Proactive Fast Connection Recovery Scheme for a Failure in Elastic Optical Networks

Dinesh Kumar¹, Rajiv Kumar² and Neeru Sharma³

¹Research Scholar, Department of Electronics & Communication Engineering, Jaypee University of Information Technology, (H.P.), India.
²Associate Professor, Department of Electronics & Communication Engineering, Jaypee University of Information Technology, (H.P.), India.
³Associate Professor, Department of Electronics & Communication Engineering, Jaypee University of Information Technology, (H.P.), India.

(Corresponding author: Dinesh Kumar)
(Received 10 March 2020, Revised 06 April 2020, Accepted 10 April 2020)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: This paper presents a proposed link based fast connection recovery scheme for a failure in elastic optical network (EON). In this scheme a backup path is reserved in advance and re-route the traffic immediately after the failure happens in the network. We analyse three network parameters such as bandwidth blocking probability (BBP), recovery time (RT), and network capacity utilization ratio (NCU) for randomly generated source to destination request for three topologies that is COST239, ARPANET and NSFNET and compare the results for shared link protection (SLP), dedicated link protection (DLP), and our proposed link based recovery scheme (PLBRS). Our proposed scheme shows the minimum RT compared to other two strategies.

Keywords: Elastic optical networks, Frequency slots, shared link protection, Dedicated link protection, and proposed link based recovery scheme.

Abbreviations: BBP, Bandwidth blocking probability; DLP, Dedicated link protection; EON, Elastic optical networks; FS, Frequency slots; ILP, Integer linear programming; NCU, Network capacity utilization ratio; RAFF, Re provisioning after the first failure; RT, Recovery Time; PLBRS, Proposed link based recovery scheme; SLP, Shared link protection; WDM, wavelength division multiplexing.

I. INTRODUCTION

As reported by Cisco [1] the number of internet users increases three fold from last few years correspondingly the requirement of higher bandwidth is also increases. The different applications like video conferencing, cloud computing, high definition television (HDTV), and online gaming etc. required very high bandwidth. The optical network plays an important role for the transmission of more information online.

The existing Optical networks used the wavelength division multiplexing (WDM) for the transmission of 40Gbps or 100Gbps. But this WDM scheme is infeasible to transfer more than 100Gbps. This WDM scheme based on the fixed bandwidth spectrum of 50GHz channel spacing and fixed modulation formats [2]. This fixed grid cannot meet the demand of higher bandwidth. The EON is a new paradigm in optical network, used to provide variable bandwidth as required by the users [3]. EON provides a granular fine frequency slots (FS) multiple of 6.25 GHz. EON consider the FS continuity and contiguity constraint. The routing and spectrum assignment problem is also considered in EON [4]. The survivable networks have the ability to quickly restore the failure in EON [5]. This can be done by providing a spare capacity in existing optical network. In literature the survivability is categorized into pre-protection and restoration schemes. Protection scheme reserve the alternate route for connection failure in advance, whereas the restoration scheme dynamically search the backup after failure happened in the network. This scheme is more efficient than protection scheme [6].

Many studied have been done for the protection of single link failure and double link failure. Guaranteed survivability has been provided [7]. Dual link failure recoverability is proposed [8]. Protection schemes for two link failure are designed [9] [10] where the link disjoint alternate routes are available. All these schemes provide guaranteed protection [11]. However, they require large amount of backup capacity. Other approach to handle the two link failure is re provisioning after the first failure (RAFF) [12]. In RAFF, every request is allocated a alternate route in the spare capacity for a link failure in the network.

After the recovery of the first failure, the new backup alternate routes are provided for unrecoverable failure. In this way the affected request can restore quickly using new alternate backup route, when the second failure happened. In [13] p-cycle network proposed, where the RAFF spare capacity can reconfigured dynamically.

