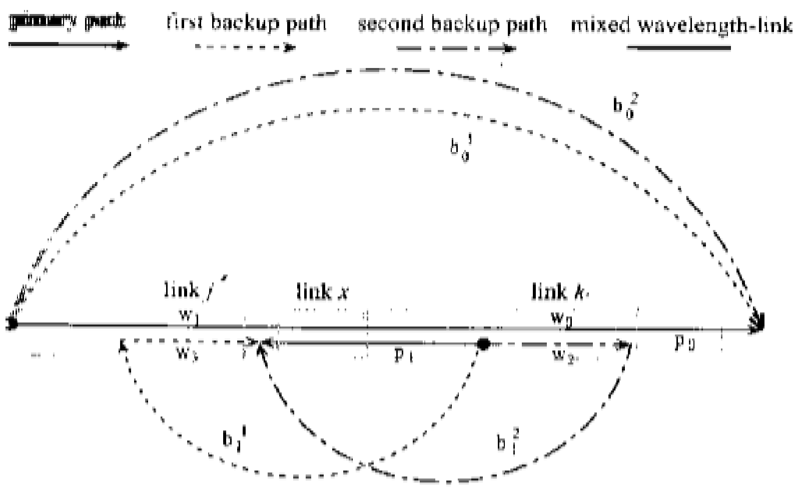


Fig.2.3; Wavelength Assignment of SPP

With the advent of wavelength division multiplexing (WDM) technology, more number of wavelengths per fiber (≥ 100) is accommodated with each wavelength operating at the rate of at least 10Gbps(Gerstel and Ramaswami, 2002). An optical switch capacitate signals in optical fibers or integrated optical circuits to be selectively switched from one circuit to another, which is the basic underlying principle of telecom applications. Photonic switches are the systems that perform and control switching of light, unconstrained of how the light itself is switched. A significant portion of the optical switches in use are made up of photonic switches. In any good network, there should not for any cause be a noticeable downtime despite the numerous problems generally associated with telecommunication or optical networks. The network from the begining needs proper and adequate planning which should include protective and restoration measures. This becomes necessary to first design a network plan, that is to precalculate or to see that failures do not take place indiscriminately. This means that any failure that occurs will automatically find a free backup route without the notice of either the network operator or the end consumers. Since failures are bound to happen, it will only be automatically reflected on the system panel of the control room to show that there was a self healing implementation from the occured failures.

Due to these, this work is to plan a greenfield events of perfect network where a telecommunication operator, has to determine where to allocate or site some WDM network nodes. There should be a desire on how to interconnect the nodes with links at least cost but with continous services assured even in the face of multilink or node failures. It will forestall any architectural restrictions, and impositions against service demands.

Primarily, this work like it was stated earlier, is to design a mesh network where every node is connected with an OXC without wavelength converters but still satisfy wavelength continuity constraints thereby optimizing the whole network system optically. The aims and objectives of this work are to be actualized using matheuristic algorithm method called REACTIVE SEARCH OPTIMIZATION (RSO). It will sequentially define the network components and optimization tasks by methodically describing the algorithm for getting a set of "promising path" that can help to cut down the greenfield network cost by reducing both fibre and duct usage. The network link paths will subsequently be used for network optimization using integer linear programming (ILP) and two of the explain tools of the algorithm method known as simulated annealing (SAN) and Simulated allocation (SAL). The ILP program functions in two folds; Arc-flow and link-path formulations, both to produce optimal results based on the qualities of promising path sets. The main features of the optimization tasks being used here are to see that duct costs, nodes and link costs are included and that wavelength assignment is integrated with path optimization and with duct and link placement.

The promising path generator (PPG) and the SAN + SAL (matheuristics) algorithm are the working tools here. This thesis as earlier said will use the RSO method to empirically evaluate the (PPG) algorithm by comparing its results with the best final results obtained from ILP programs using other networks as examples. Finally, will show a few graphs which demonstrate that matheuristics stabilize at their final solutions within a reasonably short time and that will draw a conclusion or verify the topic and objectives of this work.

2.2 WDM Network Planning of Greenfield Characteristics

There are many network design scenarios, characterised by what normal network parameters are known for, such as node positions, duct and link placements and also what parameters and to which extent they can be extended; (for example link equipment as in fibre). However, if the node positions are unknown, it is a greenfield network design scenario in which the operator must decide where to place the nodes based on the aim of where the end-users are densely located. So here, the network is planned to always know the node locations and that some new volume of traffic demands are given which must be satisfied. The network design plan is characterized as follows, where "+" sign means that the links or the nodes are extentable while the opposite sign means not extentable. The introduction OF WDM wave length division multiplex into the net work creates a design parameter that will intrgerate SONET and SDH for ease of providing Nodes positions ,duct and Link placements at vantage Locations.The purpose of introducing the wave length Division Multiplex in a green field or Normal field is to enable mulitlple signals be carried on same fibre (modulation).How ever the situation od dispersion which is inherent in WDM must be giuided

Table 2.2: classification of network design planning scenario.

Nodes		Links				Traffic	
Equipment deployed	New equip. Allowed	Ducts exist	New ducts allowed	Fibre deployed	New fibre allowed	Existing routes	Network design problem Types
-	+	-	+	-	+	-	(Node restricted) Greenfield
-	+	+	-	-	+	-	(Duct restricted) greenfield
+	-	+	-	+	-	-	Totally capacitated Routing
+	-	+	-	+	-	+	Totally capacitated Routing Extension
+	-	+	-	+	+	-	Node cap routing ext. & link deployment ext.
+	-	+	-	+	+	+	Node cap routing ext. & link deployment ext.
+	+	+	-	+	-	-	(link) capacitated routing
+	+	+	-	+	-	+	Link capacitated routing Extension
+	+	+	-	+	+	-	Duct resticted routing and Deploymentextension
+	+	+	-	+	+	+	duct restricted routing ext. and deployment extension
+	+	+	+	+	+	-	Routing and deployment Extension
+	+	+	+	+	+	+	(General) extension

The Plan shows that the most common scenarios are the greenfield, the duct restricted and the extension network design. Hence forth, the nodes and some traffic demands are considered with the goal to design their placement and capacities of the links.

2.2.1 Optimizing the Network for Link Costs

Link: Every link comprises of one duct containing a number of fibre pairs which each carries M wavelengths to a differet direction. There is also a potential links which is a set of L to identify, yet non-existing links from which the actual network links must be chosen during the design process. Below is an example of network with given nodes and potential links and traffic demand matrix.

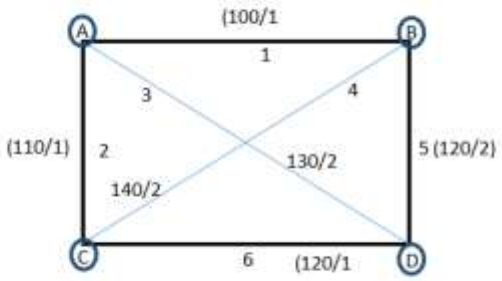


Fig 2.1: WDM network planned on 6 links with a traffic demand matrix box containing 3 demand volume.

