# Demonstration of Parallel Service Re-Provisioning over Advanced Reservation enabled Software Defined Optical Transport Networks

**Wei Wang[1], Yongli Zhao[1], Ye Zhu[1], Liangkai Huang[1], Boyuan Yan[1], Jie Zhang[1]**
**Haomian Zheng[2], Xin Liu[2], Yi Lin[2], Jianrui Han[2], Young Lee[2]**
*(1) State Key Laboratory of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecomm., China*
*(2) Huawei Technologies Co., Ltd. {weiw; yonglizhao; lgr24}@bupt.edu.cn, {zhenghaomian; liuxin; yi.lin}@huawei.com*

**Abstract:** For the first time, re-provisioning is introduced into advanced reservation enabled optical transport networks as a novel perspective for optimization. Demonstration results show parallel service re-provisioning (PSRP) can improve the efficiency of network resource significantly.
**OCIS codes:** (060.4250) Networks; (060.4256) Networks, network optimization; (060.4510) Optical communications

## 1. Introduction

Driven by the development of Internet and cloud computing, advanced reservation (AR) has been introduced to transport networks as a novel kind of request, which is essential to support initial-delay-tolerance/deadline-driven network applications (i.e., grid computing, data backup, etc.) [1]. Different from traditional immediate reservation (IR) request, AR requests allow certain initial delay by specifying a sliding start time before a given deadline.

The calendaring features of AR requests enable network operators to plan their networks via optimization-oriented scheduling. However, such features also make the service provisioning more complicated, since two basic issues should be considered to accommodate an AR request, i.e., 1) scheduling of exact transmission time window; 2) routing and wavelength assignment (RWA) in advance [2]. The problem of AR provisioning has been investigated with various optimization objectives (e.g., time-spectrum fragmentation) [3-6], which attempt to accommodate each coming AR request with an optimal solution. In general, this kind of optimization is achieved in a serial perspective, because the AR requests are provisioned one by one in order of their arrival. Consequently, the network may not be planned in the optimal condition from the global view. Actually, the reserved resource for each scheduled AR service would not be activated until the actual start time arrives, and the network operator still have opportunities to *re-provision* (e.g., re-schedule/re-RWA/withdraw) them during the initial-delay time. As depicted in Fig.1 (a), where AR service 1, 2 and 3 arrives one by one, service 1 and 2 were in light-load condition before the arrival of service 3, which specifies a sliding time window $[t_2, t_5]$. However, there exists opportunities to re-provision service 2 before its actual start time $t_3$ arrives. Based on this consideration, this paper focuses on the re-provisioning problem for AR enabled optical transport networks as a novel perspective for optimization, i.e., load balance of network.

For the first time, this paper introduces the concept of re-provisioning into AR enabled transport optical networks. We propose a re-provisioning enabled control architecture with three parallel service re-provisioning (PSRP) schemes, and they have been implemented based on Open Network Operating System (ONOS) to verify their efficiency. Demonstration results show that re-provisioning is valuable for AR enabled transport networks, and the proposed PSRP schemes can improve the efficiency of network resource significantly.

## 2. AR re-provisioning enabled control architecture

The AR re-provisioning enabled control architecture is designed based on software defined networking (SDN), which can provide the centralized control ability with a global view. As shown in Fig.1 (b), it is composed of three layers. 1) Transport SDN (T-SDN) Controller; 2) Northbound Applications (APPs); 3) Physical Networks.

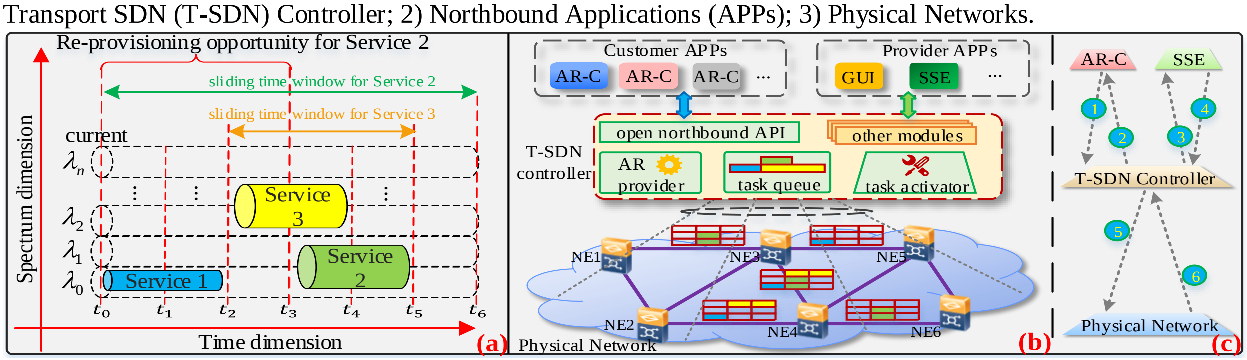

Fig.1 (a) re-provisioning opportunity for AR services; (b) AR re-provisioning enabled control architecture; (c) work flow.

