Zone-based Head-Tail Spectrum Allocation in Elastic Optical Network

Varsha Lohani
Electrical Engineering
Indian Institute of Technology Kanpur
Kanpur, India
lohani.varsha7@gmail.com

Anjali Sharma
Electrical Engineering
Indian Institute of Technology Kanpur
Kanpur, India
anjalienix05@gmail.com

Yatindra Nath Singh
Electrical Engineering
Indian Institute of Technology Kanpur
Kanpur, India
ynsingh@iitk.ac.in

***Abstract*—Whenever a connection request arrives, it has to satisfy continuity and contiguity constraint for Routing and Spectrum Assignment. It is the crucial issue in Elastic Optical Network. Consequently, fragmentation in the optical spectrum occurs. Various de-fragmentation methods have been used in the past to resolve this problem. The de-fragmentation methods reduce the fragmentation problem, but these methods are pretty expensive and disrupt the existent traffic. In this paper, the Spectrum Allocation problem is taken into consideration because if the spectrum assignment is done correctly, fragmentation can be minimized.**

***Index Terms*—Elastic optical network, Routing, Modulation and Spectrum Allocation, Fragmentation, De-fragmentation, Blocking Probability.**

I. Introduction

The demand for high bandwidth for communication is increasing exponentially. One way to handle such demand is by using optical fiber as a medium because its bandwidth is very high (around few *THz*). Wavelength Division Multiplexing based optical networks use such high bandwidth to accommodate lightpath requests [1]. But according to International Telecommunication Union - Telecommunication Standardization Sector (ITU-T)[2] such a network has fixed wavelength grids, i.e., *50GHz or 100GHz* spaced channels which leads to inefficient use of bandwidth.

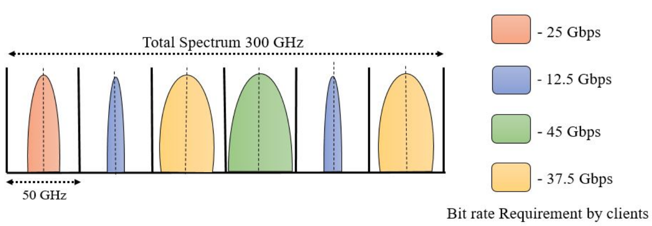

Fig. 1. Fixed grid network

Jinno *et al.,* [3] proposed a novel architecture to tackle the above problem using flexible grid technology and a network incorporating it, is termed as Elastic Optical Network (EON). EON uses Optical-Orthogonal Frequency Division Multiplexing (O-OFDM) technology which provides flexibility in the optical spectrum and can accommodate sub-channels as well as super-channels [4]. According to ITU-T G.694.1, the whole optical spectrum divided into slots of sizes *6.25GHz, 12.5GHz, 25GHz, etc* [2].

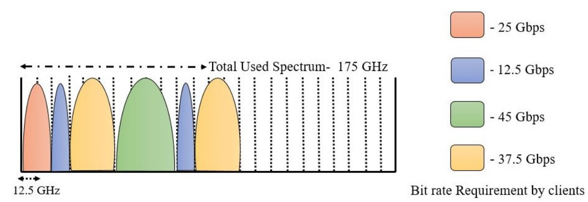

Fig. 2. Flexible grid network

Whenever a request arrives at a node for connection, a route for that request is allocated in such a manner that from end-to-end path resources must be available, this problem is called Routing and Spectrum Allocation (RSA).

The rest of the paper is composed as follows. EON's characteristics are discussed in section II. In section III, Spectrum assignment literature survey is done. Routing and Spectrum Allocation in EON is explained in section IV. In section V, problem formulation and expected results for the proposal are discussed.

II. Elastic Optical Network

The elastic optical network is an advancement over WDM based network. It promises to accommodate maximum connections efficiently [5]. Few properties of EON are sub-wavelength accommodation, super-wavelength accommodation, and mixed rate accommodation as shown in Fig.3. In EON, the whole spectrum is divided into slots (in this paper *12.5GHz*) and multiple slots are allocated to connection requests using RSA methods.

