Experimental Demonstration of Multicast in an Optical-label Switching Router with Mixed Data Rates of 10 Gb/s and 2.5 Gb/s

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Abstract *This paper experimentally demonstrates multicast packet forwarding in an optical-label switching router with mixed data rates of 10 Gb/s and 2.5 Gb/s. The demonstration employs multi-wavelength conversion in integrated Mach-Zehnder interferometer with semiconductor optical amplifiers.*

Introduction

The optical-label switching (OLS) technology supports transparent all-optical routing and sophisticated network functions by processing the short label in the electronic domain while leaving the data payload in the all-optical domain [1]. In this way, the routing is independent of the payload data format and bit rate. Moreover, with the help of electronic circuit, the router can support various network functions such as time-to-live and multicast. Growing multimedia conferencing and streaming applications demand optical-layer multicast that has been proposed and demonstrated in various architectures such as broadcast-and-select and one-to-many (multi-) wavelength conversion [2-3]. However, these architectures suffer from scalability problems. We proposed and demonstrated a scalable, multicast-capable optical-label switching router using cross-gain modulation (XGM) in a semiconductor optical amplifier (SOA) as the multi-wavelength conversion (MWC) method [4]. This method had a bit rate of 2.5 Gb/s. In this paper, we demonstrate the OLS router capable of mixed data-rate multicast and unicast routing at 10 Gb/s and 2.5 Gb/s data rates with all-optical contention resolution in the wavelength domain [5].

Experiment Descriptions

The OLS router forwards multicast packets to dedicated multicast linecards that utilize multi-wavelength conversion [4]. Fig. 1 shows the experimental setup. In the figure, $(m,n)_{in}$ and $(m,n)_{out}$ represent the nth wavelength on the mth input and output fiber, respectively. For simplicity the setup does not include fixed wavelength converters (FWC) at the outputs of the arrayed waveguide grating router (AWGR) and the label rewriters. The setup has two input linecards and one multicast linecard. The payload of linecard 1 runs at 10 Gb/s while that of linecard 2 runs at 2.5 Gb/s. The subcarrier-multiplexing transmitter (SCM TX) before each line card generates optical packets with the payload on the baseband and a 155 Mb/s label on the 14 GHz subcarrier. The label extractor (LE) separates the label and the payload [6]. Then, the burst-mode
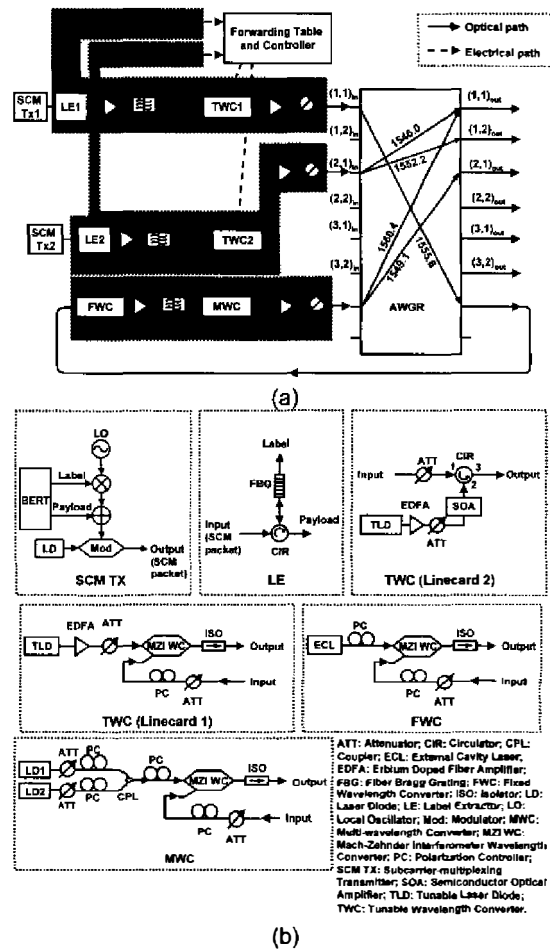

(a)

(b)

Fig. 1. (a) Experimental setup. (b) The details of the modules in (a). In the AWGR the wavelength values for switching from a certain input to a certain output are shown.

