Protection of a Multicast Connection Request in an Elastic Optical Network Using Shared Protection

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Abstract
Elastic Optical Networks (EONs) allow to solve the high demand for bandwidth due to the increase in the number of internet users and the explosion of multicast applications. To support multicast applications, network operator computes a tree-shaped path, which is a set of optical channels. Generally, the demand for bandwidth on an optical channel is enormous so that, if there is a single fiber failure, it could cause a serious interruption in data transmission and a huge loss of data. To avoid serious interruption in data transmission, the tree-shaped path of a multicast connection may be protected. Several works have been proposed methods to do this. But these works may cause the duplication of some resources after recovery due to a link failure. Therefore, this duplication can lead to inefficient use of network resources. Our work consists to propose a method of protection that eliminates the link that causes duplication so that, the final backup path structure after link failure is a tree. Evaluations and analyses have shown that our method uses less backup resources than methods for protection of a multicast connection.

Keywords:
Elastic optical network, multicast protection, multicast tree, segment protection.

1. Introduction

The emergence of multicast applications such as video conferencing, Internet Protocol Television (IPTV) and e-learning increases the demand for bandwidth [1]. The current optical network based on Wavelength Division Multiplexing (WDM), with a fixed grid, can no longer effectively follow these emerging and dynamic applications, due to the limited number of optical channels [2]. This limit has motivated the research community to turn to so-called Elastic Optical Networks (EONs). These optical networks form the core of modern communication systems and are evolving to offer data transmission rates of up to 1 Terabit per second [3]. Most of the multicast applications are real time and transmit data from one source to multiple destinations. In an elastic optical network, an optical tree has a continuous spectrum on the paths leading to each destination. It is this optical tree that is implemented for each multicast connection. Generally, the demand for bandwidth on an optical channel is enormous so that, if there is a single (fiber) link failure, it could cause a serious interruption in data transmission. All traffic requests over the failed link will be affected and will result in significant data loss. If the failure occurs in a link that is part of an optical tree, then more data may be lost because, the optical tree is used to transport data to several destinations. It is therefore imperative to propose a mechanism to protect the fiber links against failures. The primary tree of a connection is the path used by the data before a link failure occurred.
A protection mechanism must associate a backup path with each primary tree, and the backup path must transmit the data in case there is a link failure in order to avoid interruptions. Different schemes of protection have been developed in the literature. These methods are path based[4], segment-based[5], tree-based[6], p-cycle based[7], etc. In segment-based protection schemes the primary tree is divided into segments, and then each segment is protected separately. A segment in a primary tree can be defined as the path between two segment nodes of the tree and a segment node is either a destination node, or the source node. or an intermediate node (of the optical tree) that has the splitting capability[8] . Once the segment nodes and the source node are identified, each segment of the primary tree is protected by discovering a backup segment that is link-disjoint from its corresponding primary segment. Segment-based protection schemes are reported to have better performance than other known schemes in terms of resource efficiency and blocking probability [8]. The backup path is the set of segments taken by the data after link failure. Furthermore, if the final backup structure is not a tree one, this result in duplication of data at certain nodes in the network. Although there are several multicast protections schemes. The problem of final backup structure exists in both shared and dedicated protection methods. In this paper, we study the problem of final backup structure in the case of shared protection methods because share-based protection is more efficient in terms of spectral resources than dedicated protection [9] .

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The goal of our work is to optimize the use of the resources of an Elastic Optical Network after recovery from a link failure. For the single link-failure case, an efficient segment-based protection method has been proposed for static multicast traffic to eliminate the link causing resource waste so that the final structure of backup respects the tree structure after a failure.

In what follows, we review the existing works in section 2, on shared-based protection methods, then we propose in section 3 the formalization of the problem. Section 4 presents our approach for solving the formulation problem. Section 5 concerns the evaluation and analysis of the results. The last section is devoted to the conclusion.

2. Related works

In literature, two main groups of protection methods exist: shared path protection methods and dedicate protection methods.

