Immediate Request vs Book Ahead Request Allocation in Elastic Optical Network

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***Abstract*—The elastic optical networks promise unparalleled capacity for future high bandwidth applications. The routing and spectrum assignment strategies are needed to provide the requested services effectively. The spectrum resources should be available for any new incoming request. However, sometimes the spectrum resources are not available at the time of arrival of a request, but it may be available after some time. A proper request provisioning and scheduling mechanism can impact the network performance significantly. In this paper, we address the resource provisioning in Elastic Optical Network, by considering the temporal aspects (start time and holding time). We compare the network performance in three different cases- an immediate request provisioning with and without waveband converter, and book-ahead/reservation-based request provisioning with fixed start time. We compare the performance by considering the average initial delay, blocking probability and spectrum efficiency. This study assumes that in book-ahead reservation all the requests are initial delay tolerant and have a fixed transmission duration.**

I. INTRODUCTION

The optical networks are known for there unbeatable high data -rate support. The WDM- Wavelength Division Multiplexed- technology proved to be very useful in increasing bandwidth utilization manifolds in optical networks. Thus it is used in the backbone network and is the enabling technology for the worldwide internet. The future bandwidth requirement is not going to be limited to a few Gbps, but it will be hundreds of Gbps or Tbps. Thus, it becomes essential to look out for new avenues, where it is possible to accommodate future large bandwidth requirements. Elastic optical networks (EONs) present an opportunity to efficiently utilize spectrum space by allocating channels of high granularity (12.5 GHz or 6.25 GHz). The main highlight of flexible-grid EON is its ability to use the spectrum resources efficiently so that there is no spectrum wastage, unlike fixed-grid WDM [1].

In [2] ,B.C. Chatterjee et al. have underlined some of the main features of EON, for example, mixed data rate accommodation, sub-wavelength and super-wavelength accommodation by using segmentation and aggregation respectively. In the tutorial, they uncover the intricacies of EON. They present the architecture and operating principles together with different aspects of routing, spectrum assignment, fragmentation, survivability, traffic grooming and quality of transmission. Routing and Spectrum Assignment (RSA) techniques help in finding the resources for incoming connection requests. Thus, the RSA techniques play a significant role in managing the connection requests and the spectrum effectively.

While performing the RSA, there arises a situation when resource allocation to a new connection request fails, even when resources are available. The reason is that the available resources are either not continuous or not contiguous, just scattered in the spectrum. It leads to inefficient usage of the spectrum resources. This event during routing and slot assignment is called fragmentation. There are some methods in literature to address this fragmentation issue. But, these methods are costly in terms of hardware requirements and computations. It is evident from the works in literature that the main cause of fragmentation is inefficient spectrum management and scheduling.

While considering the scheduling aspect of connection request provisioning, there are two models for traffic reservations, Immediate request reservation (IR) and Book-Ahead request reservation (BA). An IR request immediately needs the resources, and there is no specified holding time by the client. There has to be a tear-down request to relinquish the connection. A BA-request does not require to be served immediately and thus, supports applications where an initial delay is tolerable, e.g., data backup, grid computing, etc. For instance the applications that have a specific start time and holding time, and need to have guaranteed service, e.g., video conferencing and live broadcast [3].

A. *Organization*

In this paper, we discuss the book-ahead mechanism together with RSA and calling it RS-TA- Routing and spectrum-time allocation. In section-II we discuss related work in WDM based conventional network. In section III, we discuss RS-TA with book-ahead/ AR mechanism and its pre-requisites. We also discuss the algorithm to accommodate requests with the book-ahead mechanism and continuity-contiguity constraint. Section IV presents the comparison between immediate request allocation- with and without waveband convertor, and book-ahead request allocation. In section V, we put together our observations to conclude this work and present insights for future works.

II. Related Work

In [4], an extensive survey of advance reservation services in WDM optical network has been presented. They have covered all the aspects involved in designing such a network like type of network architectures and implementation, types of advance reservations, type of traffic (static and dynamic) based advance reservation etc. The Book-Ahead reservation mechanism has been studied in WDM- based network, to provide an effective RWA solution. In [5], authors have discussed the coexistence of advance and immediate reservation in a system. There are similar related works which use high spectral efficiency of EON together with optimized scheduling procedure.In [6], Chen *et.al*, formulated an integer linear programming for optimization of static scheduling using advance-reservation in spectrum and time domain. They also proposed two sub-optimal algorithms- having different request ordering strategies, namely smallest arrival time first and minimum bandwidth requirement first.

