A Holding-time-aware Routing and Spectrum Allocation Algorithm In Elastic Optical Network

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***Abstract*—we design a metric to measure the occupied holding time difference of frequency slots. With the metric, a routing and spectrum allocation algorithm in dynamic scenario is proposed to improve the network spectral utilization. Evaluation results show the proposed algorithm outperforms obviously in blocking probability.**

Keywords—holding time; routing and spectrum allocation ; dynamic scenario

I. INTRODUCTION

The demand of more bandwidth for diverse applications and bandwidth-intensive services has shown explosive growth in recent years. The elastic optical network （EON）has been proposed as a promising candidate to fulfill the demand. Although elastic optical network presents a lot of advantages, it also raises some new challenges for future optical networks. A fundamental issue in elastic networks relies on choosing a proper routing and necessary number of contiguous frequency slots (FSs) from end-to-end to accommodate the demands, which is referred to as the routing and spectrum assignment (RSA) issue. For the RSA problem, how to find work route and accomplish spectrum allocation optimally is a key issue. [1-3]

A lot of researches referring to RSA algorithms have been published. The most typical algorithm addressing RSA issue is to utilize K-shortest path (KSP) algorithm to route and employ first fit (FF) algorithm to allocate spectrum. The strategy is simple enough and performs well in static scenario. However, in dynamic scenario, the spectral utilization decreases since the FF algorithm keeps margin to improve in allocating spectrum dynamically. For spectrum allocation issue, the authors in [4] and [5] proposed two metrics for spectrum fragmentation respectively and two spectrum allocation algorithms separately to improve the spectral utilization. However the metrics proposed in these literatures mainly rely on the number of the probabilities to accommodate different slot-size demands in free contiguous FSs in a path to measure the capacity of the path. It ignores utilizing the relationship of occupied holding time of the FSs in allocating spectrum so as to fit for static scenario rather than dynamic scenario. Meanwhile, the reported algorithms ignore the capacity impact of paths interfered with the work route calculated by the routing algorithm. Although the algorithm proposed in [1] has considered the capacity impact of other paths interfered with the work route and gets acceptable performance, it also fits for static scenario rather than dynamic scenario.

In this paper, we propose a simple new metric to measure the occupied holding time difference of FSs in a link or a path firstly. With the new metric, two spectrum allocation methods are presented. Both of the methods employ KSP algorithm to find the available route as short as possible. Then one method tries to find the way which minimizes the occupied holding time difference of FSs to allocate spectrum as the baseline algorithm. The other method tries to find the way which minimizes the total sum of occupied holding time difference in all shortest paths which inferred with the work route, which tends to minimize the total capacity impact in the shortest paths so that they can accommodate more demands. Compared with the baseline algorithm and typical algorithm mentioned above, simulation results show the proposed algorithm outperforms in blocking probability, which implies the proposed algorithm achieves better spectral utilization.

II. ALGORITHM PRINCIPLE

A. Metric

Firstly, a metric is proposed to measure the occupied holding time difference in a link. In dynamic scenario, the relationship of occupied holding time among occupied FSs is important when determining how to allocate spectrum. For example, the occupied holding time difference between two adjacent FSs means the necessary waiting time to enable the two FSs all available after one of them has been free, which refers to the capacity of the two FSs to satisfy new demands. In order to accommodate more demands in the future, it is necessary to design a metric to measure the occupied holding time difference in a link. Therefore, we focus on the occupied holding time difference between adjacent two FSs. By getting the sum of the occupied holding time difference between each adjacent two FSs, the metric measures the performance of overall holding time difference in a link after allocating spectrum by certain way. We call the sum , the metric, as holding time difference, where the occupied holding time of a free FS is set as 0. Obviously, the holding time difference in a link is less means the spectrum allocation is more reasonable. The desired result of spectrum allocation in one link is shown as fig.1 (a), where the occupied FSs are arranged according to their occupied holding time with an increasing order.

