

High Speed Data Transfer using Optical Code Processing in WDM Networks

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Abstract— For effectively utilizing WDM networks, OBS (Optical Burst Switching) where the wavelengths are reserved on demand basis is considered. We have proposed an OC-TAG (Optical Code based Tell-And-Go) protocol that uses optical-code based processing for handling the out-of-band control packet for fast data transfer over the WDM network. However, the OC-TAG is not enough for the fast data transfer since if the data transfer request is blocked, retransmission is necessary. In this paper, to reduce the retransmission, we propose a contention resolution facility utilizing fiber delay lines for the OC-TAG. Through computer simulations, we show the effect of introducing our architectures.

Keywords— OBS, Optical code, Fast data transfer, Fiber delay line, Retransmission

I. Introduction

For effectively utilizing the WDM network, OBS (Optical Burst Switching) where the wavelengths are reserved on demand basis is considered [1–3]. In such a network, when the burst transfer request arises at the source node, the wavelength is dynamically assigned between source and destination nodes, and the burst is transferred using the assigned wavelength. Here, the burst corresponds to the upper-layer protocol data unit such as the file or block in the case of file transfer. The wavelength is immediately released when the data transfer is successfully finished.

A common thread to the OBS is a quick setup of optical path for the data transmission by cutting down the overhead time in the pre-coordination. We have investigated an OC-based architecture for setting up the lightpath between source and destination nodes via two-way reservation in [4]. This OC-based architecture enables fast lightpath establishment. However *two-way reservation*

scheme [4, 5] has an inevitable performance limit caused by two-way propagation delay (round-trip time), hence in this paper, we apply the OC-based architecture to *one-way reservation* scheme [1–3] for fast data transfer.

An one-way reservation also has the overhead time dependent on the number of hop-counts that the burst traverses. It is a protocol processing time such as the routing of control signals, wavelength assignments, or unexpected delay due to the high load of control signals. To reduce the overhead time in the one-way reservation scheme, the high-speed processing of the signaling message at each hop is imperative. However, conventional electronic processing is not fast enough and will eventually become a bottleneck as the bit rate of data link becomes larger. Therefore, to reduce the overhead time in OBS network, we propose an OC-TAG (Optical Code based Tell-And-Go) protocol [6]. Our method allows variable length bursts without buffering, and hence fast burst transfer over the WDM network can be established. The optical-code based processing is introduced for signaling messages in an optical domain.

However, the optical-code based processing is not enough for the faster data transfer since if the data transfer request is blocked, a round-trip propagation delay is necessary to retransmit the data transfer request. In order to reduce the retransmission, a contention resolution facility utilizing fiber delay lines is introduced for each node. Through computer simulation, the data transfer delay which is defined as the time from when the burst transfer request arrives at the source node to when the data is successfully received by the destination node, is evaluated. And we show that it can be dramatically improved through our method.

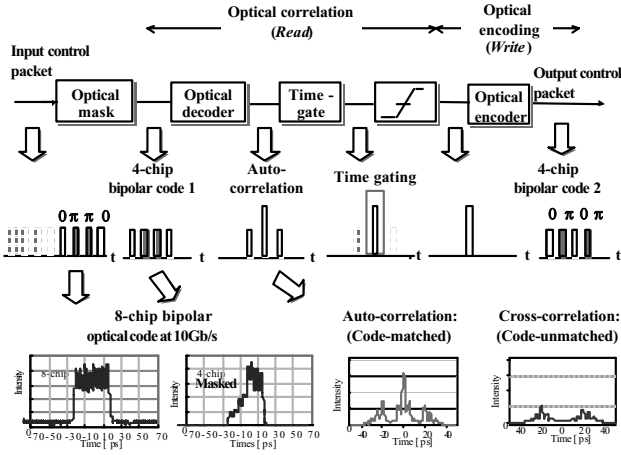


Fig. 1. Optical correlation (read) and encoding (write)

The rest of the paper is organized as follows. In Section 2, we present a brief description of our protocols and its enabling architecture. In Section 3, we present the contention resolution scheme using FDL architectures and show the efficiency of our architecture. Finally, we conclude our paper in Section 4.

