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Improving Spectrum Utilization in Elastic Optical Networks for Multicast Traffic Demands

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Abstract: Elastic optical networks (EONs) have a scalable and flexible mini-grid architecture compared to the conventional fixed-grid wavelength division multiplexing optical networks. In EONs, there is scope to optimize optical resources. In this paper, the primary target is to increase spectrum utilization efficiency for traffic demands. The approach presented here is a grooming, routing and spectrum assignment technique for multicast traffic demands in elastic optical networks for static type of traffic demands. The simulation results show better spectrum utilization.

Keywords: elastic optical network, multicast, routing, spectrum assignment, static.

I. INTRODUCTION

Elastic optical network is one of the emerging technologies that are being accepted by many researchers to meet the ever-increasing bandwidth demand of Internet traffic. Elastic optical network (EON) has replaced the conventional wavelength division multiplexing optical networks as EON has flexible grid architecture and it can provide flexible bandwidth allocation for different traffic demands. EON is based on the SLICE architecture and it can provide bandwidth to each traffic demand just as much as it requires. Following the ITU-T standard scheme, each spectrum frequency slot has a size of 6.25GHz/12.5 GHz/25 GHz. The underlying modulation technique followed by EON is the Orthogonal Frequency Division Multiplexing Technique (OFDM) where multiple subcarriers can simultaneously carry data without interfering with each other.

The problem of routing and spectrum assignment in EON is the problem of selecting a suitable path for traversing data from its source to its intended destination(s). The problem of spectrum allocation is the process of assigning spectrum to each traffic demand by following some policies so that the data traverse through the optical fiber by modulating at some spectrum frequency slots. The integration of routing and spectrum assignment problem is the well-known RSA problem which must maintain the following spectral constraints: spectrum continuity, spectrum contiguity and spectrum non-overlapping constraints. The spectrum continuity constraint ensures that all the links of a path should be assigned same range of spectrum. The spectrum contiguity constraints ensure that the frequency slots assigned to any link should be adjacent or contiguous to each other in the frequency domain. The spectrum non-overlapping constraint ensures that a frequency slot should not be assigned to more than one traffic demand. In this paper, a grooming, routing and spectrum assignment approach is applied to static multicast traffic demands. The objective of this work is to increase spectrum utilization efficiency of traffic demands.

II. RELATED WORK

The authors in [1], proposed an approach of optical traffic grooming that could groom at the optical layer in elastic optical networks and it eliminates the need of optical-electrical-optical conversions at intermediate nodes. Routing and spectrum allocation approaches are studied in this article, the equipment requirements and ILP formulation to solve RSA problem are also discussed here. The analysis of the heuristic results show that there is significant amount of transmitter saving and spectrum wastage is also reduced. A dynamic traffic aggregating of traffic demands with same source into a single-transmitter is proposed in [2]. The simulation results reflect significant savings of transmitters and better spectrum usage than non-grooming approaches.

In [3], the authors proposed a multipath routing approach integrated with traffic grooming in elastic optical networks. The traffic demands are split into smaller sized sub-traffic demands and transmitted separately to enable flexible spectrum allocation. Spectrum wastage due to guard band slots is mitigated and bandwidth-variable transmitter usage is also reduced due to grooming of traffic demands with same source and some common links. The simulation performances on the proposed approach reflect reduction in bandwidth blocking probability and increase in network throughput compared to existing single path traffic grooming approach and multipath non-grooming approach.

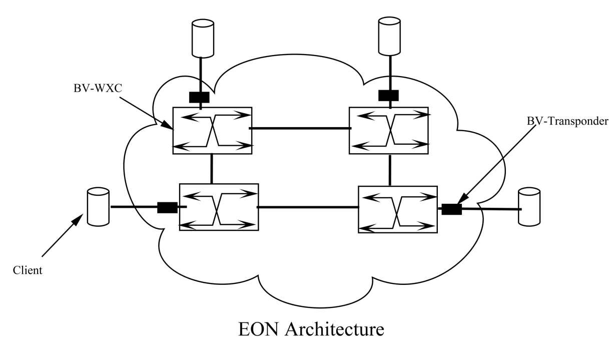

Figure 1: The Elastic Optical Architecture

III. THE MULTICAST TRAFFIC GROOMING ROUTING AND SPECTRUM ASSIGNMENT PROBLEM IN EON

The problem of traffic grooming routing and spectrum assignment in elastic optical networks is formulated in this section. The primary objective of this work is to increase the spectrum utilization in case of static traffic. The spectrum utilization is defined as the total number of slots that is being utilized in the network.

