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Path-Based Recovery Scheme for a Failure in Elastic Optical Networks

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ABSTRACT: From the last few years, the number of internet users increases threefold. Due to the more use of online services such as online gaming, video conferencing, and high definition video streaming (HDVS), etc. For these applications, we need higher bandwidth. The Elastic Optical Network (EON) offers a very high data rate and provides high bandwidth. Here, we proposed a recovery scheme which is more efficient as compared to the existing schemes. Our purposed strategy shows a more acceptance rate for randomly generated source-destination requests. For simulations, 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 path-based recovery scheme (PBR) provides lesser BBP and lower NCU for both topologies and optimal recovery time than shared path protection (SPP) and dedicated path protection (DPP). The proposed scheme here avoids the congestion in the network, and uses minimum network spectrum.

Keywords: Shared path protection, Wavelength division multiplexing, Elastic optical network, Bandwidth variable transponder.

Abbreviations: BBP, bandwidth blocking probability; DPP, dedicated path protection; EON, elastic optical network; FS, frequency slot; HDVS, high definition video streaming; HDTV, high definition television; FON, flexible optical network; OFDM, orthogonal frequency division multiplexing; SPP, shared path protection; NCU, network capacity utilization; PBR, path-based recovery scheme; BVT, bandwidth variable transponder; QAM, quadrature amplitude modulation.

I. INTRODUCTION

As reported by cisco [1], from the last few years the number of internet users increases by three-fold. The use of different applications such as video conferencing, high definition video streaming (HDVS), high definition televisions (HDTV), and multicasting are also increased, which require more bandwidth. The existing wavelength division multiplexing (WDM) homogeneous grid cannot meet the futures higher bandwidth demand, where the channel spacing is 50GHz, the bit rates are 10 Gbps, 40 Gbps, and 100 Gbps and is not feasible to transfer higher data rate. If a client requires lower bandwidth for the data transmission and the channel space allotted is 50 GHz and the end-users used only 30GHz, then the 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 [2]. Hence the optical networks offer very high bandwidth more and can fulfill this future higher bandwidth requirement [3].
The spectrum sliced elastic optical network (SLICE) is a appropriate replacement for a conventional homogeneous WDM grid. 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 more [3], 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 a shorter distance, 16-QAM, quadrature phase-shift keying (QPSK) and binary phase-shift keying (BPSK) used for longer distance [4]. The EON has the ability to meet the future client bandwidth requirement. In EON the efficiency and utilization of the network are greatly improved. 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, the assignment finds an unused frequency slot (FS) [2, 5] to meet the traffic demand and estabalished a light path connection. The allotment of the spectrum in EON is in a contiguous manner. As the number of connection acceptance rates increases, the BBP also inceases and the recovery time decreases, this indicates the availability of FS for backup light path. There are two types of spectrum constraint occurreed in EON, one is spectrum continuity, and other is spectrum contiguity.

The spectrum continuity constraint requires the allotment of the identical FS to each fiber along the light path. The spectrum contiguity constraint requires allotment of successive FS to each light path.

The failure of any link due to a fiber cut, bending of fiber or node failure in the optical network results huge data loss to the network operators and also affects the Quality of Services (QoS). The survivability in EON can be improved by using the various techniques [6, 7]. The rerouting of data from the failed link to the alternate safer route or backup route is called the recovery scheme in the 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 recovery schemes, one is advance reservation (AR) or Protection and other is immediate reservation (IR) or restoration, in AR the backup resources are reserved in advance at the time of connection setup, whereas in later the alternate backup route is dynamically searched after the failure happened in the network [8, 9].

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 demand 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 is the number of nodes. The rest of the paper is organized as follows, the related work on survivability is presented in section II, section III discussed our proposed strategy, section IV explains the performance of our proposed scheme and comparison between the results, section V provides the conclusion.

II. RELATED WORK

There is a lot of literature available for the survivability of EON. The first, last fit strategy for the recovery of failure in EON for the primary route and spectrum allocation has been presented [2, 4]. The RSA problem in EON with BVT is discussed [3]. The advance reservation (AR) and Immediate reservation (IR) protection schemes are provided [7]. The mixed-integer linear programming (MILP) for DPP is presented [9] and the comparison with SPP is explained [10]. The multi-layer recovery, spectrum sharing, energy efficiency failure, and blocking probability for the shared path protection scheme is discussed [11]. The comparison between shared path protection (SPP) and dedicated path protection (DPP) are discussed [8]. The Shared Backup Path Protection (SBPP) with Routing and Spectrum Assignment (RSA) for EON is presented [12]. 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 [13]. The dedicated protection scheme for EON by using integer linear programming (ILP) is discussed [14]. 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 [15]. 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 [10], 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 [16] 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 [17].

