On Finding the Multicast Protection Tree Considering SRLG in WDM Optical Networks

Yonggang Li, Yaohui Jin, Lemin Li, and Longjiang Li

ABSTRACT—In this letter, a new sharing mechanism, SRLG sharing, is proposed, which allows the links of the same shared risk link group (SRLG) in a primary light tree to share protections in WDM optical networks. In previous studies, how to share spare resources with SRLG constraints has not been studied in multicast optical networks. In this letter, considering SRLG sharing, we propose a novel algorithm –multicast with SRLG sharing (MSS)– to establish a protection light tree. Finally, the algorithm MSS and the algorithm multicast with no SRLG sharing (MNSS) are compared through a simulation to show that our new sharing scheme of SRLG sharing is more efficient than that of no SRLG sharing in terms of spare resource utilization and blocking probability.

Keywords—WDM optical networks, multicast protection, SRLG sharing.

I. Introduction

In the research concerning WDM networks, the term "shared risk link group" (SRLG) denotes the relationship between links with a shared vulnerability [1]. When there is a failure in a conduit or right-of-way, all the fiber links passing through the conduit may fail at the same time. The SRLG-disjoint [2] path pair has been proposed to meet the SRLG constraints. In multicast research, a "light tree" is established from one source node to multiple destination nodes in WDM networks. To protect the primary light tree, a protection tree must be provided to meet the requirements of survivability. Sharing protections has been confirmed to save the spare resources. The notions of "self-sharing" and "cross-sharing" [3] have been proposed as means to establish the protection tree. Self-sharing means that a protection path can share not only with other protection paths but also with other edges on the primary tree. Cross-sharing discovers sharing potential among protection paths, and thus the protections of the different primary trees can share the same idle protection edges. So far, in the study of the protection of multicast sessions [3], [4], researchers have not dealt with SRLG constraints. For the purpose of saving network resources, the study in [3] considers self-sharing and cross-sharing; however, how to share resources between SRLG groups is not studied. Furthermore, dynamic link-states are not considered in [3]. In a primary multicast tree, multi-link failures of a single SRLG breakdown may interrupt multiple lightpaths. Finding a way to protect multiple lightpaths synchronously and how to share resources is our main object in this letter. We propose a novel algorithm, multicast with SRLG-sharing (MSS), to establish the protection light tree. In order to integrate self-sharing and cross-sharing, SRLG sharing sets the different link-cost to the different resources, which may be self-shared or cross-shared. For comparison, we also carry out the algorithm multicast with no SRLG-sharing (MNSS) to get the protection tree by using self-sharing and cross-sharing under SRLG constraints. Through the analysis of simulation results, we find that our algorithm MSS outperforms MNSS.

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II. SRLG Sharing

A multicast tree is shown in Fig. 1. The four lightpaths have the same source S. Thereafter, the data flows on these lightpaths are all the same. Though the primary lightpaths are related to the same SRLG, their protections can be shared.

For example, two links of the lightpaths S→1 and S→2 are

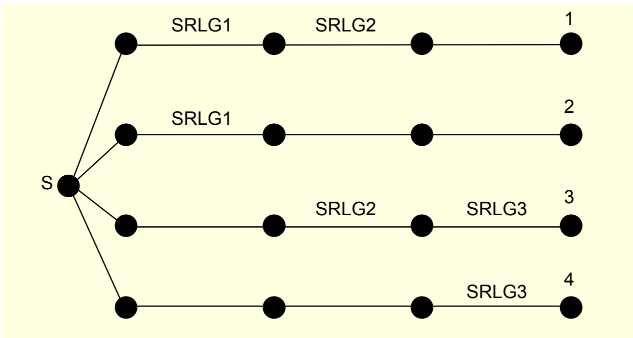

Fig. 1. A multicast tree with SRLG.

both associated with SRLG1. Their protections can share the links of S→4 and other idle resources. Accordingly, the lightpaths S→3 and S→4 are related to SRLG3. Their protections can share the links of S→2 and the idle resources. Otherwise, the lightpaths which are related to the same SRLG but have different sources can not share any resources.

III. Proposed Heuristic Approach

In this section we present the notation used throughout the letter, the link-cost model used to compute the protection tree, and the procedure of our algorithm.

