An all-optical packet-switched ring network

P. K. A. Wai,1 Lixin Xu,2, L. F. K. Lui,1 L. Y. Chan,1 C. C. Lee,1 H. Y. Tam,3 and M. S. Demokan3

1Photonics Research Centre and Department of Electronic and Information Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong
Phone: +852 2766-6231, fax: +852 2362-8439, email: pkuai@polyu.edu.hk
2Department of Physics, University of Science and Technology of China, Hefei, 230026, China
3Photonics Research Centre and Department of Electrical Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

Abstract: We demonstrated an all-optical packet add-drop node for a uni-directional all-optical packet-switched ring network. All-optical add, drop, and clearance of packets are performed based on all-optical processing of packet headers. The header and payload rates are 5 Gb/s and 10 Gb/s respectively.

©2004 Optical Society of America
OCIS codes: (230.1150) All-optical devices; (190.1450) Bistability; (140.3520) Lasers, injection-locked

1. Introduction

To support future multi-media services required to be delivered over long distance, optical networks utilizing fast packet switching are expected to provide the required capacities and flexibility. Most of the research on optical packet switching to date converts the packet headers into the electrical signals for processing [1]. Recently, we demonstrated an all-optical add-drop node for packet-switched networks using two stage injection-locked Fabry-Perot laser diodes (FP-LDs) [2]. In this paper, we proposed and demonstrated an all-optical add-drop node constructed from a FP-LD and two SOAs. The packet add, drop, and clear functions are carried out based on the outcome of all-optical processing of the packet headers. No high speed electronics are needed. The add-drop node can be used to construct uni-directional optical packet-switched ring networks which can be used in local area networks (LAN) as well as metropolitan area networks (MAN). The demonstrated header and payload rates are 5 Gb/s and 10 Gb/s respectively.

2. Design of the network and network node

Figure 1a shows a uni-directional ring network and Fig. 1b shows the schematic of one of its node. The network is assumed to be slotted. A node consists of an input port, output port, add port and a drop port. The node is constructed with three all-optical logic devices. The AOHP serves as an all-optical header processor and it also determines whether a packet in the ring can be sent to the local drop port. AOS-1 and AOS-2 are simple all-optical on/off switches. AOS-1 controls whether a transit packet in the ring is allowed to continue on in the ring and AOS-2 determines whether a packet from the add port of the node can be placed in the ring. The proposed node operates as follows. If the address header of a transit data packet in the ring entering the node through the input port matches with the address of the node carried by the control signal input to AOHP, the AOHP will (i) transmit the data packet, (ii) generate a control signal that will set AOS-1 to block the packet, and (iii) send another control signal to set AOS-2 to transmit. As a result, the data packet is removed from the ring and passed to the drop port. Thus the packet drop function of the node is achieved. At the same time AOS-2 allows a packet from the local add port, if any, to be placed in the ring to fill the vacated time slot. If the address header of the transit data packet in the ring does not match with that of the node, AOS-1 is set to transmit while AOS-2 and AOHP are set to block. In this case, the packet in the ring is transmitted to the next node while no packet is allowed to be added to the ring. In order to
avoid differentiating an empty time slot from an occupied time slot, we define the address of empty packets such that they are accepted by all the nodes in the network. In addition, a node will continue to transmit empty packets even if it has nothing to send. As a result each node is continuously accepting empty packets from the node upstream and sends empty packets to the node downstream even if there are no user data packets in the network. Finally, we use the bistability and multimode injection locking properties of FP-LD to implement the AOHP and we use the cross-gain modulation property of SOAs to implement the AOSs.

3. Experimental Results

Figure 2 shows the experimental setup of the all-optical packet add-drop node. A FP-LD serves as the AOHP. The data packets at 1542.76 nm are generated by externally modulating a tunable laser (TL-1) using a 10 Gb/s non-return-to-zero (NRZ) pulse pattern generator and a LiNbO\(_3\) modulator. Four type of packets are used with header addresses ‘0111’, ‘1011’, ‘1101’ and ‘1110’ for pk-1, pk-2, pk-3, and pk-4 respectively intending for node 1 to node 4. The header and data rates are 5 Gb/s and 10 Gb/s respectively. The control packets at 1540.16 nm are generated using a 10 Gb/s NRZ pulse pattern generator, a 660 MHz pulse pattern generator, and two 10 Gb/s LiNbO\(_3\) modulators on the output of a tunable laser (TL-2) with 5.9 dBm injected power and +0.22 nm wavelength detune. The header of the two-level control packets contains ‘0100’, the complement of the address of pk-2.

Figures 3a to 3d show the synchronized timing diagrams for the signals at the AOHP: (a) the input data packets, (b) the input control packets, (c) the aligned headers of the input data and control packets, the switched data packets at (d-1) 3 ns/div and (d-2) 1 ns/div. We note that pk-2 is successfully switched to the drop port. The output of the FP-LD is filtered at 1540.16 nm is then split into two portions and injected into two different SOAs which serve as the all-optical on/off switches. The other portion of the original data signals are also split into two parts and injected into the two SOAs. One part serves as the data from the local add port. Figures 3e to 3j show the timing diagrams for the AOS-1 and AOS-2: (c) the data from the local add port (which is the same as the original data signal in this demonstration,) (f) the input control packets to AOS-2 which only allow local packets from the add port to pass through if there are packets dropped from the network. Pk-2 is chosen for convenience in synchronization, (g) the output of AOS-2 at 1542.76 nm, (h) the input control packets to AOS-1 which performs the clear-packet function for the pass-through port, (i) the output of AOS-1 at 1542.76 nm. Note that pk-2 is blocked so that the dropped packet is clear from the data signal, and (j) the combined output from AOS-1 and AOS-2 using a polarization beam combiner. We intentionally offset the output of AOS-2 (add port) to demonstrate that the add function is properly implemented. A polarization beam combiner is used to in order to eliminate the interference noise when combining two signals at the same wavelengths [4].

3. Conclusion

We have successfully demonstrated an all-optical add-drop node which can perform on-the-fly header processing, packet clearance, and packet add-drop using an injection-locked Fabry-Perot laser diode as all-optical header processor and two SOAs as all-optical on-off switches. The header rate is 5 Gb/s and the data rate is 10 Gb/s. The node can be used to construct unidirectional all-optical packet-switched networks for LAN or MANs.

5. References


Fig. 2 Experimental setup. Note: TL – tunable laser; FP-LD – Fabry-Perot laser diode; SOA – semiconductor optical amplifier; EDFA – erbium-doped fiber amplifier; TBPF – tunable bandpass filter; ODL – variable optical delay line; PC – polarization controller; PBC – polarization beam combiner.

Fig. 3 Synchronized timing diagram at the AOHP: (a) input data packets, (b) input control signal, (c) aligned headers of both input packets and input control signal, switched data packet at (d-1) 3 ns/div, and (d-2) 1 ns/div.

Fig. 1. Schematic of the proposed all-optical add/drop node. The alphabet labels correspond to the timing diagrams in Fig. 3.

Fig. 3 (cont’d) Synchronized timing diagrams at AOS-1 and AOS-2: (e) local data packets (same as (a) in this demonstration), (f) switched control packets from AOHP output; (g) switched local data packets from AOS-2 (add port), (h) control packets from AOHP complementary to (f), (i) output data packets from AOS-1 (pass-through), and (j) data packets at the node output.