Designing of p-Cycle Based Survivable Multicast RSA in Elastic Optical Networks

Susmita Das, Joy Halder and Uma Bhattacharya

Abstract Nowadays, Elastic Optical Network (EON) has attracted a lot of attention due to its efficient spectrum allocation. The popularity of different multicast applications is on the rise and survivability against single link failure has become a crucial issue. Our proposed scheme has considered pre-configured cycles or p-cycles for the protection of multicast sessions. Simulation shows quite good results in terms of blocking probability while ensuring survivability.

Keywords Elastic optical network (EON) · Orthogonal frequency division multiplexing (OFDM) · Dynamic · Multicasting · Distance adaptivity

1 Introduction

In present day, the demand of large data transmission is on the rise which has led to intensive research in the area of optical networks. In order to overcome the drawbacks of the under-utilization of a wavelength in Wavelength Division Multiplexing (WDM), Orthogonal Frequency Division Multiplexing (OFDM) technology was introduced in optical networks. This OFDM-based Elastic Optical Networks (EONs) have brought high scalability and efficiency to the utilization of spectrum [1]. Protection of EONs is very significant, as any failure in the network may cause severe disruption in data transmission. An efficient Routing and Spectrum Allocation (RSA) has been designed for optimization of network resources [2]. For dynamic environment, the requests are handled as they arrive. Distance adaptive spectrum resource alloca-

---

S. Das (✉) · J. Halder · U. Bhattacharya
Department of Computer Science and Technology, Indian Institute of Engineering Science and Technology, Shibpur, India
e-mail: susmitad900@gmail.com

J. Halder
e-mail: mailmejoy1991@gmail.com

U. Bhattacharya
e-mail: ub@cs.iiests.ac.in

G. R. Kadambi et al. (eds.), *Emerging Trends in Photonics, Signal Processing and Communication Engineering*, Lecture Notes in Electrical Engineering 649,
https://doi.org/10.1007/978-981-15-3477-5_14

Table 1 Modulation formats ith FS capacity and transparent reach

Modulation format	FS capacity (Gb/s)	Transparent reach (km)
BPSK	25	4000
QPSK	50	2000
8-QAM	75	1000

tion is an efficient attribute of EON that can lower the spectrum utilization, based on the distance between the source-destination node pair [3] (Table 1). Recently, the applications of multicasting such as medical imaging and teleconferencing are being widely used and have eventually garnered some attention [4, 5]. For multicast session protection in EONs, different protection schemes such as Dedicated Path Protection (DPP) scheme and Shared Backup Path Protection (SBPP) scheme have been proposed [6, 7]. Pre-configured cycles (p-cycles) scheme is an approach which can be implemented to protect failure of links in EONs [8, 9]. The p-cycles provide a short recovery time along with spectrum efficiency compared to other protection schemes. Path-length-limited p-cycle design has been considered for this approach [10]. For the placement of subcarriers, the first fit and the exact fit policies have been considered [11]. In this paper, we have proposed **Online p-cycle based First fit Multicast Routing and Spectrum Allocation (O-PFM-RSA)** heuristic and **Online p-cycle based Exact fit Multicast Routing and Spectrum Allocation (O-PEM-RSA)**.

The problem definition has been illustrated in Sect. 2 with proposed work and complexity analysis. In Sect. 3, the simulation results have been explained. The conclusion has been drawn in Sect. 4 along with references.

2 Problem Definition

A directed graph $G = (V, E)$ is considered as the EON network in this paper, where V is the set of nodes present in the network and E is the directed fiber links set. We denote a multicast request as $r(s, D, B)$, where s is the source node, D is the destination nodes set for the multicast request and B is the total traffic demand to be transmitted. Our main objective is minimization of the blocking probability and protection of the network against single link failure using p-cycle in dynamic environment.

A. Proposed Work

In this paper, we have proposed two similar schemes; O-PFM-RSA which is based on the first fit policy and O-PEM-RSA which is based on the exact fit policy. In first fit policy, a request is placed on the first available free block of subcarriers, which can accommodate it. While in case of exact fit, find a free block which is exactly the size of the required number of subcarriers. In case of not finding such a block, use

the first free block available which can satisfy the request.
The scheme is described in the following steps:

1. All the cycles in the graph are enumerated.
2. For each set of node pairs, we calculate the first k shortest paths from the source node to the destination node.
3. All the blocks which are available are calculated for each fiber link.
4. A primary light tree is formed for a multicast request $r(s, D, B)$ by combining the available shortest path for each sub-request of the multicast request.
5. Check whether the new primary light tree is link disjoint with all the links which are already in use.

5a. If the primary light tree is link disjoint with all the links which are being used, then check whether an already existing cycle in the network can be extended to protect this new multicast request.

5b. If the primary light tree is not link disjoint with the links already occupied, then obtain a completely new cycle which can protect this new multicast request.

6. Obtain the modulation format for the multicast request depending upon the distances of the paths chosen. Calculate the number of subcarriers required to fulfill the traffic demand of the multicast request.
7. Search the available free blocks on the chosen paths for the primary light tree and the p-cycle protecting the request.

