Performance improvement of wavelength-routed networks using prior transmission

C. Y. Li and P. K. A. Wai
Photonics Research Centre and Department of Electronic and Information Engineering
The Hong Kong Polytechnic University, Hung Hom, Hong Kong
{enli,enwai}@polyu.edu.hk

Abstract
We propose a prior transmission method to improve the performance of wavelength-routed networks when the traffic duration is not much longer than the path end-to-end propagation delay.

1. Introduction
Wavelength-routed (WR) network is a feasible approach to satisfy the demand on transmission bandwidth by the rapidly increasing Internet traffic [1]. In WR networks, once a connection (lightpath) has been established between nodes, bit-rate/format transparency of data transmission is guaranteed. Recently, new architectures of WR networks such as optical flow switching [2] and lightpath data interchange [3] have also been proposed for specified applications. Owing to its two way resource reservation nature, however, WR network is well-known to be transmission bandwidth efficient only if the traffic duration $T_d$ is much longer than the lightpath setup time $T_{setup}$. As traffic becomes bursty, the capability to support short duration traffic is also important for WR networks. Undoubtedly, reducing $T_{setup}$ is the straightforward way to improve the performance of WR networks with short duration traffic. As shown in Section 2, the minimum $T_{setup}$ is the round trip time of the source to central control node or that of the source-destination nodes, depending on whether the centralized or distributed lightpath setup approach is used. $T_{setup}$ will be more than a millisecond if the end-to-end distance is 100 km or longer. We therefore need methods to lower the negative impact to the performance of WR networks caused by large $T_{setup}$. In this paper, we propose a prior transmission method that can improve the blocking performance of WR networks when the traffic duration $T_d$ is not much longer than $T_{setup}$.

2. Prior transmission

Figure 1(a) shows the timing diagram when traffic arrives at a WR network source node at time $t_{arrival}$. The source sends of the lightpath setup message immediately and gets the feedback acknowledgement message at time $t_{ack}$. If the lightpath setup is successful, the source will send data traffic at time $t_{LP_start}$ to the destination along the path reported by the acknowledgement message. Occasionally, we can assume $t_{ack} = t_{LP_start}$ because the difference between $t_{ack}$ and $t_{LP_start}$ is often very small if compared to $T_{setup}$ and $T_d$.

The bandwidth utilization overhead caused by the lightpath setup is $(t_{LP_end} - t_{arrival}) / (t_{LP_end} - t_{arrival})$ or approximately $T_{setup} / (T_d + T_{setup})$. If the centralized control approach is used for lightpath setup, $T_{setup}$ depends on the round trip delay from the source to central control node and is likely independent of the source-destination path length. Because of reliability and performance consideration, however, distributed control approach is often used. In such situation, $T_{setup}$ will mainly depend on

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the round trip delay from source to destination and we can write it as \( T_{\text{setup}} = H \times T_{\text{cp}} + 2T_{\text{path}} \), where \( H \) is the number of intermediate nodes on the path, \( T_{\text{cp}} \) is the processing time of the lightpath setup message at an intermediate node, and \( T_{\text{path}} \) is the source to destination propagation delay. Since the data traffic can pass through a node only if the node and its optical switch have been properly configured, \( t_{LP, \text{start}} \) must be larger than \( t_{\text{arrival}} + H \times T_{\text{cp}} + \max(2T_{\text{path}}, T_{\text{sw}}) \), where \( T_{\text{sw}} \) is the configuration time required for the optical switches at the intermediate nodes.

Figures 1(b) and 1(c) demonstrate the operation principle of the proposed prior transmission method. As shown in Fig. 1(b), without waiting for the acknowledgement message, the source node sends the data traffic at time \( t'_{LP, \text{start}} \) to the destination along a predefined path. Similar to that of \( t_{LP, \text{start}} \), we have \( t'_{LP, \text{start}} \geq t_{\text{arrival}} + H \times T_{\text{cp}} + T_{\text{sw}} \). If the path reported in the acknowledgement message is the same as the predefined path, the source will continue the traffic transmission until time \( t'_{LP, \text{end}} \). We can therefore shorten the lightpath reservation time by a maximum \( 2T_{\text{path}} - T_{\text{sw}} \). If the acknowledgement message reports a different path as show in Fig. 1(c), the source will restart the transmission from beginning to send the traffic along the new path to the destination. In this situation, the traffic transmission will be ended at time \( t_{LP, \text{end}} \). Note that no extra resource will be wasted and no traffic conflict will be caused by the unsuccessful prior transmission.

3. Performance evaluation

Figures 2 and 3 plot the lightpath setup blocking probability of WR networks with different \( T_{\text{setup}} \). The network topologies used in Figs. 2 and 3 are NSFNet and 8×8 Manhattan Street Network (MSN), respectively. There are eight channels per link. The loadings in the networks are 0.8 and 0.32 erlangs per node. From the figures, we observe that both WR networks with and without the proposed prior transmission will have similar lightpath setup blocking probabilities if \( T_{\text{setup}} \) is either very small or very large. In other regions of \( T_{\text{setup}} \), however, the WR networks with prior transmission have lower lightpath setup blocking probability. Moreover, the traffic duration flexibility can be largely improved in WR networks if the proposed prior transmission method is used. For example, as shown in Figs. 2 and 3, the traffic duration in normal WR networks should be at least hundred times longer than \( T_{\text{setup}} \). Otherwise, unnecessary blockings will be caused. The proposed prior transmission method effectively reduce the required traffic duration from hundreds times to ten times of the \( T_{\text{setup}} \) without increasing the blockings.

4. Conclusions

As traffic becomes bursty, support to short duration traffic is important for WR networks. Simulation results show that the proposed prior transmission method can significantly improve the network performance.

References

2. V. W. S. Chan, OECC, (2010), paper 8A1