Multicast Routing Techniques to Make Optical Network Survivable Against Single Link/Node Failure

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Abstract— Link/Node failures are very common in any networks but these failures have a huge impact on the overall performance of the network. Due to these link/node failures sometimes it is impossible to communicate in b/w the network or to send or receive data from sender to receiver. So to overcome such problems researchers created few techniques which can tackle with these problems and can overcome them. In this paper those techniques are reviewed. These algorithms are used for protection of both single-link and single link/node failure scenarios.

Keywords— SNH, MPH, OPP-SDP, OPP-SDS, STEINER.

I. Introduction

Optical Fiber has prevailed as the medium of choice for high-speed communications [1]. Furthermore, now days bandwidth intensive multicasting applications such as video conferencing, live auctions, distributed games, online video streaming, digital HD-TV and video on- demand are applications that are becoming widely popular and this can only be possible with the great capabilities of the optical fiber. These multicasting applications are based on the calculation of light-trees, utilizing optical splitters in the network nodes [3]. On the other hand, the vast amount of information that a fiber carries, as well as the amount of information loss in case of a failure on a light-tree that can affect the traffic to multiple destinations have led to the necessity of development of efficient multicast protection techniques .in this paper all the present techniques will be discussed and we will see how will these algorithms help to avoid link failures and loss of data. In this paper algorithms such as

1. STEINER NODE HEURISTICS (SNH)
2. SHARED DISJOINT-SEGMENTS ALGORITHM (H-SDS),
3. OPTIMAL PATH-PAIR-BASED SHARED DISJOINT-SEGMENTS ALGORITHM (OPP_SDS_H)
4. OPP-BASED SHARED DISJOINT PATHS ALGORITHM (OPP-SDP)

In order to support multicasting in an optical WDM network, which will form tomorrow's Internet backbone, we need multicast capable wavelength routing switches (MWRSs) [14] at network nodes, which transfer a stream of bits from one input port to multiple output ports. Fig.1 shows a MWRS with optical–electronic optical (O/E/O) conversion employing opaque cross-connects [15]. A signal arriving on the input fiber Link D is replicated into three copies in the electronic domain.

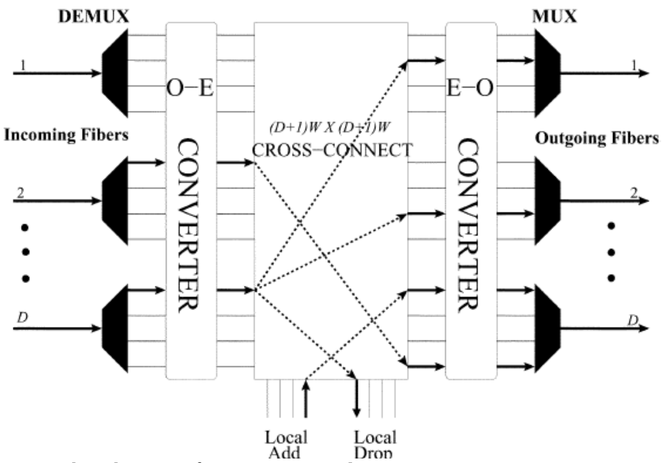

Fig1. Switch architecture for supporting multicasting using opaque Cross-connect and O/E/O conversion (W = number of wavelengths per fiber)[23].

