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An Efficient Optical Recovery Searching Technique with Optimal Fault Evaluation using Genetic Algorithm for Mesh Network

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Abstract— Link protected routing structures have a fundamental requirements in connection-oriented optical communication networks for achieving reliable communication for each connection in case of failure irrespective to the link failure between any of the nodes. Currently many techniques are proposed for protecting the network, such as 1+1 protection mode, in which a signal is transmitted on two link disjoint circuits, and the destination chooses the stronger of the two signals, hence recovery from failures is instantaneous; 1: N and 1:1+N protection, in which a p-Cycle can be used to protect a number of bidirectional connections. However using any of these methods does not ensure the optimal survivability with limited numbers of auxiliary (recovery) links while maintaining cost minimization, path priority and link failure probability. These considerations are practically unavoidable in the many situations for example if a link path is passes through a geologically sensitive site or under development areas that link will always have higher probability of failure and an additional measure must be taken to handle it properly similarly a path many be preferred for the point of future requirements. This paper presents a genetic algorithm based solution for the addressed problem for that we formulated it as optimization problem and a proper objective function is derived to achieve fittest results.

INDEX TERMS— Genetic Algorithm, Network Link Protection, Optical Network

1. INTRODUCTION

It has been widely noted that transferring a user's data along a single active (or working) optical path might not be sufficient to fulfill the service availability requirements in the presence of various network outages and unexpected failure events. Network failures occur due to various reasons including accidental fiber cut due to construction or human error [12]. Reliability of networks is achieved through path protection utilizing backup paths reserved in advance or dynamically establishing backup paths after calculating their routes after each failure. The first approach is called protection and the latter is called restoration. The protection can be classified into two types: dedicated protection and shared protection [12]. In shared protection, multiple backup paths can share the same resources if their working paths do not go through the same link, i.e., not in the same shared risk link group (SRLG). Therefore, shared Protection requires fewer network resources than dedicated protection, which allocates independent backup paths to each working path. Shared protection, on the other hand, requires longer recovery time than dedicated protection since signaling and switch reconfiguration processing at intermediate nodes are necessary. The recovery time can be shortened if backup routes candidates are computed in advance. The designing of an optical network can be divided into costs for bandwidth management (costs with nodes) and costs for signal transmission (costs with links) [9]. The node location is one of the first pieces of information that the network designer has, corresponding to the location of the central offices where the traffic is added and dropped. The first stage of the overall network design process is the topological design; at this stage the connections between the nodes are established. The network topological design should guarantee a reliable network, and this depends on which links are going to be implemented [12]. The traffic to be transported by the network is hard to forecast and is continuously changing [9]. In practice, several traffic scenarios are defined and evaluated, then the lowest cost network that will remain feasible for the majority of the scenarios is implemented [9]. Therefore, the utilization of methods to quickly design physical topologies ensuring the routing of the required traffic and guaranteeing the network survivability at minimum cost is crucial. In this work, we address the problem of jointly designing the physical topology, ensuring survivability, and minimizing the network cost of an optical transport using genetic algorithm. The rest of this paper is organized as follows. Section II provides the related work to the study. In Section III, some standard techniques are discussed followed by the working of the genetic algorithm in next section V presents the proposed method Section VI shows the simulation results in various different scenarios. Finally, Section VII presents our conclusions and further research directions.

2. LITERATURE REVIEW

The key building blocks of the NPOT (network planning and operation tool), consisting of network description repositories, the physical layer performance evaluator, the impairment aware routing and wave-length assignment engines, the component placement modules, failure handling, and the integration of NPOT in the control planes study with implementation is presented in [1]. Implementation of a hybrid 1+N and 1: N protection scheme, in which on-cycle links are protected using 1: N protection, while straddling links, or paths, are protected using 1+N protection with extensions to protect multipoint connections are introduced in [2]. An integrated Integer Linear Program (ILP) to design an optical datacenter network in presented in [3], which solves problems simultaneously for disaster protection scheme, exploiting anycasting for providing more protection, but uses less capacity than dedicated single-link failure protection. [12] Introduced a novel measures to evaluate the degree of backup resource sharing and that of fiber utilization the proposed method iteratively redesigns groups of paths that are selected in the order determined by the measures. The scheme applying Generalized Dedicated Protection and Network Coding (GDP-NC) to ensure both optimal

