A contribution to the problem of links only for protection in WDM mesh networks

Stefanos Mylonakis, Member IEEE
smylo@otenet.gr

Abstract- *This paper presents a WDM mesh network planning and designing that satisfies given demands with a predefined way, a m:N WDM and optical fiber system shared protection (OMS-SP) and a restoration approach. This restoration approach is based on the shortest path algorithm ignoring the failed link, so a dynamic restoration method is used. At first, the restoration uses links only for protection and at second, the restoration does not use such links .The results are compared on optical path layer.*

Key words: WDM networks, protection, restoration, shortest path, links only for protection**.**

1.Introduction

All optical networks employing wavelength division multiplexing (WDM) and wavelength routing have been a viable alternative to emerging applications in future wide-area networks. However, the failure of a network component (e.g. a fiber link) can lead to the failures of all of the lightpaths that travel through the failed link. Therefore , a restoration technique should be considered to ensure service continuity and alleviate of such disruptions for the WDM all optical network. Several approaches are available for ensuring the network survivability.

Methods for recovering from failure are either protection based or restoration based. In the restoration based method , the resources available within the network are used to restore services affected by a failure. This method does not guarantee successful recovery , as an attempt to establish a new connection may fail due to resource shortage at the time of failure recovery.Research has been done [1]-[11] in relation to the methods and the problems associated with planning, protection and restoration of optical networks. There are several approaches to ensure fiber network survivability [1],[2].In [1] also used extra links to optimize the network topology and for protection to reduce its cost forming ring but in this paper extra links are used only for protection in mesh networks. In the [3] the author analyzes the Mathematical Theory of Connecting Networks and Telephone Traffic. In [4] the authors begin with an overviews on the future of optical networking. A historical look at the emergence of optical networking is first taken, followed by a discussion on the drivers pushing for a new and pervasive network, which is based on photonics and can satisfy the needs of a broadening base of residential, business and scientific users. In [5] the authors begin with an overview of the existing strategies for providing transport network survivability and continue with an analysis of how the architectures for network survivability may evolve to satisfy the requirements of emerging networks . In the [6] new options and insights are provided about, an existing ring-based network is evolved to a future mesh network, the mesh efficiency is much better than rings when the facilities graph is very sparse, the options of mesh protection or restoration rank need capacity, the enrichment and the connectivity of our network connectivity as well as with the description of the p-cycles, showing this new concept can realize ring-like speed with mesh like efficiency. They could be further adapted for use in IP or DWDM layers with GMPLS-type protocols or centralized control plane. In the [7] a perspective on optical layer protection and restoration based on the services offered by carriers using the optical layer, is provided. It also gives taxonomy of protection techniques in a more abstract fashion for the purposes of standardization and based on the classification adopted in SONET/SDH standards. In contrast, taking a services-based view provides a way to distinguish between protection schemes based on implementation costs and the associated services enabled by protection scheme. The [8] looks at several aspects of optical layer protection techniques from an implementation perspective. The authors discuss the factors that affect the complexity of optical protection schemes, such as supporting mesh instead of ring protection, handling low-priority traffic and dealing with multiple types of failures. The paper also looks at how the client layer interacts with the optical layer with respect to protection, in terms of how client connections are mapped into the optical layer, and how protection schemes in both layers can work together in efficient ways. Finally, they describe several interesting optical protection implementations, focusing on the ones that are different from conventional SONET like implementations. In [9], a preplanned local repair recovery strategy is described for GMPLS architecture. The allocation of primary paths is provided using the interference concept, in order to set a threshold between resources dedicated to working paths and those allocable for local backups in case of failure. The tests of the strategy are shown for a sample national optical network, aimed at valuing local-repair recovery times at different failure location and seriousness.The [10] examines different approaches to protect a mesh-based WDM optical network from failures of its elements. These approaches are based on two survivability paradigms 1)path protection/ restoration and 2)link protection restoration. So it examines, the wavelength capacity requirements, the routing and wavelength assignment of the primary and backup paths for path and link protection, as well as the protection switching time and the restoration time for each of these schemes and susceptibility of these schemes to multiple link failures. The [11] presents a wavelength routing scheme with spare reconfiguration (SR) to construct dependable all optical WDM networks to reduce the blocking probability compared with the general wavelength routing with just shared lightpaths by choosing a positive tuning cost.