The ILP model provided two cases, first is whole cycle reconfiguration and other is additional cycle configuration. Hence, alternate backup route provisioning after the recovery of the first failure and before the second failure occurs. Thus, all connection demand whose primary paths are affected by first failure need to have a provisioned of alternate backup route. Here, We present a new proactive protection scheme to handle the single link failure [14]. Despite as the
A. Notations Used
Here, failure of the link detecting by the adjacent nodes. The different network parameters are used for the switching protection, such as message processing time, optical cross-connects and the propagation delay in the optical network etc are given as follows:

- The processing time of the message $m_p$ at the nodes is 10 $\mu$s.
- The delay due to signal propagation $p_b$ for each signal is 400 s, which corresponding to 80 km length [15].
- Optical cross-connects, $c_i$ takes any value that is 10 s, 10 ms, 10 ns and 500 s.
- The time to detect the failure $f_s$ is about 10 $\mu$s.
- $l_b$ be the no. of links, for the backup path from source to the destination node.

Let $G (N, L, f_s)$ 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 $\forall l \in L$
- $f_s$: Set of FS for each link
- $t_s$: Transmitting node
- $d_s$: Destination node
- $r$: Connection request $\forall r \in R$, that is $\{(s_1, d_1), (s_2, d_2), \ldots, (s_i, d_i)\}$ where $\forall (s,d) \in V, s \neq d$ and $\forall i \in \mathbb{R}$.

p_r: Primary route of the $i^{th}$ connection request where $i \in \mathbb{R}$.

b_r: Backup route of the $i^{th}$ connection request where $i \in \mathbb{R}$.

B. Shared Link Protection (SLP)
In SLP, the nearest node of the failed link detect the failure of the link [16] and immediately itself established the connection with the receiving node by the alternate backup route. Here, the backup FS is reserved in advance. In SLP the optical cross connects $c_i$ are not allowed for the sharing of backup FS. The destination nodes send acknowledgement when it receives connection setup message from the source node. The total time taken for connection establishment is

$$F_d + (l_b + 1) \times c_s + 2 \times l_b \times p_b + 2 \times (l_b + 1) \times m_p$$

C. Dedicated Link Protection (DLP)
In this scheme, the nearby node establishes the connection between the failure link after detecting the failure by using advance reserved FS. The response of DLP is slower than our proposed link protection scheme (PLP).

The switching time for the DLP is

$$F_d + 2 \times l_b \times d_b + 2 \times (l_b + 1) \times m_p$$

D. Proposed Link Based Recovery Scheme (PLBRS)
In this scheme, the nearby node immediately establishes the connection between the transmitting and receiving nodes. This scheme share the backup resources as SLP. The recovery time for the proposed scheme is given by

$$RT_{plbrs} = t_c + l_s$$

$RT_{plbrs}$ be the recovery time for proposed scheme and $t_c$ and $l_s$ be the connection setup time between the adjacent node to the receiving node and acknowledgement time from receiving node to the source node. We assume $n_r$ be the nodes on the backup route between link nodes to receiving node. $T_{r-s}$ and $T_{r-a}$ be the connection establishment time from link node to the receiving node and receiving node to the source node. $T_c$ is the total connection setup time from link node to the receiving node and back to source node.

$$T_{r-s} = (m_p \times c_s) + l_{r-s}$$

$$T_{r-a} = n_r \times m_p + l_{r-a}$$

Hence, $T_c = T_{r-s} + T_{r-a}$

Fig. 1. An example of proposed link based recovery scheme (PLBRS).

Here, we consider six nodes in Fig.1 A-B-C-D be the primary route, if link B-C fails then the backup route is provided through B-E-F-C. For backup route the FS is
reserved in advance. The recovery setup message is generated at the link source node immediately after the detection of the failure of link at link source node to the receiving link node.

And evaluate the performance of different network parameters in MATLAB 2015 on i5, 7400 intel core processor with 3GB system and 8 GB RAM by randomly generated source and destination demands/request.

III. RESULTS AND DISCUSSION

Here, we consider three different topologies as given in Fig. 2 (a), (b) and in (c) that is COST 239, ARPANET and NSFNET.

Fig. 2 (a) COST 239 (11Nodes, 26 Links) (b) ARPANET (20 node, 32 links) (c) NSFNET (14 Nodes, 22 links).