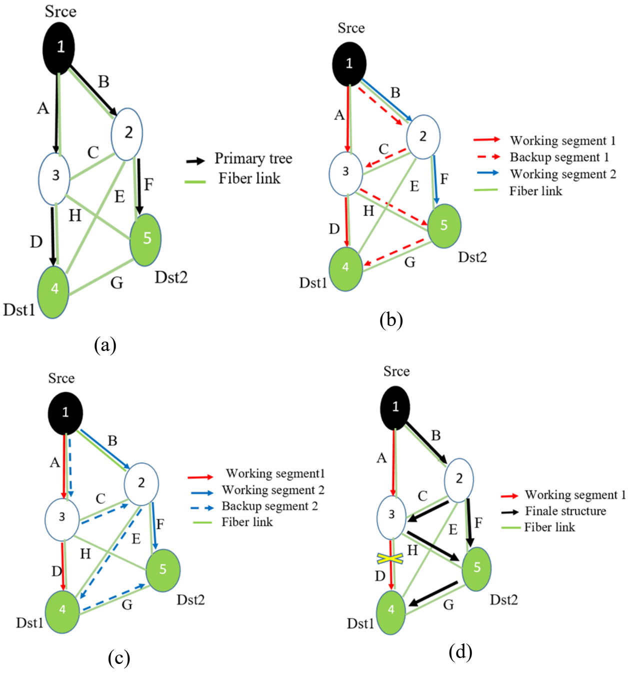
As mentioned in the previous paragraph of section 1, our article focuses on shared protections. Therefore, in the following, a discussion of shared methods is made.

Der-Rong et al. [10] have proposed an approach named Segment Based Protection (SBP) to protect multicast connection requests by shared segment. They consider a single link failure and propose two heuristic approaches to solve the multicast protection problem. The first relates to static multicast requests, the second for dynamic multicast requests. These algorithms make it possible to determine the primary paths then, after an update of the cost of the link, determine the backup segments which are link-disjoint to the primary paths. Cail et al. [11], proposed a shared path protection method an Elastic Optical Networks (EON). This proposal is based on the adaptive distance for multicast connection requests. The authors formulated a Mixed Integer Linear Programming (MILP) that, protects multicast connection requests against a link failure. The performance evaluation of the heuristic algorithm proposed gives a result close to the optimal result obtained from the result of the MILP formulation. Walkowiak et al.[12], proposed a shared backup path protection approach and an integer linear programming model for Routing and Spectrum Allocation (RSA) with shared-based protection in EON[13]. This approach only considers the failure of a single link and the objective is to optimize spectrum resources in the network. Two heuristic approaches are taken to solve this problem. Shao et al. [14], have proposed two escape route approaches, one said to be aggressive and another to be conservative. The concept of conservative backup sharing is the same as in that of WDM optical networks, where the backup is shared if the light paths of the traffic demands are disjoint and they have the same bandwidth, whereas in the aggressive policy of sharing backup, the bandwidth of the light-paths can be different and the backup is shared as long as two are disjointed[15].

The protection methods aforementioned in this section do not take into account the structure of the backup path after a link failure. Indeed, when this structure is not a tree: a non-conservation of tree structure occurs. This involves a waste of spectral resources. Let illustrate this situation by figures.

Let the physical topology of the Optical Elastic Optical Network with a multicast connection request, where node 1 is the source node, node 4 and node 5 are the destination nodes of this multicast connection request. The network operator calculates for this connection request the primary tree (shown in

Fig. 1 (a) Primary tree, (b) backup segment 1 of working segment 1, (c) backup segment 2 of working segment 2, (d) final structure after link D failure) After that, found the primary tree is divided into two working segments. It is clear here that each working segment consists of two links where, the first segment is in red and the second segment in blue. The network operator for the sake of fault resilience must also match a set of backup segments to the multicast connection request. For each working segment, the backup segment is found.



(a) (b) (c) (d)

Fig. 1 (a) Primary tree, (b) backup segment 1 of working segment 1, (c) backup segment 2 of working segment 2, (d) final structure after link D failure

backup segment 1 of the working segment 1 is B→C→H→G shown in

Fig. 1 (a) Primary tree, (b) backup segment 1 of working segment 1, (c) backup segment 2 of working segment 2, (d) final structure after link D failureand the backup segment 2 of the working segment 2 is A→C→E→G shown in Fig.1:

(a) Primary tree, (b) backup segment 1 of working segment 1, (c) backup segment 2 of working segment 2, (d) final structure after link D failure. If there is, link failure on one of the working segments, its backup segment will be activated. For example, if the link D fails, the backup segment B→C→H→G will be activated. And the final structure after recovery from a breakdown represented in black line shown in

Fig. 1 (a) Primary tree, (b) backup segment 1 of working segment 1, (c) backup segment 2 of working segment 2, (d) final structure after link D failureis not a multicast tree. In fact, node 5 receives the same information from two different sources.