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resource utilization among dedicated protection approaches and instantaneous recovery for single unicast flows, which can be split into multiple parts in all-optical networks. We demonstrate that the proposed GDP-NC survivable routing problem is polynomial-time solvable, owing to the ability to bifurcate flows in presented in [9]. Application of NC in core optical networks has recently emerged [2], [9], which in general aim to minimize the capacity consumption for a matrix of traffic demands. With shared M : N protection, N working connections are protected by a common pool of M protection paths, where the protection resources are used only after a failure occurred in the network. Such a concept was generalized to 1 + N protection [13] by ensuring the spare resources hot stand-by similarly to 1 + 1 protection, provided with the capability of performing linear combination operation on the input symbols of the N working paths at the source OXC. Although 1 + N protection has all the merits of dedicated protection approaches while keeping the capacity consumption low, it requires the topologies with 1 + N-connectivity, which serves as a stringent constraint on its applicability.

3. Link Protection in Optical Network

Link protection is designed to safeguard networks from failure. Failures in high-speed networks have always been a concern of utmost importance. A single fiber cut can lead to heavy losses of traffic and protection-switching techniques have been used as the key source to ensure survivability in such networks. Protection architectures like Path protection and Link protection safeguard the above-mentioned networks from different kinds of failures. In path protection, a backup path is used from the source to its destination to bypass the failure. In Link protection, the end nodes of the failed link initiate the protection. These nodes detect the fault and are responsible to initiate the protection mechanisms in order to detour the affected traffic from the failed link onto predetermined reserved paths.
Broadly two types of protection are used, Ring type and Mash type.

3.1 Ring Type: In the case of a link or network failure, the simplest mechanism for network survivability is automatic protection switching (APS). APS techniques involve reserving a protection channel (dedicated or shared) with the same capacity of the channel or element being protected.[2] When a shared protection technique is used, an APS protocol is needed to coordinate access to the shared protection bandwidth.[3] An example of a link-based protection architecture at the Optical Transport Network layer is a Bidirectional Line Switched Ring (BLSR). In a BLSR, every link can carry both the working and backup traffic at the same time and hence does not require backup links. Unlike a UPSR (see SONET), in a BLSR, under normal circumstances, the protection fiber is unused and this is beneficial to ISP's since they can use the protection fiber to send lower priority traffic (using protection bandwidth) like data traffic and voice traffic.
There are two architectures for BLSRs. The four-fiber BLSR and the two-fiber BLSR. In a four-fiber BLSR, two fibers are used as working fibers and the other two are used as protection fibers, to be utilized in the case of a failure. Four-fiber BLSRs use two types of protection mechanisms during failure recovery, namely ring and span switching. In span switching, when the source or destination on a link fails, traffic gets routed onto the protection fiber between the two nodes on the same link and when a fiber or cable cut occurs, service is restored using the ring switching mechanism.

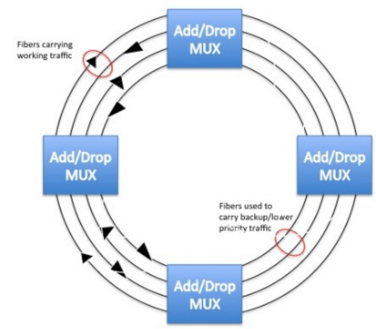

Figure 1: A four-fiber BLSR: Two fibers are used as working fibers and the other two are used as protection fibers, to be utilized in the case of a failure.