III. Related Work

Rosa *et al.,* [7] proposed a spectrum allocation policy which is exact-fit, and compared with the first-fit policy. In first-fit, the available slots with lowest index are allocated to the connection requests and in the exact-fit the size of required and assigned slots must be same.

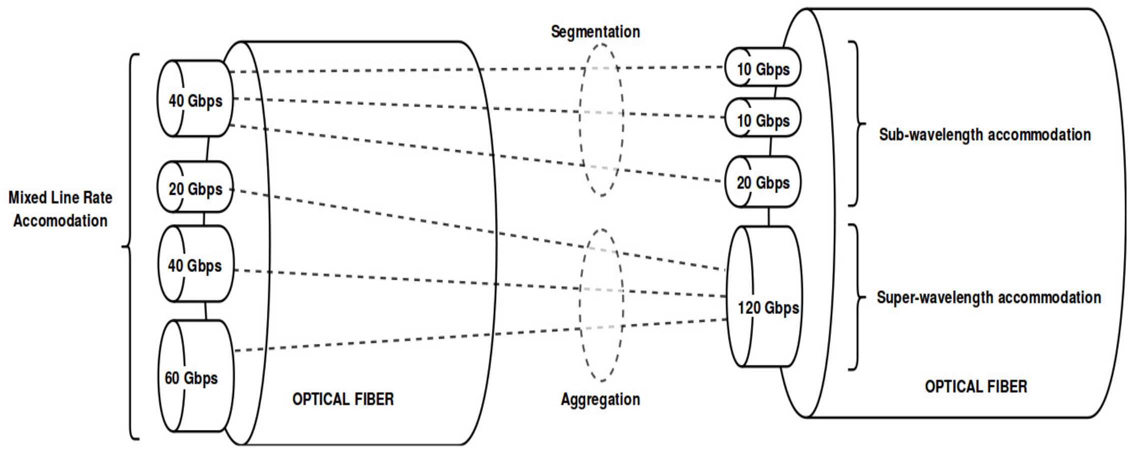

Fig. 3. Properties of EON [6]

Fadini *et al.,* [8] gaves first-last fit policy which allocates odd slots to the available slots with lowest index and even slots to the available slots with highest index. Improvising on this method, in the current paper, we are proposing a head-tail fit policy.
Some other possible policies are last fit, random fit, least used and most used. They are explained in [9].
Tessinari *et al.,* [10] proposed a new method for spectrum allocation which we are building in our paper. It is Zone based spectrum as explained in section V.

IV. Routing and Spectrum Assignment in Elastic Optical Network

Routing and Spectrum Assignment in Elastic Optical Network can be solved as a whole problem or divided into two separate sub-problems, i.e., routing of lightpath request and allocation of spectrum slots to that path. The flowchart shows the process of routing and slots allocation to a lightpath request *LR(s, d, n)*(where *s* is the source node, *d* is the destination node, and *n* is the number of slots required by the request) [11].

In this paper, we are considering the second case. For RSA, following constraints must be satisfied:
(1) Spectrum non-overlapping: slots must not be overlapping over the whole spectrum.
(2) Spectrum contiguity: allocated slots must be adjacent as shown in fig.5.
(3) Spectrum continuity: adjoining slots must have the same index all along end-to-end path as shown in fig.5.

The above constraints give rise to the problem of fragmentation in the optical spectrum. Fig.5 shows that uneven distribution of slots to the connection requests results in accommodation of the minimum number of the request. As a consequence of this, blocking probability in the network increases. Fragmentation problem can be resolved by proper spectrum allocation.
In this paper, our objective is to assign slots in such a way

