ID - 47

FREQUENCY SPECTRUM ANALYSIS OF MIXED-LINE RATE IN FLEXIBLE OPTICAL NETWORKS

S. Suthaharan[1], P. Rukshani[1], and C. Vanuja[1]
[1]*Department of Physical Science, Vavuniya Campus of the University of Jaffna, Sri Lanka*

Introduction

Optical networking is a promising solution of Internet growth since it uses wavelength division multiplexing technique [1]. The ever increasing demand for bandwidth is posing new challenges for transport network providers. A feasible solution to meet such challenge is to use optical networks with the aid of WDM technology. WDM is a multiplexing technique of data transmission in which it divides the huge transmission bandwidth available ona fiber into several non-overlapping wavelength channels and enables data transmission over these channels simultaneously [2]. WDM is mostly used for optical fiber communications to transmit data in several channels with slightly different wavelengths. WDM uses a multiplexer at the transmitter and a demultiplexer at the receiver to join the several signals together and to split them apart respectively. The channels in WDM are typically using 50 GHz or 100 GHz rigid grid spectrum spacing as specified by the International Telecommunication Union (ITU) [3]. For instance, 50 GHz fixed grid space is capable to transmit 100 Gbps based transmission rate and commercialized [4].

In our research study, we have focused on shared protection method in WDM optical networks. A single fiber consists of 4.4 THz total spectrum width which can be divided into 88 channels each of 50 GHz fixed grid [5]. Flexible optical networks (or Elastic optical networks (EON)) have recently been introduced to use the frequency spectrum more efficiently [4]. 12.5 GHz fine granular frequency slots or flexible grids are used for setting up lightpaths instead of using 50 GHz or 100 GHz fixed grid spacing in flexible optical networks [6].

Optical fiber has a risk of failure in terms of fiber-cut which causes loss of huge amount of data and therefore, the communication services can be interrupted. In survivability, the path through which transmission is actively realized is called working path or primary path whereas the path reserved for recovery is called backup path or secondary path. Protection is one of the approaches in survivability of optical networks in which pre-assigned backup paths are setup or reserved at the time of admitting a connection which are link-disjoint with their corresponding primary paths. Shared protection is one of the traditional protection methods in which backup resources can be shared by the backup paths or secondary paths.

Spectrum efficiency is the optimized use of spectrum so that the maximum amount of data can be transmitted with the fewest transmission errors. Spectrum efficiency can be computed by dividing the total traffic data rate by the total spectrum used in a particular network. The total traffic data rate can be computed by multiplying the data rate by the number of connections. The total spectrum will be the multiplication of the frequency used for a single wavelength and the total number of wavelengths used in a network [7].

To the best of our knowledge, this is the first paper that is investigating variation of the spectrum efficiency of traditional shared protection and flexible optical networks using mixed-line rate(MLR) in various scenarios. Our findings are as follows. The spectrum efficiency of MLR is significantly varied, when applying traditional shared protection in EON. Unlike spectrum efficiency of MLR in dedicated protection, spectrum efficiency of MLR in shared protection method is considerably higher. Finally, spectrum efficiency in MLR using EON is significantly varied when compared to spectrum efficiency in MLR using WDM.

Methodology

The traditional shared protection in WDM usingflexible optical networks is illustrated in Figure 1, with a network topology of six network nodes and seven network links. Solid arrows denote working (W) path and dashed arrows denote secondary (S) paths. Working path W1 and its corresponding secondary path S1 are shown with their wavelength w1 for WDM and frequency slots f1. (Note that, working path and its secondary path can also use different frequency slots).