The grooming of traffic demands along with shortest path routing and firs-fit spectrum assignment approach, proposed for static multicast traffic demands is presented in this section. If the incoming traffic demand has the same source with an existing traffic demand then their trees are compared to check for some common links, if there is a common link then the bandwidth demand is added in the common links, such that while allocating spectrum on that link no extra slot for guard band is required in between them. The algorithm 1 presents a heuristic approach to solve grooming, routing and spectrum assignment problem in case of static traffic demands (SGRSA).

Algorithm 1: Static Multicast Traffic Grooming Routing and Spectrum Assignment (SG-MRSA) in EON

Input: The physical network graph G (V, E) and multicast traffic demand (s, {D}, b)
Output: A solution for the static multicast traffic grooming, routing and spectrum assignment problem

1. Compute the shortest path tree for the traffic demand (using union of shortest paths found by Dijkstra's algo)
2. **if** *a traffic demand j has same source with an existing traffic* i **then**
3. **if** *i and j have common links in their respective trees* **then**
4. add $b_i + b_j$ on the common links
5. **else**
6. treat i and j as individual traffic demands
7. **end**
8. **end**
9. Check for spectrum continuity and contiguity constraints
10. **if** required number of slots are available **then**
11. assign spectrum in all the links of the shortest path multicast using First-Fit spectrum assignment strategy
12. **end**

V. RESULT DISCUSSION

The performance of the proposed heuristic for grooming routing and spectrum assignment approaches are evaluated on two standard network topologies the 14 nodes NSFNET network topology and 28 nodes US-Backbone network topology. The network topologies for NSFNET and US-BACKBONE are shown in the Figure 2 and Figure 3 respectively.

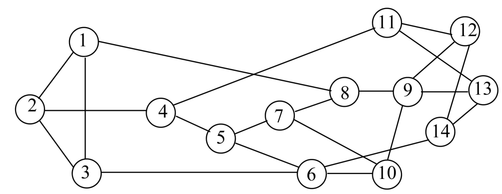

Figure 2: The 14 nodes NSFNET network topology

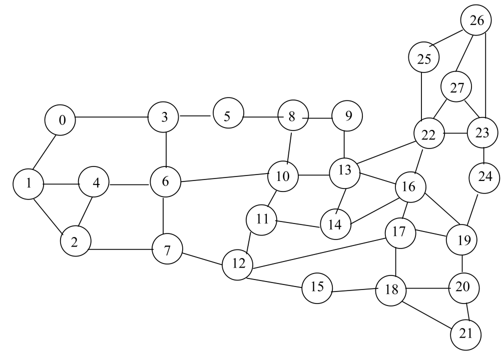

Figure 3: The 28 nodes US-BACKBONE network topology

The Figure 4 and Figure 5 illustrates the relationship between maximum slot index of spectrum slot allocated in the network with the number of traffic demands to be established in the NSFNET and US-BACKBONE networks respectively.

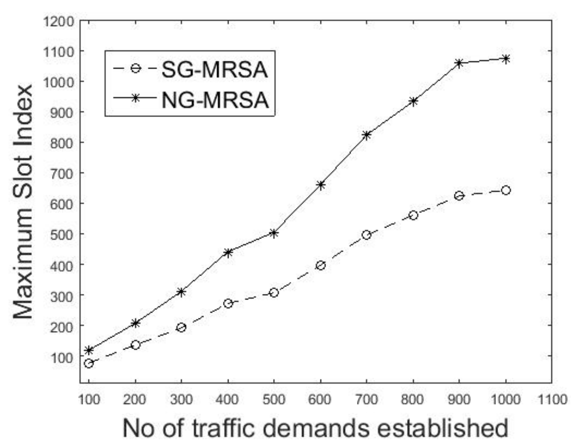

Figure 4: The relationship between maximum slot index of spectrum slot allocated in the network with the number of traffic demands to be established in NSFENT network.