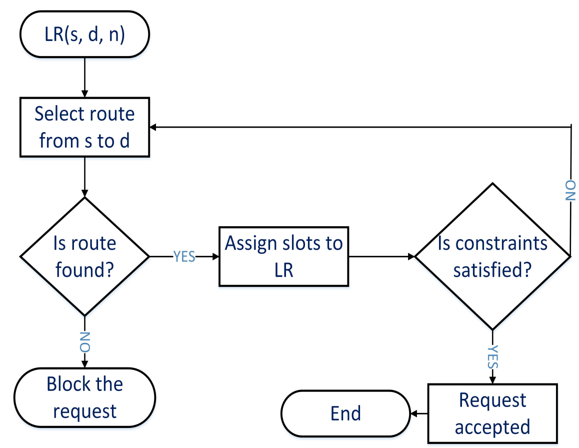

Fig. 4. RSA process

that there is mitigation of fragmentation. We are considering only the spectrum allocation problem.

V. Problem Formulation and Results

An optical network represented by *G(N, L, n)* where *N* is the set of nodes, *L* is the set of links and *n* is the number of frequency slots (FS) carried by an optical fiber. Let a lightpath request *LR(s, d, G)* (where *s* is the source node, *d* is the destination node, and *G* is the required Gbps by request) arrives at a node, we need to provide a path from *s* to *d* using a routing algorithm. Next step is to allocate resources to the connection.
For spectrum allocation, the number of slots assigned in the presence of guard band(=1) is given by:

$$No.\ of\ FS = \frac{Required\ Bandwidth}{FS\ Width \times modulationlevel} + 1 \qquad (1)$$

In this paper, the zone-based method with the heading and

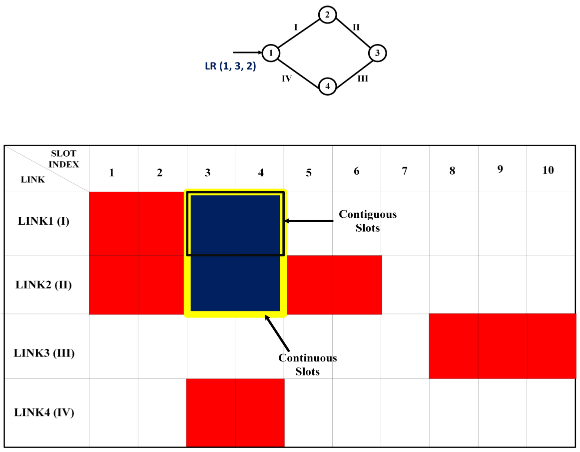

Fig. 5. Ligthpath request while satisfying constraints

tailing index of the spectrum for spectrum allocation is described.

In [10], the zone-based method is proposed for the spectrum allocation in which the whole optical spectrum divided into *"Zones"*. Each zone has fixed numbers of slots. For example, if there are bit rate requirements of *50 Gbps, 150 Gbps, 400Gbps and 1 Tbps* and considering *16-QAM* modulation format, then using *Eq. 1* number of slots can be calculated. Depending upon the number of slots partitions are created. As from the paper, we can conclude that the blocking performance of Zone-based method is far better than the spectrum sharing and spectrum partitioning.

Now the question arises how to allocate zones to the

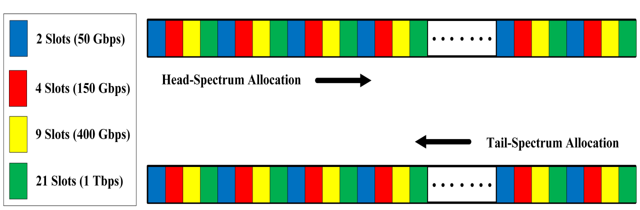

Fig. 6. Zone based Head Tail Spectrum Allocation

connection request? For this, we have improved the above algorithm by incorporating head-tail fit into the zone-based method. In this, we are allocating low data rate requests from the head and then tail index alternately and high data rate requests from the tail and then head index alternately, as explained in Algorithm 1. For example, if first connection require *50 Gbps* then allocate it from the head of the optical spectrum, and after sometime again *50 Gbps* is required, at that time, slots assignment is done from tail end. This will reduces the delay due to spectrum allocation and can accommodate maximum number of connections.