1. Definition and Notation

A given network is denoted by $G(N, L, W, S)$. Multicast sessions arrive at the network dynamically, and only one session arrives at a time. We assume that each required bandwidth is a wavelength and that the network has no wavelength conversion. The notations are summarized as below:

$G(N,L,W,S)$**:** graph representing an optical network
N: set of nodes
L: set of fiber links
W: set of available wavelengths
S: set of SRLG identifiers
$C(e)$: initial cost for link e
$C'(e)$: dynamic cost for link e
$M\{s, D\}$: multicast session, where s is source node, D is set of destinations
T_p: set of links used by the primary light tree
T_b: set of links used by the protection light tree
l_j : set of links used by the primary lightpath from s to j
b_j : set of links used by the protection lightpath from s to j
l_b: set of protection links in G
S_j : set of links are the same SRLG as links in l_j
α, β: parameters regulating the link-cost.

2. Link-Cost for Computing Protection Trees

We adjust the link-cost according to (1) before computing the protection tree for an incoming multicast session.

$$C'(e) = \begin{cases} +\infty & \text{if } e \in (l_j \cup S_j) \\ \alpha C(e) & \text{if } (e \in l_b) \wedge (e \notin T_p) \\ \beta C(e) & \text{if } (e \in T_p) \wedge (e \notin l_j) \\ C(e) & \text{otherwise.} \end{cases} \quad (1)$$

In order to encourage sharing of the network resources, we set two rewarding parameters α and β. Normally, the rewarding parameters α and β are set between 0 and 1 [5], which makes the regulated link-cost less than the initial link-cost, so the regulated link can be easily shared. As shown in (1), α and β regulate the link-cost of all existing protections and T_p. While computing the protection path for l_j, the working path l_j and all links in S_j have to be locked, so their cost is set to infinite. In order to share all exiting protections, cross-sharing is encouraged, so these link-costs are regulated by α to maximize sharing protections between the different primary trees, as shown in the second line of (1). In the third line of (1), the links belonging to the primary tree can be self-shared with the protections of the lightpaths in the primary tree. These link-costs are regulated by β. Through (1), regulating α and β can make the network operate in a better state. We can select the appropriate α and β through the simulation in section IV.

3. Procedure of MSS

Input: $G=(N, L, W, S)$; a multicast session $M\{s, D\}$.
Output: T_p and T_b, or NULL if no satisfying light trees.
Step 1. Initialize the link-costs in G. Establish the primary tree T_p by using a shortest path tree (SPT) algorithm.
Step 2. Adjust the link-costs according to (1) and compute a minimal cost protection path b_j for destination j in D. If b_j is found, add it to T_b. If it has not been found, block the session and return NULL.
Step 3. If there remains any destination in D that has not been processed, switch j to the next destination in D and go to step 2. If all destinations in D have been processed, update the network state and output T_b.

The time complexity of MSS mainly depends on the running times of the SPT algorithm, whose time complexity is $O(|D||N|^2)$. In the worst case, the complexity of step 2 is $O(|D|(|N|^2+\log|N|)$. The overall complexity of the algorithm is $O(|D||N|^2)$.

IV. Simulation and Analysis

We simulated a dynamic network environment with the assumptions that the multicast sessions would arrive according

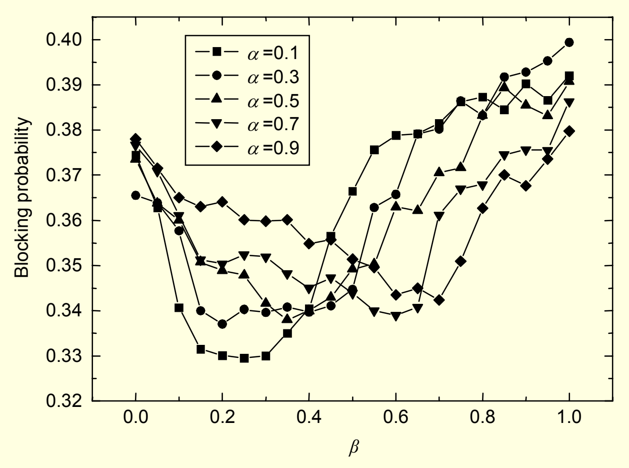

Fig. 2. Blocking performance effected by α and β.