receiver (BMRX) recovers the label, and the switch control makes routing decisions according to the label content and the forwarding table. The tunable wavelength converter (TWC), following the instruction from the switch control, tunes to the target wavelength corresponding to a certain output port of the AWGR and copies the payload onto this wavelength. The TWC in line card 1 is an SOA-MZI utilizing XPM while that in line card 2 is an SOA
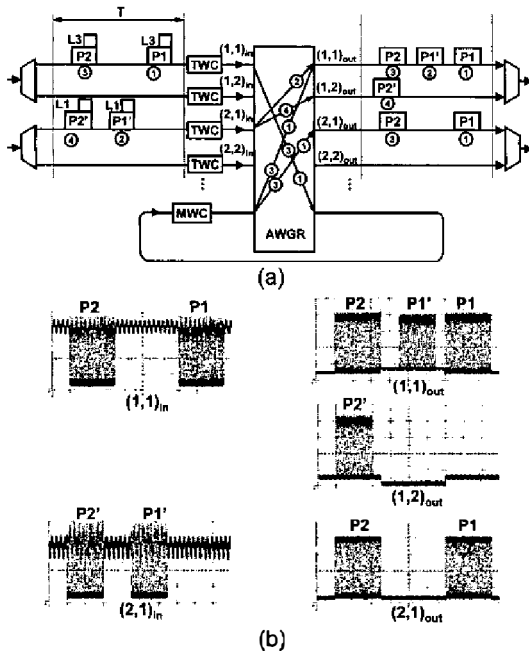
(a)

(b)

Fig. 2. (a) Timing diagram. (b) Packet traces on oscilloscope. T = 2.06 μs. The time axes of the oscilloscope traces are pointing to left; the time scale is 206.4 ns/div. The numbers in circles show the order of packet arrival and switching. TWC: tunable wavelength converter; AWGR: arrayed waveguide grating router; FWC: fixed wavelength converter; MWC: multi-wavelength converter.

utilizing XGM. The converted payload travels to the desired output port of the AWGR. For a multicast packet, the switch control sends the packet to the multicast linecard, where the MWC (the SOA-MZI utilizing XPM) duplicates the payload onto multiple wavelengths. These wavelengths then lead the payload through the AWGR to multiple desired output ports. For simplicity this experiment only demonstrates two fixed wavelengths for multicast.

Fig. 2 shows the timing diagram and the oscilloscope traces of the packets. Different labels indicate different destinations. The packets with L1 and L2 desire to go to output fiber 1 and 2, respectively. The preferred wavelength is the first wavelength on the fiber. L3 flags multicast packets that desire to go to both output fiber 1 and 2. In the description below, the notations $(m,n)_{in}$ and $(m,n)_{out}$ follow those in Fig. 1. In the experiment, packet P1 with label L3 arrives at $(1,1)_{in}$ first. The switch control sends the payload to the multicast port that duplicates the payload and forwards the two copies to $(1,1)_{out}$ and $(2,1)_{out}$. P1' with L1 arrives at $(2,1)_{in}$ later and goes to $(1,1)_{out}$. Another multicast packet P2 with L3 arrives at $(1,1)_{in}$ and travels to $(1,1)_{out}$ and $(2,1)_{out}$. When P2' with L1 reaches $(2,1)_{in}$, the port $(1,1)_{out}$ is still occupied. Thus, P2' has to go through contention resolution in the
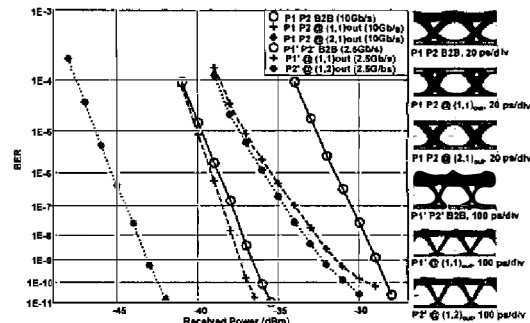

Fig. 3. Bit-error rate measurement results and eye diagrams. B2B: back-to-back.

wavelength domain and travel to $(1,2)_{out}$ [5]. The packet sequences then repeat to facilitate the bit-error rate (BER) measurement. The oscilloscope traces show that the router produces the desired results. The input packets have inverted-logic purposely chosen to facilitate the switching experiment with inverting wavelength converters in the switching fabric. Fig. 3 shows the packet-by-packet BER measurement results with eye diagrams. All the BER curves can reach below 10^{-10}, indicating proper router operation. The bend of the BER curves for 10 Gb/s outputs is due to the jitter accumulation in the cascaded SOA-MZI WCs. In a separate experiment, we were able to confirm suppression of the bend by introducing 3R regeneration. The power values in the BER curves contain average power changes purely due to logic inversion and packet switching [5]. A rough correction shows that at 10^{-9} BER, the power penalties for the two 10 Gb/s outputs are 1.0 dB and 1.6 dB, respectively; while those for the two 2.5 Gb/s outputs are 2.8 dB and 2.5 dB, respectively. The penalties for 2.5 Gb/s outputs are mainly due to an imperfect extinction ratio by XGM.

Summary

This paper experimentally demonstrates multicast packet forwarding in an OLS router with mixed data rates of 10 Gb/s and 2.5 Gb/s with all-optical contention resolution in the wavelength domain. The multicast function employs MWC using an integrated SOA-MZI. The results prove that the router is functioning correctly with the BER lower than 10^{-10}.

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