III. BOOK-AHEAD REQUEST (BAR) PROVISIONING

The RSA algorithms are used to find and provide resources (spectrum slots) for incoming connection requests while following the constraints. These constraints are continuity and contiguity constraints. The RSA requires the contiguity over slots and continuity of slots over links. By introducing the temporal aspect (specific start time and holding time), there is time continuity constraint as well. Now the RSA becomes three- dimensional- the number of hops, number of spectrum slots and number of time slots, fig.1. Hence, we call the RSA used in this paper as, RSTA- Routing, Spectrum and Time Allocation. In [4], the traffic models are classified as immediate reservation (IR) and advance reservation (AR)/ book-ahead (BA) requests. The connection request is immediately established in IR when a connection request arrives and holding time is assumed unknown for dynamic traffic and infinite for static traffic. BA request specifies both the starting time, which is some time in future, and a finite holding time.The spectrum slots are reserved for the connection request, but the slots can be used by some other request before the start time of this particular connection request. Fig.2 represents the difference between IR and BA requests.

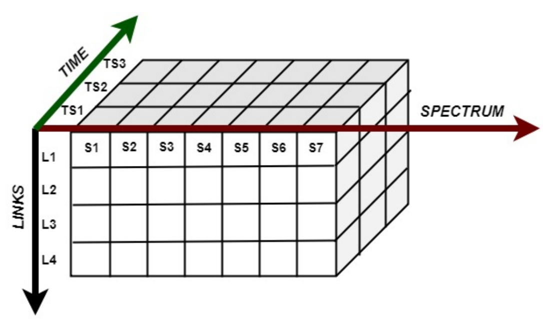

Fig. 1. 3-D(Links, spectrum slots and time slots) parameters of RS-TA scheme

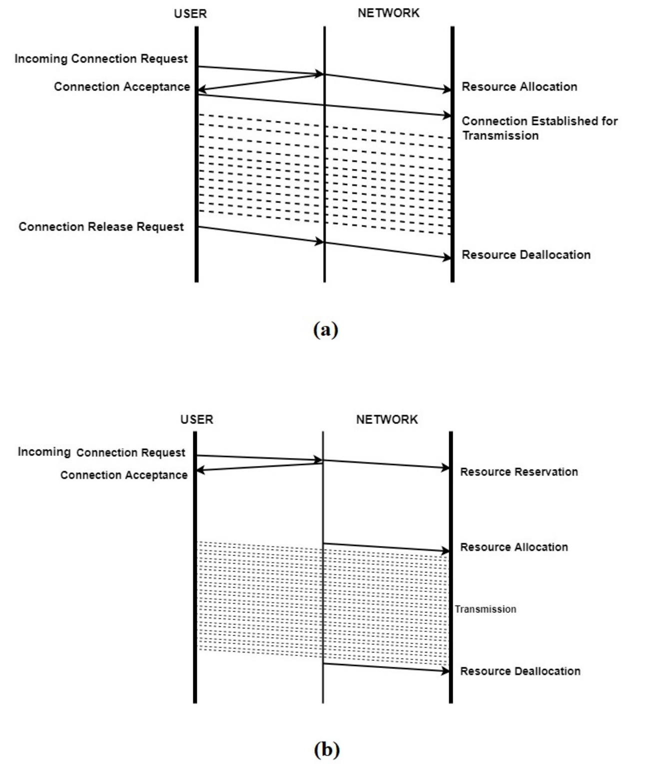

Fig. 2. Traffic reservation, assuming spectrum slots are available, (a) immediate reservation,and (b) book-ahead/ advance reservation.

Some important terminologies used in context of BA request are-

- **Current time-** t_c- The present time at which the resources are to be calculated and provisioned.
- **Holding time-** H_t- The time for which the connection request uses the spectrum resources. The client specifies this time in a book-ahead request.
- **Book- ahead time**- The time difference between current time, t_c, when request is provisioned and actual requested start time, t_s.
- **Horizon**- Network allows resources to be reserved from current time to some future time. This time range is Horizon. It is integer multiple of some small time slots. Any connection request can be established only at the beginning of these time slots. t_h is the time instant where horizon ends. Fig.3 represents the time map for BA request with all the time instants mentioned above.

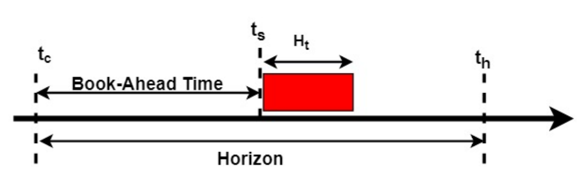

Fig. 3. A time map for fixed start time book-ahead request

TABLE I
TRANSITIONS BETWEEN DIFFERENT STATES

STATE 1 $\longrightarrow$ STATE 2	If present time is the starting time and required spectrum slots are available
STATE 1 $\longrightarrow$ STATE 3	If the starting time is in future and required spectrum slots are available
STATE 1 $\longrightarrow$ STATE 5	Either the start time has passed or required spectrum slots are not available at start time
STATE 2 $\longrightarrow$ STATE 4	If present time is the starting time and spectrum slots have been allocated
STATE 3 $\longrightarrow$ STATE 2	If the starting time has arrived and spectrum slots are available for allocation
STATE 4 $\longrightarrow$ STATE 3	If there is a high priority request, then running request preempted to release resources
STATE 4 $\longrightarrow$ STATE 5	When the holding time is over, spectrum slots are released