In this paper a restoration algorithm of the source and destination nodes ignoring the failed link is used with a kind protection, *the links only for protection* .So this algorithm is used for two cases , first when these links are used and second when such links are not used on path layer.

This paper is broken down in the following sections: Section 2 describes the problem and provides a solution, the method general description, an application, attributes and discussion, Section 3 draws conclusions and finally ends with the references.

2.The problem and its solution

2.1 The problem

The following problem is solved. At first, how to plan and or design a WDM mesh network to satisfy given demands and at second, which the results of the comparison of the restoration with links only for protection versus the restoration without such links when the restoration is executed by source destination node pairs ignoring the cut link on optical channel layer? For this problem solution, a large number of simulations is executed with random demands and the corresponded capacity so that the effectiveness of the studied cases is showed. The following parameters are given. a) Network topology. b) The capacity of WDM multiplex system. c) The number of node pairs, the node pairs that the demands (requests for connection) must be satisfied as well as their predefined lightpaths. d) The 1:7 optical fiber shared protection. The network is a circuit switched one with identical nodes . On the network nodes are installed the OXCs (WDM-OXC and FIBRE-OXC) and the restoration relies on the ability of the latter to execute cross-connections after a failure has occurred in the network. There are two kinds of cross connections and these are the FIBRE-OXC and the WDM-OXC .The FIBRE-OXC does switching ,selection , routing, and loop back on the optical fiber layer and works on bundles of multiples fibers in an optical route. WDM-OXC does the switching and the routing on the path layer. The WDM-OXC has multiplex and demultiplex systems that convert the simple optical signals to an aggregated optical signal and vice versa. A lightpath is an all optical channel from source to destination to provide a circuit switched connection between these nodes. An optical channel passing through a cross-connect node may be routed from an input fiber to an output fiber without undergoing optical-electronic-optical (O-E-O) conversions. It is assumed that different wavelengths are assigned on all links along the route because nodes have wavelength conversion capabilities and called WDM-OXCs with wavelength interchange capability. Restoration architectures offer either centralized restoration or distributed restoration or some combination of both. The restoration can be applied at the optical path or on optical line layer.

2.2 Symbols

The following symbols are introduced for the description.

q, p, r node, edge and link number respectively.

k is the capacity of WDM system.

n , the number of source – destination nodes pairs of the network.

G(V,E) , the network graph.

$V(G)=\{v_1, v_2, v_3, \dots , v_q\}$, the network node set .

$E(G) =\{e_1, e_2, e_3,\dots , e_p\}$, the network edge set when links only for protection are not used .

Xn , a column matrix (nx1) with elements the connection group size of the corresponding source-destination node pairs and corresponds to the successful requests for connection .

Y, is the matrix, (2px1)with the occupied (busy) capacity of optical fiber network links before a cut link.

W, P, T the matrixes,(2px1) with elements the working, protection and total WDM and optical fiber systems per link respectively before a cut link.

A, is matrix (2p x n) which presents the network active links that passes the connections before a link cuts. Its elements are 1 (active links) or 0 (no active links).

2.3 The formulation

The solution of the planning and designing problem is based on the following equations.

$$Y= A * Xn \tag{1}$$

It means that the knowledge of each node pair demands which are its requests for connection and their predefined lightpaths create the necessary wavelengths for their satisfaction for each link.

$$W=Y/k \tag{2}$$

This equation means that dividing the number of the necessary busy wavelengths of each link with the capacity of the multiplex system creates the necessary working WDM and optical fiber systems for each link. The roundup is done for the larger integer.

$$P=W/7 \tag{3}$$

This equation means that dividing the number of the necessary working WDM and optical fiber systems of each link with the number seven creates the necessary protection WDM and optical fiber systems. The 1:7 shared protection WDM and optical fiber systems of each link means that the maximum number of working WDM and optical fiber systems that sharing a protection WDM and optical fiber system is seven. It is a practical way to reduce the cost of the protection network. The roundup is always done for the larger integer.