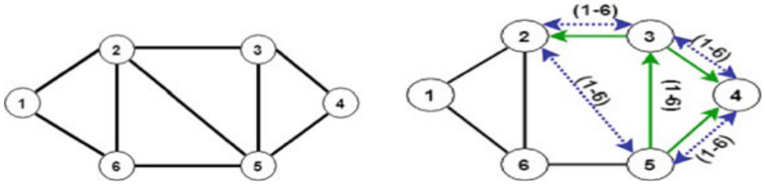
7a. In case of O-PFM-RSA, place the required subcarriers on the first free block encountered.

7b. In case of O-PEM-RSA, obtain the block whose size is same as the required subcarriers. If such a block is found, place the subcarriers. If no such free block is present, place subcarriers in the large enough block encountered first.

8. If the subcarriers cannot be accommodated in the links, then the request is blocked.

The maximum number of subcarriers present in each fiber link in the network has been considered as 258. There has been no use of spectrum converters for this approach. Hence, the non-overlapping constraint, spectrum continuity and spectrum contiguity constraints have been maintained.

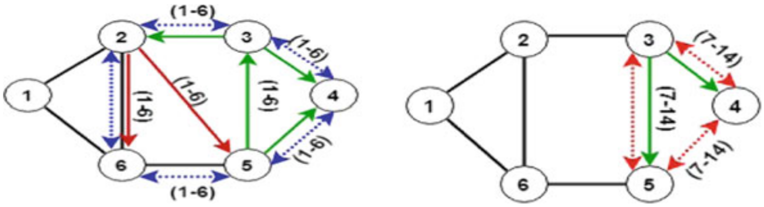
Let us consider the network shown in Fig. 1a and there are already some multicast requests present with subcarriers $(1-6)$ and a p-cycle is already protect-



(a) The network considered

(b) Requests already placed in the network from earlier

Fig. 1 Initial network condition



(a) One new request placed in the network

(b) Another new request placed in the network

Fig. 2 Placement of requests in the network as they arrive

ing them as illustrated in Fig. 1b. One new multicast request (2, {6, 5} , 124) needs to be placed on the network. The primary light tree for this multicast request has been chosen as 2 → 6 and 2 → 5. It is observed that the already existing p-cycle $2 \leftrightarrow 3 \leftrightarrow 4 \leftrightarrow 5 \leftrightarrow 2$ can be extended to protect the new multicast request. The new p-cycle after including the new multicast request is $2 \leftrightarrow 3 \leftrightarrow 4 \leftrightarrow 5 \leftrightarrow 6 \leftrightarrow 2$ as shown in Fig. 2a. The highest number of subcarriers required is calculated taking the appropriate modulation format and placed in each link of the new p-cycle. Let us consider a new request (3, {4, 5} , 129). The primary light tree for this multicast request has been chosen as 3 → 4 and 3 → 5. The new primary light tree is not link disjoint with the previous primary light trees and also the p-cycle which can protect them cannot be extended. Hence, a new p-cycle $3 \leftrightarrow 4 \leftrightarrow 5 \leftrightarrow 3$ is used to protect the new multicast request as shown in Fig. 2b. Now, for provisioning the previous multicast request, assume that $(1 - 6)$ subcarriers has already been reserved. So, for this multicast request, the next index will be considered.

B. Complexity Analysis

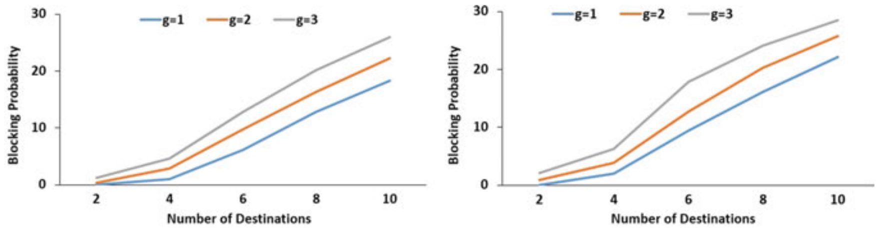
For cycle enumeration in the graph, time complexity is $O(V + E)$. The k shortest paths for each multicast sub-request has time complexity of $O(kV(E + V log V))$, where E is the amount of edges which are present in the graph, V is the number of nodes in the graph and k is the number of paths to be computed. For finding the free blocks in each link, the time complexity is $O(S|E|)$, where S is the number of subcarrier in each fiber link. The time complexity for formation of a primary light tree and placement of subcarriers is $O(n|E|)$. The run time complexity is $O(kV(E + V log V) + (V + E) + n|E| + S|E|)$ which is polynomial time.