II. OC-TAG: Fast Data Transfer Protocol

A. Optical read/write of signaling message

In OC-TAG, optical control packet carries the signaling message from the source to the destination. Mapping the information of the message onto optical codes allows ultrafast read/write of the message in optical domain. The read and write operations can be done by optical correlation and encoding, respectively. These are shown in Fig. 1. By taking the correlation between the incoming code and the template codes in parallel, a distinction of auto- and cross-correlation tells whether the code is matched or unmatched. Fig. 2 shows the architecture of optical processor which process the control packets using optical correlation and encoding. Unique to the optical correlation and encoding is that the processing speed is only limited by the velocity of light in the passive optical devices [8]. The feasibilities of the optical correlation and encoding have been experimentally demonstrated at 10 Gb/s with 8-chip long codes [8]. The bit rate can be increased up to hundreds of Gb/s.

B. OC-TAG protocol

Our OC-TAG protocol (Fig. 3) is described as follows. Note that our OC-TAG waits Δ after sending the RESERVE signal, where Δ is a time to configure the OXC at intermediate nodes, and do not include any electronic processing delay. Importantly, Δ is independent from hop-

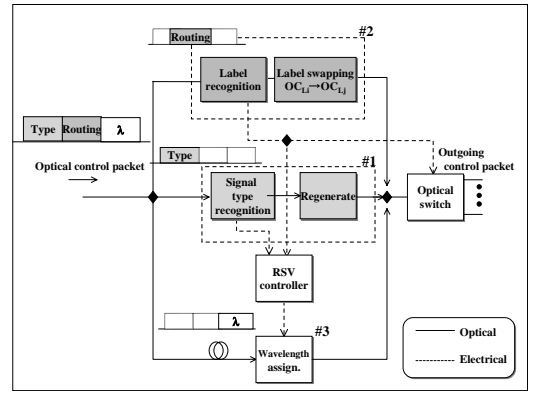


Fig. 2. Architecture of optical processor

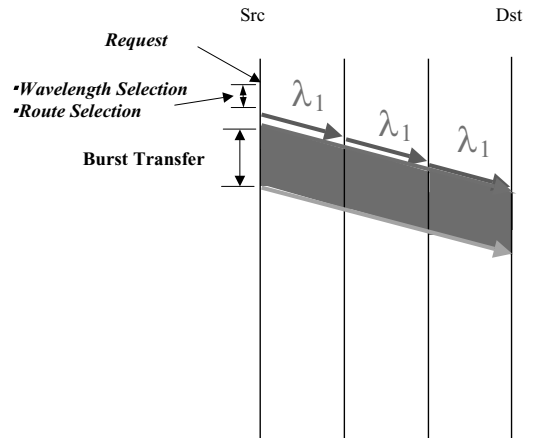


Fig. 3. Our OC-based Tell-and-Go Protocol (Successful case)

counts because control packets need not wait for the completion of OXC configuration.

Source node operation

- If a burst transfer request is received from a terminal, the usage conditions of the link wavelengths connected to the send node are checked, and the empty wavelengths are recognized as the candidate wavelengths. One wavelength is randomly selected from the candidate wavelengths. Then the wavelength is written into the RESERVE signal, and the signal is sent to the next node. After the RESERVE signal is sent, the send node waits for Δ , and then transmits the data burst.
- If the ACK signal from the destination node is received, the terminal is known to have been completed.
- If the NACK signal receives, the terminal knows the burst transfer fails.
- If the data burst ends, the wavelength used to transmit the burst is written into the RELEASE signal. Then, the RELEASE signal is sent to the destination node

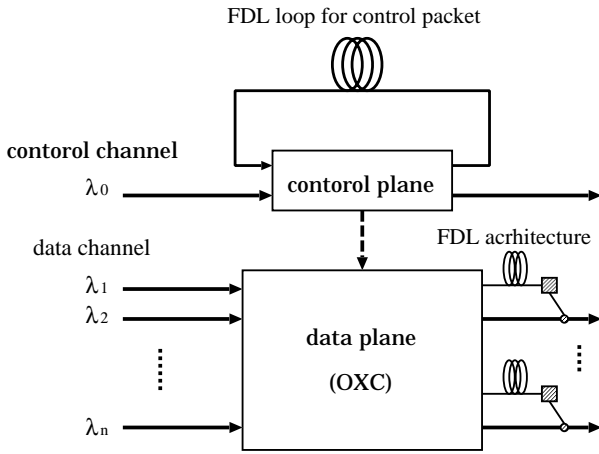


Fig. 4. OXC with FDL architectures

in order to release the reserved wavelength.

Intermediate node operation

- If the RESERVE signal is received, the set of reserved wavelengths written to the RESERVE signal and the set of empty wavelength at the next link are an intersection set.
- If the NACK signal or the ACK signal is received, it is sent to the next node without any change.
- If the RELEASE signal is received, the reserved wavelength at the next link are released and the RELEASE signal is sent to the next node.

