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A Resource Efficient Recovery Strategy for a Failure in Elastic Optical Networks

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***Abstract:** In the last few years, internet traffic increases continuously due to the more use of live streaming and social sites. To accommodate such high traffic demand the more bandwidth is required. The elastic optical network (EON) is a promising solution for the capacity expansion that can meet the future bandwidth requirement. The EON can provide a higher bit rate. In this paper we purposed a recovery strategy for failure in EON. Our purposed strategy shows the more acceptance rate for randomly generated source (s)-destination (d) requests. Here we considered two topologies viz. COST239 and NSFNET. Then evaluate their performance for Recovery Time, bandwidth blocking probability (BBP) and network capacity utilization (NCU), in which our purposed scheme provides lesser BBP and lower NCU for both topologies and low recovery time than shared path protection (SPP and dedicated path protection (DPP).*

***Keywords:** Dedicated path protection, International telecommunication union, Bandwidth variable transponder, Elastic optical network.*

I. INTRODUCTION

With the increased number of internet users in the last few years, the use of different applications such as video conferencing, high definition televisions and multicasting are also increased, which require more bandwidth. The existing wavelength division multiplexing (WDM) fixed grid cannot meet the futures higher bandwidth demand, where the wavelength spacing is 50GHz, the bit rates are 10 Gbps, 40 Gbps, and 100 Gbps. If a client requires lower bandwidth for the data transmission and the channel space allotted is 50 GHz as per international telecommunication union (ITU) standard, rest of the spectrum gets wasted. According to Tele Geography the bandwidth demand up to 2020 is expected to about 1,103.3 Tb/s [1]. Hence the optical networks are required to fulfill this future higher bandwidth requirement [2]. The spectrum sliced elastic optical network (SLICE) is a suitable replacement for a conventional fixed WDM grid.

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The network which uses orthogonal frequency division multiplexing (OFDM) is known as the elastic optical network (EON) or flexible optical network (FON). The EON divides the spectrum size as 6.25, or 12.50 GHz or more [2], the bandwidth variable transponder (BVT) is used and it ranges from 10Gbps to 200Gbps. The BVT is used in EON to tune the bandwidth for regulating the transmission bit rate or modulation format. The BVT supports a very high data rate by using different modulation formats such as 64-quadrature amplitude modulation (QAM) used for shorter distance, 16-QAM, quadrature phase-shift keying (QPSK) and binary phase-shift keying (BPSK) used for longer distance [3]. The EON has the ability to meet the future client bandwidth requirement. In EON the efficiency and utilization of the network are greatly improved. There are few resemblances between the WDM and EON, the new challenges in EON are due to their flexibility.

EON has so many properties like flexibility in data rate, low power consumption, low signal distortion, low signal attenuation, low cost, and small space requirement. In EON routing and spectrum, assignment finds an unused frequency slot (FS) [1] [4] to meet the traffic demand and set up a light path connection. The allotment of the spectrum in EON is in a contiguous manner. As the number of connection acceptance rates increases, bandwidth blocking probability (BBP) decreases. The main constraint in the spectrum assignments is spectrum continuity, spectrum contiguity and spectrum nonoverlapping. The spectrum continuity constraint requires the allotment of same FS to each fiber along the light path. The spectrum contiguity constraint requires the allotment of FS to the light path is consecutive. The nonoverlapping constraint allows any FS to the light path.

The failure of any link due to a fiber cut a single or multiple failure or node failure in the optical network results in more data loss and also affects the Quality of Services (QoS). The survivability in EON can be improved by using the various techniques [5] [6]. The rerouting of data from the failed link to the alternate route is the common recovery schemes in optical network. This alternative backup route may be provisioned at the time of connection setup or it is dynamically searched after the failures occurred. There are two types of resource recovery schemes, one is advance reservation (AR) and other is immediate reservation (IR), in AR the backup resources are reserved in advance at the time of connection setup, whereas in IR the alternate backup route is dynamically searched after the failure information received at the source node [7] [8].

In this paper, we define three network parameters that are bandwidth blocking probability (BBP), network capacity utilization (NCU) and recovery time for the randomly generated source (s) – destination (d) connection request for two existing topologies viz. COST239 and NSF network.