Table 3.4: Decision box for fig. 3.1

L	Between	C_1^{duct}	C_1^{fibre}
1	A-B	100	1
2	A-C	110	1
3	A-D	130	2
4	B-C	140	2
5	B-D	120	2
6	C-D	120	1

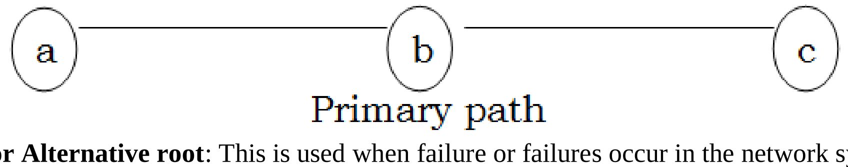
	A	B	C	D
A	0	7	0	0
B	0	0	0	6
C	0	0	0	5
D	0	0	0	0

Each of the links is numbered and labelled with (duct/fibre) cost. The cost model used here is
the cost of link L is $C_1^{link} = C_1^{duct} + F_1 C_1^{fibre}$,
where; F_1, is the number of fibres deployed on link L. The cost of the whole network is the sum of all the link costs. This shows that the cost of nodes can be optimised.
Traffic Demand: The traffic is static and it is given as a set of value denoted by D. Demand number d consist of a source node "n_d^{sc}" and a destination node "n_d^{dst}". Each demand d has a traffic volume V_d, measured in numbers of wavelengths. For ease of simplicity, it is assumed that there is no set of any hop limit or length limit on the path which supplies demands.
Nodes: It is assumed that the OXCs in the nodes have unbounded switching capacities but no node is capable of wavelength coversersion so the wavelength continuity constraint must be satisfied and gives the advantages of wavelength re-use in the network. The wave length re-use must be differentiated from wave length converter.

2,4 Network Protection Optimization

Considering the various ways of guiding the network traffic from failures. The links can be planned to be in state S∈ {0, 1......S] showing that state S = 0, denotes network normal state i.e: a fully stable network but network can exist in state S = L, such that state S > 0 which is a failure state in which link S is broken or malfunctioning. There can be single link failure and multiple link or node failures.
Given a set of paths all supplying the same demand, with identical source and destination nodes, it is said to be single link/node failure and it is resistant if it is such that no matter which single link/node failure occurs, there are still some working paths in the set. However,if for every pair of paths in a path set, there is failure state at least one path is unaffected by the failure, it means that the set of paths is intergrated into a link/node failure disjointed. Hence, if there is existence of a failure resistant set of paths suppling a demand, there is also existence of a failure disjointed set of paths supplying the demand. The paths used when there are no failures in the network are called the primary paths while the additional paths used in case of failures are called the backup paths.0r alternative Rout

Primary path: This is the path commonly used by network signal when the network system is stable and there are no failures. It is the shortest path of least cost.



a**Backup path or Alternative root**: This is used when failure or failures occur in the network system.

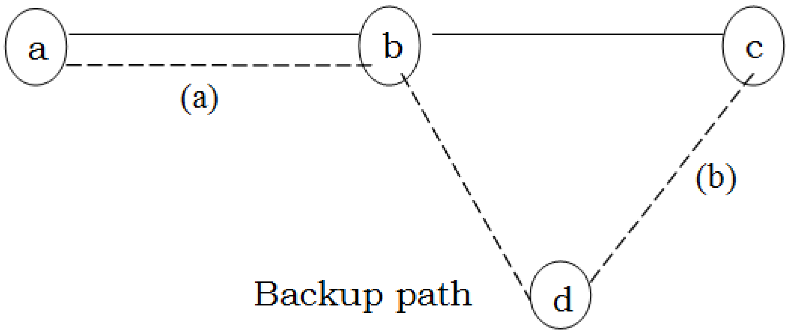


Fig. 3.2: Traffic paths (a) primary path (b) backup path.a

The workdesign is exclusively considered as m:n path protection of the optical network, protecting the traffic against failures in the following network procedures;

- Nominal design (ND)
- Total rerouting protection (TRP)
- Path diversity proection (PDP).

2,4.1 Shortest, Disjoint and Backup Paths.

Given a network as a set of nodes and a set of links, each link annotated with a cost, we can consider the following for a given traffic demand between a source and destination node:

K_s shortest paths: Find a set of K_s shortest paths from the source to the destination node with least cost. If fewer than K_{s1} exist, find as many as possible.

K_d disjoint paths: find a set of K_d link disjoint path such that the total cost of the used links is minimal. But fewer than K_{d1} exist, find as many as possible.

K_b backup paths: Removing temporarily from the links constituting the K_s shortest paths, find a set of K_b backup paths from the source to the destination node with least cost. If fewer than K_b paths exist, find as many as possible.

The shortest paths are useful for routing demands in the ND plan where no failure-disjointed backup paths are needed. The disjointed paths are useful for the protections scenarios. The backup paths typically take the long way round from the source to the destination node and are useful when trying to design a network with ring structures as it is being done here (Self healing), because each primary route usually uses one of the shortest paths and the alternateive route takes one of the backup paths. Noteably, the disjionted paths cannot in any way be found simple by iteratively finding and removing the shortest path. However, the disjointed paths constitute a set of edges P, which can be found in a directed network by a simple algorithm.

1. Let i ←I and P ← { }
2. Find the shortest path P, if it does exist (if there is no path from source to destination). stop
3. Let P ← $p \uplus p$. that is for each edge/node in p. if it is already in P. remove it from P. otherwise add it to P.
4. Reverse the edge of the shortest path and negate the sign of the cost on the path links.
5. Let $i \leftarrow i+1: if\ i\ < kd\ go\ to\ step\ 2\ else\ stop.$

Let $P_n, b_n^1\ and\ b_n^2$ represent the primary path, the first backup route and the second backup route where "n" stands for the common requestt of the network. (fig 2,2)

Let us assume that each common demand request requires a bandwidth of a particular wavelength channel providing 3 paths namely $P_o, P_1\ and\ P_2$ and all the nodes through which it transverse has full conversion capability. Each fibre link is on both way operations i.e bi-directional. The already defined paths; Kd, Ks and Kb have their associated wavelengths of w_o, w_1, w_2 as the case may be are given below.

- Wavelength (w_o): The wavelength that is used by the primary request path P_o.
- Wavelength (w_1): The wavelength used by the backup path and shared with primary path.
- Wavelength (w_2): wavelength that are used and shared by both primary and backup path b_1^2.

W_2 on link Kd needs be assigned to backup path b_1^2 .i.e. second backup and the backup link on link Kd, w_1 needs to be assigned to backup path b_1^1 i.e first alternative route; the reason is that b_1^1 can share the primary wavelength w_2 in the link (K_s) and also the path b_1^2 which has w_3 and can share the wavelength of w_o which transverse through the system.