One copy is dropped locally at the node, and the remaining two are passed to different channels on outgoing fiber links 1 and 2. These switches with splitting capability create a "light-tree" [14], [16] with the source node as the root and the destination nodes as leaves. Full wavelength conversion is inherent in such cross-connects and, hence, no explicit wavelength convertors are needed. Fiber cuts in an optical network occur often enough to cause service disruption, and they may lead to significant information loss in the absence of adequate backup mechanisms. If the optical fiber carrying a data for the multiple destination the link failure can cause a huge amount of data loss. Although significant work has been done for protecting and restoring unicast connections in wdm mesh network in which several schemes, such as link protection, path protection, and sub-path protection with or without sharing, are discussed [17]–[20], little work has been done on efficient protection of multicast connections where several replicas of information bit streams are transmitted to a set of destination nodes simultaneously. Below we explain multicast protection approaches. The basic schemes are *link* disjoint and *arc*-disjoint trees. These schemes are the basic ones as they are not those efficient techniques. Two trees are said to be *link-disjoint and arc-disjoint* if they do not share any link along their edges. Such link-disjoint trees and node disjoint trees can be used to provide dedicated protection [21] where both primary tree and backup tree carry identical bit streams to the destination nodes. When a link fails, the affected destination nodes reconfigure their switches to receive bit streams from the backup tree, instead of the primary tree. The pitfalls of this approach include excessive use of resources and inability to discover link-disjoint trees in a mesh network, which may lead to the blocking of a large number of multicast sessions while trying to establish them.

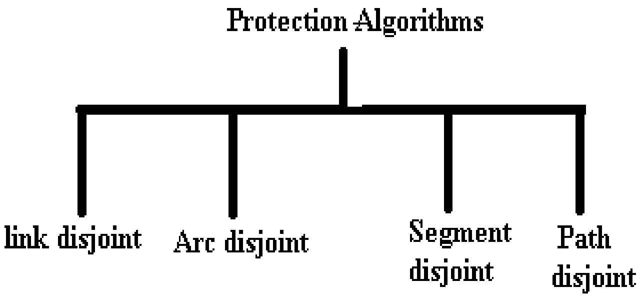

Fig2. Various Multicast Protection Techniques.

In fig2 it is shown that the algorithms are basically divided into categories these categories are as given below

1. Link-disjoint
2. Arc- disjoint
3. Segment disjoint
4. Path disjoint

In link disjoint firstly we have to calculate a primary tree from a graph using MPH,PPH and such algorithms then we have to make the tree link disjoint means we have to remove the primary link from the graph and then calculate the secondary tree from the graph using same either MPH or PPH.

In Arc disjoint firstly we have to calculate a primary tree from a graph using MPH,PPH and such algorithms then we have to make the tree Arc disjoint means we have to remove the primary Arc from the graph as shown in fig3. And then calculate the secondary tree from the graph using same either MPH or PPH.

In Segment disjoint firstly we have to calculate a primary tree from a graph using MPH,PPH and such algorithms then we have to Identify the primary segment on the primary tree. Then make cost =0 for the arcs along the primary tree. Remove the links along the primary segment. Create a backup segment arc- disjoint to the primary segment. Update cost =0 for already fond backup segments. Replace the links along the primary segment. . And then calculate the secondary tree from the graph using same either MPH or PPH.

In Path disjoint firstly we have to calculate a primary tree from a graph using MPH,PPH and such algorithms then we have to Identify the segments on the primary tree. We have to do it for every primary segment. Find an optimal path b/w end nodes of the segment Update cost =0 for already found optimal path. . And then calculate the secondary tree from the graph using same either MPH or PPH.

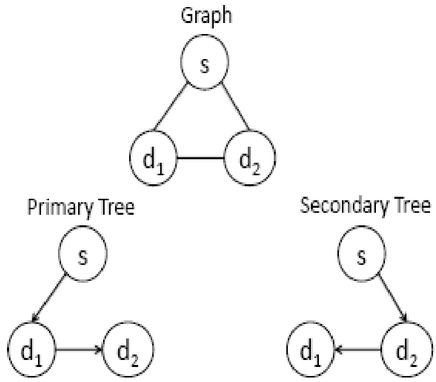

Fig3. Arc Disjoint trees [SNH].

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II. VARIOUS ALGORITHMS FOR PROTECTION AGAINST LINK/NODE FAILURE

There are many algorithms which are there to protect the network against link/node failures. In this paper we discussed few which are as given below.