The s-d request for these two topologies is to be generated by using N (N-1)/2, Where N be the number of nodes. The rest of the paper is organized as follows, the related work on survivability is presented in section 2, section 3 discussed our proposed strategy, section 4 explains the performance of our proposed scheme and comparison between the results, section 5 provides the conclusion.

II. RELATED WORK

There is much literature available for the survivability of EON. The first and last fit strategy for the survivability of failure in EON for the primary route and spectrum allocation has been discussed in [3] [1]. The RSA problem in EON with BVT is discussed in [2]. The advance reservation (AR) and Immediate reservation (IR) protection schemes are provided in [6]. The mixed-integer linear programming (MILP) for DPP is presented in [8] and the comparison with SPP is explained in [9]. The multi-layer recovery, spectrum sharing, energy efficiency failure and blocking probability for the shared path protection scheme is discussed in [10]. The comparison between shared path protection (SPP) and dedicated path protection (DPP) are discussed in [7]. The Shared Backup Path Protection (SBPP) with Routing and Spectrum Assignment (RSA) for EON are presented in [11]. An ILP has been proposed with SBPP for the survivability of a failure in EON.

The more dedicated recovery strategy for the failure in EON is presented in [12]. The dedicated protection scheme for EON by using integer linear programming (ILP) is discussed in [13]. The metaheuristic approach which includes Tabu Search Based Algorithm (TS) and an Adaptive Frequency Assignment (AFA), which provide nearly optimal solutions for large simulations are discussed in [14]. There are many heuristic algorithms that have been proposed which include Adaptive Frequency Assignment (AFA) with SBPP. The comparisons between SBPP and DPP with ILP formulation with or without variable transponders are provided in [9], which shows that the SBPP and variable transponder improve the performance in EON. The hybrid protection algorithm also called hybrid protection light path which defines the power consumption and resource availability that has been proposed in [15] for EON. For every request the shortest backup path with minimum resource utilization has been selected. The inter-data transmission services for EON and an ILP model and heuristic algorithm are proposed to solve the routing and spectrum allocation problems, that improve the resource utilization ratio are provided in [16].

The recovery after the failure of the primary route has been explained in [17]. The multipath restoration strategy has been presented in [18]. The recovery of multilink failure based on load awareness is discussed in [19] and the survivable algorithm is discussed in [20]. The restoration in EON is presented in [21] and provides better resource utilization as compared to the protection scheme. Multipath recovery has been discussed in [22]. P-cycle restoration is presented in [23] provides a 100% recovery against single link failure.

III. EXISTING STRATEGIES

In this paper, we presented an SPP and DPP and an efficient recovery scheme for failure in the optical network.

3.1 Notations Used

We consider that the failure of the link is detecting by the adjacent node. The various parameters are used for the protection switching time such as message processing time, optical connect and propagation delay in the network, etc. are given below.

- The message processing time at a node, Mt is 10 μs.
- The propagation delay is dp of each signal on the link is 400 s, which corresponds to 80 km length.
- Optical cross-connects, Co does not have any fixed values, and it takes as 10 ns, 10 ms, 10 s and 500 s.
- The time to detect the failure Ft, is about 10 μs.
- The number of hops lh, the node adjacent to link failure to the source and destination node.
- The number of links lb, for the backup path from source to the destination node.

Let G (V, E, λ) represents the network topology (Nodes, Links and wavelengths) and different notations are as follows:

v	Set of the nodes $\forall$ v ϵV
e	Set of the Links $\forall$ e ϵE
λ	Set of Wavelength for each link
s	Source node
d	Destination node

Connection request $\forall$ r ϵR , that is {(s1, d1), (s2, d2)….(si, di)} where ∀ (s,d)ϵV, ∀ s≠d, ∀ iϵV.

Primary route of the ith connection request where ∀ iϵR.

Backup route of the ith connection request where ∀iϵR.