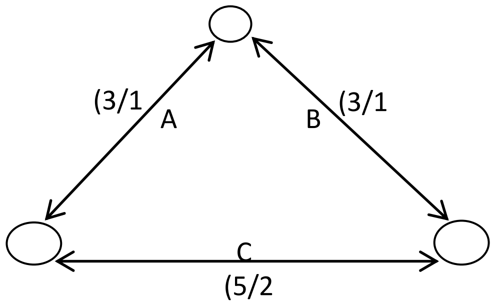
It follows that wavelength w_2 and w_3 are nodes to be recognized by shared by b_1^2. For operational reasons under "ND" normal condition, w_2 and w_3 are redunant, simply because b_1^1can share the primary wavelength link w_1 on the link path of the first alternative route.This arrangement is such that when there is a primary route failure for route b_1^1, the primary features and the wavelength of the alternative route which is b_1^2becomes operational in which the w_3 are converted to w_o and the $w_3$is saved. This is the application of the principle of frequency re-used. In real life optical network system, the improvement and protection of the network using the described shared path self healing ring is achieved with use of WDM mesh network.)

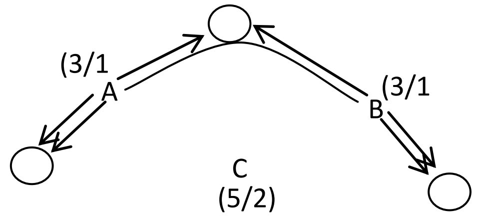
2.4.2 Promising Path Generation

Planning a greenfield scenerio for protecting network provides opportunities for the network designer/planner to optimize the network by locating links wherever it seems best but it has its complexities of link selections to the optimization task. In many cases this added complexities that make the enhancement process prohibitively slow for realizing the set objectives.

Therefore, instead of optimizing both the placement of links and the reouting of traffic, an integrated optimazation approach is used. Meaning that the problem can be split into two stages, each of manageable complexity. In the first stage a set of primising links is exhtracted from the set of all potential links, based on rough estimates of their cost, and their usefulness for the traffic demands. In the same way, some promising paths i.e, cost efficient paths-for each demands are computed. In the second stage, the network is optimized by only choosing paths from the set of promising paths. The first stage is called the promising path generation (PPG). Given a set of traffic demands and the cost of constructing each link in the network, we must select a subset of the links. At first attempt, one might compute the shortest path for each demand and then select the union of the used links. However, if there is an intial cost for constructing the duct of each link, too many long links might be selected. See the figure below where it is assumed that the traffic demands corresponding to 1 fibre between all nodes pairs. It is show that the best choice of paths and links demands not only on the cost of the ducts and fibres, but also on the traffic to be carried.

Union of shortest





Link A: $3 + 1 \times 1 = 4$ Link A: $3 + 2 \times 1 = 5$
Link B: $3 + 1 \times 1 = 4$ Link B: $3 + 2 \times 1 = 5$
Link C: $5 + 2 \times 1 = 7$ Link C: $0 + 0 \times 1 = 0$
Total cost: = 15Total cost: = 10

Figure 2-5: The union of the shortest paths including too many direct, long links, Duct/fibre cost are shown next to the links.

If there is a lot of traffic between two nodes, it may pay to design a direct link, rather than hopping through several distant internmediate links/nodes. As the direct link is usually slightly shotter than the sum of the length of the intermediate links, the fibre cost will be smaller.
Thus, we must use an algorithm for selecting links that strikes the right balance between the two extremes, using a lot of direct links producing a full connected mesh and sending all long-distant traffic through paths with many hops producing more or less minimum spanning tree.
In all these, a balance has to be structed or reached by following an algorithm set up, which will initially sort the traffic demands ascendingly according to the cost of designing a direct link (meaning the pure duct cost). To each link it is assigned a traffic load and cost per traffic unit and then use an algorithm to iteratively update the values by routing the traffic demands one by one. Whenever, a traffic demand is routed along a path, the traffic load on each link is incremented accordingly and its cost per traffic unit is recalculated based on the new traffic load. Finally it can use the cost per traffic values as link cost in a path finding algorithm. The whole algorithm design is put below as a promising path generation algorithm and the function route (d, costpertraffic, ks, kd, kb) is used to find paths for demands d.
Therefore, the promising path generation algorithm is designed as follows;

Promising paths (links, $cost^{duct}$, $cost^{fibr}$, demands, K_s, K_d, K_b) =
For d ∈ demands do /* Intialize $cost^{direct}$ */
L {l ∈ links/ Src_1 = Srcd ^ $dst_1 = dst_d$}/* find direct links*/
If L ≠←{ } then
$Cost_d^{direct} \leftarrow \min \{cost_1^{duct}/I \in L\}$
Else
$Cost_d^{direct} \leftarrow \infty$
Sort demands according to $cost^{direct}$
for I ∈links do $traffic_1 \leftarrow 0$ /* initialize traffic */
for l ∈ links do $costpertraffic_1 \leftarrow cost^{duct}$/* initialize costpertraffic */
for d ∈demands do /* main loop: */
Paths ←route (d, costpertraffic, 1,2..l) /* Route traffic demand */
for P ∈ paths do
for I ∈P do
$Traffic_1 \leftarrow traffic_1 + volume_d$ /* update traffic */
$Costpertraffic_1 \leftarrow cost\ (1, traffic_1)$ /traffic /* update costpertraffic */
for d ∈ demands do

Rd ←route (d, costpertraffic, K_s, K_d, K_b) /*perform final routing*/
Return {Rd|d ∈demands}

The function route (d, costpertraffic, K_s, K_d, K_b) is used to find paths for demand "d" based on the link cost values in costpertraffic, up to K_s, K_d, and K_b backup paths as discussed earlier. The cost of carrying $traffic_1$ wavelengths on link l is calculated by the function cost (1, $traffic_1$) based on the duct and fibre costs and then the number of wavelengths per fibre, (w).One of the effects benefit of this algorithm that makes it work is that short links between neighbouring nodes tend to be loaded with the traffic before demands between more distant nodes that are routed, thereby enabling them to use some of the short links instead of creating long, direct links.

Going through the algorithmic method, it was seen that it is important that there are traffic demands between neighbouring nodes so that short links between these nodes are created. This is assured by creating a dummy demand with volume zero for any node pair that does not have an explicit traffic demand. A further slight improvement of the algorithm can be made by tempororily adjusting the costpertraffic values as if $volume_d$ wavelengths were added to every network link just before calling the route functions.