A. STEINER NODE HEURISTICS

This algorithm is based on the calculation of the Steiner tree. The Steiner Tree Problem (STP) in graphs is a classical combinatorial optimization problem where the target is the calculation of the shortest interconnection for a given finite set of graph nodes. The mathematical formulation of the problem is as follows: Given a connected, undirected, simple, weighted graph $G(V,E)$ with a positive cost function for every edge, and a subset Z of V, find the connected subgraph $T*$ with the minimum cost among all connected subgraphs that contain set Z. A subgraph $T*(V*,E*)$ of graph $G(V,E)$ is a graph such $V* \subset V$ that and $E* \subset E$. It is obvious that $T*$ is a tree, and we call it the Minimum Steiner Tree (MST). Except of the required nodes of set Z, $T*$ possibly contains some other nodes $S \subset (V - Z)$, which are called *Steiner nodes*. Let $|V| = n$ and $|Z| = k$. For $(2 < k < n)$ the problem is NP-complete, hence it cannot be solved exactly in polynomial time [4].

To calculate Steiner tree we have many techniques such as MPH, PPH.

STEINER NODE HEURISTIC [22] consists of the following steps

1. Calculate Steiner Tree $T*$ ($V*$, $E*$) using MPH and find
   its cost, called C.
2. For every node $vi \in \{V - V*\}$ do the following:
   (a) $\{Z\_\} = \{Z\}+vi$.
   (b) Calculate Steiner Tree Ti (Vi, Ei) on
   G (V, E) for set $\{Z\_\}$, using MPH, and find its Cost,
   ci.
   (c) $\{Z\_\} = \{Z\}$.
3. Find vj and Tj : $c j = mini\{ci\}$.
4. If $cj \geq C$, the solution is $T*$ ($V*$, $E*$), STOP.

The procedure for the calculation of arc-disjoint or node-disjoint trees is as follows:

(1) Calculate the primary light-tree using a multicast
routing algorithm,
(2) *For **arc-disjoint trees***: Remove the arcs of the primary
tree from the network graph, else *for **node-disjoint trees***: Remove its intermediate nodes and their corresponding arcs from the network graph
(3) Calculate the secondary tree on the resulting graph using a multicast routing algorithm.

In the above given algorithm first calculate the Steiner tree using MPH and find the network cost then add Steiner node to the existing sub graph and again calculate Steiner tree if the cost of the network decrease then update the Steiner tree otherwise take another Steiner tree and so on. After finding the primary tree, for arc disjoint tree remove the existing arc from the network graph and for link disjoint tree remove the primary nodes from the network graph. Calculate the secondary tree on the resulting graph using a multicast routing algorithm.

B. SHARED DISJOINT SEGMENTS ALGORITHM (H-SDS):

H-SDS [MPH] describes the algorithm to protect segments of a primary tree created using H (where H is MPH.)While finding a backup segment for an unprotected segment on the primary tree, the cost of the arcs along the primary tree and already-found backup segments is updated to zero, thus enhancing sharing of the current backup segment with the partially computed sub graph.

1. Create a primary tree using h.
2. Identify the primary segment on the primary tree.
3. Make cost =0 for the arcs along the primary tree.
4. For every primary segment, repeat step 5 through 8.
5. Remove the links along the primary segment.
6. Create a backup segment arc-disjoint to the primary segment.
7. Update cost =0 for already fond backup segments.
8. Replace the links along the primary segment.

As a result, the additional cost for computing each new backup segment is minimized. We call the previously mentioned shared disjoint segment scheme using H H-SDS. Finding a backup segment between the end-points of a primary segment may not always be possible if the primary segment has already been computed.