In a two-fiber BLSR, the protection fibers are contained within the working fibers (like a four-fiber BLSR) and both the fibers are used to carry working traffic whilst keeping only half the capacity on each fiber for protection purposes. Two-fiber BLSRs also benefit from the ring switching but cannot perform span switching like a four-fiber BLSR.
Due to its efficiency in protection, BLSRs are widely deployed in long haul and interoffice networks, where the traffic pattern is more distributed than in access networks. Most metro carriers have deployed two-fiber BLSRs, while many long-haul carriers have deployed four-fiber BLSRs since they can handle more load than two-fiber BLSRs.

3.2 Mash Type: The techniques mentioned above for SONET and WDM networks can also be applied to mesh network architectures provided there are ring decompositions for the mesh architectures; and use well defined protection-switching schemes to restore service when a failure occurs. The three most notable ring-based protection techniques for mesh networks are ring covers, cycle double covers and p-cycles (pre-configured protection cycles).
The main goal of the ring cover technique is to find a set of rings that covers all the network links and then use these rings to protect the network against failures. Some network links in the ring cover might get used in more than one ring which can cause additional redundancy in the network and because of this reason, scaling down redundancy is the primary focus of this technique.

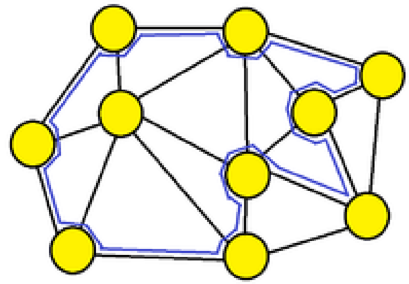

Figure 2: p-cycle in a mesh network creating ring like structure.

The cycle double covers technique provides one protection fiber for each working fiber (like in SONET rings) keeping 100% redundancy. This technique was initially proposed to remove the additional redundancy issue caused by the ring cover scheme.

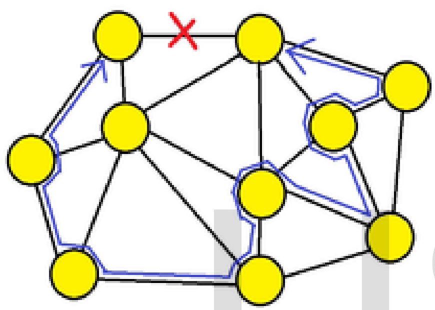

Figure3: Failure on a p-cycle showing the 2 nodes involved in recovery.

The p-cycle technique is based on the property of a ring to protect not only its own links, but also any possible link connecting two non-adjacent ring nodes called chordl links. By doing this, p-cycles reduce the redundancy required to protect a mesh network against link failure. There are two types of p-cycles namely link p-cycles and node p-cycles. Link p-cycles protect all channels on a link whereas a node p-cycle protects all the connections traversing a node.

One of the best features of p-cycles is its ability to allow savings in spare resources and they are also recognized to be the most efficient protection structures as for capacity minimization. However, p- cycle planning is an NP-hard problem and is not scalable.[1]

Another technique called the generalized loopback technique can be included under ring-based approaches. Although its not strictly considered as one of the mesh-based ring protection techniques, its usage of a loopback operation is similar to the APS operation in rings to switch the signal from working to the redundant capacity.

4. Genetic Algorithm

A simple Genetic Algorithm is an iterative procedure, which maintains a constant size population P of candidate solutions. During each iteration step (generation) three genetic operators (reproduction, crossover, and mutation) are performing to generate new populations (offspring), and the chromosomes of the new populations are evaluated via the value of the fitness which is related to cost function. Based on these genetic operators and the evaluations, the better new populations of candidate solution are formed. With the above description, a simple genetic algorithm is given as follow [6]:

1. Generate randomly a population of binary string
2. Calculate the fitness for each string in the population
3. Create offspring strings through reproduction, crossover and mutation operation.
4. Evaluate the new strings and calculate the fitness for each string (chromosome).
5. If the search goal is achieved, or an allowable generation is attained, return the best chromosome as the solution; otherwise go to step 3.