3.2 Shared Path Protection (SPP)

In this scheme, the nearby node of the failed link detecting the link failure and send the link failure message to the source node and the destination node. Then the source node sends a connection setup message to the destination node and the optical cross-connects organize each node for the backup path protection, at the time of connection establishment the backup path is reserved in advance. The optical cross-connects are not configured to allow for the sharing of backup wavelengths. The destination node after receiving connection setup message sends a confirmation message to the source node. For completing connection setup the total time is

$$Ft+lh\times dp+(lh+1)\times Mt+(lb+1)\times Co+2\times lb\times dp+2\times (lb+1)\times Mt \quad (1)$$

3.3 Dedicated Path Protection (DPP)

In DPP, the adjacent node to the failure link sends the link failure message to the source and destination node. Then the source node sends a connection setup message to the destination node by a backup path that is reserved in advance at the time of connection setup and also the optical cross-connects are configured at the time of connection setup and not required at the time of connection switching time. The response of the DPP is slower as compared to our proposed scheme. The total switching time for the DPP is

$$F_t + l_h \times d_p + (l_h + 1) \times M_t + 2 \times l_b \times d_p + 2 \times (l_b + 1) \times M_t \quad (2)$$

3.4 Our Proposed Strategy

In this scheme, the nearby node of the failure link provides the notification message to the source and destination node and then immediately the source node establishes a backup path to the destination node.

The recovery time for the proposed scheme is

$$RT_{ps} = T_c + T_a \quad (3)$$

RTps be the recovery time for the proposed strategy and Tc and Ta be the connection setup time from source to destination and acknowledge time from the destination to source. We assume ns-d be the nodes on the backup route between source to destination and nd-s be the nodes from destination to source node and ls-d be the length of the backup route from source to the destination and ld-s be the length of acknowledgement from destination to source node. Ts-d and Td-s be the connection setup time from source to destination and destination to source.

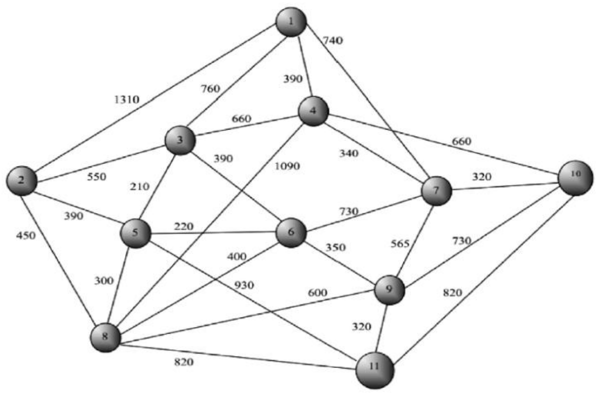
$$T_{s-d} = n_{s-d} \times (M_t \times C_o) + l_{s-d} \quad (4)$$

$$T_{d-s} = n_{d-s} \times M_t + l_{d-s} \quad (5)$$

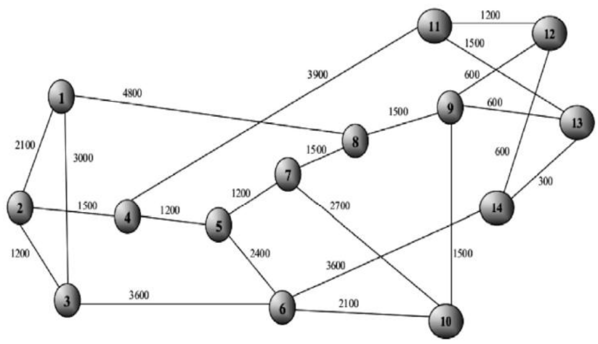
Hence, $T_c = (T_{s-d} + T_{d-s})$ (6)

$$T_{a,d-s} = n_{d-s} \times M_t + l_{d-s} \quad (7)$$

$$T_a = T_{a,d-s} \quad (8)$$



(a)

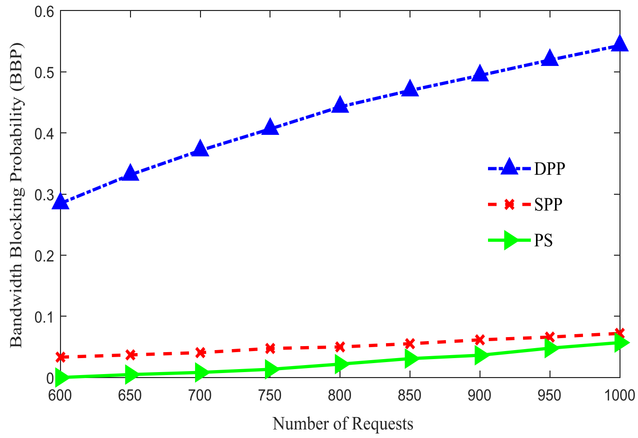


(b)

