Advanced All-Optical Switching Technologies and Photonic Communications Systems

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Abstract: We demonstrate a photonic packet routing system incorporating optical-labels and all-optical contention resolution in wavelength, time, and space domains. Rapid optical packet switching with 600 psec has been achieved with error free operation.

1. Introduction

Optical-packet switching is an attractive technology geared towards integration of data and optical networking. The immense bandwidth provided by optical networking and the capability to switch packets directly at the optical layer are a powerful combination for the Next Generation Internet where scalability, agility, and performance are important considerations. Early optical-packet switching technologies investigated bit-synchronous, fixed size packet switching. More recently, IP-over-optical emerged as a novel concept targeting seamless integration of data and optical networking [1]. In essence, simplifying the conventional open systems interconnection (OSI) layer protocol stacks including SONET and ATM, to perhaps IP directly over wavelength-division multiplexing (WDM) networking technology may provide significant savings in equipment and operation costs while offering higher performance. For these reasons, the current circuit-switching networking infrastructure is expected to evolve eventually to a packet switching networking infrastructure. In this process, interoperability between packet, burst, and circuit switching can facilitate the network upgrades. Optical-label switching (OLS) technology [2,3] is a truly flexible networking technology for accommodating IP-over-optical on a WDM platform by means of optical-labels.

2. Optical-Packet Switching and Optical-Label Switching Overview

Fig. 1 illustrates a schematic of an Optical-Label Switching Router integrated at UC Davis. New signaling information is added in the form of an optical-label by the edge router, and the optical-label is carried in-band within each wavelength in the multi-wavelength transport environment. The optical-label containing routing and control information will propagate through the network along with the data payload. Each optical-label switching router will sense this optical-label, look-up the forwarding table, and take necessary steps to forward the packet. During this processing and switching time, the packet is delayed by the optical fiber loop at the transport-input interface before entering the switch fabric. The prototype optical router to be discussed achieves this in 250 nsec and a 50 meter fiber loop was utilized. If the packet is to be forwarded to a wavelength/path where there is already another packet being forwarded, the optical-label switching router (OLSR) will seek forwarding by an alternate wavelength, by buffering, or by an alternate path. This wavelength, time, and space domain contention resolution [4] is a key to implementing
optical-routers without heavily relying on time-buffers as conventional electronic routers do. In particular, the OLSR can handle variable length packets arriving asynchronously while handling burst and circuit traffic. The successful OLSR integration has led to experimental demonstration of optical contention resolution and the field network trial of the OLSR.

3. Systems and Network Demonstrations

Fig. 3 (a) and (b) respectively show the setup and results of multi-hop optical label switching packet routing experiments. Three types of packets, P1, P2, and P3 with labels L1, L2, and L3 respectively ingress into the optical label switching networks. The experiment incorporated the OLSR router with an all-optical label swapping module with 2R regeneration for the data payload. According to the forwarding table content, at each hop, L1, L2, and L3 contents trigger the packets P1, P2, and P3 to be forwarded to relevant directions or destinations. At each hop, an all-optical label swapping [4] takes place with the new label content on each packet generated by the OLSR controller. This controller, as mentioned in section 2 also conducts contention resolution in wavelength, time, and space domains with a switching speed of approximately 600 psec [5]. Based on the forwarding decision, the switch controller sends a control signal to the tunable wavelength conversion to switch to the designated wavelength within the switching fabric, which in turn triggers switching in the wavelength, time, and space domain switching based on the optical switching fabric architecture. Packet by packet bit-error-rate measurements took place on the P3 at each hop. Fig. 3(b) shows packet BER measured on P1. A negative power penalty after 2 hop OLSR is mainly due to the 2R regeneration and the decrease of received average power after two packet droppings. The eye diagrams of the switched payload are shown as insets in Fig. 3 showing clear openings.

4. Summary

The optical-packet switching and optical-label switching will play key roles in the future optical Internet. The seamless integration of data and optical networking with full interoperability can be achieved by optical-label switching. Recent progress achieved by a number of research groups including demonstration of cascaded OLS routers, edge routers, and the field network trial show promising future for this technology.

5. References


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