2.5 The All-optical network sharepaths protection enhancement using integer linear programming (ILP).

The network problems that have been under considerions are variants of the multifailure commodity flow problems. Some of them were addressed in the literature. Here, they are being considered as the optical network design problems in the mathematical formulation through the use of ILP programs.
This is because the ILP programs can act as useful benchmarks for optimizing network design matheuristically because they can be passed directly to ILP optimizers. The optimizers used here are GAMS and CPLEX; GAMS is a preprocessor which takes the formulation or data entered, recast them in a shape that the CPLEX machine can handle and performs some simple pre-optimizations, before passing to another CPLEX which is the real optimization tool to produce results.
There are two major ways to express multiflow failure problems in the ILP programs; as in

1. Arc-flow formulation
2. Link – path formulation

The major difference is that in the arc-flow formulation, it is up to the optimizer to design the paths that will supply demands whereas in the link-path formulation one must precompute some paths for each demand, the optimizer only selects from the precomputed paths. However, here, the arc-flow forulation is adopted because it is easier, less cost and gives optimal result values like the later if only all possible paths are given as inputs.

2.5.1 Arc- flow formulation

In the arc-flow the network is considered as a set of N nodes, and at each node some wavelengths are introduced, either from neighbouring nodes or from traffic source located in the node. The exact same amount that entered must leave the node and this what is called conservation principle.
The flows are then indxed by the demands they supply and the wavelengths they use. The traffic flows along directed edges which the directed edges from node **n** to node **m** is carried together with the edge from node **m** to node **n** in a link {**n, m**}. This implies that it is not possible to have more than one link between two nodes in the arc-flow. The optimization procedures for the arc-flow formulation is shown below schematically.

Parameters programs Data

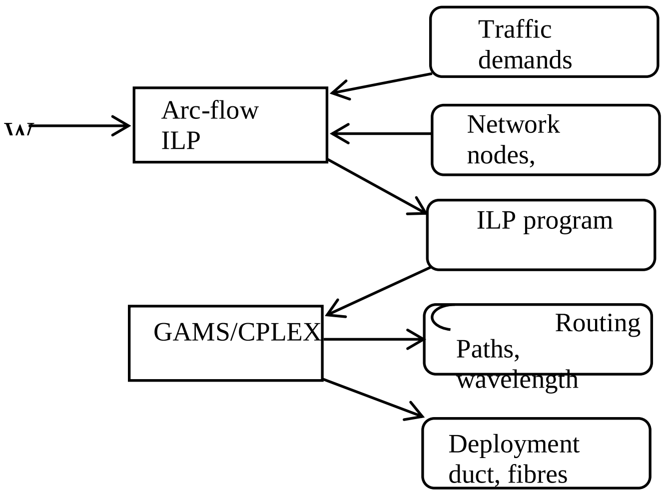


Figure 3.4 Optimizing WDM network using the arc-flow based ILP.

A simple generator produces the ILP program based on the traffic and network data then passes it to the GAMS/CPLEX optimizer which produces result.
Here in this work, we use the arc-flow formulation method to protect network from failure both the TRP and PDP network protection model (i.e: using it to design network protection in both model). The results will be compared.

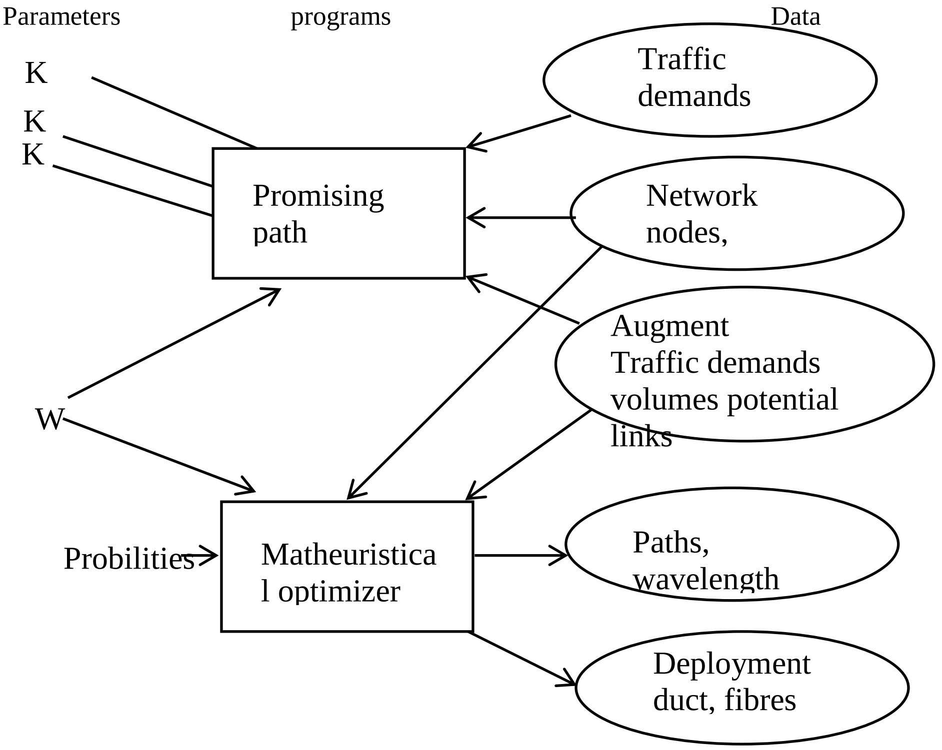


Figure 2.6 Optimizing WDM network matheuristically (SAN + SAL Approach).

The ILP programs serve as formal approach of the network design problems which can be used directly as input to ILP optimizer, but there are some other variants of the multicommodity flow problem. This work uses heuristical approach which is more viable to present the two instances of matheuristics that perform optimization by stochastic algorithms: **Simulated annealing** and **simulated allocation**. The overal structure is shown in figure above.
Network are assumed to be in a set of states {0...... S} in which each set of a state, there is a failed edge unless otherwise stated. Each state S corresponds to one edge failure. Though the state formulation is a general approach that allows modelling node failures by letting all edges incident with a node failure in state S be in ∈. But conventionally, S = 0 is considered to be in the normal state where there are no failures, that is, $\in_o = \{ \}$.

In all the network design problems, they share the following indexes, constants, basic variables and objective function; but there are different constants peculiar to each of them.

Indexes:

d ∈ {1.......D} **Traffic demands**
S ∈ {0.......S} **Network states**
C ∈ {1.......w} **wavelengths**
M, n∈ {1.......N} **Network nodes**
(nm) ϵ ε≤ {1.......N}^{2} **Directed edges**
(nm) ∈ ε_s< E **Directed edges affected in state S**
{n, m} ∈ L ≤ p{1.......N} **undirected links**

Constants.

$V_d^s \epsilon N_o$ $\quad$ *Volume of lightpaths to be realized for demand d in state S*
$n_d^{src} \epsilon \{1 \dots \dots N\}$ $\quad$ *Indix of the source node for demand d*
$n_d^{dst} \epsilon \{ 1 \dots \dots . N\}$ $\quad$ *Index of the destination node for demand d*
$C_{\{n,m\}}^{duct} \epsilon R_+$ $\quad$ *Cost of designing the duct on link* $\{n, m\}$
$C_{\{n,m\}}^{fibre} \epsilon R_+$ $\quad$ *Cost of deploying a fibre pair on link* $\{n, m\}$

Basic variables:

U{n, m} ϵR_+ Number of required fibre pairs on link {n, m}

α {n, m} ϵ {0, 1} Number of required ducts on link {n, m}

R_1 stands for a set of real numbers that help to speed up the ILP optimizers.

