Routing and Spectrum Allocation Heuristic for Sliced Elastic Optical Network System

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***Abstract*—We proposed a heuristic algorithm, Minimum Hops with Least Slots spectrum (MHLS), to solve the Routing and spectrum assignment problem in elastic optical networks. The proposed MHLS is implemented in conjunction with the transponder supporting slice-ability.**

Keywords*—*Elastic Optical Network, Off-line routing, SBVT

I. Introduction

During the last decades, extensive growth in the internet traffic of the core optical networks is observed [1]. Also, the nature of traffic is changing and becoming more dynamic and less predictable [2] mainly due to the implementations of bandwidth hungry and Internet of Things (IoT) applications. This has urged the request from the network operators to exploit the maximum residual capacity of the existing deployed network architecture. To better utilize the residual capacity of the existing infrastructure, the data transport layer needs to push to maximum capacity. The key enabler technology for optimal exploitation of data transport is Dense Wavelength Division Multiplexing (DWDM) transmission technology. The traditional fixed-grid DWDM based optical networks typically hold 50 GHz spectrum spacing systems as defined by International Telecommunication Union (ITU) standards. This non-granular distribution of the spectrum leads to inefficient scaling performance to cope with the growing internet traffic demand. This mismatch cause the inefficient utilization of spectrum and is expected to degrade the utilization performance with increasing data rates. To overcome this bottleneck, a more granular approach in the spectrum slicing is adopted and the fixed-grid systems are evolved towards flex-grid systems. An optical network based on flex-grid systems is equipped with adaptive transceivers and network elements (NE) that are capable to provide the flexibility according to the traffic demands. Such combination of adaptive transceivers and NE enables next-generation optical network known as Elastic Optical Network (EON), allowing services providers to tackle the continuous growth of traffic volume efficiently [3]. The flexibility in EONs is generally achieved by dividing the spectrum into flexible slots and allocating them by considering traffic demands [4]. With the evolution of DWDM towards EONs, along with the benefits of flexibility, some new challenges also arise. Most significant of them is the optimized management of the spectrum that is the Routing and Spectrum Assignment (RSA). RSA in EON is analogous to Routing and Wavelength Assignment (RWA) in DWDM. RSA is NP-hard problem [5] which is the tight coupling between RSA. In RSA, the primary target is to route the traffic over the spectrum in such a way that minimum resources are utilized to accommodate a specific traffic request. RWA considers the continuity constraint but in RSA, an additional constraint of contiguity of spectrum slots is also considered over the routing path.

In this paper, a novel heuristic algorithm, MHLS is proposed to solve the offline RSA problem in EONs. The proposed MHLS algorithm is implemented in conjunction with the Flex-Optical carrier source module (Flex-OCSM) SBVT as it provides better hardware and in-device utilization of resources [6]. The synergic use of MHLS and Flex-OCSM provide effective improvement in the spectrum utilization compared to existing benchmark algorithms. The proposed algorithm is run over the random network topology to validate its performance.

II. Proposed MHLS to Solve RSA

In this section, the proposed heuristic algorithm MHLS is comprehensively explained. For performance evaluation purposes, we are considering some traditional algorithm, naming them as benchmark algorithm. These algorithms are First Fit (FF), Most Sub-carrier First (MSF) MSF and Longest Path First (LPF). The MHLS heuristic is designed while considering two general key points. The first is the total number of Hops $\mathcal{H}$ and the second is the total number of slots FS for each traffic request in the network. In algorithm MHLS, the input parameter is $\mathcal{D}$, which represents the set of offline traffic demands that needed to be fulfilled. For each demand from the respective source to the destination, required traffic bit-rates in Gb/s is known. Well, the main function of the MHLS, is for each t request from $s \rightarrow d$ (Line 1), first calculates the optical reach (OR) for the respective s and d (Line 4). Then $\mathcal{H}$ is calculated (Line 5) using $Dijkstra - shortest - path$ algorithm and OR for given traffic request t. MHLS, find an appropriate modulation level M for the given traffic request with the help of OR and required bit-rates (Gb/s) (line 6) [7]. Transmission data rate $\mathcal{Z}$ is calculated after selecting M (Line 7). After the calculation of $OR, \mathcal{H}, M$ and $\mathcal{Z}$, slots FS calculation is performed (line 8). For a given s and d, FS are calculated as $FS_{s\rightarrow d} = \frac{t_{s\rightarrow d}}{\mathcal{Z}_{s\rightarrow d}}$. After calculating all these parameters, a new parameter is being introduced $\mathcal{N}_{\text{P}}$ (Line 9), which is the product of two parameters FS and $\mathcal{H}$. $\mathcal{N}_P$

Algorithm 1 Minimum Hops with Least Slot Spectrum

Require: *Total number of slots required by given* $s \to d$ *in network*
Ensure: *Physical Topology Graph* $\mathcal{G}$ *with* $\mathcal{V}$ *number of nodes*

