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Power Efficiency with Optimized Power Routing and Dedicated Path Protection in Elastic Optical Networks

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Abstract

In the current era, the power consumption increases as per increased demand. So it creates the necessity to reduce power consumption wherever feasible. Due to the flexible nature of bandwidth allocation and efficient spectral design, elastic optical networks (EONs) are leading transmitter of traffic data. To ensure the seamless flow of these traffic data, network survivability is the quintessential requirement. In order to achieve the high level of survivability, dedicated path structures due to fast switching time are utilized with additional backup resources. The power consumed by these backup resources is also increased. Shortest path routing (SPR) is the prominent method applied to achieve power efficiency in EONs against single link failure. Power efficient dedicated path protection with optimized power routing (OPR) in single link failure is elaborated in this paper to resolve the power saving issues. An Integer Linear Programming (ILP) model is formed to optimize the required power that needs to concern the optimized power path and power efficient dedicated path allocation. The maximum network components that are in an idle state switch into sleep / off mode optimizes required power. The evaluation results strongly illustrate that applied OPR improves power saving during low traffic than SPR with the dedicated path protection. In addition, overall required power saturates when there are enormous traffic demands.

Keywords: *Dedicated path protection; elastic optical network; optimized power routing; power consumption; shortest path routing.*

1. Introduction

In recent times the power saving with optimal use of network components has experienced a lot of research attention in elastic optical networks (EONs). Nowadays, a large number of services are relying on telecommunication networks. The power requirement is growing because traffic demands are increasing. Since 2007 the power requirement by telecommunication networks observes 10% growth yearly [4]. A survey of 2007 reveals that 5.5% of total power is consumed by internet alone [5]. Survivable green EONs need to consider both survivability and power consumption. Therefore power saving method is proved to a vital part of EONs which can be achieved by optimized power routing (OPR). Protection scheme serves spectrum allocation efficiency. Due to the absence of power conscious optimization spectrum efficiency may increase power consumption. In EONs, power efficiency can be achieved by power efficient solution. International Telecommunication Union grid has specified fixed bandwidth channel for conventional wavelength division multiplexing (WDM) networks. The fixed bandwidth channel is referred to as fixed grid or fixed spectral band. The capacity of a fixed spectral band (e.g., 50 GHz) is underused as traffic demand is lesser, leading to large amount of capacity wastage [22]. The modern telecommunication networks become more flexible, efficient and scalable with advanced optical networking [12]. The fixed spectral band is divided into the narrow spectral band that enhances the elasticity of WDM optical networks category. Here the fixed spectral band of 50 GHz and the narrow spectral band of 12.5 GHz are reviewed [6]. 12.5 GHz spectral band referred to as frequency slots. In EONs, the constraints of the requirement of the same group of frequency slots must be used on all the links crossed by the route of demand pair is referred as spectrum continuity and the requirement that all frequency slots allocated to the route of demand pair must be adjacent is referred as spectrum contiguousness [17]. In OPR, some spans become most used, and some spans remain empty because of already activated spans are preferred for routing of traffic demand. The maximum number of the channels in the WDM network is limited, but some spans require more the number of channels than the limit due to OPR [23]. In WDM networks, there is capacity wastage due to the fixed spectral band. OPR in EONs utilizes the capacity wastage that increases the number of the channel with advances in optical component technology [3]. They (EONs) are beneficial due to their better spectrum utilization, flexibility in bandwidth assignment [8]. Here, EONs are fulfilling the desired aspect of exponentially growing traffic demands. In EONs, the channel with the desired spectral band is formed by combining a group of contiguous slots in the state of using the channel of a preset fixed spectral band. It improves the elasticity of spectral band allocation which reduces capacity wastage resulting in improved overall spectrum frequency usage [2]. In this context survivability is based on dedicated path protection against single link failure which requires additional resources and power also [14]-[16]. The dedicated path is a basic technique used for network protection in which each demand pair has dedicated backup paths disjoint to its primary path in advance. It is preferred in case of single link failure due to fast switching time [22]. For this improved elastic optical networks, both survivability and power efficiency are important aspects. There is a need to resolve both simultaneously. When survivability is on focus, more redundant resources become active leading to more power consumption [12]. When reducing power consumption is the target, the resilience of a network become vulnerable, which emphasis maximum the network component that was not used by the routing of traffic demands to switch off. Therefore, both have inverse nature with one another. In EONs, minimization of power consumption can be obtained by optimizing these network devices applying different techniques. In this paper the power optimization with the OPR and power efficient dedicated path protection is investigated in elastic optical networks. An ILP model is proposed to minimize the power consumption and improve the power efficiency with the OPR and power efficient dedicated path protection. Simulation results shows that the OPR and power efficient dedicated path protection can save power consumption, improve the power efficiency and reduce the required spare capacity compared to shortest path routing. The two elastic optical network components bandwidth variable cross-connects (BV-OXCs) and Erbium-doped fiber amplifiers (EDFAs) are considered for the study of power consumption in this paper.