$$T=W+P \tag{4}$$

The total network WDM and fiber systems per link with protection.

$$\sum_{i=1}^{2p} (kTi)$$

$$PR=\frac{\qquad}{\sum_{i=1}^{2p}\sum_{j=1}^{n} A_{i,j} * X_j} - 1 \qquad (5)$$

The general protection ratio with Ti, Ai,j ,Xj the elements of the corresponded matrixes. The analytical format of Ti is written below when the optical channels of WDM and fiber systems of protection are used.

$$T_i = \left\lfloor \frac{\sum_{j=1}^{n} A_{i,j} * X_j}{k} \right\rfloor + \left\lfloor \frac{1}{7} \left\lfloor \frac{\sum_{j=1}^{n} A_{i,j} * X_j}{k} \right\rfloor \right\rfloor \qquad (6)$$

The second term is ought to the using of protection channels. The brackets mean the rounding (floor number).The maximum value of the protection ratio is written below.

$$PR\ max \sim \sum_{i=1}^{2p} (kT_i) \qquad (7)$$

It is valid when the first term of eq.5 is very larger than the second one and the denominator of the first term is 1. It is when there is one connection of one hop in the network. The protection percentage is larger than 100%. The minimum value of the protection ratio is written below.

$$PR\ min \sim 1/7 \qquad (8)$$

It is valid when the network coverage is very large and closing its fullness. It is when about all optical channels are busy. The protection percentage is 14.28%. When 2 links only for protection are used the protection ratio is modified as follows.

$$PR=\frac{\sum_{i=1}^{2p} (kT_i) + 2k}{\sum_{i=1}^{2p}\sum_{j=1}^{n} A_{i,j} * X_j} - 1 \qquad (9)$$

It is because the capacity of two WDM and fiber systems is added. So the protection ratio is improved more. The maximum value of the protection ratio is the same as eq.7 when the first term of the numerator is very larger than the second one. In other case the second term (2k) is added to the eq.7. The protection percentage is larger than 100%. It is written as below.

$$PR\ max \sim \sum_{i=1}^{2p} (kT_i) + 2k \qquad (10)$$

The minimum value of the protection ratio is the same as eq.8 when the network coverage is very large and the term of extra protection links is closing to zero when is divided by network coverage. In other case one second term is added to the eq.8. The protection percentage is 14.28% plus one percentage term. The minimum value of the protection ratio is written below.

$$PR\ min \sim \frac{1}{7} + \frac{2k}{\sum_{i=1}^{2p}\sum_{j=1}^{n} A_{i,j} * X_j} \qquad (11)$$

2.4 General description

The operation of the WDM optical fiber mesh network is described and the connections are proceeded by predefined working paths. The suitable data drive both cases and then simulated the actual dynamic behavior of the network. Simulation language is critical to the economic feasibility of the entire investigation. TURBO PASCAL is used to program the model. The following methods are used in this paper. These methods have two parts. The first part or the planning and designing part and the second part or the restoration part. The restoration algorithm uses the shortest path algorithm.

