Packet Multiplexing based on BGP Routing Information on Slotted OPS Networks

Yuki Okamura¹, Hideaki Imaizumi¹, Kenji Hisadome², Osamu Ishida², Yuji Sekiya¹, and Hiroyuki Morikawa¹
The University of Tokyo, Komaba 4-6-1, Meguro-ku, Tokyo, 153-8904, Japan.¹
NTT Network Innovation Laboratories, Hikarino-oka 1–1, Yokosuka, Kanagawa, 239–0847 Japan.²
E-mail: okamura@mlab.t.u-tokyo.ac.jp

Abstract—In this paper, we propose a packet multiplexing technique with flow aggregation based on BGP routing information for slotted optical packet switching (OPS) networks and evaluate its performance.

Index Terms—Slotted Optical Packet Switching, BGP Flow Aggregation, Packet Multiplexing

I. INTRODUCTION

Optical packet switching (OPS) networks have been researched as one of promising technologies for providing high capacity with lower power consumption [1]. In general, OPS networks can be divided into two categories: slotted (synchronous) and unslotted (asynchronous) networks. In a slotted network, packets with fixed length are synchronized at input port of each node before being switched. On the other hand, in an unslotted network, the packets are not synchronized and are switched one by one on the fly. Generally, slotted networks can achieve better performance than unslotted networks [2], [3], [4].

In the case that the slotted network is applied to traffic composed of variable-length information such as IP traffic, it causes a difficult problem when the largest data size in the traffic exceeds the fixed length. There are two approaches to solve the problem: (1) to select the largest data size in the traffic as the packet length and (2) to apply segmentation and reassembly protocols at the edge nodes between IP network and OPS network. However, the former could lead to lower bandwidth utilization, depending on the average data size of the traffic [4], while the latter increases system complexity and will become a problem at very high speed.

In order to increase bandwidth utilization on the slotted networks exploiting the former approach, we propose a packet multiplexing technique [5] with flow aggregation based on BGP (Border Gateway Protocol) routing information and evaluate its performance by simulation with real IP traffic data.

II. PACKET MULTIPLEXING WITH FLOW AGGREGATION

Fig. 1 illustrates the mechanism of packet multiplexing performed at an ingress edge node.

An incoming IP packet from IP networks is buffered into a particular packet multiplexing buffer in accordance with its destination. In the case that the length of the incoming packet exceeds the threshold length \( T_h \), the packet will immediately be converted into an optical packet and forwarded into the OPS network. In this case, if there is any other packet in the buffer, all packets in the buffer are converted and forwarded as an optical packet prior to the incoming packet in order to avoid packet reordering. Otherwise, the packet will be stored in the buffer until (1) total packet length exceeds \( T_h \), or (2) timeout \( T_o \) is reached. When either case happens, all packets in the buffer will be multiplexed into one optical packet and forwarded into the OPS network.

Fig. 1. Mechanism of Packet Multiplexing

An optical packet containing multiple IP packets will be demultiplexed at an egress edge node. Due to this property, all IP packets towards the same edge node can be multiplexed into the same optical packet. However, if the current routing protocols are simply applied to OPS networks, it will be difficult to identify an egress edge node at an ingress edge node because current routing protocols do not propagate location information of edge nodes, especially beyond AS (Autonomous System) borders. Therefore, in order to obtain better performance of packet multiplexing, it is very important to detect as many IP packets towards the same edge node at an ingress edge node as possible.

Herein, we propose a flow aggregation technique based on BGP AS \( AS \_PATH \) attributes as shown as the red line in Fig. 2. This approach is to aggregate IP packets towards a same destination AS. This technique can be performed with the

Fig. 2. Flow Aggregation
destination AS number of an AS_PATH attribute in the BGP (Border Gateway Protocol) routing table. The performance is expected to be better than that of destination prefix-based aggregation because a flow towards a destination AS includes multiple flows towards different destination prefixes.

The approach to achieve theoretically ideal performance is to aggregate IP packets towards the same egress edge node as shown as the black line in the figure. This approach, however, requires some modification to routing protocols such as BGP. One example of the modification is to enhance AS_PATH attributes to be able to indicate locations of edge nodes. This performance will be used as an ideal case in the evaluation to compare with the proposed approach.

III. PERFORMANCE EVALUATION

In order to evaluate and compare the performance among the three approaches, we conduct simulations with real traffic data. We assume that OPS is applied to current Tier-1 AS networks and edge nodes are located at borders between the Tier-1 ASes and other ASes. We use real traffic data from WIDE (AS2500) [6] towards Tier-1 ISP A in U.S. . Although the actual link bandwidth is 100Mbps, we use the data as traffic data in a 10Gbps link by shrinking the inter-packet interval. As a result, the traffic data is on average 1.3Gbps and the duration is 72 seconds.

Evaluation items are the as follows: (a) increase ratio of average optical packet length to average IP packet length, (b) decrease ratio of the number of optical packets to incoming IP packets, and (c) average buffering delay.

Fig. 3 shows the results of the evaluation item (a). The left figure in Fig. 3 shows the results varying Th with To of 1000us. The average length of optical packets multiplexed with destination AS-based aggregation was 12% higher than that with network prefix-based aggregation. In the ideal case, the average length of optical packets multiplexed with edge node-based aggregation was only 8% higher than that with destination AS-based aggregation. The right figure shows the results varying To with Th of 80%. As To gets longer, the average length of optical packets increased for all approaches. At Th of 2000us, the average length of optical packets multiplexed with edge node-based aggregation increased 74%, while that with destination AS-based increased 66% at the maximum . Destination AS-based aggregation showed good performance close to edge node-based aggregation.

Fig. 4 shows the results of the evaluation item (b). The left figure in Fig. 4 shows the results varying Th with To of 1000us. Destination AS-based aggregation reduced up to 38% of the number of incoming IP packets. The average number of optical packets multiplexed with destination AS-based aggregation reduced 5.4% as compared to that with network prefix-based aggregation, and increased 3.1% as compared to that with edge node-based aggregation. The right figure shows the results varying To with Th of 80%. The number of optical packets multiplexed with destination AS-based aggregation was up to 5.2% lower than that with network prefix-based aggregation and was up to 2.8% higher than that with edge node-based aggregation.

Fig. 5 shows the results of the evaluation item (c). The left figure shows the results varying Th with To of 1000us. The average delay of edge nodes-based aggregation was 0.4 ms at a maximum, while that of destination AS-based aggregation was 0.5ms at a maximum. The right figure shows the results varying Th with To of 80%. Unlike the evaluation item (a) and (b), the average buffer delay linearly increased without saturation as To gets longer. The result indicates that longer To could cause inefficiency and there could be the optimum value of To. When To is 2000us, the average delay was maximum. The average delay of edge nodes-based aggregation was 0.6ms, while that of destination AS-based aggregation was 0.8ms.

IV. CONCLUSIONS

In this paper, we proposed a packet multiplexing technique with flow aggregation based on BGP routing information to detect IP packets towards the same edge node in order to increase bandwidth utilization in slotted OPS networks. In addition, we evaluated its performance on simulation environment with real IP traffic data.

The results showed that packet multiplexing with out proposed flow aggregation towards destination AS increased 60% of the average packet length, decreased 38% of the number of packets, and the average buffering delay caused as a secondary effect was 0.45ms under a specific parameters.

REFERENCES