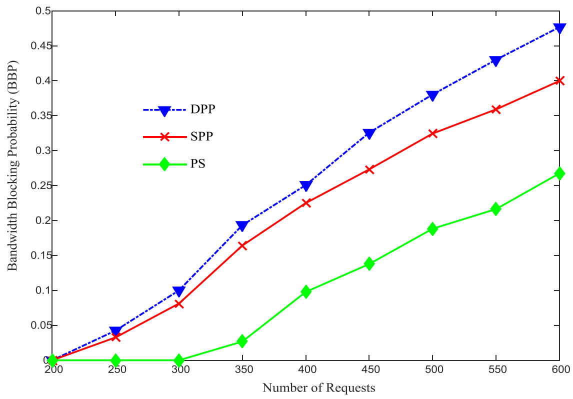
Fig. 1 (a) COST 239 (11Nodes & 26 Links) (b) NSFNET (14 Nodes & 22 Links).

IV. RESULTS AND DISCUSSION

We evaluate the performance of three network parameters in MATLAB 2018 on i5-7400 Intel® core(TM) 3GB system with 8GB RAM, by randomly generated source (s)-destination (d) requests. Figure 1 (a) and (b) shows COST239 with 11 nodes and 26 links and NSFNET topologies with 14 nodes and 22 links respectively.

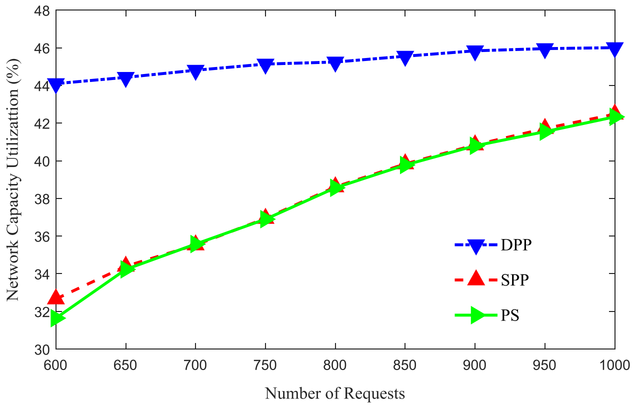


(a)



(b)

Fig. 2 (a) Bandwidth blocking probability (BBP) vs. no. of requests for COST239 (b) Bandwidth blocking probability (BBP) vs. no. of requests for NSFNET.



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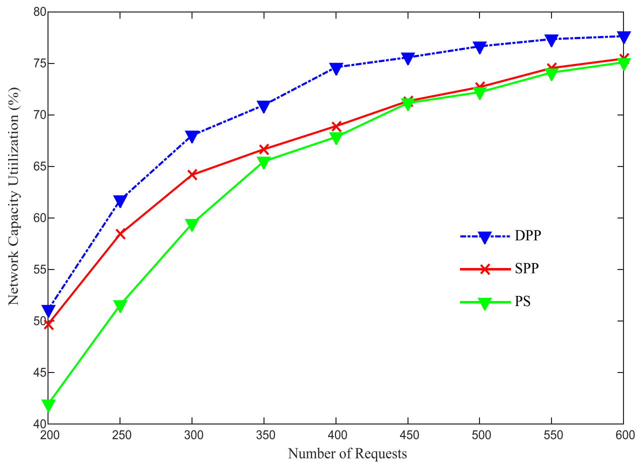
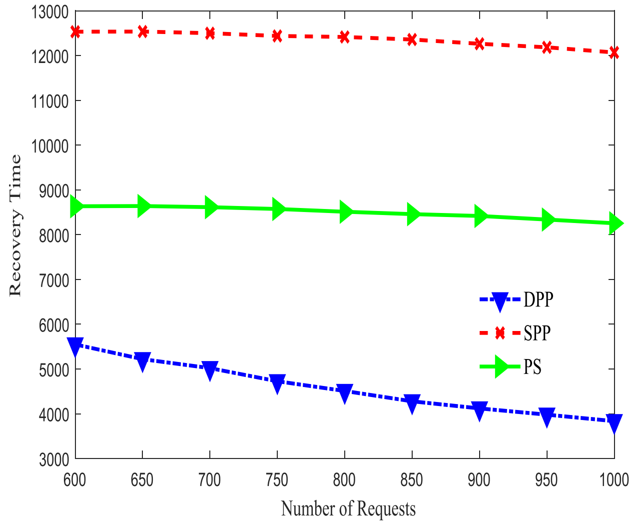
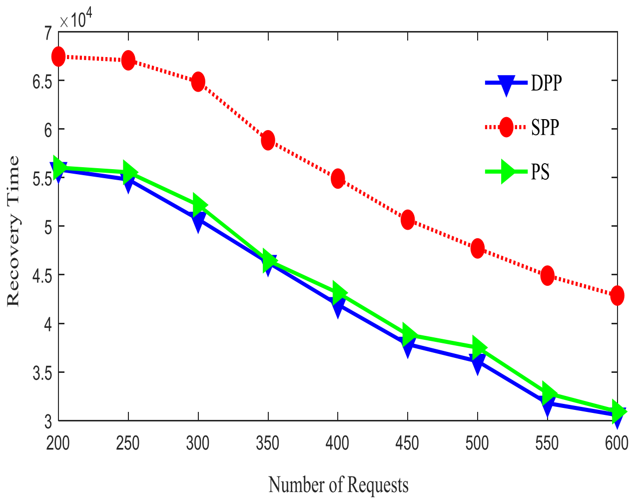