At first step (Network parameters) initially the following data are known, network topology, node number, edge number, link number and wavelength number per WDM and fiber system. This information allows the computer to draw a graph with Fiber and WDM OXCs are on the vertex of the graph. Each edge corresponds to two links with opposite direction to each other. The computer reads the adjacency matrix and it is informed about the network topology. At second step (Connection selections), the connection node pair number, the connection node pair selection for connections and their predefined lightpaths are done. The random number generation is activated and gives values to the connection groups of each node pair. At third step (Failure-free Network and Wavelength allocation), wavelength allocation is initiated. A connection starts from the source node and progresses through the network occupying a wavelength on each optical fiber and switch to another fiber on the same or other wavelength by WDM-OXC, according to its predefined optical path up to arrive at the destination node. This procedure is repeated for all connections. At forth step (Results) ,the wavelengths that each link needs for the full satisfaction of network demands are known and WDM and optical fiber system calculation starts with all fibers have the same wavelength number. The working WDM and fiber system calculation per link is implemented using the WDM capacity as well as the total network working WDM and fiber systems. By m:N (1:7) WDM and optical fiber system shared protection, the protection fibers per link are calculated as well as the total network protection WDM and fiber systems. At the end, the number of WDM and fiber system per link and the total network WDM and fiber systems are calculated. If there is no failure, the method is terminated. When a failure occurs (Network with failure) and a link is cut, the working and protection optical fibers of this link are also cut and the network topology changes. The connection groups that passed through the cut link are also cut. The computer is informed of the cut link and modifies suitably the network parameters and starts the restoration procedure. The cut optical fibers sets their wavelengths to zero, the connection groups that passing through the cut link are noted and set their using wavelengths to zero and through the others to free, the matrix A changes as well as the number of the group size that passing through fibers. The restoration procedure is executed by source-destination nodes ignoring the cut link on optical path layer, is presented (i) when links only for protection are used and (ii) when no such links are used .The results are presented and compared. At fifth step (The seeking for cut connections), after a failure occurs, the effected connections are resetting.In this step , the connections that effected by the failure are determined dynamically. The determination procedure checks the connections that passing through the cut link noting these in suitable matrix. Matrixes are not used for each link because it needs large memory and the method is slower. At sixth step (Wavelength allocation for restoration) a new wavelength allocation is initiated dynamically using the shortest path algorithm ignoring the cut link. A connection starts from the source node and progresses through the network occupying a wavelength on each optical fiber and switch to another fiber on the same or other wavelength by WDM-OXC, according to the shortest path algorithm optical path calculation up to arrive at the destination node. If a wavelength cannot be found, the connection is blocked and rejected. This procedure is repeated for all connections that are effected by failure. In this step, the links only for protection are used (1) or no used (2).At the seventh step (Results), for each case, the restoration percentage is calculated, the cut link is noted as a full restored cut link or no and the method is terminated. When all links are studied as cut and a large number of experiments are done the fully restored minimum and maximum percentage limits are also calculated. It is written previously that each case has two sections, the planning and designing section and the restoration section. The planning and designing section is common for both cases. Its worst case time complexity depends of the network topology and the total number of connections. It is $O(t*q^2)$ where t the total number of the connections. The restoration section has three steps. The number of the connections that effected by cut links is a small percentage of the total network connections for both cases. So the step six adds smaller time complexity than step five. It means that the worst *case time complexity of the restoration section depends of the step five and it is* $O(t*q^2)$. Both cases have the same worst case time complexity because the previously parameters are not changed.

2.5 Application

It is assumed that the topology of the network is presented by the graph G(V,E) . It is an optical mesh network with the circuit switched. This mesh topology is used because it is simple, palpable and it is easy to expand to any mesh topology. Each vertex represents the central telecommunications office (CO) with the OXCs while each edge represents two opposite links. The vertex set has q=11 elements which are $V=\{v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8, v_9, v_{10}, v_{11}\}$ and the edge set has p=19 elements which are $E=\{e_1, e_2, e_3,\ldots, e_{16}, e_{17}, e_{18}, e_{19}\}$.When the links only for protection are used one edge (e_{20}) is added and p=20. Each edge link has several optical fibers. All optical fibers have the same capacity as the WDM system. All nodes are identical. The number of working connections that pass through each optical fiber is different. The connections of each node pair form connection groups according to its predefined path and transverse the network. At first part (Network planning and design), network planning and designing is flexible to meet the needs of the network. The number of node pairs is n=11*(11-1)=110.The source destination demands and their preplanned working paths are not showed because their matrixes are large. The WDM and fiber system protection protocol is the m:N which is a shared one with 1:7. No further calculations and results are presented for the network planning and designing because their matrixes are very large. At second part (The performance study and the comparison of two cases), this study evaluates the effectiveness of the studied cases through extensive simulations. Here are the results of the comparison of the case 1 versus case 2. The comparison is done cutting one by one all the network links for a large number of experiments. For each experiment the number of the links with full restoration and the corresponded percentage are calculated. The last is called *fully restored cut link percentage*.