2.4.3 The Total Re-routing Protection Network Design (TRP)

Having introduced the general or conventional procedures of the arc-flow formulation method, it is now being used to enhance optical network designed in TRP model.

The TRP design problem is done by extending the nominal design problem to include the network multifailure states. Ordinarily, if the source or destination node of demand d fails in state S, it cannot in any way supply the demand in which case the network is set as V_d^s = 0. There are bound to be some other reasons why a network operator may set $V_d^s \neq V_d^o$.

Despite the general parameters and data of the arc-flow formulation, there are still some additional variables and constriants applicable to any particlar or model used in ensuring protection of the network. Such variables and constraints are as in TRP.

Additional Vatiables:

$X_{d(nm)}^{cs} \in N_O$ $flow\ of\ demand\ d\ on\ wavelength\ c\ along\ edge\ (nm) in\ state\ S$

$V_d^{cs} \in R_+$ $Volume\ of\ demand\ d\ carried\ on\ primary\ wavelength\ C\ in\ state\ S$

Constriants:

$\sum_c V_d^{cs} \geq V_d^s$ **The total volume of demand d in each state must be supplied by lightpaths of various wavelengths.**

σ **{n, m} = 0** $\Longrightarrow$ $U_{\{n,m\}} = 0$ **Without a duct, there can be no fibres on link (n, m).**

There is also the constraints of flow conservation for paths, what goes into node **n** on wavelength C in state S must come out again. There must also be right calculation of required number of fibres in any states S on any wavelength C.

2.4.5Path Diversity Protection Network Design (PDP).

In the PDP design problem, X_{dm}^{cs} is used to keep track of the flow in every state S, and find the required capacity t_{dnm}^c as the maximum of the X_{dnm}^{cs} over all the states.

Its variables and constraints are the same with that of the TRP except that;

Variables

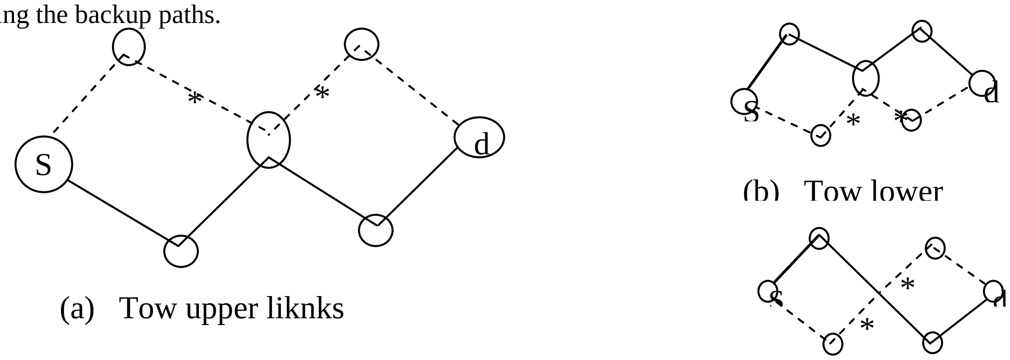
$t_{dnm}^c \in R_+$**Required capacity for demand d on wavelength C along edge (nm).**

constraints

$X_{dnm}^{cs} \leq t_{dnm}^c$**calculating the required capacity for demand d on wavelength C along edge (n m).**

2.6.1 Handling Multiple Link Failures Protection Using SHR

The formulations so far given are capable enough to handle multiple link/path failures, if it is all possibly set. This means that any given set of failed link ε_s, if the network connectivity is strong enough will handle itself to recover failed link/path within a reasonable short time frame if the ILP programs presented will be able to find a solution. For example, considering the network below, with just one demand from S to d, and three failure states such as; (1) one where two upper links fail, (2) one where two lower links fail, and (3) one where an upper and lower link fail alternatively. So both TRP and PDP are able to fix all situation in each case using the backup paths.



(a) Tow upper liknks

(b) Tow lower

(c) An upp and lower

Figure 3.6: Multiple link failures

This section of the work x- rays the characteristics of self- healing ring. It is diagramatically shown and explained in the figure above.

It is called SONET SHR which is very useful technique for survivability of optical networks. Here networks are designed to have ring architeres. SHR is more useful than other protection technique like APS (antomatic protection switching) because of its flexibility in handling both link and node failures. It uses add/drop multiplexing (ADM) techniques. Unidirectional SHR (USHR) and bi-drectional (SHR) are two types of SHRs. The difference between them is the direction of the traffic flow under normal condition. In USHR, the normal traffic flow goes around the ring in one direction as shown in figure 3.4 (a-b). Any traffic routed to the protection ring because a failure is carried in the opposite direction. But in SHR, working traffic flows in both directions.

However, a bidirectional logical-ring network employs OXC nodes which partitions the network into segments and then interconnects other segments at subchannel level to form logical ring structures. Every segment is independent, which includes a subset of (ADMs) nodes and two pairs of links, one working and the other for protection. The formation of the logical rings from the interconnection of independent segment subchannels preserves the self-healing advantages of conventional bidirectional ring networks and allows greater flexibility to effeciently accommodate bandwidth upgrate request and more robust traffic flow.

2.5 RULES OF SHARING MIXED WAVELNGTH-LINKS

(A) Notations and Assumptions

Assuming each connection request arrives at the network orderly, and there is only a connection request that arrives at a time. Assume each connection requires the bandwidth of one wavelength channel, each fiber link is bi-directional, and the network has the full wavelength conversion capacity. The following notations are introduced.

- j: Fiber link in the network;
- fwj: The number of free wavelength-links on link j;
- pwj: The number of primary wavelength-links on link j.
- bwj: The number of backup wavelength-links on link j.
- mwj: The number of mixed wavelength-links on link j.
- Cr_n: Connection request n.
- $p_n: Primary\ path\ for\ cr_n.$
- $b_n^1\ and\ b_n^2: Backup\ paths\ for\ cr_n.$
- $mp_n^j: Takes\ value\ of\ 1\ if\ primary\ path\ p_n\ has\ used\ a\ mixed$ $wavelength - link\ on\ link\ j;\ 0\ otherwise.$
- $mb_n^{\alpha,j}\ (\propto\ \epsilon\ \{1,2\}): Takes\ value\ of\ 1\ if\ backup\ path\ b_n^{\alpha}\ has\ used\ a$ mixed wavelength-link on link j; 0 otherwise.
- $s_j^{r,b}: Takes\ value\ of\ 1\ if\ backup\ path\ r\ and\ b\ can\ share\ the\ backup$ wavelength-links on link j based on the rules; 0 otherwise.
- $d_j^{p,q}: Takes\ value\ of\ 1\ if\ pathsp\ and\ q\ have\ the\ same\ direction\ on\ link\ j;$ $0\ otherwise.$
- $|\Omega|$ The number of elements in set Ω.