1: Input $\mathcal{D}_{s\to d,t} \forall(s,d,t) \in \mathcal{V}$
2: Output Ψ
3: **for all** $\mathcal{D}_{s\to d,t} \in \mathcal{D}$ **do**
4: $OR_{s\to d}$ = calculate_optical_reach;
5: $\mathcal{H}_{s\to d}$ = calculate_hops($OR_{s\to d}$);
6: $M_{s\to d}$ = find_modulation_level ($OR_{s\to d}$);
7: $\mathcal{Z}_{s\to d}$ = find_data_rate ($M_{s\to d}$);
8: $FS_{s\to d}$ = Slot_calculation ($\mathcal{Z}_{s\to d}$);
9: $\mathcal{N}_{\mathrm{P}} = FS_{s\to d} \times \mathcal{H}_{s\to d}$;
10: **end for**
11: Sort the $\mathcal{N}_{\mathrm{P}}$ in the ascending order;
12: Ψ = sorted $\mathcal{N}_{\mathrm{P}}$;
13: **return** Ψ;

helps us find the total number of slots required by given s and d in the network. The same steps will be repeated for the entire traffic matrix $\mathcal{D}$ (line 3-9). After that, sorting is done in the ascending order of the $\mathcal{N}_{\mathrm{P}}$ (line 11) and save as output in matrix Ψ (line 11). The proposed algorithm MHLS is reported in Algo. 1, combines two parameters $\mathcal{H}$ and FS, then sort it in ascending order and then sequentially served to our design network. Results reflect that the proposed *MHLS* minimize Blocked Requests (BR), Blocked Traffic (BT) and Slots Used (SU) in the network as compared to other considered benchmark algorithm.

III. Results and Performance Analysis

This section compares simulation results in the proposed algorithm MHLS and benchmark algorithms (FF, MSF and LPF). The performance of the proposed MHLS is analyzed under dynamic network parameters such as varying number of nodes, node degree, optical reach and the nature of traffic (heterogeneous traffic and homogeneous traffic). This permits us to demonstrate which algorithm performs better in minimum blocked requests (BR), blocked traffic (BT) and spectrum-slots used (SU) in the network. The random physical network topology considered in this work have 20 nodes, 50 bi-directional links and a node degree of 2.5. In heterogeneous case, traffic is randomly distributed on links such that the network has an average traffic per node. First, traffic matrices are created by setting each traffic demand equal to a uniformly generated number in the range [0:1] and then scaling these values to achieve a given target average traffic per node. While for homogeneous traffic, traffic is uniformly distributed on the network's links. We consider 50 Gb/s, 100 Gb/s and 150 Gb/s of homogeneous traffic per node and 1000 Gb/s, 1500 Gb/s, 2000 Gb/s and 2500 Gb/s of heterogeneous traffic average per node. The detailed comparison of homogeneous traffic scenario is depicted in Fig. 1. Results in Fig. 1 reveal that the performance of MHLS is significantly better compared to other benchmark algorithms. At first, for 50 Gb/s traffic performance for algorithm MHLS: BT and BR is around 5.7% and 27.1% is SU, for FF: its BR and BT is 6.3%, and SU is 28.9% while for MSF: BR and BT is 9.20% and its SU is 32.30% and for LPF: BR and BT is 9.40%, and its SU is 33.20%. Lesser the value of BR, BT and SU, the better the algorithm's performance, which results in efficient utilization of network resources. As input traffic rate increases to 100 Gb/s and 150 Gb/s, the performance of MHLS enhances with $\approx$ 23%, 25% less BR, BT and with 12%, 14% less SU as compared to FF, MSF and LPF as shown in Fig. 1. For heterogeneous traffic profile, results are demonstrated in Fig. Fig. 2. The results in Fig. 2 depicts that at the traffic of 1000 Gb/s, MHLS accommodates

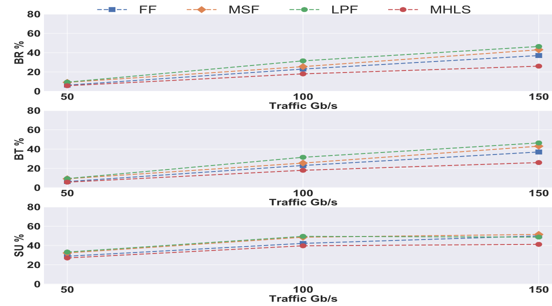

Fig. 1: Homogeneous traffic analysis

Fig. 2: Heterogeneous traffic analysis

$\approx$ 10%, 8% and 6% more traffic requests and saving 3%, 4%, and 6% spectrum compared to FF, MSF and LPF. As the traffic rate increases to 1500 Gb/s, 2000 Gb/s and 2500 Gb/s, the performance of MHLS outperform FF, MSF and LPF against all the considered performance parameters (BR, BT and SU).

Furthermore, as traffic rate increases, demand of spectrum resources increase which in turn demands for efficient ordering policies. Due conventional methods of traffic grooming and handling continuity/contiguity constraints in traditional algorithms, FF, MSF and LPF can not deliver efficiently compared to MHLS. MHLS offers better traffic grooming with a better ordering policy, enabling more traffic requests and saving more spectrum than other algorithms, even for large-sized real optical networks.

IV. Conclusion

In this paper, a novel heuristic algorithm MHLS is proposed in conjunction with the Flex-(OCSM) SBVT, which can accommodate the maximum number of traffic requests and minimize the total amount of block traffic and frequency Slot usage. To evaluate the performance of MHLS, simulations are conducted for a random generated topology with different traffic scenarios. Furthermore, for analysis purposes, a comparison is also presented with traditional algorithms.

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