After it, the minimum and maximum percentages are also calculated. For each experiment, the number of connections

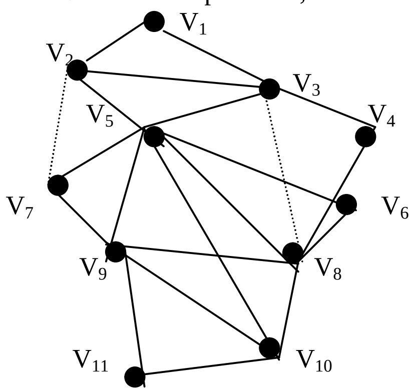
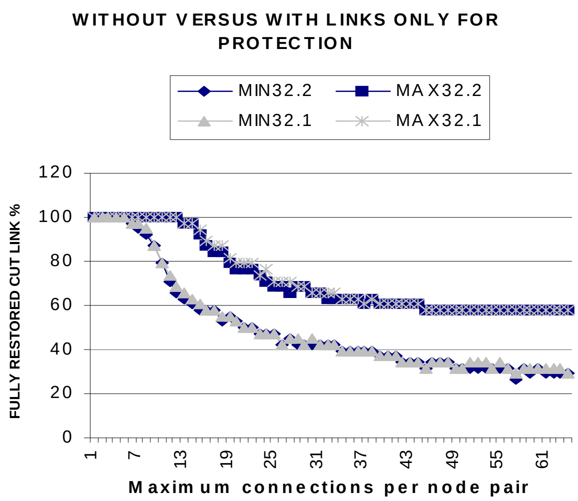


Figure 1.The mesh topology of the network.

of each node pair is random with its maximum value to be adjusted. The fully restored cut link minimum and maximum percentage limits for both methods are showed side by side.

Figure 2. The fully restored cut link percentage



minimum and maximum limits versus maximum connections per node pair for the compared casesMIN32.1, MAX32.1, MIN32.2, MAX32.2.

The fully restored cut link percentages depend of the circumstances because a large number of experiments are done. The capacity of WDM optical fiber system takes values of 32 and 128 OCh (wavelengths). The source destination connections are created from a random number generator with adjustable maximum value but their predefined working optical paths remain as previously. The random number generator is adjusted to take values between 1 to 64 and traffic level is increased largely. The procedure of the calculation is executed cutting one by one all the network links and calculated if it is full, partial and none restoration *with* using the capacity of the protection WDM and fiber systems. This procedure is repeated for ten thousands times. So the curves of the fully restored cut link percentage versus the maximum number of connections per node pair are compared for both cases and for two capacities of the WDM and fiber system.

It is showed from the figures 2 and 3. When the maximum connection number per node pair versus to the WDM and fiber system capacity is small, all cut links restored fully. When it increases more, all cut links may be restored fully. After a value of it, all links can not be restored fully. So the figure may be separated into three regions. When the capacity increases the regions broaden. A number of parameters is studied and compared for both methods to show the restoration depends. The figure 2 represents that the limits of the case 1(the links only for protection <V_3, V_8> and < V_8, V_3> are used) are better than those of the case 2(links only for protection are not used). The same is valid for the figure 3. The minimum limits of the case 1, are better than those of the case 2 and they are in the range of +2.64% (max(MIN32.1-MIN32.2)=2.64%) as well as its maximum limits they are in the range of +5.27%% (max(MAX32.1-MAX32.2)=5.27%), for the figure 2 in which the capacity of the WDM and fiber system is 32 OCH. The minimum limits of the case 1, are better than those of the case 2 and they are in the range of

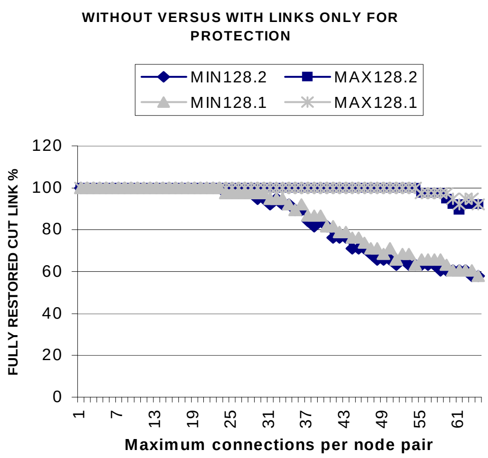


Figure 3. The fully restored cut link percentage minimum and maximum limits versus maximum connections per node pair for the compared cases MIN128.1, MAX128.1 , MIN128.2,MAX128.2.