T-SDN Controller is the hypervisor of the underlying physical network. Three modules are introduced particularly to manage AR requests. 1) AR provider is an enhanced connection manager, which is used to accommodate AR requests with AR provisioning algorithms; 2) The task queue stores the information of the scheduled AR services; 3) Task activator monitors the task queue, and would activate the scheduled services when their actual start time arrives.

Northbound APPs provide supplemental functionalities and interfaces for transport customers and providers. In AR scenario, AR client (AR-C) is used by customers to issue AR requests, and service scheduling expert (SSE) is designed for transport provider to optimize the scheduled AR requests via re-provisioning from the global view.

Physical Network is responsible for carrying customers' traffic, as indicated by the scheduled AR services.

The work flow of the proposed architecture is illustrated as Fig.1 (3). 1) AR-C issues AR requests and submits them to T-SDN controller; 2) the controller provisions AR requests and sends back the results to AR-C; 3) T-SDN controller informs SSE the scheduled status when load unbalance occurs; 4) SSE re-provisions some AR services and commits the updated information to T-SDN controller; 5) Once the actual start time of a scheduled AR service arrives, T-SDN controller would activate the reserved resource in physical network. 6) Physical network sends back the results.

### 3. Parallel service re-provisioning schemes for AR enabled optical transport networks

This paper discusses the problem of AR re-provisioning in wavelength division multiplex networks, and simplifies the network resource as wavelengths without considering modulation format and wavelength conversion capacity. For a pending AR request, after being provisioned, it could be denoted as $R(t_s,t_e,t_d,p,\lambda)$, where $t_s$ and $t_e$ denote the accurate start time and end time respectively, $t_d$ is the initial deadline, $p$ is the path (a set of links) from source to destination, and $\lambda$ is the set of reserved wavelengths from time $t_s$ to $t_e$ on path $p$. As shown in Fig.2 (a), heavy-load occurs at time 4 when service 3 is provisioned with wavelength [3, 4] at time slot [3, 4]. To handle this kind of un-optimal condition, the PSRP scheme, which aims to balance the load of network from the global perspective, is designed as follows.

Step1, heavy-load detection. At a given time $t_r$ for re-provisioning, for each time slot $t(t_r < t < t_{max})$ before the end of the predicted time slots $t_{max}$, calculate the wavelength consumption ratio $WCR_l^t$ of each link $l$ on the network topology as $WCR_l^t = RW_l^t / TW_l$, where $TW_l$ is the total number of wavelengths on link $l$ and $RW_l^t$ is the number of reserved wavelengths on link $l$ at time $t$. All the $(l, t)$ pairs whose $WCR_l^t$ is higher than a predetermined threshold $WCR_{hv}$ would be taken as the elements of the heavy load block set $H_{hv}$, i.e. $H_{hv} = \{(l,t) \mid WCR_l^t > WCR_{hv}\}$.

Step2, target services selection. For each $(l,t) \in H_{hv}$, find all the AR services which have been scheduled to occupy the wavelengths on link $l$ at time $t$ as target service set $\mathcal{R}_l^t = \{R(t_s,t_e,t_d,p,\lambda) \mid t_s \le t \le t_e, l \in p\}$. Since that one AR service may cross multiple heavy load blocks, to remove the overlapping services, we get the union set $\mathcal{R}$ of all the $\mathcal{R}_l^t$, and define an auxiliary set $H(R(t_s,t_e,t_d,p,\lambda))$, i.e., $H(R(t_s,t_e,t_d,p,\lambda)) = \{(l,t) \mid l \in p, t_s \le t \le t_e, (l,t) \in H_{hv}\}$ to denote all the heavy load blocks caused by $R(t_s,t_e,t_d,p,\lambda)$. In Fig.2 (a), service 2 and 3 are taken as the target services.