The remaining part of the paper is adjusted as follows. The dedicated path protected EON with power efficiency is discussed in Section 2. Routing algorithm is discussed in Section 3. Power efficient ILP optimization model in EONs is developed in Section 4. Simulation and results are analyzed in Section 5. Lastly, the conclusions are summarized in Sections 6.

2. Power Efficient 1:1 Dedicated Path Protection

In elastic optical networks, power efficient 1:1 dedicated path protection is explained with the help of Fig. 1. Allotted FS 2-3 of traffic demand traverses primary path (1-5-4). There are two dedicated paths (1-2-3-4) and (1-6-7-4) are rendered in the network with additional resources. The failure of the primary path (1-5-4) affects allotted FS 2-3 of traffic demand. The affected traffic demand of the primary path can be protected by one of the dedicated paths (1-2-3-4) and (1-6-7-4).

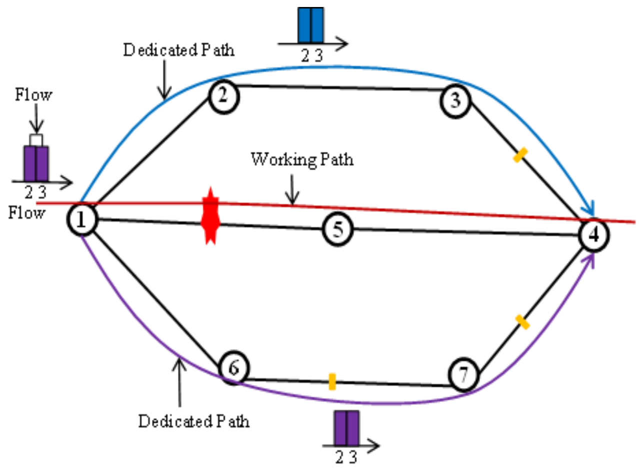


Fig. 1: Power efficient dedicated path protection in elastic optical network.

After routing of all traffic demands, in order to provide protection by the dedicated path (1-2-3-4) that involves one sleep link (3-4) while by the dedicated path (1-6-7-4) that includes two sleep links (4-7) and (6-7). When the failure occurs, the dedicated path can recover by switching from sleep to active. When the failure occurs, the dedicated path can recover by switching from sleep to active. The dedicated path (1-2-3-4) can restore by one link from sleep into active while the dedicated path (1-6-7-4) can also restore by two links from sleep into active. The dedicated path which has minimum number of sleep span saves maximum power and makes that dedicated path power efficient. The power efficient dedicated path utilizes traffic demands routed network components. The failure of the primary path (1-5-4) of traffic demand is recovered by using the dedicated path (1-2-3-4) considering power efficiency. A single dedicated path can recover the failure of primary path (1-5-4) of traffic demand having FS 2-3 because of the spectrum contiguousness requirement restricts FS 2-3 for splitting onto different dedicated path [18]-[20].

3. Routing algorithm

Transmission of data from origin to final destination is termed as Routing algorithm. Shortest path routing and optimized power routing are the two kind of routing this paper deals with. A short description about both of them is given below.

3.1. Shortest path routing (SPR)

There may be the possibility that for a certain path from origin node to destination node, data can be sent through combination of different intermediate span. The routing of demand pair from origin node to destination node follows as minimum as possible in length of path is referred to as shortest path routing. It means shortest path length is mostly selected for a given demand pair to establish the connection. This shortest path can be found out by Dijkstra's algorithm [21].