This situation, due to an incorrect choice of backup segment, leads to a waste of the spectral resource. Even if we establish backup paths after failure, it will be difficult to configure the final structure to get a tree. because deleting some links to get the final tree structure after link failure may cause interruption of flow to some destinations. In order to solve the above problem, we propose a segment-based protection for multicast connection requests in the case of shared protection.

3. Specification of the problem

In what follows the system model, the assumptions and the formulation of the problem are given.

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3.1 System model and assumptions

The Elastic Optical Network (EON) is represented by a graph $G = (V; E)$, where $V = \{v_{1,}v_{2,} \dots v_n\}$ is the set of nodes of the network and $E = \{e_{1,}e_{2,} \dots e_m\}$ is the set of optical fiber links. Let the multicast connection request $\mathrm{Mcr} = (\mathrm{s}; \mathrm{D}; \mathrm{B})$: where s is the source node, $\mathrm{D} = \{\mathrm{d}_1, \mathrm{d}_2 \dots \mathrm{d}_{|\mathrm{D}|}\}$ is the set of destinations and B represents the bandwidth required in Gbps. Pt: the primary tree for multicast connection request. the primary tree is divided into a set of working segments $\mathrm{Ws} = \{\mathrm{ws}^1, \mathrm{ws}^2, \dots, \mathrm{ws}^z\}$. ws_{mn}^i is a link for working segment ws^i where m is the source node and n destination. $\mathrm{Bs} = \{\mathrm{bs}^1, \mathrm{bs}^2, \dots, \mathrm{bs}^z\}$ is a set of backup segments where, $\mathrm{bs}^\mathrm{i}$is the backup segment for ws^i which are link disjoint.

The following assumptions are made:

- The network links are bidirectional and consist of two unidirectional fibers.
- All nodes on the network have multicast capability, but no frequency conversion capability.
- Each connection established on the network must correspond to a primary and backup path so as to have links disjoint.
- Any primary tree failure concerns a single link on this tree.

3.2 Problem formulation

Our problem can be formulated as follows.

- **Given**: The EON represented by a graph $\mathrm{G} = (\mathrm{V}; \mathrm{E})$ with a multicast connection request Mcr.
- **Goal**: is to find the primary tree Pt and a set of backup segment BS to admit Mcr.
- **Constraints**:
  - ✓ The primary tree and the backup segments must have links disjoint.
  - ✓ there is no waste of resources and backup segment must conserve a tree structure
  - ✓ Two working disjoint segments can share the same backup segment.

4. Proposal

In order to solve the formulated problem (see section 3.2), we proposed a segment-based algorithm called Multicast Protection with Conservation of Tree Structure (MPCTS). The algorithm can be divided up into two parts: first part, research and allocation of resources from the primary tree and the second part, search and allocation of resources for the backup segment. The proposed algorithm MPCTS is represented in algorithm 1, the input to the the algorithm is

the graph G and a request of a multicast connection $\mathrm{Mcr} = (\mathrm{S};\ \mathrm{D};\ \mathrm{B})$. The MPCTS first, execute the Dijkstra algorithm on the graph G to find the primary tree. The above created tree is the primary tree, and the required bandwidth is assigned in terms of number of slots required. Next, the primary path is partitioned into a set of working segments. for each working segment, we remove this working segment and look for another path from the source to the destination using Dijkstra. this path is the backup segment. Finally if backup paths are found which will be disjoint to the primary paths then spectrum slots are allocated to backup segments. Spectrum is assigned using First-Fit spectrum assignment technique[16].

Algorithm1: algorithm for Multicast Protection with conservation of Tree Structure (MPCTS).