(B) Mixing Primary Wavelength-Links

The mixed wavelength-links are this kind of wavelengths that can be released by failed primary paths and can be re-used by other backup paths. Assuming the connection request cr_n arrives at the network.After finding $p_n, b_n^1\ and\ b_n^2, the\ following\ two\ cases\ were\ considered:$

Case 1: A primary wavelength-link on link j used by primary path p_n can be changed to a mixed wavelength-link and can be shared by previous backup path $b_m^{\alpha}\ (\alpha\ \epsilon\ \{1,2\},\ \forall m\ \leq n-1)$.

C. Sharing Mixed Wavelength − Links

A mixed wavelength-link on link j used by previous primary path p_k and shared by backuppath $b_i^{\alpha}(\alpha \in \{1,2\}, \forall k, i\ \leq n-1) can\ be\ shared\ by\ backup$

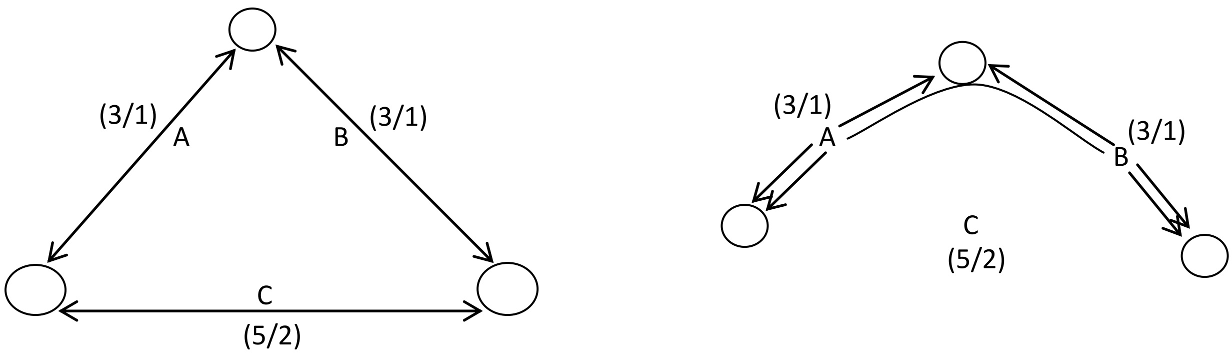
$$path\ b_n^{B}(\beta \in \{1,2\})$$

3.5 Promising Path Generation

Planning a greenfield scenerio for protecting network provides opportunities for the network designer/planner to optimize the network by locating links wherever it seems best but it has its complexities of link selections to the optimization task. In many cases this added complexities that make the enhancement process prohibitively slow for realizing the set objectives.

Therefore, instead of optimizing both the placement of links and the reouting of traffic, an integrated optimazation approach is used. Meaning that the problem can be split into two stages, each of manageable complexity. In the first stage a set of primising links is exhtracted from the set of all potential links, based on rough estimates of their cost, and their usefulness for the traffic demands. In the same way, some promising paths i.e, cost efficient paths-for each demands are computed. In the second stage, the network is optimized by only choosing paths from the set of promising paths. The first stage is called the promising path generation (PPG). Given a set of traffic demands and the cost of constructing each link in the network, we must select a subset of the links. At first attempt, one might compute the shortest path for each demand and then select the union of the used links. However, if there is an intial cost for constructing the duct of each link, too many long links might be selected. See the figure below where it is assumed that the traffic demands corresponding to 1 fibre between all nodes pairs. It is show that the best choice of paths and links demands not only on the cost of the ducts and fibres, but also on the traffic to be carried.

Union of shortest paths



Link A: $3 + 1 \times 1 = 4$ Link A: $3 + 2 \times 1 = 5$

Link B: $3 + 1 \times 1 = 4$ Link B: $3 + 2 \times 1 = 5$

Link C: $5 + 2 \times 1 = 7$ Link C: $0 + 0 \times 1 = 0$

Total cost: $= 15$ Total cost: $= 10$

Figure 3.1: The union of the shortest paths including too many direct, long links, Duct/fibre cost are shown next to the links.

If there is a lot of traffic between two nodes, it may pay to design a direct link, rather than hopping through several distant internmediate links/nodes. As the direct link is usually slightly shotter than the sum of the length of the intermediate links, the fibre cost will be smaller.

Thus, we must use an algorithm for selecting links that strikes the right balance between the two extremes, using a lot of direct links producing a full connected mesh and sending all long-distant traffic through paths with many hops producing more or less minimum spanning tree.

In all these, a balance has to be structed or reached by following an algorithm set up, which will initially sort the traffic demands ascendingly according to the cost of designing a direct link (meaning the pure duct cost). To each link it is assigned a traffic load and cost per traffic unit and then use an algorithm to iteratively update the values by routing the traffic demands one by one. Whenever, a traffic demand is routed along a path, the traffic load on each link is incremented accordingly and its cost per traffic unit is recalculated based on the new traffic load. Finally it can use the cost per traffic values as link cost in a path finding algorithm. The whole algorithm design is put below as a promising path generation algorithm and the function route (d, costpertraffic, ks, kd, kb) is used to find paths for demands d.

Therefore, the promising path generation algorithm is designed as follows;

Promising paths (links, $cost^{duct}$, $cost^{fibr}$, demands, K_s, K_d, K_b) =

For d ∈ demands do /* Intialize $cost^{direct}$ */

L {l ∈ links/ Src_1 = Srcd ^ $dst_1 = dst_d$}/* find direct links*/

If L ≠←{ } then

$Cost_d^{direct} \leftarrow \min \{cost_1^{duct} / I \in L\}$

Else

$Cost_d^{direct} \leftarrow \infty$

Sort demands according to $cost^{direct}$

for I ∈links do $traffic_1 \leftarrow 0$ /* initialize traffic */

for l ∈ links do $costpertraffic_1 \leftarrow cost^{duct}$ /* initialize costpertraffic */

for d ∈demands do /* main loop: */

Paths ←route (d, costpertraffic, 1,2..l) /* Route traffic demand */

for P ∈ paths do

for I ∈P do

$Traffic_1 \leftarrow traffic_1 + volume_d$ /* update traffic */

$Costpertraffic_1 \leftarrow cost\ (1, traffic_1)$ /traffic /* update costpertraffic */

for d ∈ demands do

Rd ←route (d, costpertraffic, K_s, K_d, K_b) /*perform final routing*/

Return {Rd|d ∈demands}

The function route (d, costpertraffic, K_s, K_d, K_b) is used to find paths for demand "d" based on the link cost values in costpertraffic, up to K_s, K_d, and K_b backup paths as discussed earlier. The cost of carrying traffic_1 wavelengths on link l is calculated by the function cost (1, traffic_1) based on the duct and fibre costs and then the number of wavelengths per fibre, (w).

One of the effects benefit of this algorithm that makes it work is that short links between neighbouring nodes tend to be loaded with the traffic before demands between more distant nodes that are routed, thereby enabling them to use some of the short links instead of creating long, direct links.