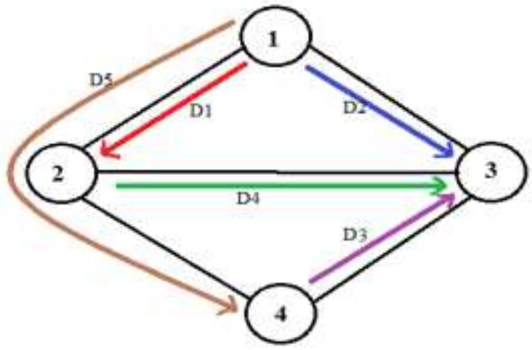


Fig. 2: Shortest path routed traffic demands.

3.2. Optimized Power Routing (OPR)

Low power consumption by Optimized Power Routing (OPR) is the factor which makes it different from conventional shortest path routing (SPR).

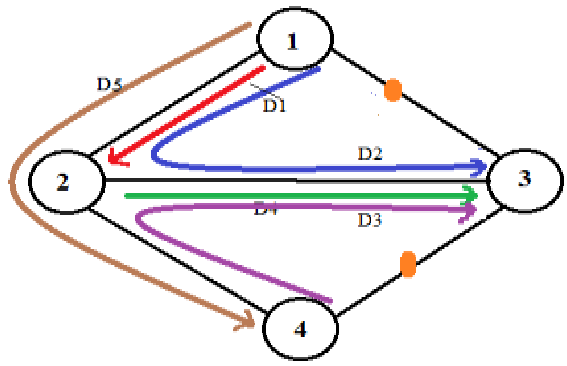


Fig. 3: Optimized power routed traffic demands.

Since, elastic optical networks have sufficient capacity or frequency slots, this algorithm only ensures that connection is established through those network components which are already in active mode. In turn, switch other components having the idle state into sleep / off mode. Consequently savings more power than SPR. The ILP model is proposed to optimized power for routing the working demand between each demand pair. The OPR utilizes a route for working demand between each demand pair through most used path. The spans and nodes are idle in the network are put into sleep / off according to their requirement in the protection path. If they are used in the protection path then sleep mode otherwise off mode [9]-[11]. So, power saving by optimized power routing is ensured as shown in Fig. 3.

4. ILP optimization model

The optimization is done with the ILP formulation to design network. The ILP model is formulated to minimize the required power in EONs with OPR and dedicated path protection. Two network components, BV-OXCs, and amplifiers are considered for the study of power requirement. This ILP model uses sets, parameters, and variables as follows.

Sets:

S: Set of network spans indexed by j.
N: Set of network nodes indexed by n.
D: Set of network demand pairs indexed by r.
P: Set of network dedicated paths indexed by p.
P_i: Set of eligible dedicated paths between demand pair r, each of which are disjoint with primary path.
D_i: Set of demand pairs that shares link i by their working paths.

Parameters:

d_r: The number of frequency slots (demand) required for demand pair r.
P_{amp}: In active mode, an amplifier (Erbium-doped fiber amplifier) consumes power in Watts.
P_{sleep}: In sleep mode, an amplifier (Erbium-doped fiber amplifier) consumes power in Watts.
Aw_j: A binary 1 for those span having working; 0 otherwise.
π_j^p: A binary data that equals 1 if dedicated path p crosses span j; 0 otherwise.
P_n: The parameter in the case of active node n equals 1, and in case of sleep node n equals 0.1.
m_j: Span j requires amplifiers in number.

Variables:

x_r^p: Equal to 1 if eligible dedicated path p ($p \in P_i$) of demand pair r is chosen for protection lightpath; 0, otherwise.
n_p: Number of spare capacity for dedicated path p.
s_j: Span j requires spare frequency slots for protection.
c: The maximum index of frequency slots assigned on network links.
Ap_j: When reserved spare on span j needed equals 1, not needed equals 0.
Sl_j: When span j is in the state of sleep equals 1; otherwise 0.
P_T: Network components (BV-OXCs and amplifiers) consume total power.

The objective of ILP is to Minimize:

$$P_T \tag{1}$$

Constraints:

$$\sum_{p \in P_i} x_r^p = 1 \quad \forall r \in D \tag{2}$$

$$d_r . x_r^p <= n_p \quad \forall r \in D, \forall p \in P_i \tag{3}$$

$$s_j = \sum_{p \in P} \pi_j^p . n_p \; \forall j \in S \tag{4}$$

$$s_j <= c \quad \forall j \in S \tag{5}$$

$$\sum_{r \in D_i} d_r <= c \quad \forall j \in S \tag{6}$$

$$Ap_j = 1 \forall j \in S \; if \; s_j > 0 \tag{7}$$

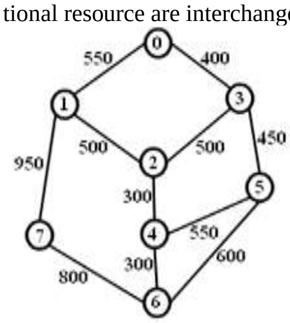
$$Sl_j = 1 \quad \forall j \in S \; if \; Ap_j > Aw_j \tag{8}$$

$$P_T = \sum_{j \in S} (P_{amp} . Aw_j + P_{sleep} . Sl_j) . m_j + \sum_{n \in N} P_n \tag{9}$$