(b)

Fig.3 (a) Network capacity utilization (NCU) vs. no. of requests for COST 239 (b) Network capacity Utilization (NCU) vs. no. of requests for NSFNET.



(a)



(b)

Fig. 4 (a) Recovery time in micro seconds vs. no. of requests for COST239 (b) Recovery time in microseconds vs. no. of requests for NSF network.

Table 1.The mean values of different network parameters for different Strategies.

Network Parameters	**COST239**			**NSFNET**		
	DPP	**SPP**	**PS**	**DPP**	**SPP**	**PS**
Recovery Time (μs)	10^3*4.5828	10^4*1.2366	10^3*8.4940	10^4*4.2869	10^4*5.5479	10^4*3.8047
BBP	0.4292	0.0515	0.0245	0.2444	0.2066	0.1038
NCU	45.2293	38.1105	37.9288	70.4041	66.8805	64.3185

4.1 Bandwidth Blocking Probability (BBP)

The BBP is defined as the ratio of the number of bandwidth request rejected to the total bandwidth demanded [13]. It has been noticed from Fig. 2(a) and (b) the BBP of our proposed strategy is very less as compared to the SPP. Hence, in our proposed strategy the large number of s-d requests accepted as compared to SPP. The mean BBP for our proposed strategy (PS), SPP and DPP are 0.0245, 0.0515 and 0.4292 respectively for COST239, and the BBP for our PS, SPP and for DPP is 0.1038, .0.2066 and 0.2444 respectively for NSF network. The rejections of the connection request in the NSF network are more than COST239. The mean values for different parameters are provided above in Table 1.

4.2 Network Capacity Utilization (NCU)

The network capacity utilization ratio is defined as the ratio of the total spectrum used to the connection request accepted in the network. The average NCU for COST 239 is 45%, 38% and 37% for DPP, SPP and for our proposed scheme (PS) respectively, while for NSFNET DPP, SPP and for PS is 70%, 66%, and 64% respectively as given in Fig. 3 (a) and (b). In NCU if 70% of the spectrum used for traffic, then slowdown will occur in-network, if this slowdown remains for a long time than a long queue of traffic will occur in the network, which causes a holdup in the traffic. In COST239 the traffic is less as compared to the NSFNET.

4.3 Recovery Time

The recovery time is the time instant from where the recovery process is started and the confirmation message received from the destination to the source. For fast recovery, a recovery time constraint is required to introduce. Recovery time in our proposed scheme (PS) is less than SPP and above than DPP as shown in Fig. 4 (a) for COST239 and also for NSF network it's lower than SPP and DPP as mentioned in Fig. 4 (b).

V. CONCLUSION

Here, we proposed a backup strategy for the recovery of failure in EON. Our proposed scheme shows the recovery time between SPP and DPP.

We evaluate the some parameters of the network like BBP and NCU ratio for two topologies that is COST239 and NSF network. Our purposed strategy shows lower BBP and NCU than SPP and DPP for COST239 and NSFNET. In the future, we can purpose a strategy for the selection of safer light path and the protection strategy for the multiple failure in the network.

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