$$T(link) = \sum_{i \in (SL-1)} \left|(time_{i+1} - time_i)\right| \qquad (1)$$

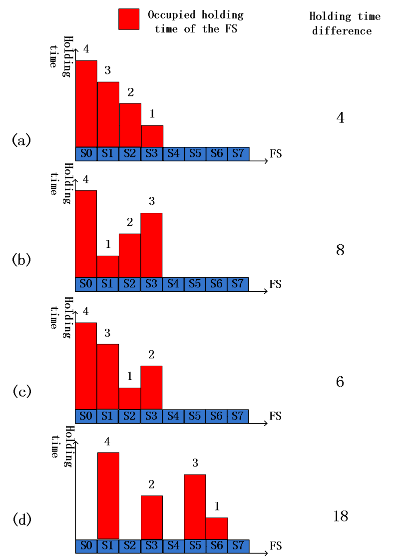

Figure1. Illustration for holding time deference in a link

We assume there are SL FSs in each link. In (1), $T(link)$ represents the holing time difference in *link*, $time_i$ represents the occupied holding time of the *ith* FS in *link* and $|time_{i+1} - time_i|$ represents the absolute value of occupied holding time difference between two adjacent FSs in *link*. Equation (1) is used to measure the holding time difference among all slots (free and occupied) in *link*. As shown in Fig.2, diverse sequence orders with the same number of occupied FSs can be identified well about their holding time differences. The Fig.1(a)-(d)show the specific calculation process illustration of the metric, which implies that if the occupied FSs are arranged with increasing order or decreasing order as possible the amount of metric will be reduced very much.

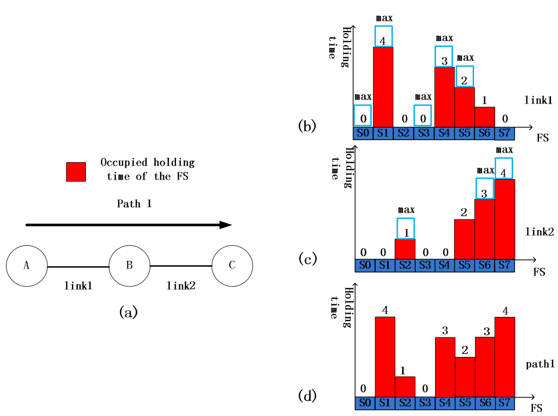

Fig.2. Illustration for holding time deference in a path

The metric can be promoted to describe the holding time difference in a path. As Fig.2 shown, for each FS in the path, we get the maximum occupied holding time among the FSs with the same index of all links in the path. Each blue rectangular marks the maximum occupied holding time of each FS in link1 or link2 over path1. Except getting the occupied holding time of each FS, the other calculation process of holding time difference in a path is the same as in a link.

B. *Proposed Algorithm*

For describing the proposed algorithm and baseline algorithm clearly, we firstly define several set as follow:

r is the route which is selected as work route for the current demand.

χ_r is the set including all shortest routes which interfere with route r, i.e. that have at least one common link with r.

φ_i is the state of the network after satisfying the current demand according to the *ith* possible way.

$T(\varphi_i, p)$ is the $T(p)$ calculated at state φ_i of path p.

$T(\varphi_i, \Sigma)$ is the sum of the $T(\varphi_i, p)$ of all paths in set χ_r at state φ_i. Eq. (2) indicates the relationship between $T(\varphi_i, p)$ and $T(\varphi_i, \Sigma)$.

$$T(\varphi_i, \Sigma) = \sum_{p \in \chi_r} T(\varphi_i, p) \qquad (2)$$

After selecting route r for a demand with KSP algorithm, we firstly calculate all of the possible ways to accommodate the demand in r. The different possible ways to accommodate a demand can cause different sums of holding time difference and capacity impact for paths in χ_r. In all possible ways, someone can minimize the sum of holding time difference of all paths in χ_r, and thus the way is the right one to allocate spectrum. The specific process is: (1) for each demand, the algorithm calculates all the possible ways to allocate spectrum in r; (2) the algorithm calculates $T(\varphi_i, \Sigma)$ for each possible way to allocate spectrum; (3) the algorithm selects the way which gets the minimum $T(\varphi_i, \Sigma)$ as the ultimate allocating method. The algorithm can achieve the total minimum holding time difference after allocating spectrum. Therefore, the proposed algorithm will be referred to as TMHTD (total minimum holding time difference).

C. *Baseline Algorithm*

After selecting route r for a demand with KSP algorithm, we calculate all of the possible ways to accommodate the demand in r. The different possible ways can cause different holding time difference in r. In all possible ways, someone can minimize the holding time difference in r, and thus the way is the right one to allocate spectrum. The specific process is: (1) for each demand, the algorithm calculates all the possible ways to allocate spectrum in r; (2) the algorithm calculates $T(\varphi_i, \gamma)$ for each possible way to allocate spectrum; (3) the algorithm selects the way which gets the minimum $T(\varphi_i, \gamma)$ as the ultimate allocating method. The algorithm can achieve the minimum holding time difference in work route after allocating spectrum. Therefore, the proposed algorithm will be referred to as MHTD (minimum holding time difference).