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Parameters programs Data

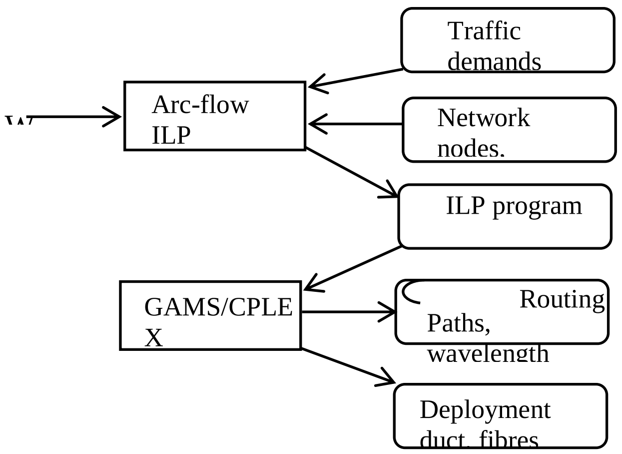

Figure 3.6 Optimizing WDM network using the arc-flow based ILP.

3.3 Emperical Evaluation of Promising Path Generation

Having designed the two major programs shown in the previous chapter, the PPG and the matheurishtic optimizer (San + Sal), it is needful to evaluate them (their effectiveness) empirically, in order to prove how good the quality of their results. There are two methods for the evaluation of the results qualities;

1. Benchmarking by comparing with the results of other algorithms which are known to be optimal or to produce good results and
2. The known-result testing by using the programs on problems with a proven optimal values.

3.3.1 Benchmarking

Comparing the programs, it is pertinent to see a way of benchmarking the PPG algorithm since the ILP solver (GAMS/CPLEX) is capable of giving optimal results if only the problem size is not too large. The results from the two methods are compared to assess their percentage quality. Because the arc-flow formulation is computationally very intensive, it is wise that only few representative of networks and their traffic demands used for the performance evaluations.

Table 3.4: The characteristics of representing networks:

Network	Nodes (N)	Links (L)	Connectivity $2\frac{L-N+I}{(N-1)(N-2)}$	Demands D	Demand volume V
ND	5	10	1	10	37
TRP	7	11	0.33	20	58
PDP	8	21	0.66	27	62

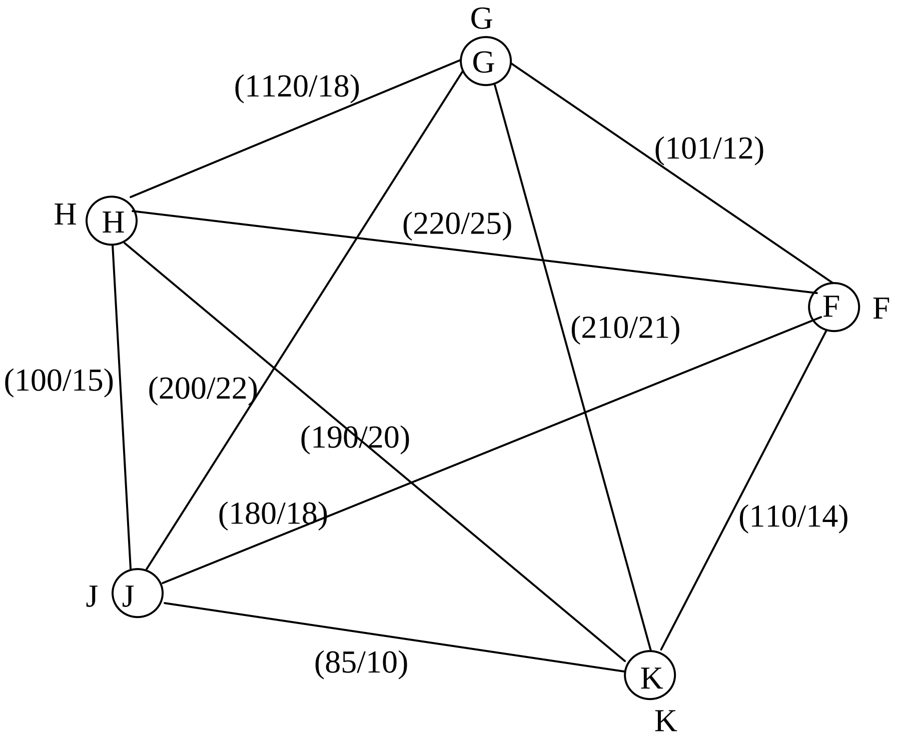

Figure 3.8: Network 1 and the traffic for quality evaluation of the PPG Algorithm.

Table 3.5: Decision box of fig. 4.1

	F	G	H	J	K
F		1	7	2	5
G	0		4	6	3
H	0	0		3	5
J	0	0	0		1
K	0	0	0	0	

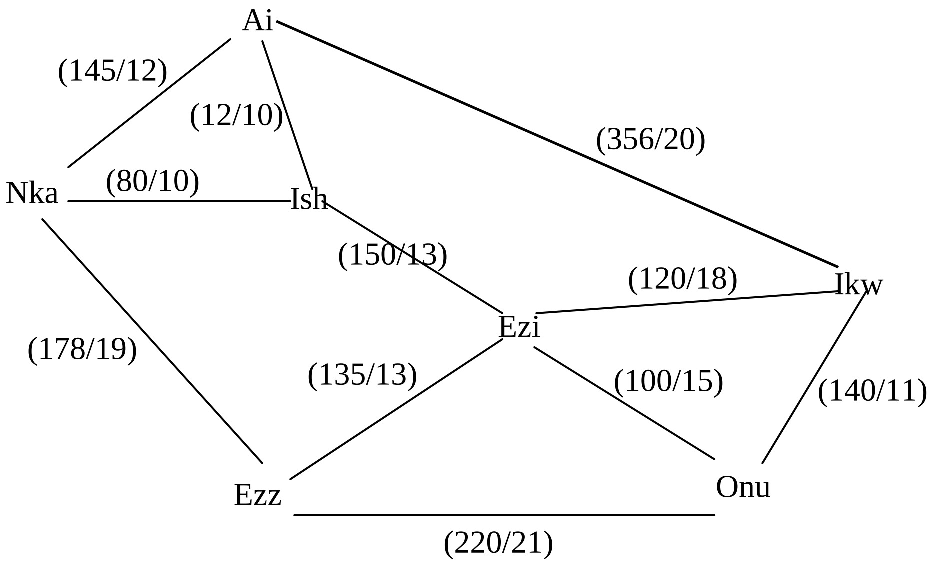

Fig 3.9: Network II and the traffic for equality evaluation of the PPG algoritum

Table 3.6: Decision box of fig.4.2

	Ai	Nka	Ish	Ezi	Ikw	Onu	Ezz
A1		1	5	2	6	1	2
Nka	0		2	1	1	1	0
Ish	0	0		5	8	3	3
Ezi	0	0	0		6	2	2
Ikw	0	0	0	0		2	4
Onu	0	0	0	0	0		1
Ezz	0	0	0	0	0	0	