+5.27% % (max(MIN128.1-MIN128.2)=5.27%) and 2.64% (max (MAX 128.1-MAX128.2)=2.64%) respectively, for the figure 3, in which the capacity of the WDM and fiber systems is 128 OCH. The range between the minimum and the maximum limits is variable. For the capacity 32CH, the

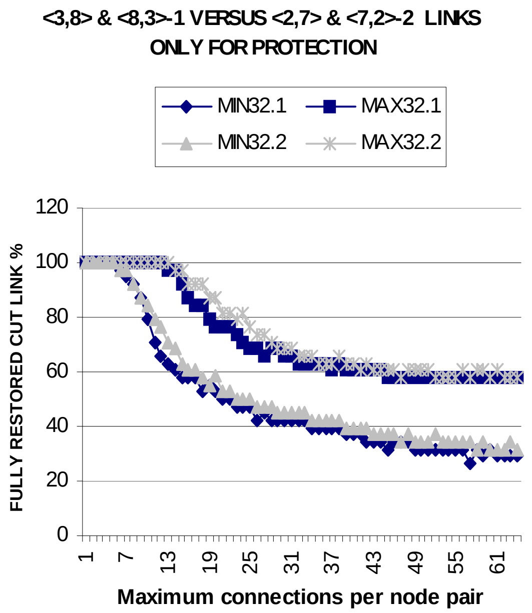


Figure 4. The fully restored cut link percentage minimum and maximum limits versus maximum connections per node pair for the compared cases MIN32.1, MAX32.1, MIN32.2, MAX32.2.

case 1 in the figure 2 has variable percentages with its values between 0 up to 34.21% (max(MAX32.1-MIN32.1)=34.21%) and for case 2 from 0 to 36.84% (max(MAX32.2-MIN32.2)=36.84%).For the capacity 128CH, the case 1 in the figure 3 has variable percentages with its values between 0 up to 36.84 % (max(MAX128.1-MIN128.1)=36.84%) and for case 2 from 0 to 36.84% (max(MAX32.2-MIN32.2)=36.84%). For the capacity 128CH, the case 1 in the figure 3 has variable percentages with its values between 0 up to 36.84 % (max(MAX128.1-MIN128.1)=36.84%)and for case 2 from 0 to 36,84%% (max(MAX128.2-MIN128.2)=36.84%). When the links only for protection are in different positions in the network the obtained improvement is different. The figure 4 represents that the limits of the case 1(the links only for protection <V_3, V_8> and < V_8, V_3> are used) and the case 2(links only for protection <V_2, V_7> and < V_7, V_2> are used). The minimum limits of the case 2, are better than those of the case 1 and they are in the range of +10.53% (max(MIN32.2-MIN32.1)=10.53%) as well as its maximum limits they are in the range of +10.53%% (max(MAX32.2-MAX32.1)= 10.53%), for the figure 4 in which the capacity of the WDM and fiber system is 32 OCH. The range between the minimum and the maximum limits is variable. For the capacity 32CH, the case 1 in the figure 4 has variable percentages with its values between 0 up to 36.84% (max (MAX32.1-MIN32.1)=36.84%) and for case 2 from 0 to 34.21% (max (MAX32.2-MIN32.2)=34.21%). The above application shows that links only for protection improve the restoration percentage when a link cuts and it is expected from the equations 9, 10 and 11.

