Performance of a distributed WR-OBS control architecture

Zhou Lan (蓝 洲), Hongxiang Guo (郭宏翔), Jian Wu (伍 剑), and Jintong Lin (林金桐)

Key Laboratory of OCLT, Ministry of Education, Beijing University of Posts and Telecommunications, Beijing 100876

Received July 23, 2004

This paper proposes a new distributed wavelength-routed optical burst switching (WR-OBS) network architecture and two corresponding control protocols. By taking advantage of merits from both just enough time (JET) protocol and two-way signaling method, this new control architecture outperforms traditional JET OBS network in points of burst loss probability, system throughput and centralized WR-OBS network in network scalability confirmed by computer simulations. Further simulation is developed to compare the performance of the two control protocols, which leads to instructive discussion in real WR-OBS network design.

OCIS codes: 060.0060, 060.4250, 060.4510, 060.1810.

The optical burst switching (OBS) network has been extensively investigated due to its potential ability to provide better utilization of optical bandwidth[1,2]. However, most currently proposed OBS schemes, such as just enough time (JET)[3,4], suffer from high burst blocking rate for large traffic loads without full wavelength conversion. In order to overcome this limitation, a wavelength-routed OBS (WR-OBS) network architecture was proposed[5,6], which provided an end-to-end reservation to satisfy specific service requirement, such as latency and packet loss rate, for burst input traffic.

Previous literatures on the WR-OBS architecture assumed a centralized network control[6,7], which was relatively easy to be implemented but had poor scalability and reliability compared with a distributed network control.

Therefore, in this paper, we propose an alternative distributed WR-OBS network architecture and corresponding control protocols. This architecture will improve the system performance greatly because of two key features. Firstly, instead of a centralized request server, every core router in the network processes the resource request from the edge node respectively. Secondly, the JET protocol is combined with two-way end-to-end resource reservation method. By means of this combination, we can not only achieve better wavelength efficiency but also satisfy specific burst loss probability without wavelength conversion.

The network architecture, illustrated in Fig. 1, can be divided into two planes from the logical point of view. Optical switch which is one segment of core router and data channels compose the data plane responsible for burst transmit. On the other hand, the control unit (CU) which is another segment of core router and the control channels compose the control plane taking charge of control information transmission. Contrast to the centralized WR-OBS network, in which a centralized request server processes all resource requests from the edge routers, CUs deal with the wavelength request from the edge router respectively. Each CU keeps track of the time slot information of local wavelength and maintains this information in a local data structure.

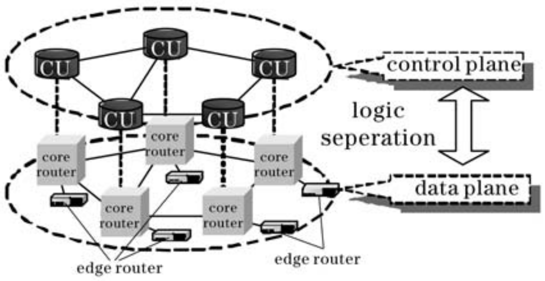
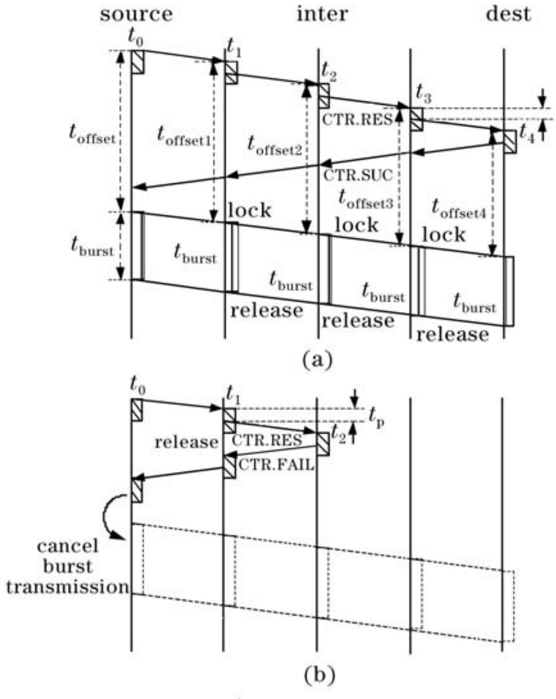


Fig. 1. Network Architecture.