5. Proposed Work

The proposed system estimates the optimal locations for auxiliary (recovery) links when only a limited numbers of auxiliary links can be established while maintaining cost minimization, path priority, and link failure probability. The proposed algorithm can be described if following steps

Step 1: The present topology of the network is presented by a NXN binary matrix (C) where a '1' represents the link between the nodes, as shown in the figure 4.

0	1	0
1	0	1
0	1	0

Figure 4: the connection matrix for 3 nodes system

The elements of the matrix cij represents the link between nodes I and j.

Similar way is used to present the cost matrix for the auxiliary path establishment between nodes, fault probability matrix for the main links and the auxiliary path preference matrix.

Step 2: the objective function is then formulated to achieve the required goals using genetic algorithm and can be written as in equation 1.

$$f = \sum Cost_{ij}(k) + \sum Fault_{ij}(k) + \left| \sum Pref_{ij}(k) \right| \quad \dots (1)$$

Where

$N_A = Number\ of\ Auxilairy\ Links\ to\ be\ estiblished.$

$Cost_{ij}(k) = is\ the\ cost\ of\ k^{th}\ aux\ link\ between\ nodes\ i\ and\ j.$

$Fault_{ij}(k) = is\ the\ fault\ probability\ of\ k^{th}\ main\ link\ between\ nodes\ i\ and\ j.$

$Perf_{ij}(k) = is\ the\ aux\ path\ preference\ of\ k^{th}\ aux\ link\ between\ nodes\ i\ and\ j.$

Step 3: for the given NA and N the total available number of auxiliary links are given by

For example Let the N = 3, and NA = 2 the number of available aux paths = 3 (by equation 2) and the available paths are, (P12, P13), (P12, P23) and (P13, P23).

Step 4: now the genetic algorithm is initiated to find the optima paths from the available paths (Step 3) which best fits (minimize) the equation (1).

6. Simulation Results

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The evaluation of the proposed work is done by simulating it for different scenarios and configurations.

Table1: Configuration of Genetic Algorithm

Parameters Name	Value
Population Size	16
Iterations	1000
Time Limit	60 (Sec.)
Tolerance	1%

Scenario:

N (Total Number of Nodes) = 3;

N_A (Aux Paths) = 1 and 2;

Connection Matrix

0	1	0
1	0	1
0	1	0

Cost Matrix

0	0.2	0.1
0.2	0	0.1
0.1	0.1	0

Fault Prob. Matrix

0	0.2	0.1
0.2	0	0.1
0.1	0.1	0

Prirority. Matrix

0	0.2	0.1
0.2	0	0.1
0.1	0.1	0

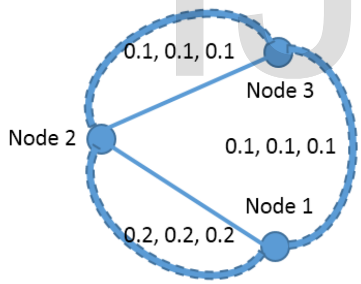

Figure 5: the structure of the network, circles are showing nodes the dashed lines are showing aux paths which can be established with the cost, prob. and priority values.

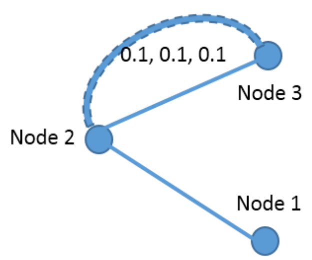

Figure 6: the finally selected aux links for $N_A = 1$ which gives optimal survivability, cost and other considerations.

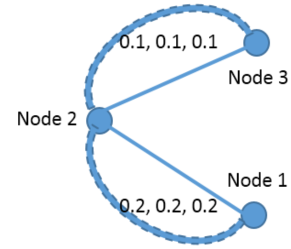

Figure 7: the finally selected aux links for $N_A = 2$ which gives optimal survivability, cost and other considerations.