Step3, re-provisioning optimization. For each $R(t_s,t_e,t_d,p,\lambda) \in \mathcal{R}$, the more elements in its $H(R(t_s,t_e,t_d,p,\lambda))$, the more heavy-load blocks it caused. In this step, PSRP try to re-provision them as the decreasing order of the elements number of their auxiliary set. Note that the re-provisioning should not exceed the tolerated time range. For instance, the maximum time ranges for service 2 and 3 are [1, 6] and [3, 5] respectively. Since that each scheduled service has already been provisioned, it is possible to re-use parts of the existing parameters (e.g., service time, route path or allocated wavelengths). Based on this consideration, three re-provisioning strategies are designed as follows.

Re-Scheduling with the Assigned Wavelengths on Existing Path (RS-AW-EP). Keeping the pre-routed path with the assigned wavelengths unchanged, RS-EP-AW can only re-schedule the target request within the tolerated time window. As shown in Fig.2 (b), RS-EP-AW migrates service 2 from time [4, 5] to [5, 6], to reduce the load at time 4.

Re-Scheduling and Wavelength Re-allocating on Existing Path (RS-RW-EP). RS-EP-RW can re-provision the target service in both time and wavelength dimension. Precisely, RS-RW-EP would find a time-wavelength area which contain most free resources in the tolerated time window to re-accommodate the target service. As depicted in Fig.2 (c), RS-RW-EP migrates service 2 from time [4, 5] to [2, 3], and it also reallocate wavelength [2, 3] for it.

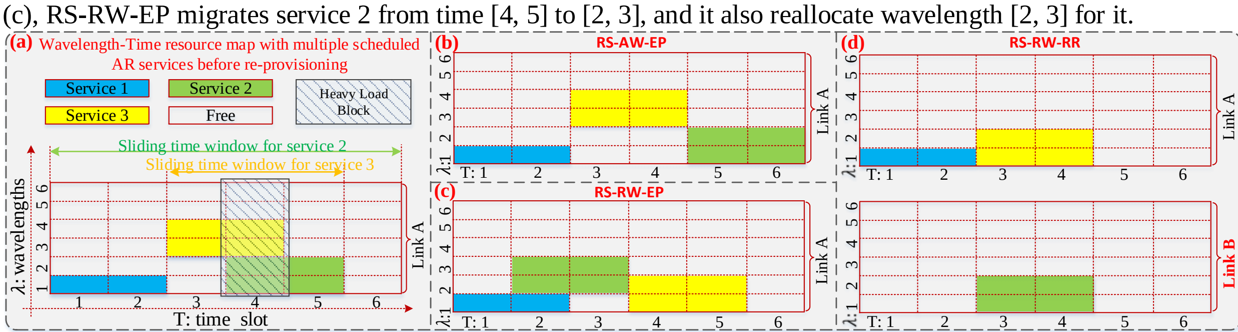


Fig.2 (a) time-wavelength resource map of one link before re-provisioning; (b) RE -AW-EP; (c) RS -RW-EP; (d) RS-RW-RR.

Re-Scheduling, Wavelength Re-allocating and Re-Routing (RS-RW-RR). By re-using none of the existing parameters of the target services, RS-RW-RR calculate several paths as candidates to locate the lightest-load time-wavelength block in the tolerated time window for each target service. Take Fig.2 (d) as an example, it is notable that RS-RW-RR finds a new path which across Link B to re-accommodate service 2 with wavelength [1, 2] at time [3, 4].

## 4. Demonstration and numeric results

In order to verify the feasibility of re-provisioning for AR services, and to investigate the efficiency of the proposed PSRP schemes, we have implemented a testbed as described in section.2. T-SDN controller is developed based on ONOS to support AR services. SSE is implemented as a northbound APP, where the PSRP schemes are embedded. Fig. 3 (a) shows the Graphic User Interface (GUI) of SSE, which is composed of two parts, i.e., 1). The SSE control panel is used to obtain users parameters for issuing AR requests and re-provisioning; 2). The two-dimensional grid board shows the wavelengths consumption ratio (WCR) in both time and link dimension dynamically. In addition, an AR request generator is implemented in SSE to generate AR requests as the quasi-Poisson model, where the initial-delay time is generated randomly as the isolation window between the arrive and hold time. As depicted in the left-bottom part of Fig.3 (a), a transport topology is constructed with six emulated nodes based on Linc-OE, which supports optical path management, and each link is configured with 40 wavelengths.