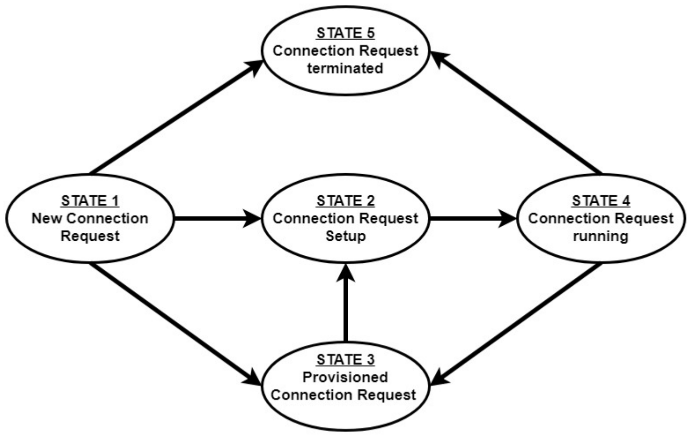

Fig. 4. Process states for book-ahead request allocation

When a connection request arrives, it is in the form (S, D, B, t_s,H_t), where S is the source node and D is the destination node of the connection request. The bandwidth demand is in term of the number of spectrum slots required for the connection request operation. In BAR, it is necessary for the client to explicitly state the starting time (t_s) and holding time (H_t). The end time of the horizon should be greater than arrival time plus holding time. The length of the horizon is in integer multiples of a time slot, where time slot duration is equivalent to the minimum holding time of a connection request. Here, if $t_h \leq t_s$+H_t, then the connection request is blocked. In our work, we consider centralized network architecture. There is a centralized controller which handles the incoming connection requests, schedules them and sets up the switches. There is no requirement of node synchronization for switches in a centralized architecture. A centralized scheduler admits a request, authenticate the user and provides information about the availability of the required resources. The scheduler connects with the node switches and synchronizes them to configure the switches to set up a connection.

In the book ahead request provisioning, we follow three steps- route finding, spectrum allocating and time scheduling. We consider here whether the present time is the start time for a connection request and if spectrum resources are present on the selected path. Path selection for a connection request is carried out by using K-shortest paths. A path is only chosen if contiguous slots are available on that path at specified start