Input: graph $\mathrm{G} = (\mathrm{V}; \mathrm{E})$, Multicast Connection Request $\mathrm{Mcr} = (\mathrm{S};\ \mathrm{D};\ \mathrm{B})$

Output: primary tree Pt, backup segment BS

```
1: Perform Dijkstra algorithm on graph G to find the primary tree
2: Allocates resources on the links of the primary tree Pt.
3: Partition Pt into a set of working segments $\mathrm{Ws} = \{\mathrm{ws}^1, \mathrm{ws}^2, \dots, \mathrm{ws}^z\}$.
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k= 1 // represents the first working segment
While ( k ≤ z) do
  // $z$, is the maximum number of working segment
  deletion $ws_{mn}^{i}$
  If ($ws_{mn}^{i}$ ∈ WS / m=t) then
  // s and t the source and destination for the current
  // working segment
    Used to reach $ws_{st}^{i}$
    Perform Dijkstra from n to j
    $bs_{mn}^{i} = ws_{mn}^{i} + nt.$
  else ( $ws_{mn}^{i}$cannot found)
      Perform Dijkstra to found $bs^i$ to $ws^i$ from its
      Source s to its destination t
    if ($Bs^{st}$ cannot be found) then
        Break; // try another warning segment
    else Allocates resources for $Bs^{st}$
    and if
    delete all the link of $Bs^{st}$ in the instream
// prevent the escape route from taking the upward direction
//to avoid possible duplication
    Add the $Bs^{st}$ to BS and increment k by 1.
  end if
//add the backup segment to all of the stay segments and
//spend to the next working segment.
end while
if (all $Bs^{st}$ of $Ws^{st}$ have been found) then
  Pt = WS
  return Pt and BS.
// primary tree and backup segments
end if
```

Consider the example for Multicast connection request Mcr = (1; {4,5}; 2) on the network (in shown in Fig. 1 (a) `Primary tree, (b) backup segment 1 of working segment 1, (c) backup segment 2 of working segment 2, (d) final structure after link D failure`). Where node 1 is the source, nodes 4 and 5 are two destinations and 2 is the number of slots. The Multicast Connection Request associated, is represented in black on the graph G. After finding the primary tree, the algorithm divides the tree into several working segments. Here we have two segments where the first segment is in red and the second in blue show Fig. 1 (a) Primary `tree, (b) backup segment 1 of working segment 1, (c) backup segment 2 of working segment 2, (d) final structure after link D failure`. Then, for each working segment, the algorithm deletes this current segment. If this segment shares the same source with another working segment, it uses this working segment to reach its destination, else the algorithm looks for a backup segment that is disjoint from it. Finally, the algorithm removes the upstream links of this working segment. in the fig.1 (a) the two working segments share a same source. When the algorithm is executed, we get the backup segment shown in the Fig. 2 (a) `Backup segment 1, (b) Backup segment 2`and Fig. 2 (a) `Backup segment 1, (b) Backup segment 2.`

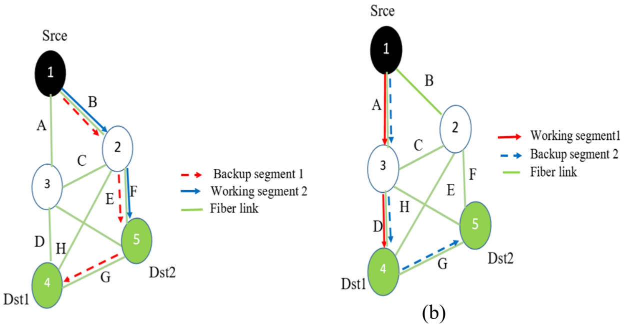

Fig. 2 (a) Backup segment 1, (b) Backup segment 2

The backup segment of working segment 1 is B→F→G and. the backup segment of the working segment 2 is A→D→G. it is clear that the finale backup structure is the tree.

5. Result and Analysis

The simulation model used is the 14 nodes NSFNET network. The number of frequency-slots (B) of each fiber is set to 100. The proposed algorithms were coded by using Java programming language. All simulations were run on a personal computer with Intel i5-2540M / 2.6 GHz CPU, 4.0 GB RAM and with Linux distribution. All the multicast requests were randomly generated. All nodes in the network can be selected as source or destinations. The number of destinations for each multicast connection request varies from 1 to 3 due to the size of the network. The number of required frequency slots of the multicasts are randomly selected between 1 and 4. Only one link failure is allowed. The failure link is randomly selected among the links of the primary tree. To evaluate our approach, we handle a number of connection requests.

To evaluate the performance of algorithm for Multicast Protection with Conservation of Tree Structure (MPCTS), we compared it to traditional Segment Base Protection (SBP) that is to say without verification of the final structure. The performances metrics for simulation are on the one hand, $S_{utiliz} = \sum Nb\_Fs * (Nb\_LPt + Nb\_LBS)$ (where, S_{utiliz} is the spectrum utilization which is the sum of total slots allotted in the network for both primary path and backup segments, Nb_Fs is the number of frequency slots, Nb_LPt is number of link of primary path and Nb_LBS is the number of link of backup segment). And on the other hand $Bs_{utiliz} = \sum Nb\_Fs * Nb\_LBS$ where, Bs_{utiliz} is the total number of slot allocated on of backup segments.