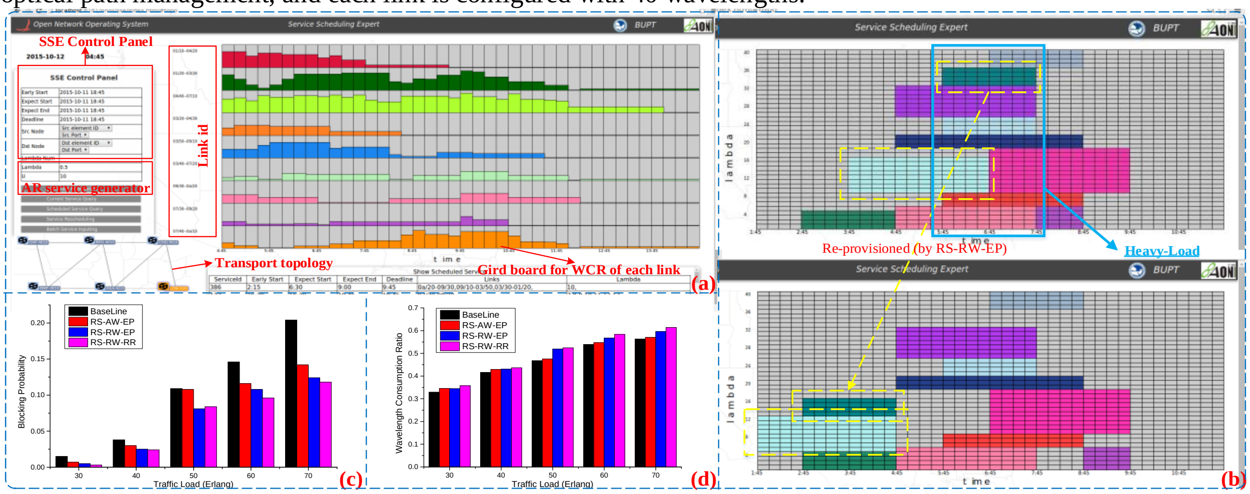


Fig.3 (a) GUI of SSE; (b) visible re-provisioning result on one link; (c) blocking probability; (d) wavelength consumption ratio.

On the above testbed, we demonstrate the feasibility and benefit of re-provisioning. When clicking one link on the visible GUI of SSE in Fig.3 (a), the gird board would be transformed to show the wavelength occupation status for the clicked link as shown in Fig.3 (b), where the colored block depicts the reserved resource for each scheduled AR service in time and wavelength dimension. The upper part of Fig.3 (b) shows that heavy load occurs at the marked area. After being optimized by RS-AW-EP, the resource condition of the same link is refreshed as the bottom part of Fig.3 (b). It is notable that some AR services are re-provisioned to release the resource in the heavy load area for upcoming requests, which may require the released resource specifically. We also evaluate the performance of the proposed PSRP schemes in terms of blocking probability (BP) and WCR by running multitudinous AR services on this testbed. Due to that running AR services on real system cost lots of time, we issue 1000 AR requests for each traffic load with the fixed departing rate 0.1. The source and destination nodes are generated randomly, and the required bandwidth (number of wavelengths) is evenly distributed between 1 and 5. Fig.3 (c) and (d) shows the results. The PSRP schemes are trigged when new coming AR requests are blocked, and they perform better than the baseline, which can only provision the new coming AR requests without re-provisioning optimization. RS-RW-RR reduces the BP and improves the WCR most significantly, because it attempts to jointly balance the load in time, route and wavelength dimension. In general, PSRP can improve the resource efficiency of AR enabled optical transport networks.

## 5. Conclusions

For the first time, we introduce the re-provisioning mechanism for AR services into software defined optical transport networks. Demonstration results show that re-provisioning is valuable for optimizing transport network from the global perspective, and the proposed PSRP schemes can improve the network efficiency significantly.

(This work is supported by NSFC project (61271189, 61571058), MCM Research Foundation (MCM20130132)).

## 6. References


[1] J. Zheng, B. Zhang, et al., IEEE Commun. Mag., 44(12), 68-74(2006)
[2] Charbonneau N., et al., IEEE/ACM Trans. on Netw., 20(1), 1-14(2012)
[3] Andrei, D., et al., IEEE/ACM Trans. on Netw., 18(2), 353-366(2010)
[4] W. Lu, Z. Zhu, J. Lightw. Technol., 31(10), 1621-1627(2013)
[5] H. Chen, Y. Zhao, et al., IEEE Commun. Lett.,19(1), 70-73(2015)
[6] N. Wang, J.P. Jue, X. Wang, et al., ICC, 5180-5185(2015)