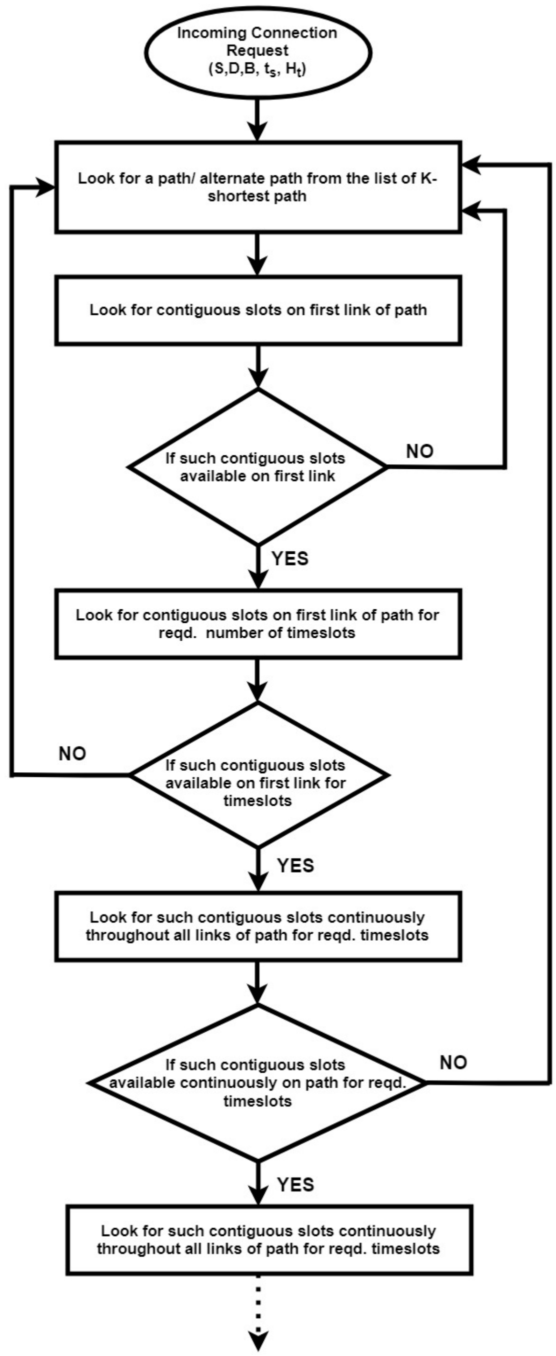

Fig. 5. Flow-chart for RS-TA algorithm

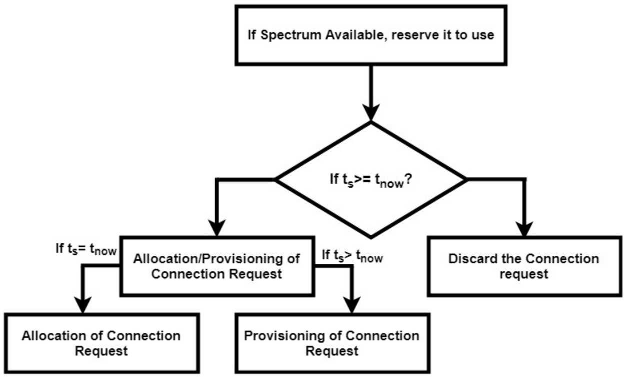

Fig. 6. Flow-chart for allocation or provision of connection request

time and for holding time. If not, it selects another path from next (K-1) paths and verifies the conditions mentioned above for spectrum resources. Once a path is selected, either the resources are allocated immediately to connection request or the request is provisioned and promised for resources at a later time. Here, first-fit slot assignment strategy is used. The book-ahead request provisioning process comprises of five process states as shown in fig.4. The figure shows the transition from one state to another under different conditions. Here, the transition from state 4 to state 3 is only applicable when there is some priority-based mechanism invloved, to pre-empt the running connection request. Fig.5 shows the flow-chart of algorithm to find route, spectrum slots and time slots. Fig.5 shows the algorithm whether the connection request will be put in allocated list or provisioned list depending on present time and start time of the connection requests.

IV. Discussion

In high volume traffic load and low volume traffic load condition, we compare the performances of BA request allocation, IR allocation and IR allocation with waveband conversion. Intuitively, the blocking probability is expected to be least for immediate reservation with waveband conversion, as continuity constraint is relaxed. Then comes the book-ahead reservation, which can show the comparable result if the length of the horizon and slot duration is correctly optimized. The introduction of the waveband converter will eliminate the continuity constraint, but the hardware cost increases. Secondly, there will not be any initial delay involved with IR allocation, for both with and without waveband convertor. In BA request with fixed start time, technically there is no delay, as the client knows when it has to start transmission and resources are available to them. With the introduction of the flexible start time, there will be some initial delay. Thus, BA request allocation will have some delay associated with it. The spectrum is expected to be used most efficiently in BA request allocation as it has temporal aspect associated with it, and the controller knows the future status of the system. So, proper allocation will lead to high efficiency. However, the computational complexity involved with BA allocation will be more than the other two because of the temporal aspect. In low traffic load condition, the performance of all three techniques is expected to be the same, when comparing blocking probability and spectrum efficiency.

V. Conclusions

In this, work we have presented a Book-Ahead mechanism for delay-tolerant incoming connection requests. There is a good reason to believe that BA request provisioning will outperform the immediate request allocation for heavy traffic load, at the cost of computational complexity. However, their performances will be nearly equivalent in low traffic load. There will be no average initial delay for immediate request allocation. However, there will be some average delay associated with BA request allocation, and it will vary with the type of time window we use. We have used the fixed type of window in this algorithm and, the results with a flexible window are still open for discussion and will increase the complexity of the algorithm.

References

[1] 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.

[2] B.C. Chatterjee, N. Sarma, and E. Oki,"Routing and spectrum allocation in elastic optical networks: a tutorial," *IEEE Commun. Surveys Tuts.,* Vol.17, no.3, pp. 1776-1800, 2015.

[3] J.Zheng, B.Zhang, and H. T. Mouftah, "Toward Automated Provisioning of Advance Reservation Service in Next-Generation Optical Internet", *IEEE Commun. Mag.*, Vol.44, no.12, pp. 68-74, Dec.2006.

[4] N. Charbonneau and Vinod M. Vokkarne, "A Survey of advance reservation routing and wavelength assignment in wavelength-routed WDM networks", *IEEE Comm. Surveys and Tutorials*, Vol.14, no.4, pp. 1037-1064, Fourth Quarter 2012.

[5] J. Zheng H. T. Mouftah "Routing and wavelength assignment for advance reservation in wavelength-routed WDM optical networks" Proc. IEEE International Conference on Communications (ICC), vol. 5, pp. 2722-2726, 2002

[6] Haoran Chen, Yongli Zhao and Jie Zhang,"Static provisioning for advance reservation in elastic optical networks", 16th International Conference on Optical Communications and Networks (ICOCN), 2017.