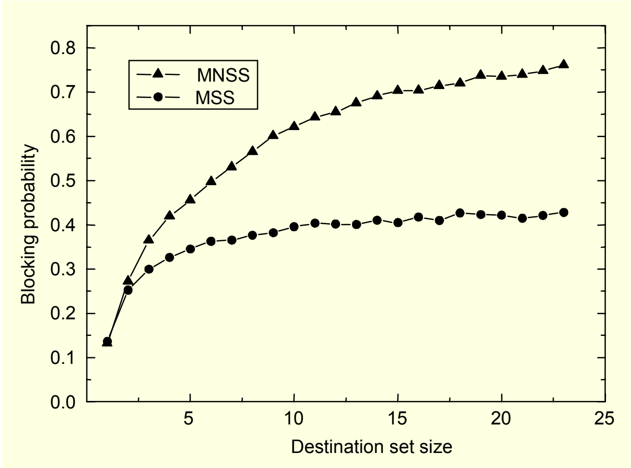

Fig. 3. Blocking performance for MNSS and MSS.

to an independent Poisson process. The network load was 5 Erlang [6], and W was set to 8. The test network is shown in [7]. The initial cost of a link joining two nodes is the distance between them. The source nodes and set D of destination nodes were randomly picked up from the nodes in the network. The SRLG information of nine groups marked from R1 to R9 was given in the network. A multicast session was accepted when its primary and protection trees were both found. Otherwise, the session was blocked. The blocking probability is defined as the number of the blocked sessions divided by that of the total sessions. According to [8], a main metric considered in the letter is the network redundancy ratio (NRR), which is defined as the ratio of the total spare capacity over the total working capacity [8].

First, we studied how to choose appropriate α and β. For a, some typical values were chosen: 0.1, 0.3, 0.5, 0.7, and 0.9. Variation of β was between 0 and 1, as shown in Fig. 2. When β was less than 0.4, setting α to 0.1 improved performance. If α was too great when β was less than 0.4, the links not in T_p could not be more easily shared than that in T_p, which made cross-sharing inefficient. Similarly, when β was greater than 0.4, setting α too low made self-sharing inefficient. Setting α to 0.1 shows the worst case when β is greater than 0.4. In Fig. 2, the performance approaches the lower bound when β is between 0.15 and 0.35, because when β approaches α, links in T_p have almost the same probability to be shared as links not in T_p. In SRLG sharing, through adjusting α and β, we can get a better and fairer network state, in which self-sharing and cross-sharing are used more fairly. Therefore, (1) has a positive effect on performance. On the basis of analysis, we set α to 0.1 and β to 0.3 approximately.

We compared the blocking probability of our scheme MSS with MNSS under dynamic traffic. Then, we investigated the network redundancy ratio.

Figure 3 shows that the blocking probability of MSS is less than that of MNSS as the destination set size increases. In our algorithm MSS, we permit the primary lightpaths related to the same SRLG to share the protections in a primary light tree. While the destination set size increases, the route of the primary light tree is not easily found. SRLG sharing is permitted in our algorithm; however, the primary light tree can find the protections easily. As a result, the blocking performance of MSS is not sensitive to the parameters of destination set size. The blocking curve of MSS is flat when the destination set size is greater than 2. On the contrary, MNSS algorithms do not apply SRLG sharing so the sharing potential of links cannot be discovered sufficiently. Consequently, the blocking probability of MNSS increases rapidly.

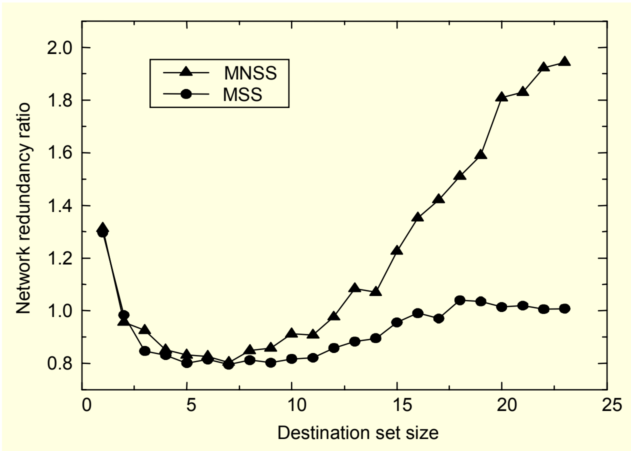

Fig. 4. Comparison of the network redundancy ratio.

We investigated the NRR in Fig. 4. The bigger $|D|$, the greater the difference in NRR between MSS and MNSS. This is because the protection in MSS has more chances to share with the primary tree when $|D|$ is large. SRLG sharing can make MSS use less spare resources than MNSS, so MSS is more efficient than MNSS.

V. Conclusion

In a dynamic environment, we studied sharing protection of multicast under SRLG constraints, and proposed the algorithm MSS. For comparison, we also applied the previous schemes to the algorithm MNSS. Simulation results show that MSS yields better solutions than MNSS.

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