Fig. 3 (a) Shows Bandwidth Blocking Probability vs. Number of requests for COST 239 and (b) represents the Bandwidth blocking probability vs. Number of requests for ARPANET (c) shows the Bandwidth blocking probability vs. Number of requests for NSFNET.
Fig. 4 (a) Shows Network Capacity Utilization vs. Number of requests for COST 239 and (b) represents the Network capacity utilization vs. Number of requests for ARPANET (c) shows the Network capacity utilization vs. Number of requests for NSFNET.

A. Bandwidth Blocking Probability (BBP)

The BBP is the number of bandwidth demand rejected to the total bandwidth demanded [17]. It has been noticed from Fig. 3(a), (b) and (c) the BBP of our proposed strategy is very less as compared to the SLP. Hence, in our PLBRS scheme the large number of source-destination requests accepted as compared to SLP. The mean BBP for our proposed strategy DLP, SLP and PLBRS are 0.18, 0.1078, and 0.1078 respectively for COST239 are 0.56, 0.18, and 0.18 for ARPANET and for NSFNET are 0.49, 0.31, and 0.31 for DLP, SLP and for PLBRS respectively. The rejections of the connection request in DLP and SLP are more than our PLBRS scheme. The mean values for different parameters are provided above in Table 1.

Fig. 5 (a) Shows Recovery Time vs. Number of Requests for COST 239 and (b) represents the Recovery Time vs. Number of requests for ARPANET (c) shows the Recovery Time vs. Number of requests for NSFNET.

<table>
<thead>
<tr>
<th>Network Parameters</th>
<th>COST239</th>
<th>ARPANET</th>
<th>NSFNET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery Time (s)</td>
<td>DLP</td>
<td>SLP</td>
<td>PLBRS</td>
</tr>
<tr>
<td>BBP</td>
<td>0.18</td>
<td>0.1078</td>
<td>0.1078</td>
</tr>
<tr>
<td>VCUI</td>
<td>26.1</td>
<td>24.94</td>
<td>24.94</td>
</tr>
</tbody>
</table>
B. Network Capacity Utilization (NCU)
The network capacity utilization is defined as the total spectrum used to the total number of request accepted in the network. The average NCU for COST 239 is 24% and 26% for DLP, SLP and for PLBRS as given in Fig. 4 (a) and (b) & (c). The average NCU for ARPANET is 68%, 61% and 61% for DLP, SLP and for PLBRS respectively and for NSFNET are 26%, 33% and 33% for DLP, SLP and for PLBRS. If NCU [18] is more than 70% then slowdown will occur in-network traffic, if this remains for a long time than a long queue of traffic will occur in the optical network, which causes a stoppage in the traffic. In COST239 the traffic is less as compared to ARPANET and NSFNET.

C. Recovery Time
The recovery time, is the time from where the recovery process is started and the confirmation message received from the receiving end to the source. For fast recovery, a recovery time constraint is required to introduce. The Recovery time is shown in Fig. 5 (a) and (c) for all three topologies that is Cost239, ARPANET and for NSFNET in our PLBRS scheme is less than SLP and above than DLP as shown in Fig. 5 (a) for COST239 (b) for ARPANET and (c) for NSFNET. The average of RT for DLP, SLP and PLBRS for COST239 are 5.00, 6.11 and 5.82 and for ARPANET are 1.24, 2.78 and 1.82 and for NSFNET are 0.65, 0.85 and 0.85 for DLP, SLP and for PLBRS respectively.

IV. CONCLUSION
Here, we proposed link based recovery scheme for a failure in EON. Our proposed scheme shows the recovery time between SLP and DLP. We evaluate the network parameters like BBP, NCU and recovery time for three topologies viz. COST239, ARPANET and for NSFNET. Our proposed PLBRS strategy shows optimized performance when compared to other strategies. In the future, we proposed a recovery scheme for a multiple failure in EON.

Conflict of Interest: Nil

REFERENCES