Destination node operation

- If the RESERVE signal is received, the reserved wavelengths in the RESERVE signal are checked. If the set is empty, the NACK signal is sent to the send node. If the set is not empty, the ACK signal is sent to the send node. Note that the ACK and NACK signals are generated in an electronic domain.

III. Contention Resolution Scheme using Fiber Delay Line

A. Structure of FDL architecture

When contention occurs inside the OBS network, the source node needs to retransmit the burst. However, as mentioned in the previous section, the retransmission of the data transfer request depends on both round-trip propagation delay and processing delay at the edge nodes. In addition, the configuration time for the OXC is also an important factor in increasing burst transfer delay. We need some contention resolution mechanisms inside the OBS network for fast data transfer. One possible approach is FDL (Fiber-Delay-Line) buffering in the optical domain [10]. Due to the lack of optical RAM memory, the FDL has been used for buffering purposes in the optical packet switches. However, since FDL only provides fixed

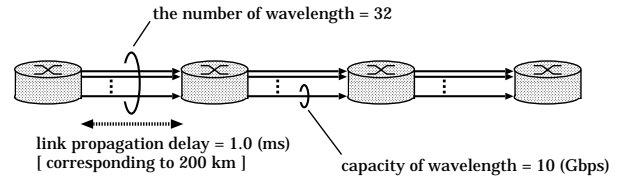


Fig. 5. Network model

delay, a rather complicated packet scheduling is necessary at each node, which leads to performance degradation of the optical switch. It is especially true in OBS because the length of offset time in OBS is directly affected by the scheduling time at the intermediate nodes. Furthermore, since the unit length of burst is much larger than that of packet, the capacity of FDL buffer in OBS should be limited in order to avoid the complicated management of the FDL buffer.

Keeping those facts in mind, we propose a simple contention resolution architecture using FDL that only provides a retrieval of the contended data request and therefore no scheduling is necessary. Our FDL architecture is different from FDL buffers in that it does not need scheduling or buffering. Since FDL only provides a fixed delay to bursts, our architecture can be designed much simpler than architecture using FDL buffers. Figure 4 has an architectural model of a node with FDL. It has a feed-back loop for the control plane and additional output ports that have FDL for the data plane. These FDLs for the data plane are prepared for every output line and can be shared by each wavelength. A contention resolution scheme using these architectures is described as follows.

If a RESERVE signal cannot make a reservation in an OXC, it is sent to the FDL loop temporarily. This FDL loop provides a fixed delay and another chance of making a reservation to a RESERVE signal. A RESERVE signal in the FDL loop will return to an OXC and attempt to reserve a wavelength. If this RESERVE signal again fails to reserve, it is discarded. However, in comparison to OC-TAG without FDL architectures, there is a stronger possibility of making a reservation in OC-TAG with FDL architectures. Burst transfer is done using an optical path in the OC-TAG protocol. Since this optical path is set up through a RESERVE signal, an interval between a RESERVE signal and burst, i.e., OXC configuration time, must be maintained. Therefore, a burst will also be sent to the FDL architecture, when a RESERVE signal is sent to the FDL loop.

B. Performance results

We evaluate our FDL architecture by comparing it with the normal OC-TAG, i.e., an OC-TAG without FDL ar-

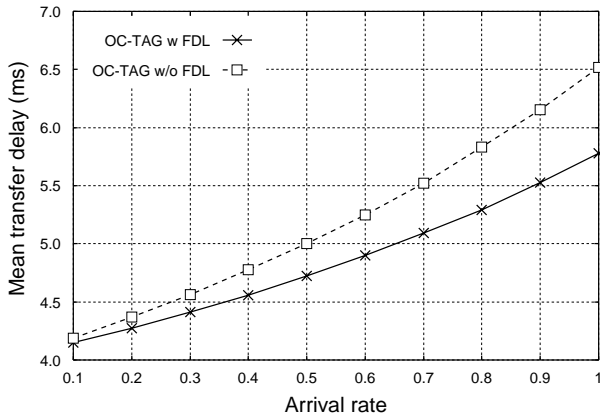


Fig. 6. Effect of FDL architectures

chitectures. We use OPNET Modeler 9.0 [11] in this simulation. Fig.5 shows the network model which we used in this simulation and some parameters. Burst transfer requests arise in all node-pairs. The arrivals of burst transfer requests at each node pair are assumed to be governed by a Poisson process with parameter e . The data transfer time for each request is assumed to be exponentially distributed with mean μ . In this paper, the arrival rate of burst transfer requests and the mean transfer length of the bursts are identically set to $e = e_a$ (burst/ms) and $\mu = 1.0$ (ms). Here, we set the OXC configuration time, $\Delta = 1.0$ (ms). In this simulation, we assumed retransmission when the burst transfer request was rejected.