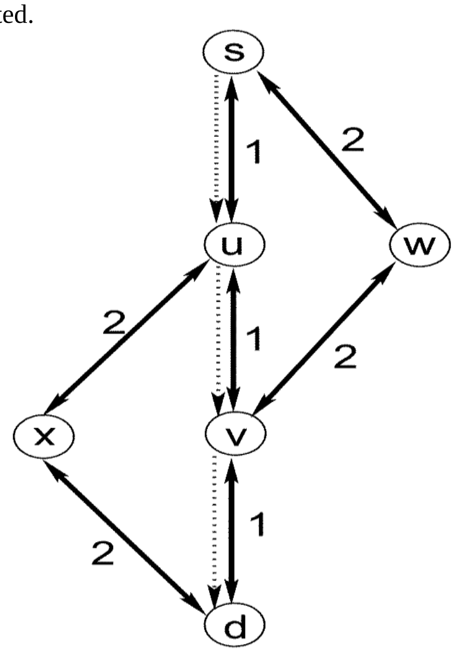

Fig4. Example where it is difficult to compute a backup segment once a primary segment (shown in dotted lines) is found, even though disjoint segments exist [23].

For example, in Fig4. The existence of a primary segment along $\langle s \rightarrow u \rightarrow v \rightarrow d \rangle$ makes it impossible to compute a backup segment that is disjoint to the primary. We can see, however, that two disjoint segments (also referred to as path-pairs) $\langle s \rightarrow w \rightarrow v \rightarrow d$ and $s \rightarrow u \rightarrow x \rightarrow d \rangle$ exist [23].

C. OPTIMAL PATH-PAIR-BASED SHARED DISJOINT-SEGMENTS ALGORITHM (OPP_SDS_H)

The OPP_SDS_H [23] is the other protection technique which can be used to protect the link/node from failure. Now it can be done by calculating a segment b/w the two nodes and then find and optimal path b/w those nodes and finally update the cost of that segment to zero and find the alternative segment and so on. The algorithm of the OPP_SDS_H is as given below

Create a primary tree using algorithm MPH.

1. Identify the segments on the primary tree.
2. For every primary segment, repeat 4 and 5.

3. Find an optimal path b/w end nodes of the segment
4. Update cost =0 for already found optimal path.

By using this above given algorithm we can actually protect the network against node/link failures.

D. OPP-BASED SHARED DISJOINT PATHS ALGORITHM (OPP-SDP)

The OPP-SDP [23] is the other protection technique which can be used to protect the link/node from failure. Now it can be done by calculating the path for the every destination node present in the network and then calculate the optimal path b/wsource and destination node. Remove the already present path and calculate the alternative one. The algorithm of OPP-SDP is as given below.

1. For every destination node of the session, repeat step 2 and 3.
2. Find an optimal path pair b/w source and destination node.
3. Update cost =0 for already found path and calculate the new one.

By using the above given algorithms we can protect the network from the single link/ node failure.

III. CONCLUSION

All above given algorithms are different from each other on the basis of their blocking probability and the cost these two parameters differentiate b/w all the proposed algorithms and tell us which of them is efficient over other. Even though there is already so much of research is already done in this area but still there is research taking place in this area so that the Optical networks can be more lossless and efficient. In this paper the algorithms which are reviewed are divided in different segments like Link-disjoint, Arc-disjoint, Segment based, Path based. All given algorithms are good to make network survivable up to certain extent against the Link/Node failure.

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REFERENCES

[1] R. Ramaswami, "Multiwavelength lightwave networks for computer communication," IEEE Commun. Mag. **31**(2), 78–88 (1993).

[2]. T. E. Stern, G. Ellinas, and K. Bala, *Multiwavelength Optical Networks: Architectures, Design, and Control*, 2nd ed. (Cambridge University Press, 2008).

[3]. L. Sahasrabuddhe and B. Mukherjee, "Light-trees: optical multicasting for improved performance in wavelength routed networks," IEEE Commun. Mag. **37**(2), 67–73 (1999).

[4]. R. M. Karp, "Reducibility among combinatorial problems: Complexity of computer computations," Chap. 8 in *50 Years of Integer Programming 1958–2008*, R. E. Miller and J. W. Thatcher, eds. (Plenum Press, 1972).

[5]. R. C. Prim, "Shortest connection networks and some generalizations," Bell Syst. Tech. J. **36**, 1389–1401 (1957).

[6]. H. Takahashi and A. Matsuyama, "An approximate solution for the Steiner problem in graphs," Math. Japonica **24** (6), 573–577 (1980).

