40 Gb/s Buffered 2x2 Optical Packet Switching Using Photonic Integrated Circuits

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Abstract: Contention resolution and forwarding of labeled optical packets at 40 Gb/s is demonstrated utilizing multiple InP based optical buffers and monolithic wavelength converters. Layer-2 packet recovery measurements are presented.

OCIS codes: (060.1810) Buffers, couplers, routers, switches, and multiplexers; (060.6719) Switching, packet

1. Introduction

Optical packet switching provides a means of communication that is high bit rate, transparent, and scalable [1]. In label switched optical packet switching, forwarding information and data are separated into lower bit rate headers and high bit rate payloads [2]. This allows for the use of low frequency electronics for processing headers and payload envelope information while transparently forwarding high bit-rate payloads optically at low switching speeds. Optical packet switches must operate asynchronously making optical buffering a necessary functionality for contention resolution to avoid temporal collisions of packets simultaneously destined for the same output port [3, 4]. Buffering of 40 Gb/s payloads has been shown previously utilizing an integrated 2x2 InP switch matrix with fiber delay lines [5]. Switches must also be able to dynamically route packets to different output ports. Wavelength converters (WCs) offer a scalable and fast switching solution. A monolithic wavelength converter based on a PD-EAM gate and SGDBR laser has been demonstrated to operate at any bit rate up to 40 Gb/s in both NRZ and RZ formats [6].

We demonstrate optical packet buffering utilizing packaged compact InP switches with fiber delay lines that erase 10 Gb/s headers and re-circulate 40 Gb/s payloads for contention resolution. Buffered 40 Gb/s payloads are then dynamically forwarded through the use of monolithic fast switching PD-EAM based wavelength converters. Buffering and forwarding decisions are made based on output destinations extracted from 10 Gb/s headers and envelopes of 40 Gb/s payloads.

2. Principle of Operation and Experimental Implementation

The basis of optical buffering, forwarding, and electronic lookup for a 2x2 optical data router is shown in Fig. 1. Transmitted optical packets occupy a timeslot (Ts) of 64 ns which consist of 128 bit NRZ headers at 10 Gb/s, 40 byte RZ payloads at 40 Gb/s, and 43.2 ns guard bands. The optical headers contain a label field that indicates the output port. The stream contains three packets and the labels alternate output port requests B, A, B respectively at a wavelength of 1560nm as shown in Fig. 2. The transmitted signal is split into two identical streams and injected to input A and input B of the system. The packet stream is optically tapped and the data enters a clock/data recovery circuit (CDR) and payload envelope detector (PED). In this experiment, a 10 GHz clock from the transmitter was used as the input of the clock recovery circuit so that the system was synchronous. Recovered headers and envelopes are sent to an FPGA based electronic channel processor (ECP) to determine the output port destination of the payloads based on the optical label and to provide a precise time reference for the payloads. The ECPs then forward the recovered payload envelopes as output port requests to a central arbiter for electronic lookup. The FPGA based arbiter uses a lookup table to determine contention and buffer control by comparing port requests and buffer queue signals. Based on the lookup table, the arbiter generates buffer control signals which pass a packet through, load a packet into the buffer, re-circulate a packet in the buffer, or unload a packet from the buffer. The arbiter also generates WC control signals which are used to switch wavelengths in order to forward packets. The buffer and WC control signals are then sent to the corresponding ECPs which forward the signals to the buffers and WCs. The buffers consist of packaged 2x2 InP switches driven by current DACs and RF opamp circuits. The fiber delay line, equivalent to 64ns, includes an attenuator, band pass filter and polarization controller. The buffers erase labels by turning SOAs off before the payloads and gating the payloads for buffering. Buffer A circulates packets 1, 2, 3 for 1, 0, 0 timeslots and buffer B circulates packets 1, 2, 3 for 0, 1, 1 timeslots respectively as shown in Fig. 2. The wavelength converters are switched by modulating the front mirror of the SGDBR laser. WC A converts packets 1, 2, 3 to 1554, 1560, 1554 nm and WC B converts packets 1, 2, 3 to 1559, 1553, 1559 nm respectively as shown in Fig. 3. Band pass filters with a band with of 1.2 nm are used to simulate an arrayed waveguide grating (AWG). Here, the filters are tuned to 1560 nm for input A and 1553 nm for input B destined for output A and tuned to 1554 nm for input A and 1559 nm for input B destined for output B. New labels would then be written in front of the forwarded payloads.