The total utilization of slot in the network is shown in Fig.3. The curve of the MPCTS approach is below the curve of the SBP approach. In other words, for a certain number of connection requests established, the total slots utilization in the network is less in MPCTS approach than in SBP approach.

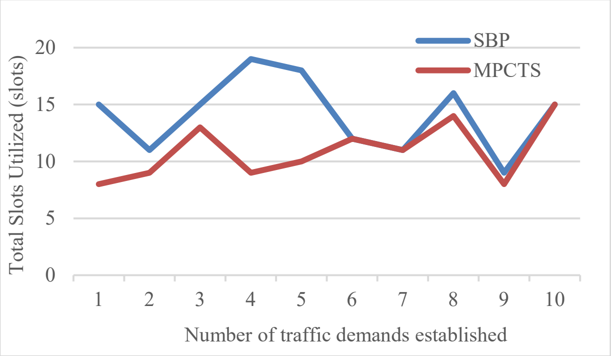

Fig. 3 The relationship between total slots utilized versus the number of traffic demands established in the network.

This is because the final structure after link failure recovery in MPCTS is a multicast tree. Obtaining a multicast tree after link failure recovery allows spectrum gains since we will no longer have duplicate slots at some nodes.

The total number of slots used in our approach between 6 and 7 traffic requests is the same as, the one used in SBP (see Figure 4). This is because both methods have a final tree structure after recovery in case of link failure.

The backup resources allocated for MPCTS and SBP are shown in Fig.4. The curve of the MPCTS approach is below the curve of the SBP approach. In other words, for a certain number of connection requests established, the total slots utilization in the network is less in MPCTS approach than in SBP approach. The MPCTS has fewer backup resources in the network than the SBP approach. This is because to have backup paths we remove in our approach the susceptible links that could prevent the formation of a tree structure after a link failure.

So we have less protection link that is characterized by less slot for backup paths. Since we will no longer have slot duplication at some nodes. The total number of slots used in our approach between 6 and 7 traffic requests is the same as, the one used in SBP (see Figure 4).

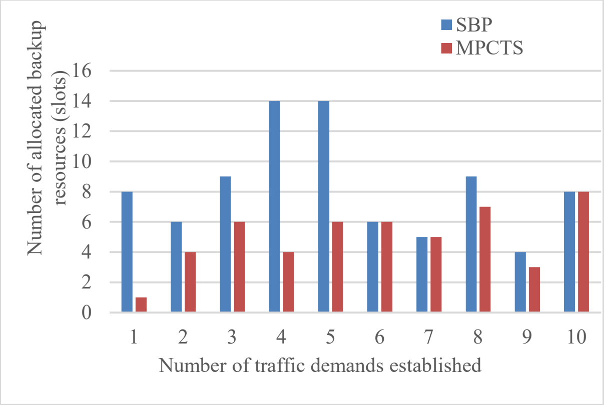

Fig. 4 The relationship between number of backup resources versus the number of traffic demands established in the network.

This is due to the fact that, both methods have a final tree structure after recovery in case of link failure.

6. Conclusion

The elastic optical network is studied by many researchers in the recent past but very few researches have focused on protection issues in elastic optical networks.

In This article, the multicast protection on EON for single Link-failure case has been studied. More specifically, the problem of the final structure of the backup path after link-failure. For a given EON and a multicast request, the goal is to find the primary tree and a set of backup segment. An algorithm for Multicast Protection with Conservation of Tree Structure (MPCTS) is proposed. This algorithm is divided up into two parts: research and allocation of resources from the primary tree and search and allocation of resources for the backup segment. we compared MPCTS with an existing segment-based protection (SBP) approach mentioned in this literature.

The results of this analysis show that the proposed MPCTS approach is better than SBP approach in terms of spectrum utilization and number of backup resources allocated. The results of this analysis show that the proposed MPCTS approach is better than SBP approach in terms of spectrum utilization and number of backup resources allocated.

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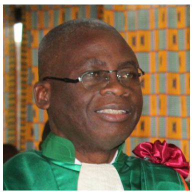

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