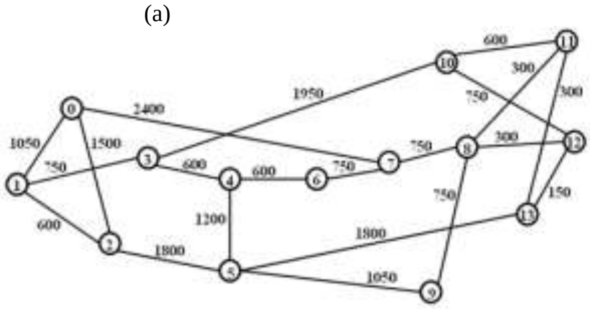
Objective (1) is to minimize the total required power consumption in the entire network. Due to the requirement of *spectrum contiguousness*, constraint (2) ensures that only one eligible dedicated path can recover the failure of corresponding primary path. Constraint (3) ensures that dedicated path p has sufficient capacity for protection and can restore the primary path between demand pair r after the failure. Constraint (4) determines the total additional frequency slots on the spans are reserved for making all the dedicated paths. Constraint (5) says that the total number of frequency slots (spare capacity) on any span j should always be lesser than the maximal FS index. For example, c value of 20 (i. e., 0-19) would be required if the largest FS index in the entire network is 19. Constraint (6) ensures that total working demands on span j by demand pairs should always be lesser than the maximal FS index. Constraint (7) shows the identification of spans those are used by protection path. Constraint (8) affirms the sleep spans which are used by dedicated path protection but not used by the routing of traffic demands. Constraint (9) estimates the total power consumption by BV-OXCs and amplifiers in active/sleep mode.

5. Simulation and results

ILOG CPLEX 12.6.3.0 is used to perform the simulations for optimized results. Intel Core i5 including 4 GB RAM and 2.4 GHz CPU is utilized to solve the equation of ILP formulation. The network topology includes (1) as presented in Fig. 4(a), 8n11s network and (2) as presented in Fig. 4(b), 14n 21s (NSFNET) network are considered to evaluate the performance by running the simulations with OPR and SPR. The traffic demand of each demand pairs is taken random with non uniform distribution of definite range [1, 5] frequency slots. Full spectrum conversion is assumed in ILP Model to optimize power consumption considering the optimized power path allocation and dedicated path protection capacity. Table 1 presents the evaluated results considering power efficient routing and protection. The word spare capacity and additional resource are interchangeable.



(a)



(b)

Fig. 4: Network topology used in simulations (a) 8n11s network (b) 14n 21s (NSFNET) network.

Table 1: For two networks total spare capacity, maximum frequency slot index and required power comparisons with SPR and OPR

Networks		8n11s	14n21s (NSFNET)
Total Spare Capacity	**SPR**	34	41
	OPR	24	34
Maximum Frequency Slot Index	**SPR**	9	7
	OPR	9	9
Required Power (in Watt)	**SPR**	16830	31012
	OPR	15030	25872
	% Decrease	10.69	16.57

When comparisons of additional resources with SPR and OPR are made that indicates the OPR requires fewer resources as compared to SPR presented in Fig. 5. The reason behind the reduction of spare capacity is some shortest paths that OPR does not use are utilized for dedicated path protection. In SPR, no shortest paths are used for dedicated path protection. While comparing the maximum frequency slot index with SPR and OPR that shows maximum frequency slot index used by the OPR is large or equal as compared to SPR in Fig. 6. Further, the required power is compared with SPR and OPR presented in Fig. 7. The OPR always require less power as compared to SPR. In Table 1, the required power is quantified. The power saving of 10.69% is achieved for 8 node 11 span and 16.57% for 14 node 21 network with OPR, which makes OPR more power efficient than SPR.