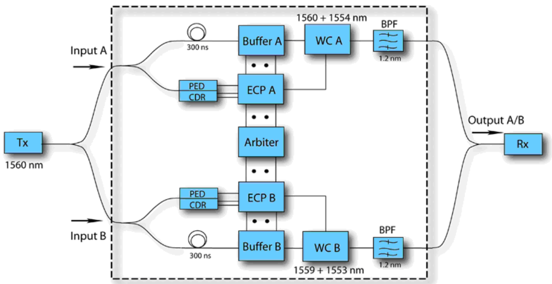

Fig. 1. Buffers , wavelength converters, and electronic lookup of a 2x2 optical packet switch

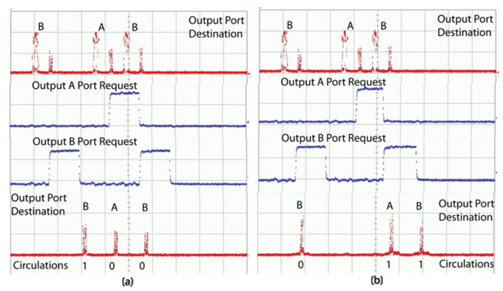

Fig. 2. Input packet stream, port request signals, and buffered payloads (a) channel A (b) channel B

3. Performance Measurements

Layer-2 packet recovery measurements were conducted for buffered packets that are dynamically wavelength converted. Packet recovery is a necessary measurement when small packets are used and rearranged but misaligned at the bit level. Packet recovery is defined as successful recovery of the entire 64 bit payload identifier followed by an 8 bit control field inside the payload. Curves were taken for back-to-back that contain headers and payloads as well as a stream that contained payloads only. Measurements were then taken for each buffered, converted, and filtered output separately. Greater than 92% packet recovery was achieved for all buffered and converted payloads. The large offset in curves is caused by the difference in duty cycles of the measured signals, insertion loss of the buffers, and extinction of the converted payloads as well as the use of a pre-amplified receiver.

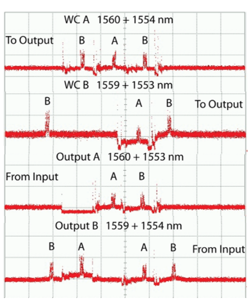

Fig. 3. Converted payloads of WC A/B and output A/B

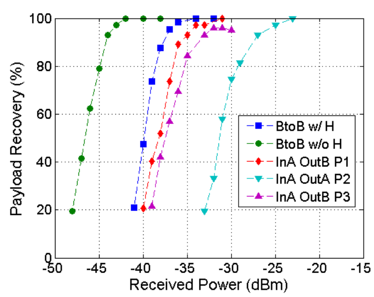

Fig. 4. Packet recovery for buffered and converted payloads from channel A.

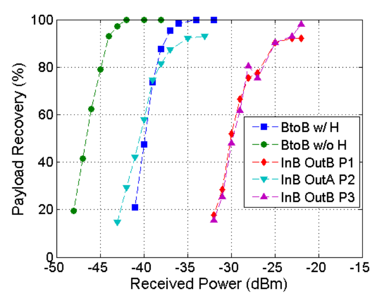

Fig. 5. Packet recovery for buffered and converted payloads from channel B.

4. Conclusions

Multiple packaged optical buffers and monolithic wavelength converters are used to demonstrate dynamic optical buffering and forwarding at 40 Gb/s. Forwarding and buffering decisions are determined for 40 Gb/s payloads from 10 Gb/s labels with greater than 92% packet recovery demonstrated.

4. Acknowledgement

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5. References

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