Longest Path First WDM Multicast Protection for Maximum Degree of Sharing*

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Abstract. In this paper, we investigate efficient approaches and algorithms for protecting multicast sessions against any single link failure while establishing multicast sessions in WDM mesh networks. Since a single failure may affect whole nodes in a multicast group and causes severe service disruption and a lot of traffic loss, protecting critical multicast sessions against link failure such as fiber cut becomes important in WDM optical networks. One of the most efficient algorithms is optimal path pair-shared disjoint paths (OPP-SDP). In this algorithm every source-destination (SD) pair has the optimal path pair (working and protection path) between the source and destination node. Since degree of sharing among the paths is essential to reduce the total cost and blocking probability, we propose the longest path first-shared disjoint paths (LPF-SDP) algorithm which decides the priority of selection among SD pairs in a resource-saving manner. Our LPF-SDP is shown to outperform over OPP-SDP in terms of degree of sharing and blocking probability.

1 Introduction

The growth of wavelength division multiplexing (WDM) technology has opened the gate for bandwidth-intensive applications [1]. In addition, the Internet services expand and multicast applications such as video conference, interactive distance learning, and a large-scale online games become more popular [2]-[6]. In high-speed WDM networks it becomes more and more important to protect multicast sessions against various types of failures. Therefore we propose longest path first-shared disjoint paths (LPF-SDP) which determines the order of selecting SD pairs appropriately. Our LPF-SDP algorithm is shown to achieve higher performance compared to the OPP-SDP algorithm. This paper is organized as follows. We propose multicast protection algorithms based on longest path first in Section 2. Performance evaluation of the proposed algorithms is presented in Section 3. Finally, we conclude in Section 4.

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2 Proposed Multicast Protection Algorithms

In an attempt to improve performance we propose an LPF-SDP heuristic algorithm which determines the priority of selecting SD pairs in a cost-saving manner. In our proposed LPF-SDP, for every destination node of a multicast session, we find an optimal path pair between a source and a destination node successively, and update the link cost along the already-found optimal path pair to zero. Since the cost of already-found optimal path pairs is updated to zero, the probability of sharing the links increases, if the route is the longest one, resulting in reduction of total cost. In this sense we propose the concept of longest path first order when the first SD pair is selected. If the SD pair with the longest path is established as the first path pair, forthcoming working and protection pairs can have more chance to share more links on the longest path. This mechanism decreases the total cost for establishing multicast trees. After the first path pair

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Input :  $G = (V, E)$ ,  $S = \{s, d_1, \dots, d_k\}$ 
Output :  $P(s, d_i) = \{P_w(s, d_i), P_p(s, d_i)\}$  : OPP between  $s$  and  $d_i$ ,  $i = 1, \dots, k$ 
          $P_w(s, d_i)$  : working path for SD pair between  $s$  and  $d_i$ 
          $P_p(s, d_i)$  : protection path for SD pair between  $s$  and  $d_i$ 
01: Algorithm SPF-SDP( $G, S$ )
02:  $P(s, d_i) = \text{FIND\_MAX\_COST\_OPP}(G, S)$ 
03: Update link cost = 0 for all edges of  $P(s, d_i)$ 
04:  $S = S - \{d_i\}$ 
05: While ( $S \neq \{s\}$ )
06:    $P(s, d_j) = \text{FIND\_MIN\_COST\_OPP}(G, S)$ 
07:   Update link cost = 0 for all edges of  $P(s, d_j)$ 
08:    $S = S - \{d_j\}$ 
09: Merge OPPs from  $P(s, d_1)$  to  $P(s, d_k)$  to make multicast trees  $T_w$  and  $T_p$ 

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Fig. 1. Proposed SPF-SDP algorithm

