

Pre-Planned Multicast Protection Approaches in WDM Mesh Networks

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Abstract This work proposes new protection schemes that optimize the routing heuristics to provision survivable unicast and multicast connection requests in WDM-mesh networks.

Introduction

The problem of protecting purely multicast connections in WDM mesh network has recently started to receive attention in the literature [1-3]. In fact, the future WDM traffic is heterogeneous in nature and only part of the traffic is multicast and the rest is unicast. Therefore we expect the presence of both unicast and multicast traffic in future optical networks. This paper studies the problem of dynamic provisioning of survivable heterogeneous unicast and multicast traffic in WDM networks. Specifically, we propose new protection schemes to provision and protect unicast and multicast connection requests against single-link failures in WDM-mesh networks.

Protection Approaches

A. Optimized Shortest Path Tree Heuristic

One approach to protect multicast traffic is to calculate primary (working) and link-disjoint backup (protection) multicast trees. Two trees are said to be link-disjoint if they do not share any link along their edges. This will provide 1+1 dedicated protection where the traffic is transmitted simultaneously on both working and protection trees, and in the case of failure, the affected multicast destinations are required to reconfigure their switches to receive the backup signal, i.e., non-signaled switchover [4]. In general, finding link-disjoint trees depends on the heuristics used to calculate the multicast trees. The less optimum the heuristic, the more difficult is to find link-disjoint primary and backup trees.

We propose a new protection scheme to calculate link-disjoint primary and backup trees. Specifically, we propose the Optimized Shortest Path Tree (OSPT) routing heuristic that is described in Table 1 to increase the sharing in the multicast tree. Using this routing approach we define a new tree protection scheme (i.e., TP-OSPT). In fact, if the Shortest Paths Tree (SPT) heuristic is used for routing [5], it would be impossible to find a backup tree (Figure.1 (a)). Using the OSPT heuristic allows us to calculate both primary and backup trees (Figure.1 (b)).

B. Arc-Disjoint Path Protection

The notion of "arc-disjointness" or "directed-link disjointness" was introduced in the literature to improve network performance by reducing the usage of the network resources while providing dedicated protection against link failure. Therefore, arc-disjoint paths were defined to be paths that may share a link in the opposite direction. We propose an Optimized Collapsed Rings heuristic (OCR) that is described in Table 2 to protect unicast and multicast connections requests against single-link failures. Using this approach we calculate primary and backup arc-disjoint multicast paths starting from the source node

and visiting all the multicast destinations in an optimized order. The first destination visited after the source is the closest destination to the source. After that, the path is expanded to include the second closest destination and so on. In Figure.1 (c), OCR heuristic is used to calculate the primary and backup arc-disjoint paths for the multicast session.

Table 1: OSPT Heuristic

1. For every multicast destination node of the multicast session with source "s", repeat (2, 3)
2. Find the minimum-cost path from "s" to the multicast destination (using Dijkstra algorithm).
3. Update cost = 0 for all the links included in the already-found path
4. Merge all the minimum-cost paths together and construct a multicast tree

Table 2: OCR Heuristic

1. Given a source "s" and multicast destinations $\{d_1, d_2, \dots, d_n\}$, we form a ring set of vertices $\{v_1, v_2, \dots, v_n\}$, where v_1 is the source "s" and v_2, \dots, v_n are the multicast destinations.
2. For primary path, find the closed destination to the source using the shortest path algorithm (e.g. d_i). Remove all the links along the path. The new source is set to be " d_i ".
3. Repeat (2) until no more vertices are included in the ring set. This will form the primary path.
4. For backup path, find the shortest path from "s" to the last destination node in the primary path and traverse the primary path backwards until the first destination is reached.

C. Link-Disjoint Path Pair Protection (PP)

Another approach to provide pre-planned protection is to compute link-disjoint path pairs from a source node to all the destination nodes of a multicast session. Therefore, the link-disjoint path pair protection approach (PP) assures that each multicast destination can be reached from the source node by a link-disjoint path pair (i.e., primary and backup paths). The set of all the primary paths from the source to the multicast destinations are combined together to form the primary multicast tree, while the set of all the backup paths form the backup multicast tree. Note that, a primary multicast tree can share links with the backup multicast tree as long as each destination can be reached by two link-disjoint paths. In Figure.1 (d), primary and backup trees share common links; however, each destination can be reached through link-disjoint paths. The disadvantage of this approach is that it uses more links to set-up primary and backup trees comparing to the other protection approaches.

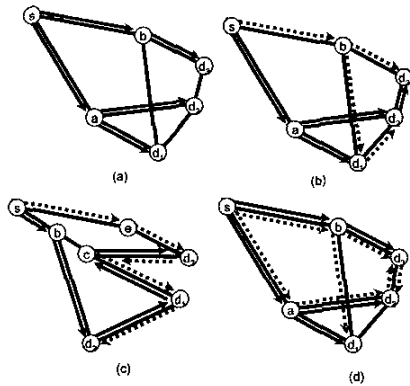


Figure.3: Calculating primary (solid) and backup (dotted) trees/routes from source "s" to destinations $\{d_1, d_2, d_3\}$.