[7]. N. Singhal, L. H. Sahasrabuddhe, and B. Mukherjee, "Provisioning of survivable multicast sessions against single link failures in optical WDM mesh networks," J. Lightwave Technol. **21**(11), 2587–2594 (2003).

[8]. C. K. Constantinou and G. Ellinas, "A novel technique for survivable multicast routing in optical WDM mesh networks," Proc. European Conf. on Optical Communications (ECOC), Geneva, Switzerland, Sept. 2011.

[9] S. Paul, *Multicasting on the Internet and Its Applications.* Boston, MA: Kluwer, 1998.

[10] C. K. Miller, *Multicast Networking and Applications*. Reading, MA: Addison-Wesley, 1999.

[11] R. Malli, X. Zhang, and C. Qiao, "Benefit of multicasting in all-optical networks," in *Proc. SPIE Conf. All-Optical Networking*, vol. 2531, Nov. 1998, pp. 209–220.

[12] Y. Sun, J. Gu, and D. H. K. Tsang, "Multicast routing in all-optical wavelength routed networks," *Optical Networks Mag.*, pp. 101–109, July/Aug. 2001.

[13] T. Znati, T. Alrabiah, and R. Melhem, "Point-to-multi-point path establishment schemes to support multicasting in WDM networks," presented at the 3rd IFIPWorking Conf. Optical Network Design Modeling (ONDM'98), Paris, France, 1999.

[14] L. H. Sahasrabuddhe and B. Mukherjee, "Light-trees: Optical multicasting for improved performance in wavelength-routed networks," *IEEE Commun. Mag.*, vol. 37, pp. 67–73, Feb. 1999.

[15] N. Singhal and B. Mukherjee, "Architectures and algorithm for multicasting in WDM optical mesh netwoks using opaque and transparent optical cross-connects," in *Tech. Dig., Optical Fiber Communications*, Anaheim, CA, Mar. 2001, paper TuG8.

[16] L. H. Sahasrabuddhe, N. Singhal, and B. Mukherjee, "Light-trees for optical networks: Optimization problem formulation for unicast and broadcast traffic," in *Proc. Int. Conf. Communications, Computers, Devices (ICCCD), IIT*, vol. 2, Kharagpur, India, Dec. 2000, pp. 561–564.

[17] B. V. Caenegem, N.Wauters, and P. Demeester, "Spare capacity assignment for different restoration strategies in mesh survivable networks," in *Proc. Int. Conf. Communications*, vol. 1, Montreal, QC, Canada, June 1997, pp. 288–292.

[18] B.V. Caenegem,W.V. Parys, F. D. Turck, and P. M. Demeester, "Dimensioning of survivableWDMnetworks," *IEEE J. Select. Areas Commun.*, vol. 16, pp. 1146–1157, Sept. 1998.

[19] O. Crochat and J. Y. Le Boudec, "Design protection for WDM optical networks," *IEEE J. Select. Areas Commun.*, vol. 16, pp. 1158–1165, Sept. 1998.

[20] G. Ellinas, A. Hailemariam, and T. E. Stern, "Protection cycles in mesh WDM networks," *IEEE J. Select. Areas Commun.*, vol. 18, pp. 1924–1937, Oct. 2001.

[21] S. Ramamurthy and B. Mukherjee, "Survivable WDM mesh networks, part I—Protection," in *Proc. IEEE INFOCOM*, vol. 2, Mar. 2003, pp.
744–751.

[22] Costas K. Constantinou1 and Georgios Ellinas" A novel multicast routing algorithm and its application for protection against single-link and single-link/node failure scenarios in optical WDM mesh networks" 12 December 2011 / Vol. 19, No. 26 / OPTICS EXPRESS B471

[23] Narendra K. Singhal, Laxman H. Sahasrabuddhe, and Biswanath Mukherjee" Provisioning of Survivable Multicast Sessions Against Single Link Failures in Optical WDM Mesh Networks"JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 21, NO. 11, NOVEMBER 2003

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