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Input :  $G = (V, E)$ ,  $S = \{s, d_1, \dots, d_k\}$ 
Output :  $P(s, d_i) = \{P_w(s, d_i), P_p(s, d_i)\}$  : OPP between  $s$  and  $d_i$ ,  $i = 1, \dots, k$ 
          $P_w(s, d_i)$  : working path for SD pair between  $s$  and  $d_i$ 
          $P_p(s, d_i)$  : protection path for SD pair between  $s$  and  $d_i$ 
01: Algorithm LPF-SDP( $G, S$ )
02:  $P(s, d_i) = \text{FIND\_MAX\_COST\_OPP}(G, S)$ 
03: Update link cost = 0 for all edges of  $P(s, d_i)$ 
04:  $S = S - \{d_i\}$ 
05: While ( $S \neq \{s\}$ )
06:    $P(s, d_j) = \text{FIND\_MAX\_COST\_OPP}(G, S)$ 
07:   Update link cost = 0 for all edges of  $P(s, d_j)$ 
08:    $S = S - \{d_j\}$ 
09: Merge OPPs from  $P(s, d_1)$  to  $P(s, d_k)$  to make multicast trees  $T_w$  and  $T_p$ 

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Fig. 2. Proposed LPF-SDP algorithm

is established, forthcoming working and protection path pairs can be established randomly or sequentially. We call this algorithm The First Longest Path Once-Shared Disjoint Paths (FLPO-SDP). Fig. 1 and Fig. 2 summarize the proposed SPF-SDP and LPF-SDP algorithm.

3 Performance Evaluation

We evaluate and compare the performance of LPF-SDP with that of OPP-SDP, FLPO-SDP, and SPF-SDP in terms of the total network cost on the sample network with 24 nodes and 43 links. In our simulation, a multicast session of size k is assumed to be established and protected. We repeat the experiment for 10,000 different multicast sessions of the same size k of a multicast group. The size of a multicast group k varies from 1 to 23 (unicast to broadcast).

Fig. 3 shows the average total cost versus session size k as the session size increases in the sample network with 24 nodes and 43 links. Since the number of links in the optimal path pairs increases as the session size increases, the average total cost grows in general as the session size increases. We notice that the LPF-SDP outperforms over the other schemes because this scheme results in the best degree of sharing. The performance of LPF-SDP is about 6% higher compared to the OPP-SDP algorithm.

Fig. 4(a) shows average total cost versus p_e as p_e increases in random networks with 24 nodes. Since the number of links in random networks increases as p_e increases, the average cost decreases in general due to increased connectivity. We also note that LPF-SDP outperforms among the schemes because the LPF-SDP scheme inherits more degree of sharing. The performance of LPF-SDP is about 5.4% higher compared to the OPP-SDP algorithm. And Fig. 4(b) shows the average cost versus session size k as the session size increases in random networks with 24 nodes. Since the number of links in the optimal path pairs increases as the session size increases, the average cost increases as well.

Fig. 3. Average cost versus session size (k) in the sample network

Fig. 4. Average total cost of establishing multicast session on random networks

4 Conclusion

In this paper, we have proposed the LPF-SDP algorithm to efficiently solve the multicast protection problem in WDM optical networks. The optimal solution by ILP has very high complexity and requires large computational cost, and OPP-SDP randomly determines the priority of selecting SD pairs. Our proposed LPF-SDP is shown to be an efficient algorithm to determine the priority of selection among SD pairs appropriately. The simulation results both for static multicast sessions and for dynamic ones in the sample network and random networks show that our LPF-SDP yields the least total network cost and the blocking performance than OPP-SDP. The proposed LPF-SDP multicast protection scheme holds the property of resource-saving while providing survivability for high-speed multicast applications in optical WDM networks.

References

1. Mukherjee, B.: Optical communication networks, New York: McGraw Hill. (1997)
2. Paul, S.: Multicasting on the Internet and its applications, Boston, MA: Kluwer. (1998)
3. Miller, C.K.: Multicast networking and applications, Reading, MA: Addison-Wesley. (1999)
4. Malli, R., Zhang, X., Qiao, C.: Benefit of multicasting in all-optical networks, Proc. SPIE Conf. All-Optical Networking, Vol. 2531. (1998) 209–220
5. Sun, Y., Gu, J., Tsang, D. H. K.: Multicast routing in all-optical wavelength routed networks, Optical Networks Mag. Vol.5. No. 3. (2001) 101–109
6. Znati, T., Alrabiah, T., Melhem, R.: Point-to-multi-point path establishment schemes to support multicasting in WDM networks, Proc. the 3rd IFIP Working Conf. Optical Network Design Modeling, Paris in France. (1999) 456–466