Analytically, the results must be better as compared to [10]. As in this method, the hop traversal for spectrum assignment

Algorithm 1 : Zone-based Head-Tail Spectrum Allocation

s is the required number of slots;
n is the contiguous available slots for each Gbps;
STEP 1: Partition the optical spectrum into zones;
STEP 2: Arrange the zones into ascending order such that smallest zone falls at first index and highest zone falls at last index;
STEP 3: Partition the zones into two groups where group 1 consists of lower value zones and group 2 contains higher value zones;
STEP 4: Allocation of zones to request;
if s is within group 1 **then**
  allocate the slots from the head of the spectrum;
else
  allocate the slots from the tail of the spectrum;
end if
if s is same as in step 4 and within group 1 **then**
  allocate the slots from the tail of the spectrum;
else
  allocate the slots from the head of the spectrum;
end if
STEP 5: if zones are not available block the request;

is reduced. For worst case scenario, the complexity is shown in Table 1, where *n* is the total number of slots.

Spectrum Allocation Policy	Time Complexity
First Fit	*O(n)*
Last Fit	*O(n)*
Exact Fit	*O(nlogn)*
First-Last Fit	*O(n)*
Zone based Head Tail Fit	*O(n)*

TABLE I
TIME COMPLEXITY FOR DIFFERENT SPECTRUM ALLOCATION POLICY

VI. CONCLUSIONS

Elastic optical network is the successor of WDM based network. It allocates resources to the connection requests efficiently. Due to additional constraints for RSA in EON, there are chances of fragmentation. To reduce this problem, we used the Zone-based spectrum allocation policy and improvised it by adding Head-Tail fit while allocating the slots. Since it is a proposal which is expected to reduce blocking probability and we are giving what is expected as a result.

REFERENCES

[1] B. Mukherjee , "WDM Optical Communication Networks: Progress and Challenges," *IEEE Journal on selected areas in Communications*, vol. 18, no. 10, pp. 1810-1824, Oct. 2000.
[2] ITU-T G.694.1, "Spectral grids for WDM applications: DWDM frequency grid," Feb. 2012.
[3] M. Jinno *et al.*, "Spectrum-efficient and scalable elastic optical path network: Architecture, benefits and enabling technologies," *IEEE Communications Magazine*, vol.47, no. 11, pp.66-73, Nov. 2009.
[4] O. Gerstel *et al.*, "Elastic optical networking: A new dawn for the optical layer?," *IEEE Commun. Mag.*, vol. 50, no. 2, pp. 12-20, Feb. 2012.
[5] V. Lohani, *et al.*, "Migration to Next Generation Elastic Optical Networks," *ICEIT MCNC 2017*, Delhi, 16-17 Feb. 2017, pp.137-141.
[6] V. Lohani, *et al.*, "Routing, Modulation and Spectrum Assignment using an AI based Algorithm," *COMSNETS-2019*, 7 - 11 Jan. 2019.

[7] A. Rosa *et al.*, “Spectrum allocation policy modeling for elastic optical networks,” *in Proc. 9th Int. Conf. HONET*, 2012, pp. 242–246.
[8] W. Fadini *et al.*, “A subcarrier-slot partition scheme for wavelength assignment in elastic optical networks,” *in Proc. IEEE Int. Conf. HPSR*, 2014, pp. 7–12.
[9] B.C. Chatterjee *et al.*, ”Routing and Spectrum Allocation in Elastic Optical Networks: A Tutorial ,” *IEEE communication surveys and tutorials*, vol. 17, no. 3, third quarter 2015.
[10] Rodrigo S Tessinar *et al.* ”Zone Based Spectrum Assignment in Elastic Optical Networks: A Fairness Approach,” *Opto-Electronics and Communications Conference* , Shanghai, China, 2015.
[11] Jinno *et al.*, ”Distance-Adaptive Spectrum Resource Allocation in Spectrum- Sliced Elastic Optical Path Network,” *IEEE Communications Magazine*, vol. 48, no. 8, pp. 138-145, Aug. 2010.