Routing and Signaling Schemes for Bandwidth-Variable (BV) Optical Networks

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ABSTRACT

Two kinds of routing and signaling schemes for bandwidth-variable (BV) optical networks are compared in the paper. One is the fix routing (FR) together with an extension to the traditional RSVP-TE (RSVP-bBV) , another is adaptive routing (AR) together with an extension to the traditional RSVP-TE (RSVP-fBV). Both are implemented on Tsinghua large-scale ASON test-bed. Experiment results show that the both schemes have different characteristics of blocking probability, and FR+ RSVP-bBV is more suitable to high dynamic BV optical networks than AR+ RSVP-fBV.

1. INTRODUCTION

Currently, optical orthogonal frequency-division multiplexing (OOFDM) has been proposed as a hopeful transmission technology candidate due to its high spectrum utilization and flexibility [1-3]. OFDM signals are not restricted to the traditional grid standards but support flexible spectrum occupancy and spacing in a gridless manner. Based on OFDM research and development, a novel kind of optical network architecture - bandwidth-variable (BV) optical networks, e.g. the spectrum-sliced elastic optical path network (SLICE) [4-6], has been proposed, and shows great advantages over traditional wavelength-division multiplexed (WDM) networks which can only provide the coarse granularity and the restriction of the rigid ITU-T grids [7].

In BV optical networks, the routing and spectrum assignment (RSA) problem has been widely investigated [6,8-9]. In [8], a shortest-path adaptive routing (AR) scheme in the gridless fashion was proposed and proved to be resource-efficient. Considering that most optical components cannot support fully gridless tenability yet, the gridless RSA schemes see little application . Based on grid, a RSA algorithm with fixed routing (FR) and first-fit spectrum assignment was proposed in [9]. It showed that when the grid size decreases to a certain level, the blocking performance of grid-based RSA schemes is almost the same as that of the gridless.

The signaling process is another problem during establishing an end-to-end connection. It is observed that signaling blocking, arising from collision among two or more RSVP-TE signaling instances that attempt to reserve the same wavelength, or spectrum segment, on a link, is dominant when the network is lightly loaded and the connection arrival rate is high [10]. And in the BV networks, there is little research about the signaling schemes, and nor is the overall network performance together with routing and signaling.

Two kinds of routing and signaling schemes for bandwidth-variable (BV) optical networks are compared in the paper. One is the fix routing (FR) together with an extension to the traditional RSVP-TE (RSVP-bBV) , another is adaptive routing (AR) together with an extension to the traditional RSVP-TE (RSVP-fBV). Both are implemented on Tsinghua large-scale ASON test-bed. Experiment results show that the both schemes have different characteristics of blocking probability, and FR+ RSVP-bBV is more suitable to high dynamic BV optical networks than AR+ RSVP-fBV.

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2. SCHEMES OF BV ROUTING AND SIGNALING

The FR+ RSVP-bBV scheme can be described as following: upon arrival of a connection request, the source node S calculates a route and initiates a PROB message to be delivered to nodes along the route to collect spectrum-available information. The PROB message contains an explicit route object (ERO) and an available spectrum resource object (ASRO) which carry the route information and the spectrum-available information, respectively. After receiving a PROB message, an intermediate node(node A or node B) updates their ASRO. If at node B, for example, the ASRO indicates there is no spectrum available, a NACK-R message will be send back to the S, informing of a routing blocking. On the PROB message propagating to the destination (node D), a RESV_CONF message containing a label request object (LRO) which records the selected spectrum segment is send back to the S. After receiving a RESV_CONF message, each node along the route reserves spectrum resources and configures optical switches. If the reservation is failed, a RLS message will be send to D to tear down the lightpath established, and then a NACK-S message will be send to the S, informing of a signaling blocking. If S receives an RESV_CONF message, a lightpath is established successfully. The procedure is show in the fig.1

The AR+ RSVP-fBV scheme can be described as following: upon arrival of a connection request, the S calculates a route with selected spectrum segment, and initiates a RESV message containing an ERO and LRO. When a node along the route receives the RESV message, it reserves corresponding resources. After the RESV message propagates to the D, a CONF message is sent back to S to configure the optical switches and initiate the flooding of link state, as shown in the fig.2.