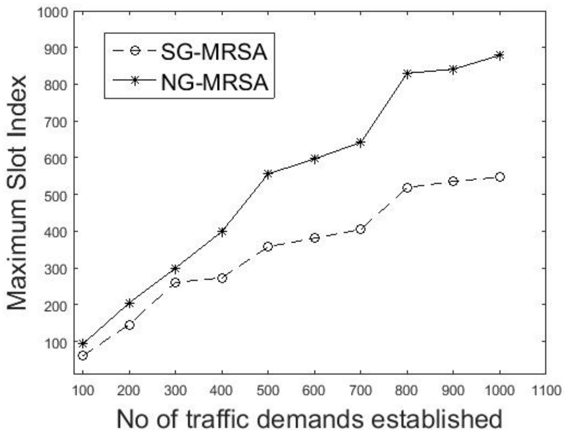

Figure 5: The relationship between maximum slot index of spectrum slot allocated in the network with the number of traffic demands to be established in US-BACKBONE network.

It is to be noted from the both the figures that the proposed SG-MRSA approach out-perform the existing non-grooming approach [4] (NG-MRSA) significantly for both 14 nodes small NSF network and 28 nodes big USBACKBONE network. To make the heuristics comparable we assume the traffic demands are static in both SG-MRSA and NG-MRSA. The SG-MRSA heuristic approach performs better than NG-MRSA approach because in SG-MRSA spectrum slots can be squeezed together without requirement of guard band slots in between groomed traffic demands. The total slots utilized in the network are counted with respect to the number of traffic demands to be established for both NSF network and US-BACKBONE networks.

In the Figure 6 and Figure 7, the performance of SG-MRSA is compared with that of NG-MRSA for NSFNET network topology and US-BACKBONE network respectively.

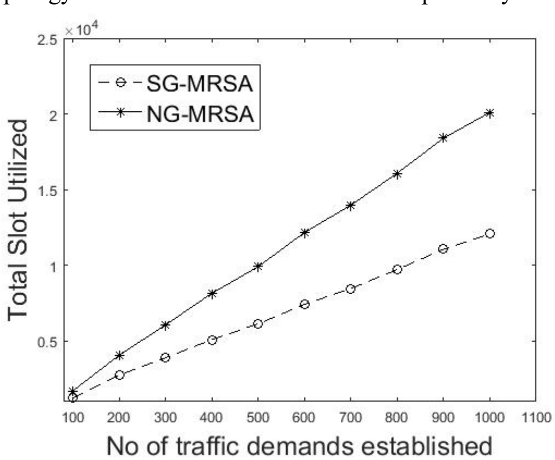

Figure 6: The relationship total spectrum slot allocated in the network with the number of traffic demands to be established in NSFENT network.

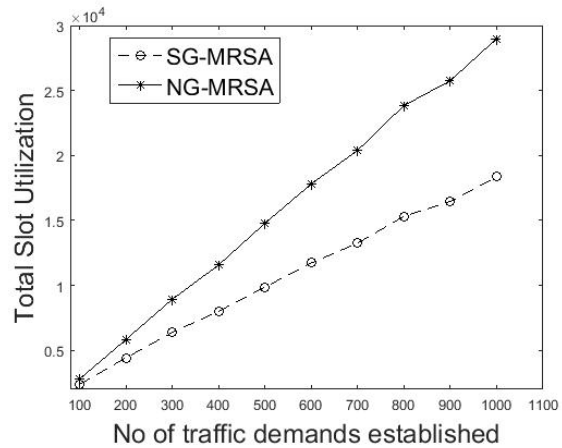

Figure 7: The relationship total spectrum slot allocated in the network with the number of traffic demands to be established in US-BACKBONE network.

The total spectrum slot utilization for SG-MRSA is less than NG-MRSA for both standard topologies. Groomed traffic demands do not require guard band slots in between so total spectrum slots required by SG-MRSA is less than NG-MRSA.

VI. Conclusion

Grooming multicast traffic demands before routing and spectrum assignment saves spectrum wastage because groomed traffic demands avoids guard band between traffic demands. The proposed approach SG-MRSA outperforms its non-grooming counter-part NG-MRSA for two standard network topologies concerning spectrum utilization.

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