Suppose that a link failure, say, failure on A-B, configuration is required as S1 and S2 are sharing link C-D. (Note that W1 and S1 are link-disjoint). Therefore, after the proper configuration at network nodes C and D, backup traffic is rerouted.In Figure 1, a working path W1 (A->B) and W2 (E->F) are configured with frequency slotsf1 and f1 respectively at the time of connection establishment. In addition to that, secondary path S1 for working path W1 and secondary path S2 for working path W2 are reserved on link C->D with frequency slotsf1 and f1 respectively (note that, working path and its secondary path can also use different frequency slots). In case of component failure on link A->B, firstly, configuration at nodes A, C, D, and C will be done and traffic is rerouted through S1. Similarly, suppose that the failure on link E->F, configuration at nodes E, C, D, and F will be performed prior to rerouting the traffic through S2. This is because resources are shared by secondary paths S1 and S2 on link C->D. In thisscenario, the number of working path is limited to as one path as shortest path for working link, that is one hop from A->B and E->F. This is because to regulate the total spectrum used by the working path. However, three links that are A->C, C->D and D->B used for secondary path S1 and E->C,C->D, and D->F used for secondary path S2. Out of the three links, link C->D is shared by S1 and S2.Therefore, a single wavelength carries a higher data rate than a single frequency slot carries. For instance, 100Gbps data rate can be accommodated in a single wavelength, whereas, three frequency slotsare needed to accommodate the same data rate. Therefore, when considering MLR in both wavelengths and frequency slots vary from SLR which has the unique data rate throughout the entire connections establishment.

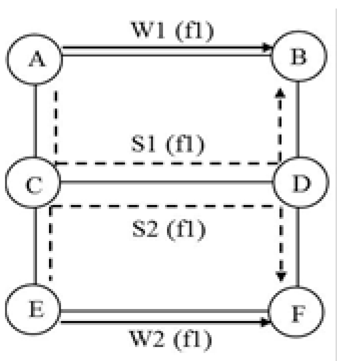

Figure 1. A scenario of traditional shared protection using flexible optical networks.

Results and Discussion

We simulate the traditional shared protection approach in flexible optical networks. To perform the experiment, we use NSFNET (14 nodes and 21 bidirectional links). We consider 352 frequency slots each of which consists of 12.5 GHz spacing. Various data rates such as 100Gbps, 400 Gbps and 1 Tbps are considered in both mixed-line rate and single-line rate with their appropriate bandwidths and follow the uniform distribution. Request arrival process followsPoisson distribution and holding time of requests follow exponential distribution with unit mean. Traffic requests arrive in dynamic network environment.

In this study, we consider shared protection in EON particularly, for MLR. This is because to measure the spectrum efficiency caused by both MLR and SLR in various scenarios. We select the Traffic bit rate ranges from 20 Tbps to 100 Tbps for all comparisons that are used to calculate spectrum efficiency. Such that they provide approximately the same spectrum efficiency (range). This helps us to find and compare the relative impact of the performance on different scenarios. Our performance study is considered in twofold. Firstly, we compare the MLR with different SLR for both shared anddedicated protection in EON, secondly, we compare the performance of the MLR for both shared and dedicated protection in WDM which are explained below.

Firstly, in Figure 2, MLR of shared protection in EON and each of the SLR in shared protection in EON are compared. In this comparison, MLR comparatively outperforms the SLR, particularly, of 100 Gbps and 400 Gbps whereas 1 Tbps performs the higher efficiency than the MLR. In addition, the comparison of MLR of shared protection in EON and MLR of dedicated protection in EON are performed as shown in Figure 3. This comparison is made because of identifying the performance of MLR in both dedicated and shared protection methods. In this comparison, it is obviously noticed that the spectrum efficiency is comparatively higher in shared protection method.

Secondly, we compare the MLR of shared protection in EON and MLR of shared protection in WDM as shown in Figure 4. This is because to compare the variation occurred between the EN and the WDM. In this comparison, MLR of shared protection in EON significantly has the higher spectrum efficiency than the MLR of shared protection in WDM. This can be observed due to the high spectral consumption occurred in WDM.

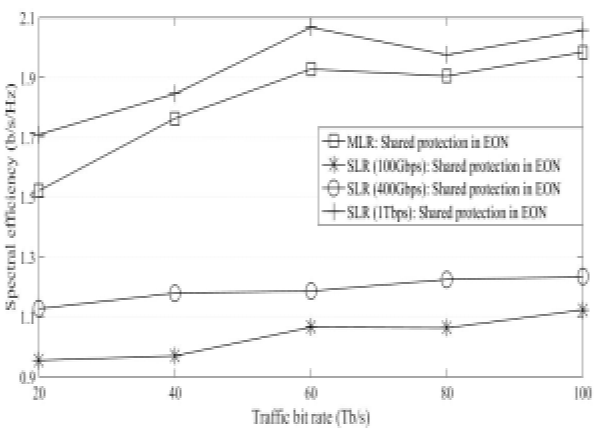

Figure 2. Shared EON (MLR vs. SLR).