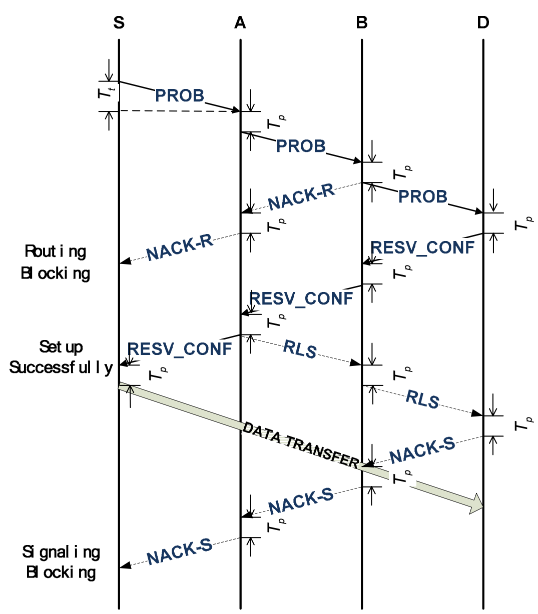


Fig. 1. RSVP-bBV signaling message flow

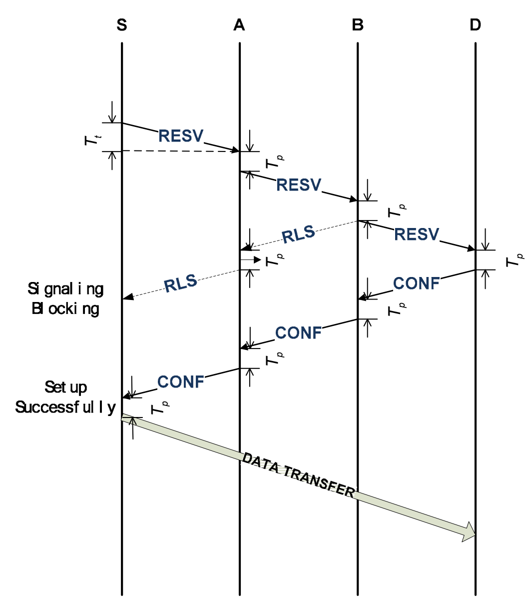
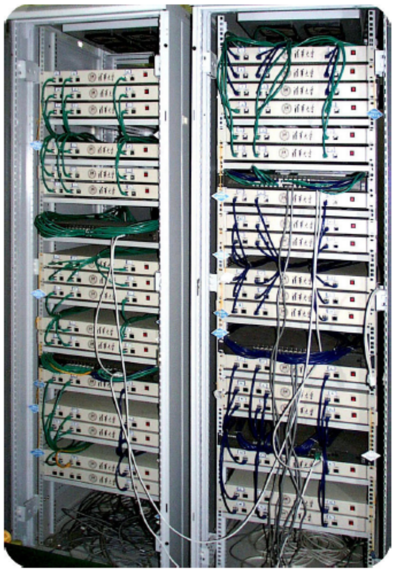


Fig. 2. RSVP-fBV signaling message flow

3. EXPERIMENT RESULTS

Both schemes are implemented on a large-scale ASON test-bed (Fig. 3) [11].As shown in Fig. 4, the control and management plane of the ASON test-bed is designed as sever-client architecture. The network manager is regarded as the server and the emulated optical nodes act as the clients. The architecture of server consists of the GUI module, the topology manager, the traffic generator, the performance manager/collector and other function modules. The architecture of client consists of the control plane (LMP, BV routing and BV signaling) and other function modules.