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

More traffic in the network increases the probability of link failure in the optical network and reduces the acceptance rate of connection request. Here, our proposed threshold based AOMDV routing minimizes network congestion and balance the connection request demand [24]. The performance of MIMO system and resource allocation is analyzed [25]. P-cycle restoration provides 100% recovery against single link failure [26].

III. EXISTING STRATEGIES

In this paper, we presented an SPP and DPP and path-based recovery (PBR) scheme for failure in the optical network.

A. Notations Used

We consider that the adjacent node to the failure in the network detects the link failure. The various parameters are used for the protection switching time such as message processing time, optical cross-connects and propagation delay in the network, etc. are given below.

— The message processing time at a node, M_{ptn} is 10 µs.

— The propagation delay is d_p of each signal on the link is 400 s, which corresponds to 80 km length [27].

— Optical cross-connects, C_o 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 F_t, is about 10 µs.

— The number of hops l_h, the node adjacent to link failure to the source and destination node.

— The number of links l_b, for the backup path from source to the destination node.

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

n Set of the nodes $\forall n \in N$

l Set of the Links $\forall l \in L$

λ Set of Wavelength for each link

s_n Source node

d_n Destination node

r Connection request $\forall r \in R$, that is $\{(s_1, d_1), (s_2, d_2)....(s_i, d_i)\}$ where $\forall (s,d) \in V$, $\forall s \neq d$, $\forall i \in V$.

P_{ri} Primary route of the ith connection request where $\forall i \in R$.

B_{ri} Backup route of the ith connection request where $\forall i \in R$.

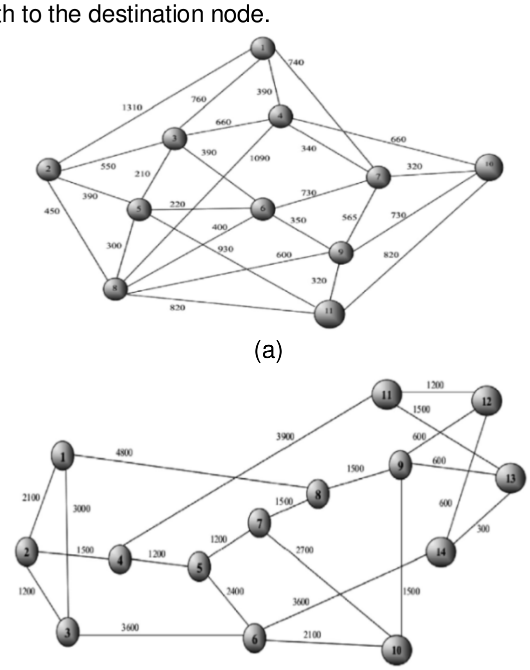
B. Shared Path Protection (SPP)
In this scheme, the nearby node of the failed link detecting the link failure and send the link failure message to the source node. Then the source node sends a connection setup message to the destination node and the optical cross-connects organize each node for the backup 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 a connection setup message sends a confirmation message to the source node. For completing connection setup the total time is

$$F_t+l_h\times d_p+(l_h+1)\times M_{ptn}+(l_b+1)\times C_o+2\times l_b\times d_p+2\times(l_b+1)\times M_{ptn} \quad (1)$$

C. Dedicated Path Protection (DPP)
In DPP, the adjacent node to the failure link sends the link failure message to the source 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 estabalishment. The response of the DPP is slower as compared to our proposed scheme. The total switching time for the DPP is

$$F_t+l_h\times d_p+(l_h+1)\times M_{ptn}+2\times l_b\times d_p+2\times(l_b+1)\times M_{ptn} \quad (2)$$

D. Our Proposed Strategy
In this scheme, the adjacent node to link failure provides the failure notification message to the source node, and then immediately the source node establishes a backup path to the destination node.