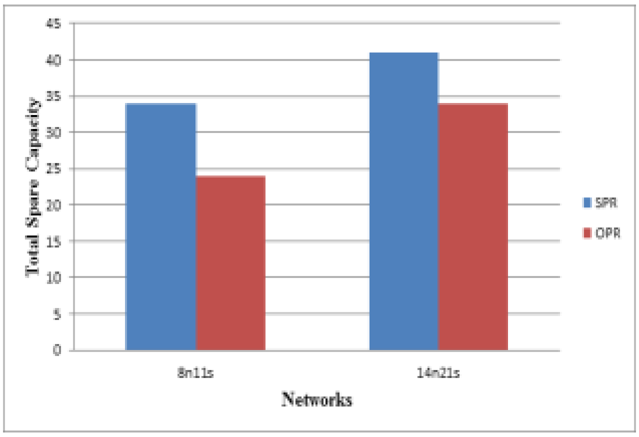


Fig. 5: Spare capacity performance.

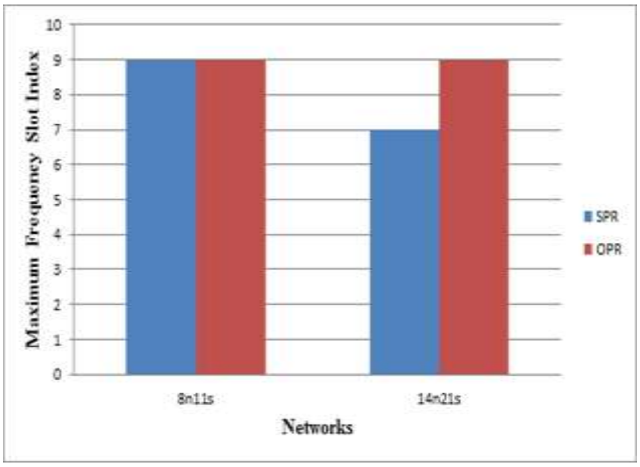


Fig. 6: Maximum frequency slot index.

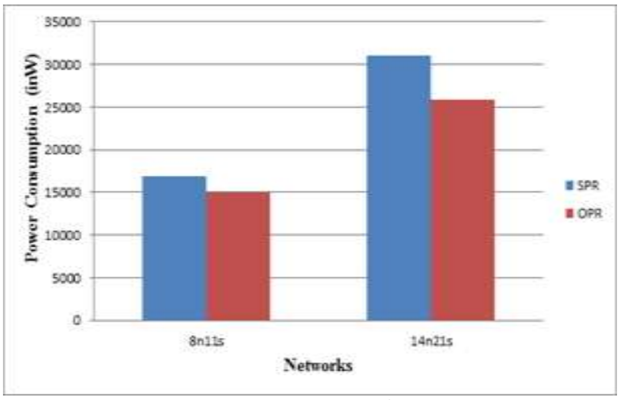


Fig. 7: Required power performance.

6. Conclusion

A new OPR is proposed in EONs considering 1:1 dedicated path protection. An ILP optimization model is formed to reduce the total required power by BV-OXCs and amplifiers. The evaluation results show that the OPR needs less total power as well as spare capacity but larger or equal maximum frequency slot index as compared to the SPR. It concludes that there is a decrease in the required power with better spare capacity efficiency at the cost of increase maximum frequency slot index when the traffic is low. The routing saves the major part of the required power to improve the power efficiency. The protection also saves power to reduce the required power. Combined routing and protection has minimized total required power to improve better power efficiency.

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References

[1] Y. Wei, G. Shen, and S. K. Bose, “Applying ring cover technique to elastic optical networks,” in Proc. ACP 2013.

[2] X. Chen, F. Ji, and Z. Zhu, “Service availability oriented p-cycle protection design in elastic optical networks,” *J. Opt. Commun. Netw.*, vol. 6, no. 10, pp. 901–910, Oct. 2014.

[3] J. Wu, Y. Liu, C. Yu, and Y. Wu, “Survivable routing and spectrum allocation algorithm based on p-cycle protection in elastic optical networks,” *J. Light Electron Opt.*, vol. 125, no. 16, pp. 4446–4451, 2014.

[4] M. Ju, F. Zhou, S. Xiao, and Z. Zhu, “Energy-efficient protection with directed p-cycles for asymmetric traffic in elastic optical networks,” in *Proc. Eur. Conf. Netw. Opt.*, pp. 1–6, Jun. 2016.