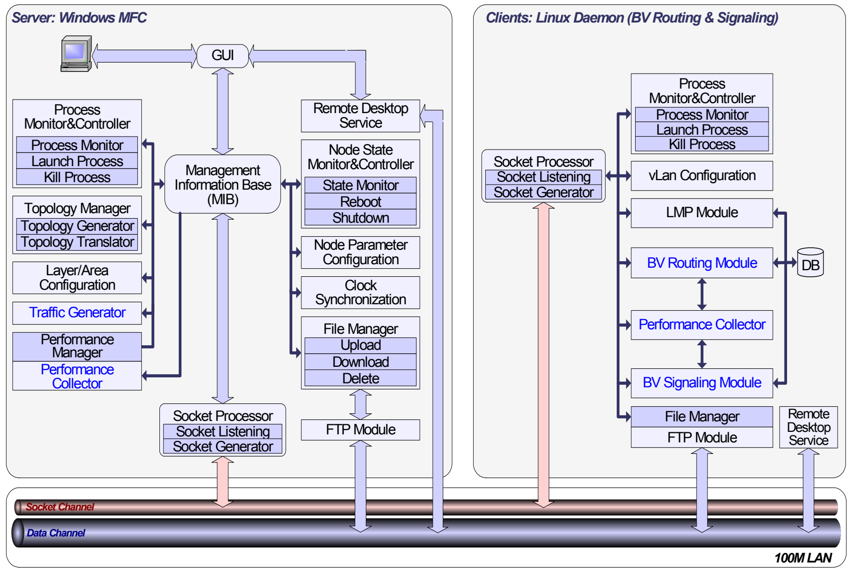


Fig. 3. ASON test-bed Fig. 4. The control/management plane architecture of ASON test-bed

During experiments, the topology adopted is the 14-node NSFNET as shown in Fig. 4. And the grid of optical spectrum is set to be 12.5 GHz, and each optical spectrum has 400 grids, which corresponds to 5000 GHz continuous optical spectrum. A fixed guard band of one grid is set between adjacent channels. It is assumed that connection requests arrive in a Poisson process and are uniformly distributed among the node pairs.

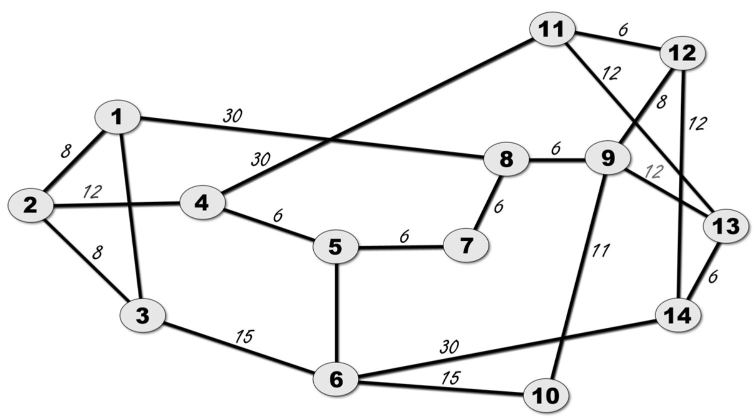


Fig. 4. NSFNET topology

From Fig. 5 it can be seen that AR outperforms FR in terms of routing blocking due to its flexible path computation which is proved by other papers. But if we take signaling blocking into account, the situation is entirely different. FR has much lower signaling blocking than AR, and thus the total BP of the FR+RSVP-bBV scheme is lower than that of AR+RSVP-fBV.