Performance Evaluation

The performances of the proposed protection schemes were evaluated through the simulation of the 14 nodes, 21 links NSF network. The following assumptions are used throughout the simulation:

- All nodes are equipped with multicast-capable switches with no wavelength conversion capability.
- Signal power loss due to light splitting is neglected because optical amplifiers are used.
- Adjacent nodes are interconnected by one (bi-directional) fiber that carries 64 wavelengths.
- Multicast traffic is assumed to constitute half of the total traffic and the other half is unicast traffic.
- For each multicast session with source s , we define the multicast group size G_p to be the maximum percentage of the network nodes that could be destinations. Therefore, for a given multicast session, the number of destinations will be uniformly distributed in the interval $[2, d]$, where:

$$d = \left\lceil \frac{G_p \times (n-1)}{100} \right\rceil, \text{ and } n \text{ is the network size.}$$

- A dynamic traffic model is used. Call requests arrive at each node according to a Poisson process and an arrival session is equally likely to be destined to any node(s) in the network.

Figure.2 shows the blocking performance of the different protections schemes. It is shown from the figure that when the multicast group size is small (less than 30%), the OCR scheme performs the best, and this is due to the fact that for small multicast group size, setting-up arc-disjoint routes requires less links for OCR. This is shown if Figure. 3 (a), where the average number of links used in the primary and backup routes/trees is calculated for the different protection schemes for small multicast group size (25%, i.e., maximum of 3 destinations for each multicast session). We can see clearly from the figure that, the primary and backup routes calculated using OCR requires less links than TP-OSPT and PP (i.e., 8.21 for OCR comparing to 8.37 for TP-OSPT and 9.16 for PP). However, as it shown in Figure.3 (b), when the multicast group size is large (50%, i.e. maximum of 7 destinations for each multicast session); the TP-OSPT scheme requires fewer links to set-up primary and backup trees (i.e., 10.27). We

should also note that, as it was expected, the PP scheme uses more links than OCR and TP-OSPT schemes to set-up primary and backup trees, this leads to the worse performance.

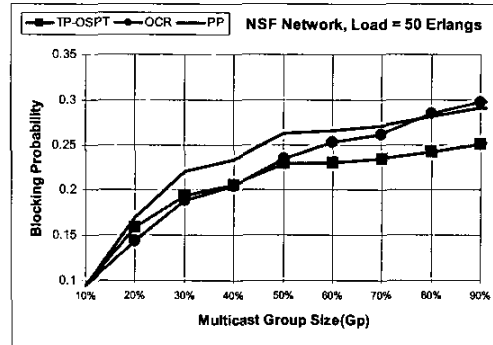


Figure.2: Performance of the different protection schemes

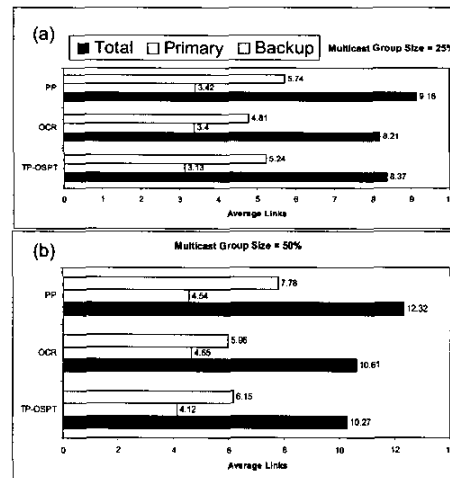


Figure.3: Average links used for primary and backup trees

References

- 1 N. K. Singhal, L. H. Sahasrabudde, and B. Mukherjee, "Provisioning of Survivable Multicast Sessions against Single Link-Failures in Optical WDM Mesh Networks," *Journal of Lightwave Technology*, vol.21, no.11, pp. 2587-2594.
- 2 N. K. Singhal, and B. Mukherjee, "Protecting multicast sessions in WDM optical mesh networks," *Journal of Lightwave Technology*, vol.21, pp.884-892.
- 3 T. Rahman and G. Ellinas, "Protection of Multicast Sessions in WDM Mesh Optical Networks," *OFC, Anaheim, CA, March 6-11*.
- 4 W. D. Grover, *Mesh-Based Survivable Networks* (Prentice Hall PTR, 2004).
- 5 Yong Sun, Jun Gu, and Danny H. K. Tsang, "Multicast routing in all-optical wavelength-routed networks", *SPIE Optical Networks Magazine*, July - August 2001, pp. 101-109.