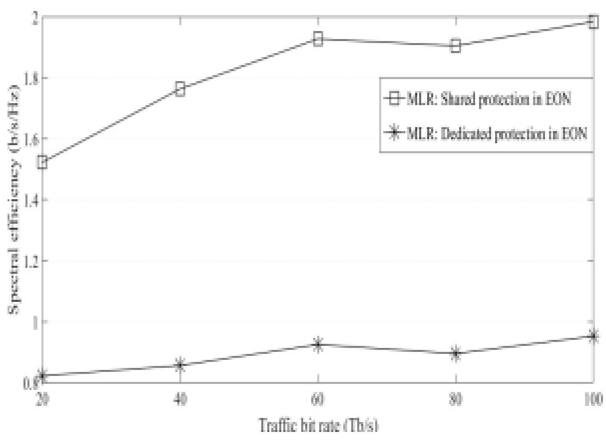

Figure 3. MLR EON (Shared vs. Dedicated).

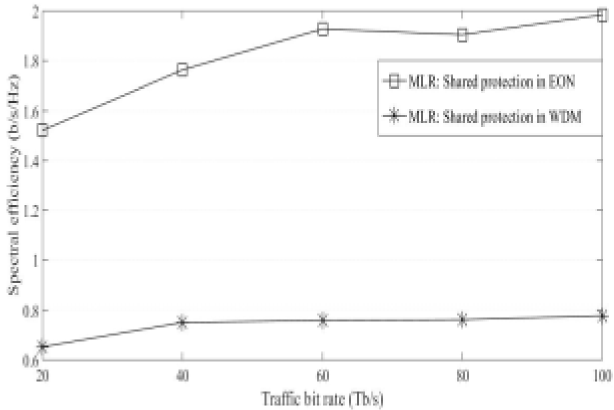

Figure 4. Shared MLR (EON vs. WDM).

In the performance study, we observe that, the spectrum efficiency in MLR is significantly considerable, when traditional shared protection in EON is applied. Further, spectrum efficiency in MLR outperforms in shared protection method, when compared it with dedicated protection method. Even though, spectrum efficiency in MLR using EON comparatively performs significant variation when compared to spectrum efficiency in MLR using WDM.

Conclusion

In this paper, we addressed the variation of spectrum efficiency for shared protection in flexible optical networks. We investigated the performance of various mixed-line rate (MLR) andTraffic bit rate in various scenarios. Our findings are as follows. Firstly, we observed that, the spectrum efficiency in MLR is significantly considerable while comparing the spectral efficiency of MLR for shared protection in EON and SLR for shared protection in EON. Secondly, the spectrum efficiency in MLR outperforms in shared protection method when MLRfor shared protection in EON and MLR dedicated protection in EON are compared. when compared it with dedicated protection method. Finally, the performance of MLR using EON is even higher when compared with MLR for shared protection in WDM.

Reference

[1] A. A. M. Saleh and J. M. Simmons, Technology and architecture to enable the explosive growth of the Internet, IEEE Communications Magazine,2011, 49(1), 126-132.
[2] A. K. Dutta, N. K. Dutta, and M. Fujiwara, WDM Technologies: Optical Networks, Elsevier Academic Press, 2004.
[3] ITU-T Recommendation G.694.1, Spectral grids for WDM applications: DWDM frequency grid. 2012.
[4] O. Gerstel et al., Elastic Optical Networking: A New Dawn for the Optical Layer?, IEEE Communications Magazine, 2012, 50(2), s12-s20.
[5] M. Liu, M. Tornatore and B. Mukherjee, Survivable Traffic grooming in Elastic Optical Networks-Shared Protection, Journal of Lightwave Technology, 2013, 31(6), 903-909.
[6] K. Christodoulopoulos, I. Tomkos, and E. Varvarigos, Elastic bandwidth allocation in flexible ofdm-based optical networks, Journal of Lightwave Technology, 2011, 29(9), 1354-1366.
[7] M. Jinno, et al., Spectrum-Efficient and Scalable Elastic Optical Path Network: Architecture, Benefits, and Enabling Technologies, IEEE Communications Magazine, 2009, 47(2), 66-73.

Environmental Science