(a)

(b)

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

The recovery time for the proposed scheme is

$$RT_{pbr}=T_{cst}+T_{ads} \quad (3)$$

RT_{pbr} is the recovery time for the proposed path-based recovery scheme and T_{cst} and T_{ads} be the connection setup time from source to destination and acknowledge time from the destination to source. We assume $n_{s\text{-}d}$ be the nodes on the backup route between source to destination and $n_{d\text{-}s}$ be the nodes from destination to source node and $l_{s\text{-}d}$ be the length of the backup route from source to the destination and $l_{d\text{-}s}$ be the length of acknowledgment from destination to source node. $T_{s\text{-}d}$ and $T_{d\text{-}s}$ be the connection setup time from source to destination and destination to source.

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

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

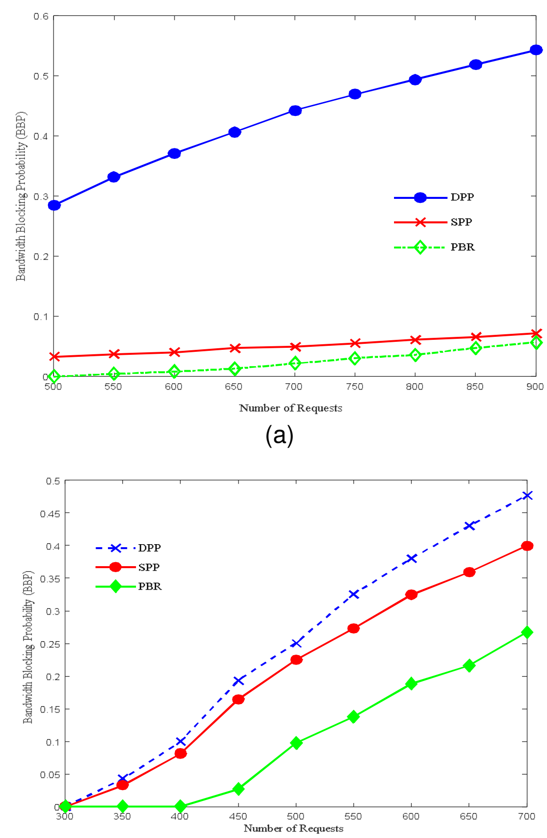
Hence, $T_c=(T_{s-d}+T_{d-s})$ (6)

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

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

IV. RESULTS AND DISCUSSION

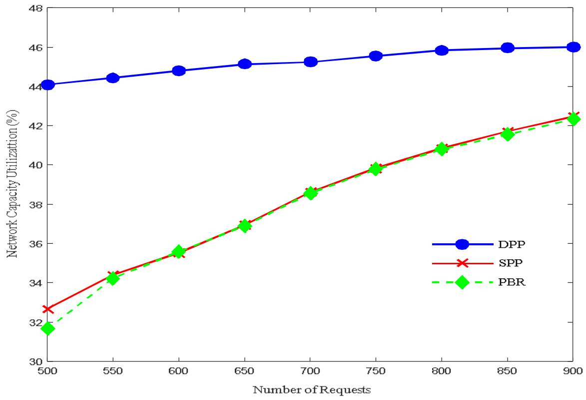
We evaluate the performance of three network parameters in MATLAB 2015 on Intel(R) core(TM) i5-8250U CPU @ 1.60GHz 1.80GHz with 8GB RAM, 64 bit operating system, by randomly generated source (s)-destination (d) requests. The recovery time constraint (RTC) for NSFNET is 150ms and for COST239 is 21ms. Fig. 1 (a) and (b) shows COST239 with 11 nodes and 26 links and NSFNET topologies with 14 nodes and 22 links respectively.



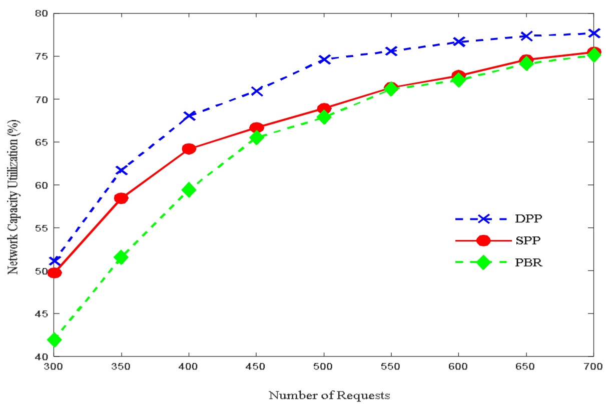
(a)

(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.