[5] Bernardetta Addis, Antonio Capone, Giuliana Carello, Luca G. Gianoli, Brunilde Sanso, “Energy aware management of resilient networks with shared protection”, *IEEE International Conference on Sustainable Internet And ICT For Sustainability (SustainIT)*, October 2012.

[6] Sofie Lambert, Ward Van Heddeghem, Willem Vereecken, Bart Lannoo, Didier Colle, and Mario Pickavet, “ Worldwide Electricity Consumption of Communication Networks”, *Optical Society of America publishing (OSA), Optics Express*, Vol.20, no. 26, pp. B513-B524, 2012.

[7] G. Zhang *et al.*, “A survey on OFDM-based elastic core optical networking,” *IEEE Communications Surveys & Tutorials*, vol. 15, no. 1, pp. 65-87, 2013.

[8] M. Jinno, H. Takara, B.Kozicki,Y. Tsukishima,Y. Sone, and S. Matsuoka, “Spectrum-efficient and scalable elastic optical path network: Architecture, benefits, and enabling technologies,” *IEEE Commun. Mag.*, vol. 47, no. 11, pp. 66–73, Nov. 2009.

[9] Y. Yan, L. Dittmann, “Energy efficiency in Ethernet passive optical networks (EPONs): protocol design and performance evaluation,” *J.commun*, vol. 6, no. 3, pp. 249-261, 2011.

[10] A. Coiro, M. Listanti, A. Valenti, and F. Matera, “Reducing power consumption in wavelength routed networks by selective switch off of optical links,” *IEEE J. Sel. Top. Quantum Electron.,* vol. 17, no. 2, pp. 428–436, 2011.

[11] M. Gupta, S. Grover, and S. Singh, “Feasibility Study for Power Management in LAN Switches,” *12th IEEE International Conference on Network Protocols*, 2004.

[12] Xiaoning Zhang and Shufang Tan, “Green optical networks with connection availability guarantee,” *Optical Society of America publishing (OSA), Optics Express* Vol. 23, no. 13, pp. 17456-17466 June 2015.

[13] J. L´opez *et al.*, “Traffic and power-aware protection scheme in elastic optical networks,” in *Proc. Telecommun. Netw. Strategy Planning Symp.*, Oct. 2012, pp. 1–6.

[14] A. Eshoul and H. Mouftah, “Survivability approaches using p-cycles in WDM mesh networks under static traffic,” *IEEE/ACM Trans. Netw.*, vol. 17, no. 2, pp. 671–683, Apr. 2009.

[15] D. Zhou and S. Subramaniam, “Survivability in optical networks,” *Network*, vol. 14, no. 6, pp. 16–23, Nov. 2000.

[16] S. Ramamurthy, L. Sahasrabuddhe, and B. Mukherjee, “Survivable WDM mesh networks,” *J. Lightw. Technol.*, vol. 21, no. 4, pp. 870–883, Apr. 2003.

[17] Y. Wei, K. Xu, Y. Jiang, H. Zhao, and G. Shen, “Optimal design for p-cycle-protected elastic optical networks,” *Photon. Netw. Commun.*, vol. 29, no. 3, pp. 257–268, 2015.

[18] W.D. Grover, and D. Stamatelakis, “Cycle-oriented distributed preconfiguration: ring-like speed with mesh-like capacity for self-planning network restoration,” in *Proc. IEEE International Conference on Communications*, Atlanta, Georgia, USA, pp. 537-543 June 1998.

[19] M. S. Kiaei, C. Assi and B. Jaumard, “A survey on *p*-cycle protection method”, *IEEE Communications Surveys& Tutorials*, vol. 11, no. 3, pp. 53-70, July 2009.

[20] R. Asthana, Y. N. Singh and W. D. Grover, “*p*-Cycles: an overview,” *IEEE Communications Surveys & Tutorials*, vol. 12, no. 1, pp. 97-111, First Quarter 2010.

[21] R. Asthana, “Study of *p*-cycle based protection in optical networks and removal of its shortcomings,” Ph.D. Thesis, Indian Institute of Technology, Kanpur, November 2007.

[22] Rajiv Ramaswami, and Kumar N. Sivarajan, *Optical Networks: A Practical Perspective.* Morgan Kaufmann, 2nd Edition, 2009.

[23] Gerd Keiser, *Optical Fiber Communications*. Tata McGraw-Hill, 4th Edition, 2010