

An Evaluation of Effects on Packet Loss Rate by Optical Packet Multiplexing based on BGP Flow Aggregation

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Abstract: We apply our proposed packet multiplexing mechanism with BGP flow aggregation to asynchronous OPS networks and evaluate packet loss ratio in a FDL buffer through simulation based on real traffic trace data.

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1. Introduction

In order to accommodate enormous amount of traffic in the future Internet, Optical Packet Switching (OPS) technology has been researched as one of promising technologies with lower power consumption[1].

One of the major issues for performing asynchronous OPS technologies with variable length packets is efficient buffering function for avoiding contention in optical domain due to the fact that optical RAM will not be mature in near future. Currently, fiber delay lines (FDLs) [2] providing contention resolution function in time domain are practical solution especially for multi-wavelength OPS [3] where contention resolution in wavelength domain can not be applied.

FDLs consists of the fixed number of FDLs in which each has different length and can provide a series of discrete delays. Due to the discreteness, short packets suffer for unnecessarily long delay and would lead enormous packet loss because one FDL can accommodate one packet even if the length is very short.

In this paper, we apply the packet multiplexing mechanism with flow aggregation based on BGP routing information previously proposed [4] into asynchronous OPS and we evaluate its performance in terms of packet loss rate through simulation with real traffic trace data.

2. Packet Multiplexing Mechanism with Flow Aggregation

This section briefly describes the packet multiplexing mechanism with several flow aggregation strategies.

Fig. 1 illustrates a border edge node between an IP network and an OPS network. Each incoming IP packet from the IP network is buffered into a particular packet multiplexing buffers in accordance with its destination. In the case that the length of the incoming packet exceeds the threshold length Th , 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 Th , or (2) timeout To has elapsed. When either case happens, all packets in the buffer will be multiplexed into one optical packet and forwarded into the OPS network.

An optical packet containing multiple IP packets will be demultiplexed at an egress edge router. Due to this property, it has to contain IP packets towards the same edge router. In order to obtain better performance of packet multiplexing, we previously proposed three strategies to detect a set of IP packets (packet flow) towards a particular edge router as depicted in Fig. 2. The first one is IP packets towards a same network prefix, the second one is towards a same destination AS, and the last one is towards a same egress edge router as an ideal cases by modifying existing routing protocols.

In the previous work, we obtained results that this packet multiplexing technique with out proposed flow aggregation based on the destination AS strategy 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.

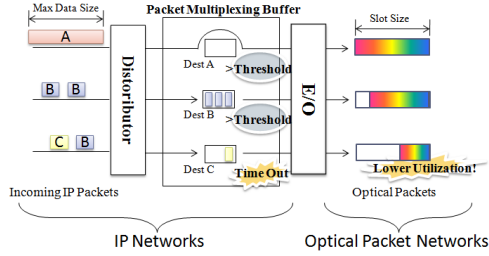


Fig. 1 Packet Multiplexing Technique with Flow Aggregation

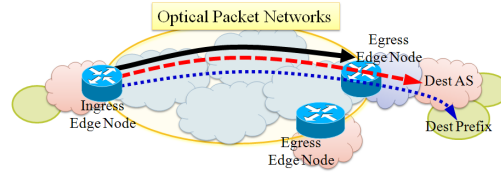


Fig. 2 Type of Flow Aggregation Strategies

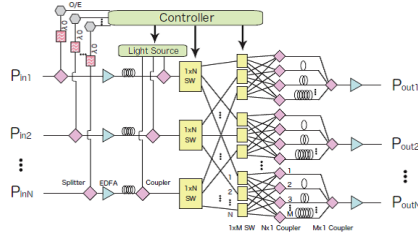


Fig. 3 Contention Resolution Mechanisms using FDLs

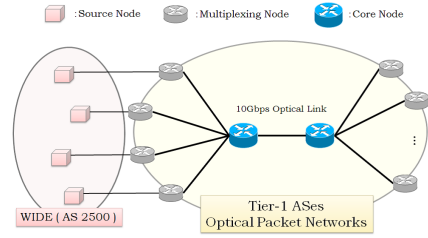


Fig. 4 Simulation Network Model

3. Evaluation of Effects on Packet Loss Rate

In this section, we evaluate the effects of the proposed mechanism to packet loss rate in asynchronous OPS networks with our proposed mechanism through simulation based on real traffic trace data. We first explain the simulation model and then show the simulation results.

3.1 Simulation Model

Fig. 3 illustrates the $N \times N$ switching node design in our simulation network.

It contains feed-forward output buffers and each buffer consists of a number of FDLs where each FDL has a different length (d_0, d_1, \dots, d_{M-1}). The series of the lengths is proportional to a unit length D and the buffer gives a series of discrete buffering delay from 0 to $(M-1) \times D$ to incoming packets.

The scheduling policy for the FDL buffer in this simulation is very simple as follows. The policy is basically that each packet will be assigned into the shortest FDL available at the moment unless the packet will cause packet re-ordering. When a packet incomes to an input port of the switching node, the scheduler first recognises its length and its destination port and confirms the state of the buffer corresponding to the output port. In the case that there is no packet in the buffer, the packet will be forwarded through the shortest FDL d_0 . Otherwise, the scheduler tries to find the longest FDL d_i which contains a packet and tries to assign the shortest FDL $d_j (j > i)$ which can avoid the contention. In the case that there is no such FDL, the scheduler operates optical switches in order to discard the packet.