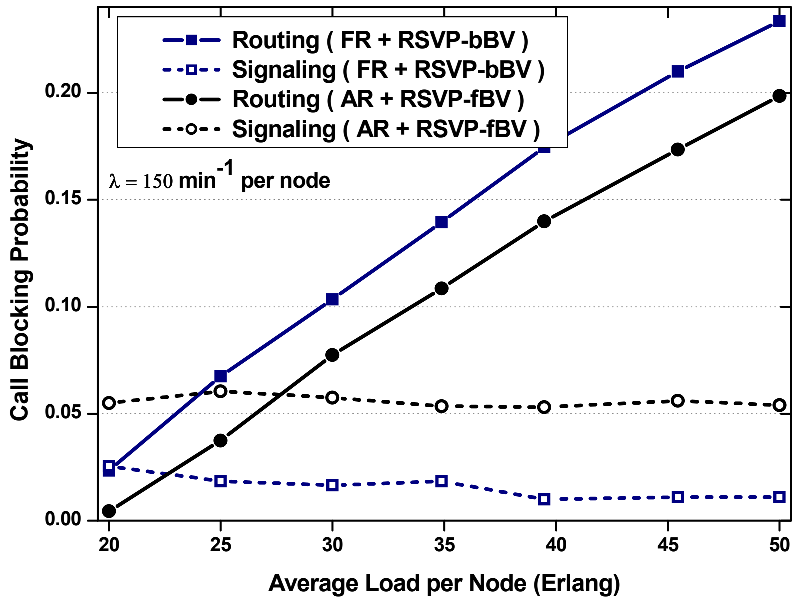


Fig. 5. Blocking probability vs. load

The comparison of BP versus traffic arrival rate λ is shown in Fig.6, where the traffic load is set to 20 Erlang per node. Since the load is light, the routing BP remains lower than 0.03. However, the signaling blocking probability rises rapidly with the increase of λ. It can be seen that AR has a more rapid incremental rate of signaling blocking probability.

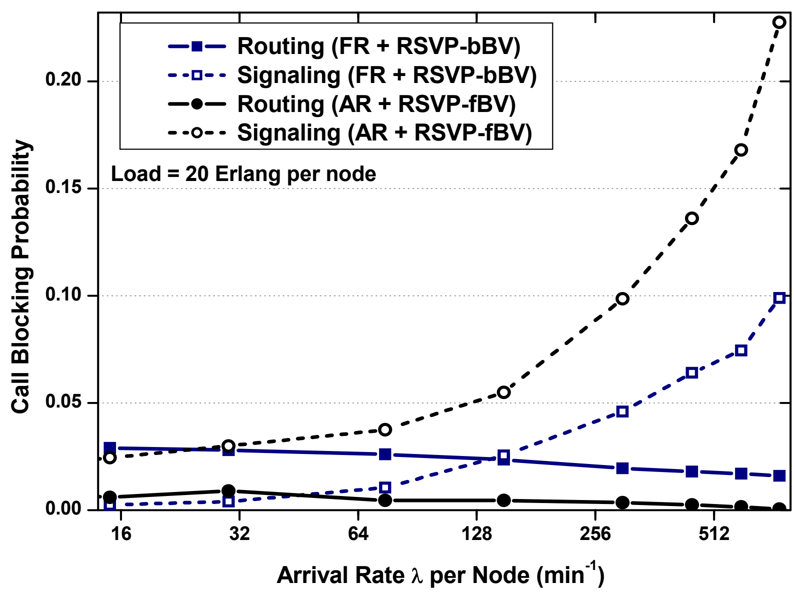


Fig. 6. Blocking probability vs. arrival rate

4. CONCLUSION

Two kinds of routing and signaling schemes for bandwidth-variable (BV) optical networks are compared in the paper. One is the fix routing (FR) together with an extension to the traditional RSVP-TE (RSVP-bBV) , another is adaptive routing (AR) together with an extension to the traditional RSVP-TE (RSVP-fBV). Both are implemented on Tsinghua large-scale ASON test-bed.

By introducing adaptive routing (AR) during the routing phase, the AR scheme can achieve a lower routing blocking probability than the FR, which means that the AR+ RSVP-fBV scheme is more suitable to those BV optical networks which are more static than dynamic.

Experiment results also show that AR has a significant higher signaling blocking probability, especially when the arrival rate is high. As a result, the total BP of the FR+RSVP-bBV scheme is lower than that of AR+RSVP-fBV in case of high arrival rate, which means the FR+ RSVP-bBV scheme is more suitable to high dynamic BV optical networks than AR+ RSVP-fBV.

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