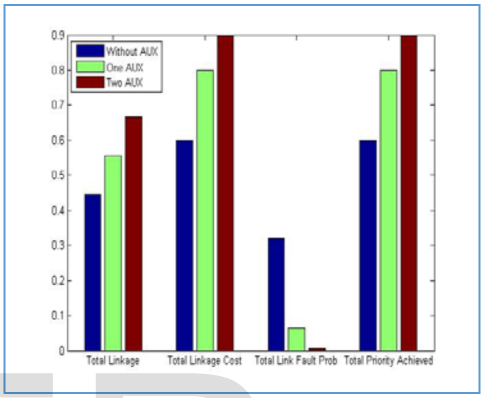

Figure 8: Comparison plot of achievements for all four requirements.

Table 2: Values for all four requirements

Property	AUX0	AUX1	AUX2
Total Linkage	0.44	0.556	0.667
Total Linkage Cost	0.60	0.80	0.90
Total Link Fault Prob.	0.32	0.064	0.0064
Total Priority Path Achieved	0.60	0.80	0.90

7. Conclusion

This paper presents a genetic algorithm based approach for selection of limited numbers of auxiliary path which maintains the optimal link survivability with maintain cost and links priority. The proposed approach is developed and simulated for the different numbers of auxiliary links and the algorithm automatically searches the links path for the best requirements fulfillments. Reduces the Link failure probability by 5 times and it also fulfils the topological requirements by 80 percent. The attachment of one more auxiliary link further increases the performance as provided the results shows that for the given topology attachment of only a single auxiliary link increases the total nodes connectivity (Linkage) by 10% and in table 2. The simulation results confirms the effectiveness of the proposed algorithm however in future some other optimization techniques and requirements parameters may also be analyzed for reducing the calculation time.

References

[1] Siamak Azodolmolky et al "Experimental Demonstration of

an Impairment Aware Network Planning and Operation Tool for Transparent/Translucent Optical Networks", JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 29, NO. 4, FEBRUARY 15, 2011.
[2] Ahmed E. Kamal "1+N Network Protection for Mesh Networks: Network Coding-Based Protection Using p-Cycles", IEEE/ACM TRANSACTIONS ON NETWORKING, VOL. 18, NO. 1, FEBRUARY 2010.
[3] M. Farhan Habib, Massimo Tornatore, Marc De Leenheer, Ferhat Dikbiyik, and Biswanath Mukherjee "Design of Disaster-Resilient Optical Datacenter Networks", JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 30, NO. 16, AUGUST 15, 2012.
[4] Sheng Huang, Charles U. Martel, and Biswanath Mukherjee "Survivable Multipath Provisioning with Differential Delay Constraint in Telecom Mesh Networks", NFOCOM 2008. The 27th Conference on Computer Communications. IEEE.
[5] Ferhat Dikbiyik, Laxman Sahasrabuddhe, Massimo Tornatore, and Biswanath Mukherjee "Exploiting Excess Capacity to Improve Robustness of WDM Mesh Networks", IEEE/ACM TRANSACTIONS ON NETWORKING, VOL. 20, NO. 1, FEBRUARY 2012.
[6] Navid Ghazisaidi, Michael Scheutzow, and Martin Maier "Survivability Analysis of Next-Generation Passive Optical Networks and Fiber-Wireless Access", IEEE/ACM TRANSACTIONS ON NETWORKING, VOL. 20, NO. 1, FEBRUARY 2012.
[7] Steven Gringeri, Bert Basch, Vishnu Shukla, Roman Egorov, and Tiejun J. Xia, Verizon Laboratories "Flexible Architectures for Optical Transport Nodes and Networks", IEEE Communications Magazine • July 2010.
[8] Serhat Nazim Avci and Ender Ayanoglu "New Diversity Coding Design Algorithms for Link Failure Recovery in Communication Networks", Communications (ICC), 2013 IEEE International Conference.
[9] Peter Babarczi, Janos Tapolcai, Pin-Han Ho, Muriel Medard "Optimal Dedicated Protection Approach to Shared Risk Link Group Failures using Network Coding", IEEE ICC 2012 - Optical Networks and Systems.
[10] Serhat Nazim Avci, Xiaodan Hu, and Ender Ayanoglu "Recovery from Link Failures in Networks with Arbitrary Topology via Diversity Coding", Global Telecommunications Conference (GLOBECOM 2011), 2011 IEEE.
[11] Yi Zhang, Pulak Chowdhury, Massimo Tornatore, and Biswanath Mukherjee "Energy Efficiency in Telecom Optical Networks", IEEE COMMUNICATIONS SURVEYS & TUTORIALS, VOL. 12, NO. 4, FOURTH QUARTER 2010.
[12] Masakazu Sato, Hiroshi Hasegawa, Ken-Ichi Sato "Efficient Iterative Design Algorithm for Enhancing Resource Utilization of Shared Protected Optical Path Networks", 2011 8th International Workshop on the Design of Reliable Communication Networks (DRCN).
[13] Ahmed E. Kamal "1+N Protection in Mesh Networks Using Network Coding over p-Cycles", Networking, IEEE/ACM Transactions on (Volume:18 , Issue: 1), Feb. 2010.
[14] Rui Manuel Morais, Claunir Pavan, Armando Nolasco Pinto, and Cristina Requejo "Genetic Algorithm for the Topological Design of Survivable Optical Transport Networks", VOL. 3, NO. 1/JANUARY 2011/J. OPT. COMMUN. NETW.