2.6 Attributes

The following attributes are studied. *The spare capacity*, a network with extra back up links only for protection uses more spare capacity than one without such links. In our example, the network without such links uses 38 optical links for protection and with such links uses 40 optical links that means more optical fibers than that without such links. *The restoration time*, a network with extra back up links only for protection obtains faster full restoration than another without such links when these protection links are used. The restoration time depends primarily of the connections quantity and secondary of the restoration rerouting hops and the fiber-cut position. In this study, the same link cuts, at the same position with the same quantity of connections (same connection group number passing through), but the restoration rerouting hops contribute to the different restoration time. In the example, the link $<V_3, V_4>$ cuts and the connection groups of the node pair [V_1, V_4], [V_2, V_4], [V_3, V_4], [V_5, V_4], [V_6, V_4], [V_7, V_4], [V_9, V_4], [V_{10}, V_4] and [V_{11}, V_4] are also cut. Their light-paths are showed in the following table 1. For full restoration when the extra links only for

Table 1.The comparison of the lightpaths.

Node Pair	Working Lightath	Full Restoration with $<V_3, V_8>$ Shortest Path	Full Restoration Shortest Path
[V_1,V_4]	**V_1, V_2, V_3, V_4**	**V_1, V_3, V_8, V_4**	**V_1, V_2, V_5, V_8, V_4**
[V_2,V_4]	**V_2, V_3, V_4**	**V_2, V_3, V_8, V_4**	**V_3, V_5, V_8, V_4**
[V_3,V_4]	**V_3, V_4**	**V_3, V_8, V_4**	**V_3, V_5, V_8, V_4**
[V_5,V_4]	**V_5, V_3, V_4**	**V_5, V_8, V_4**	**V_5, V_8, V_4**
[V_6,V_4]	**V_6, V_5, V_3, V_4**	**V_6, V_8, V_4**	**V_6, V_8, V_4**
[V_7,V_4]	**V_7, V_5, V_3, V_4**	**V_7, V_5, V_8, V_4**	**V_7, V_5, V_8, V_4**
[V_9,V_4]	**V_9, V_5, V_3, V_4**	**V_9, V_5, V_8, V_4**	**V_9, V_5, V_8, V_4**
[V_{10}, V_4]	**V_{10}, V_5, V_3, V_4**	**V_{10}, V_8, V_4**	**V_{10}, V_8, V_4**
[V_{11}, V_4]	**V_{10}, V_{10}, V_5, V_3, V_4**	**V_{11}, V_{10}, V_8, V_4**	**V_{11}, V_{10}, V_8, V_4**

protection are used the total connections hops are twenty three (23) and without such links the total connections hops are twenty five (25) .The difference is ought to the restoration rerouting hops of the connection groups of the node pair [V_1, V_4] and [V_3, V_4] that uses the such link $<V_3, V_8>$.The node pair [V_2, V_4] also uses the link $<V_3, V_8>$ but there is another shortest path .So this case obtains less restoration time. The fiber length contributes very small to the restoration time and it is negligent. *The restoration complexity*, a network with extra back up links only for protection obtains restoration with simpler way than other one without such links when these protection links are used. It is because the network has more connectivity, more available spare capacity and less restoration hops because such links also provide most direct restoration lightpaths so they use fewer network facilities and generally can provide better transmission quality. In the example, the link $<V_3, V_4>$ cuts and the connections groups of the node pairs of the above table are also cut. The lengths of the restoration lightpaths of the node pairs [V_5, V_4], [V_6, V_4], [V_7, V_4], [V_9, V_4], [V_{10}, V_4] and [V_{11}, V_4] do not change because they do not use the extra link $<V_3, V_8>$ but the length of the restoration lightpath of the node pairs [V_1, V_4] and [V_3, V_4] change from four to three and three to two respectively . So the restoration lightpaths of these node pairs are more direct. *The network connectivity*, a network with extra back up links only for protection has more connectivity than a network without such links. In our example, the degree of the vertexes V_3 and V_8, when only the extra protection back up link $<V_3, V_8>$ is used is five and without such links four as well as six and five respectively. *The network reliability*, a network with extra back up links only for protection has more reliability than a network without such links because there are more restoration paths. *The restoration efficiency*, all the above show that links only for protection improve the restoration efficient.