3 Performance Evaluation

In this section, the performance of O-PFM-RSA and O-PEM-RSA has been evaluated with the simulations being performed on COST239 network. We have varied the size of the destination node set for each multicast request as 2, 4, 6, 8 and 10. For each

Table 2 Simulation setup for heuristic algorithm

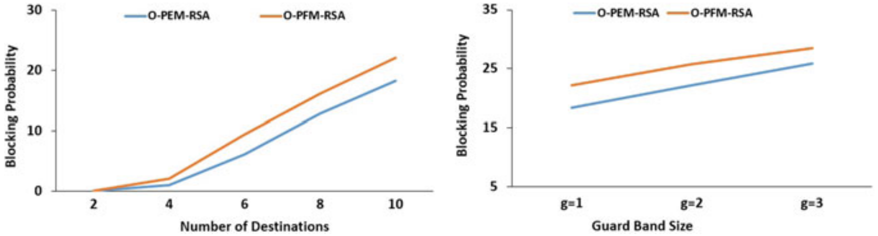
Parameters	Values
Link-disjoint paths computed(k)	5
Guard bands considered	1, 2, 3
Request demand range	100–200 GB
Number of destinations	2, 4, 6, 8, 10
Total requests for each number of destination	50



(a) Performance for varying guard band size in O-PEM-RSA

(b) Performance for varying guard band size in O-PFM-RSA

Fig. 3 Performance on COST239 network for different guard band sizes



(a) Performance comparison for 50 requests

(b) Performance comparison for different guard band size

Fig. 4 Performance comparison of O-PEM-RSA and O-PFM-RSA on COST239 network

size of destination node set, we have considered 10 different iterations of each set of 50 requests. The number of guard bands is also varied as 1, 2 and 3 (Table 2).

The graphical results for O-PEM-RSA when the size of the guardband is varied are illustrated in Fig. 3a and that for O-PFM-RSA is shown in Fig. 3b. It is observed that with the increase in size of guardband, the blocking probability increases. This is because more number of subcarriers are being used as guard in between two multicast requests, due to which some of the requests cannot be accommodated in any free block. The results of the performance comparison of the O-PFM-RSA and O-PEM-RSA for 50 requests and different guard band sizes have been illustrated in Fig. 4c and b, respectively. As per the calculated results, it is observed that the blocking probability for O-PEM-RSA approach is less compared to that of O-PFM-RSA. This is due to the fact that, with the selection of perfect sized free blocks, the number of free blocks which can satisfy a request is more compared to the case in O-PFM-RSA. As p-cycle is used as the protection scheme in both the proposed methods, the recovery time is short in case of any single link failure.

4 Conclusion

We have proposed a novel scheme O-PEM-RSA, where we have addressed the problem of ensuring survivability of EON against single link failure using p-cycles in a dynamic environment. It is an NP-Hard problem and the solution becomes intractable in case of larger sized networks. The heuristic O-PEM-RSA runs in polynomial time. In the design process of O-PEM-RSA, another scheme O-PFM-RSA has been considered. Performance evaluation of the two schemes has been carried out on COST239 network for 50 multicast requests. The comparison shows that O-PEM-RSA gives better results in terms of blocking probability. This scheme being based on p-cycles also gives better recovery time.

References

1. Gerstel O, Jinno M, Lord A, Yoo SB (2012) Elastic optical networking: a new dawn for the optical layer? IEEE Commun Mag 50(2)
2. Christodoulopoulos K, Tomkos I, Varvarigos EA (2010) Routing and spectrum allocation in ofdm-based optical networks with elastic bandwidth allocation. In: Global telecommunications conference (GLOBECOM 2010). IEEE, pp 1–6
3. Jinno M, Kozicki B, Takara H, Watanabe A, Sone Y, Tanaka T, Hirano A (2010) Distance-adaptive spectrum resource allocation in spectrum-sliced elastic optical path network [topics in optical communications]. IEEE Commun Mag 48(8)
4. Wang Q, Chen LK (2012) Performance analysis of multicast traffic over spectrum elastic optical networks. In: Optical Fiber Communication Conference. Optical Society of America, pp OTh3B.7
5. Walkowiak Krzysztof, Goścień Róża, Klinkowski Mirosław, Woźniak Michał (2014) Optimization of multicast traffic in elastic optical networks with distance-adaptive transmission. IEEE Commun Lett 18(12):2117–2120
6. Din DR, Lai IR (2015) Multicast protection problem on elastic optical networks using segment-base protection. In: 2015 International conference on informatics, electronics and vision (ICIEV). IEEE, pp 1–6
7. Cai Anliang, Guo Jun, Lin Rongping, Shen Gangxiang, Zukerman Moshe (2016) Multicast routing and distance-adaptive spectrum allocation in elastic optical networks with shared protection. J Light Technol 34(17):4076–4088

8. Ji F, Chen X, Lu W, Rodrigues JJ, Zhu Z (2014) Dynamic p-cycle protection in spectrum-sliced elastic optical networks. J Light Technol 32(6):1190–1199
9. Kiaei MS, Assi C, Jaumard B (2009) A survey on the p-cycle protection method. IEEE Commun Surv Tutor 11(3)
10. Kodian A, Sack A, Grover WD (2005) The threshold hop-limit effect in p-cycles: Comparing hop-and circumference-limited design. Opt Switch Netw 2(2):72–85
11. Rosa A, Cavdar C, Carvalho S, Costa J, Wosinska L (2012) Spectrum allocation policy modeling for elastic optical networks. In: 2012 9th international conference on high capacity optical networks and enabling technologies (HONET). IEEE, pp 242–246