The network for the simulation is illustrated in Fig. 4. This network consists of two core nodes, eight edge nodes which provide our proposed packet multiplexing/demultiplexing mechanism, and four source nodes which transmit packets to the optical network. Each link bandwidth is 10Gbps. The traffic data generated by the sources is based on real traffic trace data as shown in Table. 1. The series of real traffic trace data was captured at the link to U.S. Tier-1 AS networks in WIDE (AS2500). Although the actual link bandwidth is 100Mbps, we shrink the inter-packet gap in the captured data in order for contention to easily happen.

We assume that OPS technology is applied to current Tier-1 AS networks and so edge nodes are located at borders between the Tier-1 ASes and their customer ASes.

As parameters for the core nodes, we use 600 bytes and 20 for unit length D and the number of FDLs, respectively. For multiplexing edge nodes, we use 80% and 1ms for Th and To , respectively.

Table 1 Real Traffic Trace Data

Inter-packet Gap Compressibility	0.15 – 0.05
Traffic Rate [Gbps]	2.5 – 8.0
Packets per Second [$\times 10^6$ pps]	1.5 – 5.0
Average Packet Length [Bytes]	642

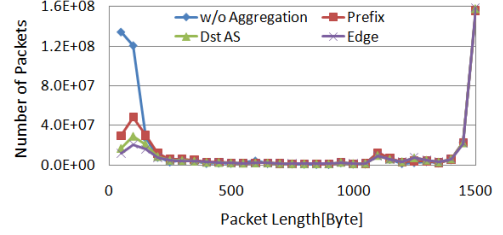


Fig. 5 Packet Distribution

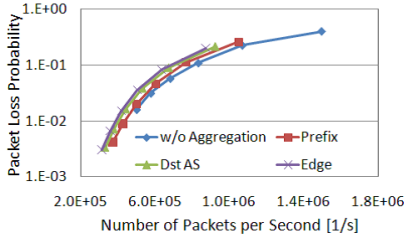


Fig. 6 Packet Loss Ratio to PPS

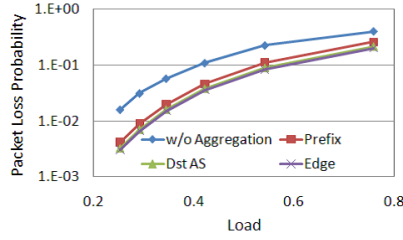


Fig. 7 Packet Loss Probability to Traffic Load

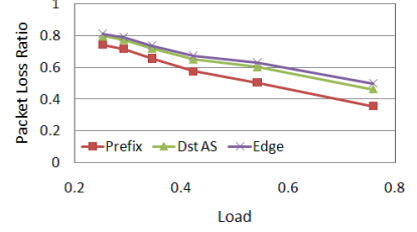


Fig. 8 Packet Loss Ratio to without Packet Multiplexing

3.2 Simulation Results

Fig. 5 shows packet length distribution for four cases: no multiplexing and multiplexing with three types of flow aggregations. In the distribution of no multiplexing case, there is a significant number of packets whose lengths are less than 200 bytes and greater than 1200 bytes. By applying the mechanism, the number of packets whose lengths are less than 200 bytes is drastically reduced. In contrast, the number of packets whose lengths are greater than 1200 bytes increases a little. This is just because the number of packets aggregating short packets is less than the number of the short packets aggregated. By applying this mechanism, the majority of packets has over 1200 bytes because there are not significant number of packets whose lengths are between 200 and 1200 bytes.

Fig.7 and Fig.8 show the packet loss rate observed at the output link in the core node. When traffic load is 0.28, the packet loss rate without packet multiplexing was 1.6%, while that with destination AS-based aggregation was $3.3 \times 10^{-1}\%$. Destination AS-based aggregation reduced 79% of the packet loss rate without packet multiplexing. However, when traffic load is 0.8, the packet loss rate without packet multiplexing was 40%, while that with destination AS-based aggregation was 22%. Destination AS-based aggregation reduced only 54% of the packet loss rate without packet multiplexing. In the ideal case, when traffic load is edge-based aggregation reduced the packet loss rate to 20%, and when traffic load is 0.8 that reduced to 46%.

Fig.6 shows the packet loss rate to the number of arriving packets per second (PPS). Despite of difference of the average packet length, the correlation of PPS and the packet loss rate was almost the same in all flow, and the packet loss rate decreased rapidly When PPS was low. Due to it, the packet loss rate with packet multiplexing reduced drastically when traffic load is low. This result showed that our proposed methods is effective for contention resolution mechanisms using FDLs in unslotted networks.

4. Conclusions

In this paper, we evaluated the effects on packet loss ratio with packet multiplexing mechanism using flow aggregation in asynchronous optical packet switching networks where fiber delay lines are exploited as a contention resolution mechanism. The results showed that the packet multiplexing mechanism with destination AS flow aggregation decreased up to 79% of the packet loss rate, compared to that without packet multiplexing. This indicates that this mechanism would be one of complementary functions which can reduce packet loss ratio in FDL buffers in asynchronous OPS networks.

References

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