As for control protocol, forward reservation protocol (FRP) and backward reservation protocol (BRP) can be involved in. Figure 2(a) shows a basic process of FRP. This process starts from burst aggregation paralleling with signal exchanging between source and destination. At time t_0, a resource request control packet (CTR.RES)is formulated at the source edge router, an



$$t_{\text{offset}n}=\begin{cases} t_{\text{offset}},\ n=1 \\ t_{\text{offset}(n-1)}-t_{\text{p}},\ n=2,3,4 \end{cases}$$

Fig. 2. FRP process.

estimated burst length and a definite offset time will be filled in the CTR.RES packet. Based on two-way signaling method, the offset time can be calculated as $t_{\mathrm{offset}} \geq H(2t_{\mathrm{prog}} + t_{\mathrm{p}})$, where, H is the total number of the hops along the path, t_{prog} is one-hop propagation delay, t_{p} is the CU processing delay. At time t_1, the CTR.RES packet arrives at some core router, then a time slot request for λ_l from $t_1 + t_{\mathrm{offset1}}$ to $t_1 + t_{\mathrm{offset1}} + t_{\mathrm{burst}}$ will be processed by CU, where t_{burst} is the corresponding burst length. If the wavelength is free during this period of time, the CTR.RES will be relayed to the next hop. On arriving at the destination, the CTR.RES will make the destination response a reservation success packet (CTR.SUC), which will finally trigger the source to transmit corresponding burst. Figure 2(b) shows the case of request fail in the core router. A fail notifying packet (CTR.FAIL) is transmitted backward, which will release the time slots reserved by corresponding CTR.RES packet. And the source edge router will cancel the data burst transmission when the CTR.FAIL packet is received. The burst will be buffered at the source edge router and wait for rescheduling at a later time.

BRP is different from FRP when the actual resource reservation takes place. In BRP, the forward sent control packet is called resource probe packet (CTR.PRB), it only finds if there is available time slots in the core routers on its way. After receiving such packet, the destination will decide which wavelength to Basic be used for burst transmission and formulate a CTR.RES packet sent in the backward direction, which will actually reserve resource for corresponding burst.

We develop a simulation platform based on mesh topology. As described in Ref. [8], we multiplex 40 heavy-tailed Pareto distribution on-off sources to realize a self-similar traffic commonly used for burst traffic evaluation. The corresponding parameters can be found in Ref. [8]. We further assume that the average burst size is on the order of milliseconds which guarantees the enough round trip time for signaling packet.

Firstly, we compare the performance of the distributed WR-OBS network with that of conventional JET OBS network. From Fig. 3, it is clear that, without wavelength conversion, conventional JET OBS suffers from higher burst loss probability than distributed WR-OBS network. And from Fig. 4, we can see that the throughput of distributed WR-OBS is higher than that of JET OBS networks for about 8—9 times under light traffic (0.3) as well as heavy traffic (0.6). This result accords with Fig. 3 and demonstrates the superiority of our newly proposed protocol in an optical network without wavelength converters. Under this scenario, we also investigate the effect of buffer size used in edge routers. From Fig. 3, we can see, larger buffer will not improve the WR-OBS network performance greatly. This is because bursts cannot be buffered at the edge router for long time. We have set a time threshold for rescheduled bursts and after this time threshold the corresponding burst will be dropped.

Secondly, we investigate the scalability issue and make a comparison between distributed WR-OBS and centralized WR-OBS. Burst loss probability is used as evaluation criterion. We fix the traffic load equal to 0.3 and change the number of routers involved. Under centralized WR-OBS network, one core router serves as a control server collecting and distributing the wavelength information in the network. Under distributed WR-OBS, our newly proposed control protocol is used. From Table 1, we can see that with the increasing of core router numbers, the burst loss probability of centralized WR-OBS increases dramatically. More than half of bursts have been dropped in a 16 × 16 mesh network. On the other hand, the situation of distributed WR-OBS is not so bad. The poor scalability performance of centralized WR-OBS is induced by the limited processing ability of one core router. It cannot process all the resource requests from the network efficiently and many wavelength requests have been dropped because of processing buffer overflow. Furthermore, the central control node has to collecting wavelength information of all the core routers. Because of transport delay induced by the network, the information coming from other core router may be outdated. This will lead the central control node to wrong decisions which will make the performance even worse.

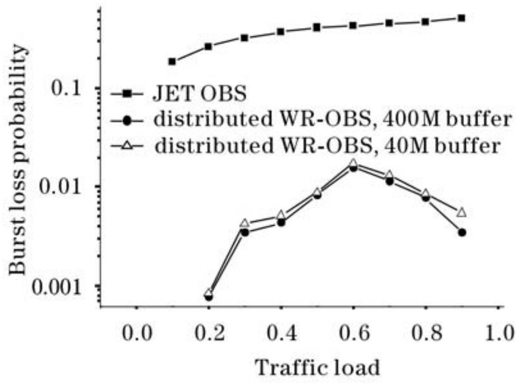


Fig. 3. Distributed WR-OBS versus JET OBS(1).