2.7 Discussion

Today installation of WDM networks is based on mesh topologies but the latter are essentially formed by a set of point-to-point links between nodes. Network survivability is an inherent part of the mesh topology because there are usually at least two paths between end nodes but the ring topology has only two paths. Thus, a network that uses a mesh topology can survive a single failure of link cut. In the dynamical restoration, the dynamic routing method requires each OXC network controller to store only necessary local information and the rerouting decision is made according to the network status (e.g. configuration, available spare capacity and so on) at the time of network component failures. As it is discussed previously, the use of links only for protection improves the network attributes. However, the great disadvantage of these links is the cost. If their use reduce the network topological cost, they are always used. Some cases in which they are used are the following. a) when the back-up optical fibers are old and their use is limited in time, in order to cover an extraordinary situation despite the whatever loss of quality in restoring traffic that may occur due to the age of fibers, b) when we use new optical fibers through existing ducts or special cable transmission channels (lower placement cost), c) the existing restoring routes require the use of optical amplifiers (EDFAs) that increase the cost much more than this method ,d)when they are going to use for network expansions or other future uses.

3. Conclusion

In the present paper I search the networks that use the type of protection that is links only for protection versus the networks without such links. The links only for protection improve the network attributes. The important disadvantage is the increased cost of these addition links. But the use of new optical fibers will increase the operation costs of the network overall, however it will eliminate most quality-related problems; in light of the latter, restoring capabilities may constitute a specification of quality in SLAs. So these links with the back-up optical fibers can cover our protection needs in a fuller and far easier way than any other method.

References

[1]. Tsong-Ho Wu. *Fiber Network Service Survivability* . ARTECH HOUSE ,1992.
[2]. A.Bononi.*Optical Networking*.Part 2, SPRINGER, 1992.
[3]. V.E.Benes.*Mathematical Theory of Connecting Networks and Telephone Traffic*.ACADEMIC PRESS ,1965.
[4]. M.O'Mahony, C.Politi, D.Klonidis, R.Nejabati and D.Simeonidou "Future Optical Networks," *IEEE Journal of LightWave Technology*,Vol 24 ,No 12, pp 4684-4696, December 2006.
[5]. James Manchester, Paul Bonenfant, Curt Newton. "The evolution of Transport Network Survivability," *IEEE Comms Magazine*, Vol 37 , No 8, pp44-51, August 1999.
[6]. W.D Grove, J.Doucette, M.Clouqueur, D.Leung, D.Stamatelakis . "New options and insights for survivable Transport Networks," *IEEE Communications Magazine*,Vol 40, No1 , pp 34-41, January 2002.
[7]. Ornan Gerstel and RajivRamaswami, Xros. "Optical Layer Survivability-A services perspective," *IEEE Comms Magazine*,Vol 38,No 3 ,pp104-113, March 2000.
[8]. Ornan Gerstel and Rajiv Ramaswami, Xros. "Optical Layer Survivability-An implementaion perspective," *IEEE JSA of Communication*,Vol 18,No 10, pp1885-1889, October 2000.
[9]. Gino Carrozzo, Stefano Giordano ,Marco Menchise ,Michele Pagano."A Preplanned Local Repair Restoration Strategy for Failure Handling in Optical Transport Networks ," *Kluwer Academic Publishers Photonic Network Communications* 4:3/4, pp345-355,2002 .
[10].S.Ramamurthy , Laxman Sahasrabuddhe ,Biswanath Mukherjee "Survivable WDM Mesh Networks ," *IEEE Journal of LightWave Technology*,Vol 21 ,No 4,pp 870-889,April 2003.
[11].Chuan-Ching Sue "Wavelength Routing With Spare Reconfiguration for All-Optical WDM Networks," *IEEE Journal of LightWave Technology*,Vol 23 ,No 6,pp 1991-2000,June 2005.

Stefanos Mylonakis (M,96) member of IEEE since 1996, was born in Chanea, Greece in 1954. He obtained a Bachelors degree in Physics from the University of Patras and two Master's degrees, in Radioelectrology (1984) and Electronic Automation (1987), both from the University of Athens. He was working as expert telecommunications engineer, engineering management in OTE (Hellenic Telecommunications Organisation).