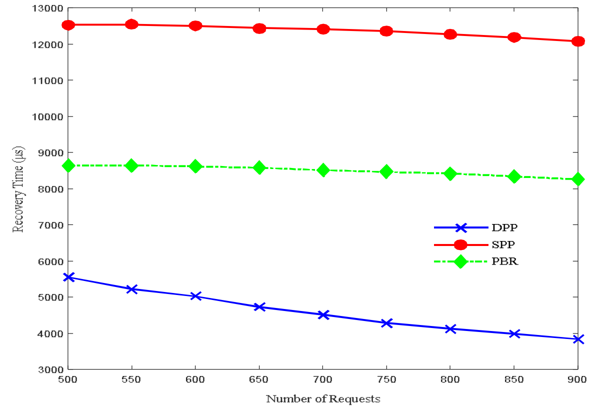


(a)

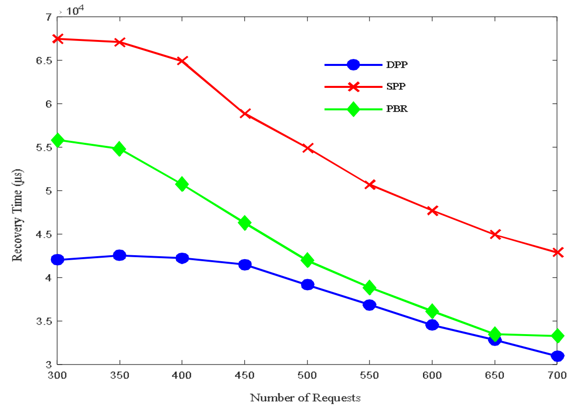


(b)

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 NSFNET.

Table 1: The average values of different network parameters for different recovery schemes.

Network Parameters	COST239			NSFNET		
	DPP	**SPP**	**PBR**	**DPP**	**SPP**	**PBR**
Recovery Time (ms)	4.58	12.36	8.49	42.86	55.47	38.04
BBP	0.42	0.05	0.02	0.24	0.20	0.10
NCU	45.22	38.11	37.92	70.40	66.88	64.31

A. Bandwidth Blocking Probability (BBP)

The BBP is defined as the ratio of the number of bandwidth demand blocked to the total bandwidth demanded [14]. 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 and DPP. The mean BBP for our proposed path based recovery scheme (PBR), SPP and DPP are 0.02, 0.05 and 0.42 respectively for COST239, and the BBP for our PBR, SPP and DPP is 0.10, 0.0.20 and 0.24 respectively for NSFNET. The blocking of the connection request in DPP and SPP are more than PBR. The mean values for different parameters are provided in Table 1.

B. Network Capacity Utilization (NCU)

The network capacity utilization ratio is defined as the ratio of the total spectrum used to the bandwidth demaded in the network.

The average NCU for COST 239 is 45%, 38%, and 37% for DPP, SPP, and for our proposed PBR scheme respectively, while for NSFNET DPP, SPP and PBR is 70%, 66%, and 64% respectively as given in Fig. 3 (a) and (b). In NCU if 70% or more spectrums 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. The PBR scheme has lower NCU as compared to SPP and DPP.

C. Recovery Time

The recovery time is the time instant from where the recovery process is initiated and the confirmation message received from the destination to the source node. For fast recovery, a recovery time constraint is required to introduce. Recovery time in our proposed scheme (PBR) is less than SPP and above than DPP as shown in Fig. 4 (a) for COST239 and also for the

NSFNET it's lower than SPP and above than DPP as mentioned in Fig. 4 (b).

V. CONCLUSION

Here, we proposed a path-based recovery scheme for failure in EON. The recovery time of our proposed PBR scheme lies between SPP and DPP. We evaluate the performance of some parameters of the network like BBP and NCU ratio for two topologies that is COST239 and NSF network. Our purposed PBR scheme shows lower BBP and NCU than SPP and DPP for COST239 and NSFNET, this indicates it uses the spectrum efficiently and more FS are available for backup light path. In the future, path-based recovery scheme can be applied for the survivability of multi-core failures in the network.

Conflict of Interest. No.

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