[1] H. Poor, "A Hypertext History of Multiuser Dimensions," MUD History, http://www.ccs.neu.edu/home/pb/mud-history.html. 1986. (URL link *include year)
[2] K. Elissa, "An Overview of Decision Theory," unpublished. (Unplublished manuscript)
[3] R. Nicole, "The Last Word on Decision Theory," J. Computer Vision, submitted for publication. (Pending publication)
[4] C. J. Kaufman, Rocky Mountain Research Laboratories, Boulder, Colo., personal communication, 1992. (Personal communication)
[5] D.S. Coming and O.G. Staadt, "Velocity-Aligned Discrete Oriented Polytopes for Dynamic Collision Detection," IEEE Trans. Visualization and Computer Graphics, vol. 14, no. 1, pp. 1-12, Jan/Feb 2008, doi:10.1109/TVCG.2007.70405. (IEEE Transactions)
[6] S.P. Bingulac, "On the Compatibility of Adaptive Controllers," Proc. Fourth Ann. Allerton Conf. Circuits and Systems Theory, pp. 8-16, 1994. (Conference proceedings)
[7] H. Goto, Y. Hasegawa, and M. Tanaka, "Efficient Scheduling Focusing on the Duality of MPL Representation," Proc. IEEE Symp. Computational Intelligence in Scheduling (SCIS '07), pp. 57-64, Apr. 2007, doi:10.1109/SCIS.2007.367670. (Conference proceedings)
[8] J. Williams, "Narrow-Band Analyzer," PhD dissertation, Dept. of Electrical Eng., Harvard Univ., Cambridge, Mass., 1993. (Thesis or dissertation)
[9] E.E. Reber, R.L. Michell, and C.J. Carter, "Oxygen Absorption in the Earth's Atmosphere," Technical Report TR-0200 (420-46)-3, Aerospace Corp., Los Angeles, Calif., Nov. 1988. (Technical report with report number)
[10] L. Hubert and P. Arabie, "Comparing Partitions," J. Classification, vol. 2, no. 4, pp. 193-218, Apr. 1985. (Journal or magazine citation)
[11] R.J. Vidmar, "On the Use of Atmospheric Plasmas as Electromagnetic Reflectors," IEEE Trans. Plasma Science, vol. 21, no. 3, pp. 876-880, available at http://www.halcyon.com/pub/journals/21ps03-vidmar, Aug. 1992. (URL for Transaction, journal, or magzine)
[12] J.M.P. Martinez, R.B. Llavori, M.J.A. Cabo, and T.B. Pedersen, "Integrating Data Warehouses with Web Data: A Survey," IEEE Trans. Knowledge and Data Eng., preprint, 21 Dec. 2007, doi:10.1109/TKDE.2007.190746.(PrePrint)