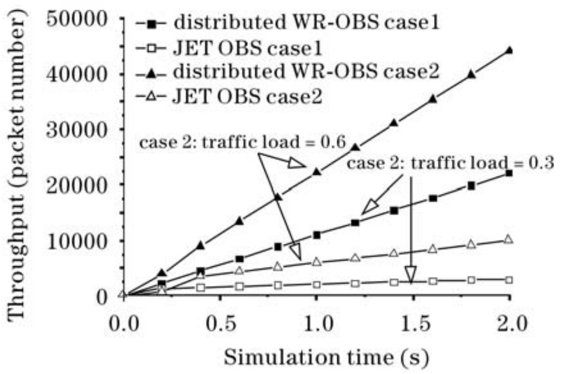


Fig. 4. Distributed WR-OBS versus JET OBS(2).

Finally, we compare the performance of two different reservation protocols under 3 kinds of situations.

Table 1. Comparison of Loss Probability between Centralized WR-OBS and Distributed WR-OBS

	2 × 2	4 × 4	8 × 8	16 × 16
Centralized ($\times 10^{-3}$)	0.3	51	740	700
Distributed ($\times 10^{-3}$)	0.27	3.4	4.5	8.2

Case 1: Part of edge routers send packets and others edge routers only receive packets, which means light traffic in Fig. 5. Packets are sent with random address.

Case 2: Light traffic. Packets are sent to a specific edge router which means fixed address.

Case 3: All the edge routers send out packets, which means heavy traffic in Fig. 5. Packets are sent with fixed address.

The simulation results have been presented in Fig. 5. It is shown that, the burst loss probability of BRP is lower than FRP in most of situations. However, with the opportunities of contention increasing from case 1 to case 3, the performance of BRP deteriorates. Especially in case 3, the burst loss probability of BRP is as high as that of FRP. Obviously, BRP has a better wavelength utilization benefit from its backward resource reservation process, which can reasonably decide burst transmission wavelength based on forward probe process. However, when heavy load is added to the network, BRP does not show its advantage, because of more control packets involved and complex signaling process. Furthermore, the implementation difficulty of BRP is high. In real WR-OBS network design, we must take these issues into consideration and make trade-off between them.

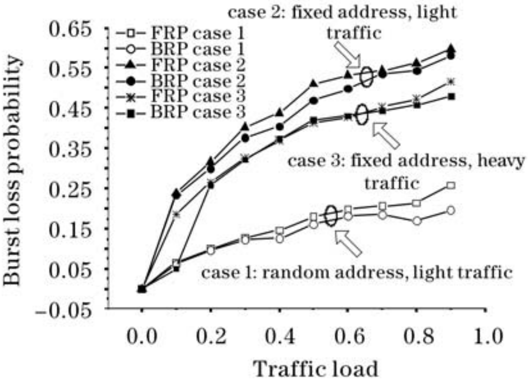


Fig. 5. FRP versus BRP.

This work was supported by the "863" High-Technology Research and Development Program of China under Grant No. 2002AA122031. Z. Lan's e-mail address is zhoulan@bupt.edu.cn or lan@yokosuka.nict.go.jp.

References

1. S. Baroni, P. Bayvel, R. Gibbens, and S. K. Korotky, J. Lightwave Technol. **17,** 743 (1999).
2. J. Zhang, M. Cao, F. Luo, and T. Chen, Chin. Opt. Lett. **1,** 513 (2003).
3. M. Yoo and C. Qiao, Proc. SPIE **3230,** 79 (1997).
4. K. Dolzer, C. Gauger, J. Spath, and S. Bodamer, J. Electron. Commun. **55,** 18 (2001).
5. E. Kozlovski, M. Duser, I. de Miguel, and P. Bayvel, in *Proceedings of IEEE LEOS 2001* **1,** 161 (2001).
6. M. Düser and P. Bayvel, in *Proceedings of ONDM 2001* **3,** 50 (2001).
7. E. Kozlovsk and P. Bayvel, in *Proc. IFIP 6th Working Conf. Optical Network Design Modeling* **4,** 101 (2002).
8. A. Ge, F. Callegati, and L. S. Tamial, IEEE Commun. Lett. **4,** 98 (2000).