The results in Fig.6 indicate that the mean burst transfer delay which is dependent on the arrival rate. If a burst transfer is blocked, then the burst has to wait for a NACK signal, and needs retransmission. This results in delayed burst transfer. We can observe from the figure that FDL architectures reduce the required time to transmit a burst. In other words, FDL architectures reduce the number of retransmissions and enable fast data transfer. Moreover, by comparing the data of each H which is the number of the hop-counts in Fig.7, we can see that our FDL architecture is more effective in a long hop than in a short one. The more intermediate nodes a burst passes through, the more difficult burst transfer becomes. Our FDL architecture improves burst loss probability per hop. Consequently its effect is larger in long hops.

IV. Concluding Remarks

In this paper, we have introduced our OC-TAG protocol based on the Tell-And-Go protocol. Our protocol allows variable-length of bursts with no buffering and fast data transfer by eliminating electronic processing delay overhead times. We next evaluate the data transfer delay. Since if a data transfer request is blocked, a round-

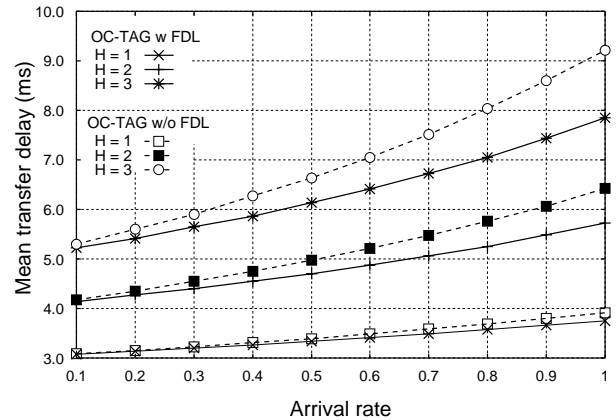


Fig. 7. Effect of FDL architectures per hop

trip propagation delay is necessary to retransmit the data transfer request. In order for more faster data transfer, we have introduced a contention resolution facilities utilizing fiber delay lines. Our future work is to combine another contention resolution facilities, such as wavelength conversion.

REFERENCES

- [1] C. Qiao and M. Yoo, "Optical burst switching (OBS) - a new paradigm for an optical internet," *Journal of High Speed Networks*, vol. 8, pp. 69–84, Jan. 1999.
- [2] J. Y. Wei and R. I. McFarland, "Just-in-time signaling for WDM optical burst switching networks," *Journal of Lightwave Technology*, vol. 18, pp. 2019–2037, Dec. 2000.
- [3] J. S. Turner, "Terabit burst switching," *Journal of High Speed Networks*, vol. 8, pp. 3–16, Jan. 1999.
- [4] S. Arakawa, I. Ogushi, M. Murata, and K. Kitayama, "A study on architecture using optical code processing for fast path setup in generalized MPLS network," *IEICE Technical Report (PNI2002-06)*, pp. 35–43, Apr 2002. (in japanese).
- [5] X. Yuan, R. Gupta, and R. Melhem, "Distributed control in optical WDM networks," in *IEEE Conference on Military Communications*, Oct 1996.
- [6] S. Arakawa, M. Murata, and K. Kitayama, "One-way reservation scheme using optical code processing for fast data transfer in WDM networks," in *Proceedings of ONDM2003*, 2003.
- [7] M. Yoo, C. Qiao, and S. Dixit, "Optical burst switching for service differentiation in the next-generation optical internet," *IEEE Communications Magazine*, pp. 98–104, Feb. 2001.
- [8] K. Kitayama, N. Wada, and H. Sotobayashi, "Architectural considerations of photonic IP router based upon optical code correlation," *Journal of Lightwave Technology*, vol. 18, pp. 1834–1844, Dec. 2000.
- [9] M. Murata and K. Kitayama, "A perspective on photonic multi-protocol label switching," *IEEE Network Magazine*, vol. 15, pp. 56–63, July/August 2001.
- [10] D. K. Hunter, M. C. Chia, and I. Andonovic, "Buffering in optical packet switches," *IEEE/OSA Journal of Lightwave Technology*, vol. 16, pp. 2081–2094, Dec. 1998.
- [11] OPNET Technologies, Inc., <http://www.opnet.com>.