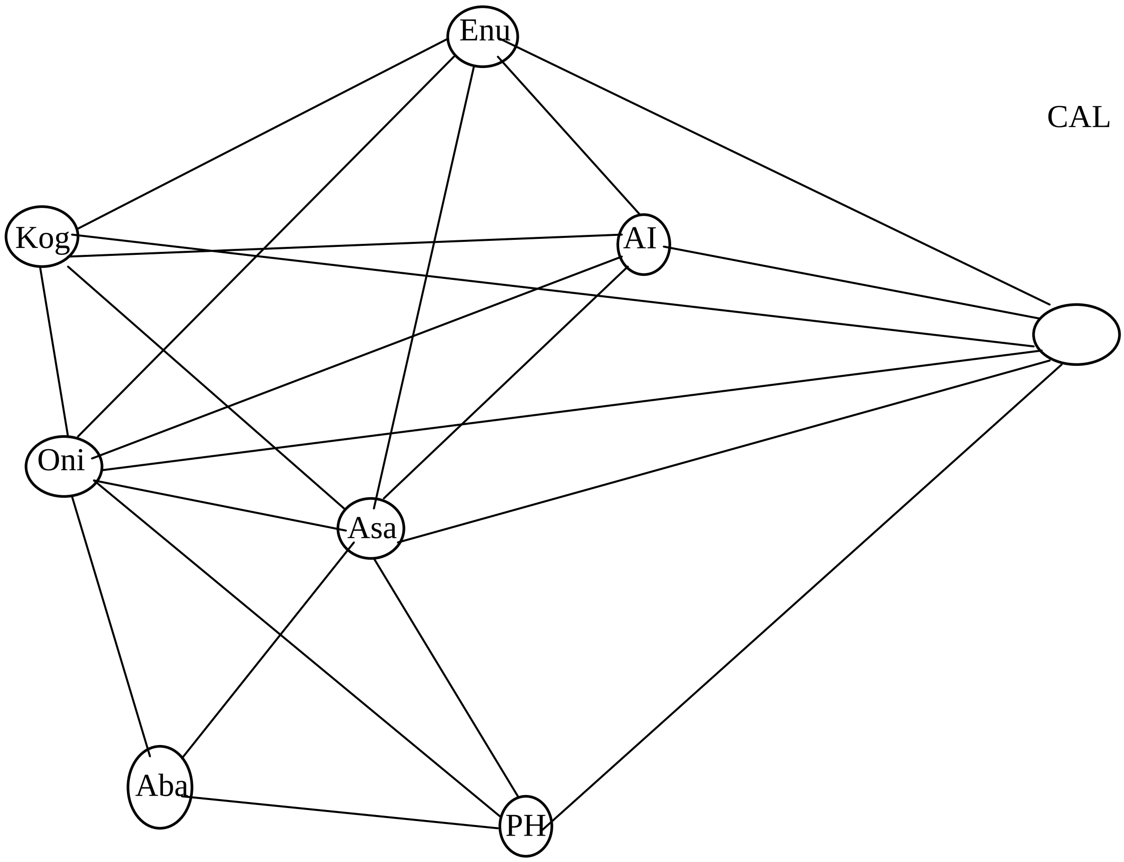

Fig 3.10: Network III and the traffic for the PPG evaluation.

Table 3.7: Decision box of fig. 4.3

	Enu	Ai	Kog	Cal	Oni	Asa	Aba	Ph
Enu		1	1	5	4	1	2	3
A1	0		1	2	2	0	1	1
Kos	0	0		3	3	1	1	1
Cal	0	0	0		9	1	3	5
Oni	0	0	0	0		1	3	4
Asa	0	0	0	0	0		1	1
Aba	0	0	0	0	0	0		1
Ph	0	0	0	0	0	0	0	

III. Result Discussions

Connectivity is a measure of the ratio between links and nodes in a connected network, where the connectivity for a linear network is 0 and for a fully connected network is 1. For each network, the PPG algroritum is run with (Ks, K_d) = (3,2) and (8,3) respectively where K_b = 0 in order to obtain a set of promising paths. To ensure a valid backup paths, k_d must be greater than 1, and the values for K_s are chosen as a compromise between a path set containing all the optimal paths and path sets of managable sizes.

IV. Conclustions/Reccommendation

The need to reduce the turn around time to the barest minimum cannot be neglected. Naturally the BUS topology has its disadvantages. Hence the object of the work is to recommend that Ring-network be adopted in all installations and the application of self-Healing be adopted'

References

[1]. B. Mukheryjee, Optical communication networks. New York: Mc-Graw-Hill, July 1997.

[2]. G. Maier, A. Pattavina, S. Patre, and M. Martinelli, "Optical network survivability; Protection techniques in WDM layer", photon. Network communication, Vol. 4,pp. 251-269, June 2002.

[3]. D. Zhou and S. Subramaniam, "Survivability in optical networks", IEEE Netw., vol. 14, pp. 16-23, Nov./Dec. 2000.

[4]. O. Gerstel and R. Ramaswami, "Optical layr survivability: A service prespective", IEEE Common. Mag.. vol. 38, pp. 104-113, Mar. 2002.

[5]. S. Ramamurthy, L. Sahasrabuddhe, and B. Mukherjee, Survivable WDM mesh network, J. Lightwave Tch., vol.21, pp. 870-883, Apr. 2003.

[6]. S. Ramasubramanian, "On failure dependent protection in optical grooming network," in Proc. DSN 2004, June 2004, pp. 440-449.

[7]. S. Ramasubramanian and A. Harjani, "Comparison of failure dependent protection strategies in optical network," Photon. Netw, Commun., vol. 12, pp. 195-210, Sept. 2006.

[8]. M. Feredrick and A. Somani, "A single-fault recovery strategy for optical networks using subgraph routing," in Proc. ONDM 2003, Feb. 2003, pp. 549-568.

[9]. W. He and A. Somani, Path-based protection for surviving double-link failures in mesh-restorable optical networks," in Proc. IEEE GLOBECOM 2003, Dec. 2003, pp. 2558-2563.

[10]. W. He, M. Sridharan, and A. Somani, "Capacity optimization for surviving double-link failures in mesh-restorable optical Netwk.," Photon. Netw. Commun., vol. 9, pp.99-111, Jan. 2005.

[11]. H. Choi, S. Subramaniam, and H. A. Choi, Loopback methods for double-link failure recovery in optical netw.," IEEE/ACM Trans. Netw., vol. 12, pp. 1119-1130, Dec. 2004.

[12]. L. Guo, H. Yu, and L. Li, "Path-based protection in WDM mesh networks subject to double-link failures," AEU-Int. J. Elect. Commun., vol. 60, pp. 467-470, july 2006.

Ezeagwu Creating Reliability In Optical Network By Installation And Implementation Of Self Healing Optical Network.." American Journal of Engineering Research (AJER), vol. 6, no. 11, 2017, pp. 223-239.