III. Evaluation Results

To compare the effectiveness of different algorithms addressing RSA issue, we design the simulation in dynamic scenario to observe the diverse performance of typical algorithm (KSP+FF), baseline algorithms (KSP+MHTD) and the proposed algorithm (KSP+TMHTD). Evaluation is carried out through simulations on NSFNET with 14-nodes and 21 unidirectional fiber links with 200 FSs, unidirectional path demands and uniform traffic demands between each node pair. The KSP algorithm is employed as the routing algorithm and a Poisson process is employed to generate the traffic demands with negative exponential holding time. The allowed number of FSs per demand within the range from 1 to 16 (step by 1) is randomly selected with equal probability. A demand is blocked if there are no enough available contiguous FSs in all first K shortest routes to accommodate the demand. We define the path (slot) blocking probability as the total number of blocked demands (slots) divided by the total number of demands(slots). Meanwhile, in order to observe details of spectral utilization, we also define the resource occupation rate as (3) shown, where R is the resource occupation rate, D is the set of all paths which have been set up to satisfy demands, $d \in D$, i is a link in d, n is the FS number needed to accommodate the demand, *time* is its holding time, N is the number of links in the network and T is the evaluation time.

$$R = \sum_{d \in D} \left(\sum_{i \in d} n_i \times time_i \right) / (SL \times N \times T) \qquad (3)$$

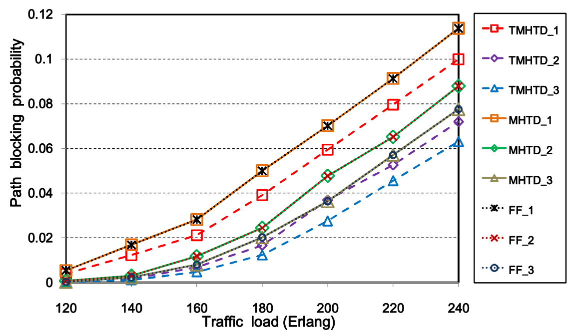

Fig.3. Path blocking probability in NSFNET

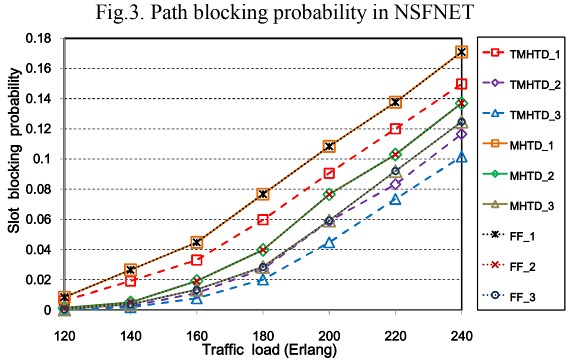

Fig.4. Slot blocking probability in NSFNET

In this evaluation, TMHTD, MHTD and FF are used to represent the proposed algorithm, baseline algorithm and typical algorithm. Meantime, we utilize the suffix to represent the value of the K in KSP. Fig.3 and Fig.4 show that in all values of the K the proposed algorithm outperforms obviously than baseline algorithm and typical algorithm in path (slot) blocking probability. It implies that the proposed algorithm is more suit for dynamic scenario than other ones. The overall consideration of holding time difference in all shortest paths interfered with the work route leads to more accommodating of new demands in the future. On the contrary, the baseline algorithm only considers the holding time difference in work route, which restrict the performance of the baseline algorithm. The baseline algorithm and typical algorithm get the same path (slot) blocking probability completely. It is because the two strategies will select the same routes and same ways to allocate spectrum in the scenario according to their calculating principle.

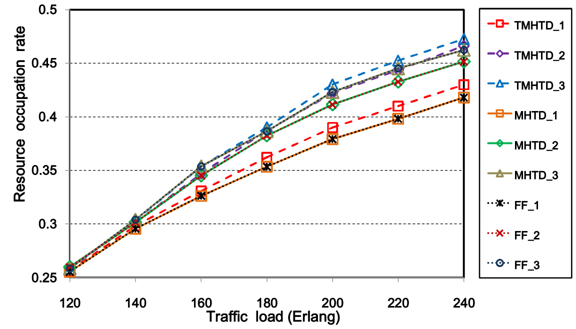

Fig.5. Resource occupation rate in NSFNET

Fig 5 shows when the arrival rate of demands is relative lower the resource occupation rate of proposed algorithm is almost same with other two algorithms meanwhile gets lower path (slot) blocking probability. When the arrival rate of demands is relative higher, the resource occupation rate of proposed algorithm is higher than other two algorithms resulting from having the capability to utilize more spectral resource to accommodate more demands. It implies the proposed algorithm improves the spectral utilization of the network.

IV. CONCLUSION

In this paper, a new simple metric is designed for measuring the occupied holding time difference of FSs. Furthermore, with the metric a novel RSA algorithm is proposed. The simulation results show that the proposed algorithm outperforms obviously than the current typical algorithms, such as KSP algorithm coordinating with FF algorithm, and the baseline algorithm in path (slot) blocking probability. It indicates that the proposed algorithm can help to improve the spectral utilization effectively.

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