DEMOMSTRATION OF IP CLIENT-TO-IP CLIENT PACKET TRANSPORT OVER AN OPTICAL LABEL-SWITCHING NETWORK WITH EDGE ROUTERS

Julie Taylor, Yash Bansal, Min Yong Jeon, Zhong Pan, Jing Cao, V.J. Hernandez, Zuqing Zhu, Zubin Wang
S.J.B.Yoo, Venakesh Akella (1) Tony Nady, Gary Goncher, Karl Ervin, Krik Boyer, Bob Davies (2)
1: Department of Electrical and Computer Engineering, University of California, Davis, yoo@ece.ucdavis.edu
2: Optical Business Unit, Tektronix, Inc, Beaverton, Oregon

Abstract *We demonstrate the transport and routing of traffic from IP client-to-IP client through a multi-hop optical label-switching network. Edge routers generate optical labels and achieve interconnection between IP clients across the network.*

Introduction

IP-over-optical is a novel concept that has been actively pursued in the past several years targeting seamless integration of data and optical networking. Optical-label switching (OLS) [1,2] is an attractive technology for accommodating IP-over-optical on a WDM platform using a thin shim layer that employs optical labels. As in MPLS networks, OLS networks require edge routers to perform optical-label generation with label-distribution-protocol (LDP). Edge routers in OLS networks also function as important interfaces for IP, MPLS, ATM, or any legacy format clients or client networks. While there are demonstrations of computer-to-computer communications using optical label switching mechanisms [3], there has been no report on multiple-hop optical label-switching network demonstrations with multi-gigabit data rate, IP transport with label generating edge routers. This paper discusses the implementation and demonstration of an edge router for a multi-hop OLS network interfacing with an OC-48 (2.488Gbps) packet over SONET (POS) legacy network.

Edge Router Integration and OLS Core Router

Fig. 1 shows an example used in this paper for interfacing POS client networks and an OLS network via edge routers. Fig. 2 shows the edge router functionality along with the ingress and egress paths to/from the OLS network. Each network interface is programmable to interface with POS, OLS, or Gigabit-Ethernet networks. However, this paper demonstates communications between POS and OLS networks. The edge router receives OC-48 frames on the POS interface, or ingress path, and terminates the SONET frames leaving PPP-encapsulated IP packets. These packets are sent to the data bus traffic controller (DBTC) in preparation for forwarding across the PDB to the edge router‘s OLS interface. The OLS interface‘s DBTC receives the packets from the PDB and passes them to the label-processing unit (LPU). The LPU uses the contents of the IP header to generate a 26-bit label containing a preamble, an egress edge router destination address, a priority, a packet duration, an optical time-to-live (OTTL), and the source address of the ingress edge router, all derived from the IP header contents. The OC-3 label and the OC-48 PPP-encapsulated IP packets are then forwarded to the physical layer interface (PLI) for sub-carrier multiplexing (SCM) and transmission to the OLS network.

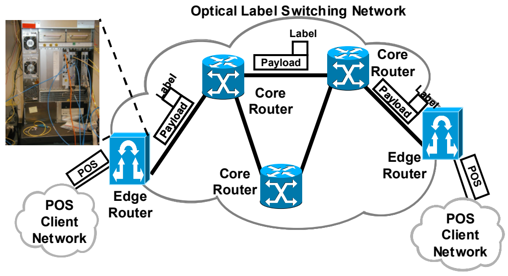


Fig. 1. Overall network

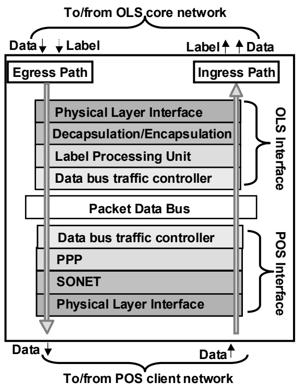


Fig. 2 Edge Router functionality

When an OLS core router receives an optical packet, it extracts the label and achieves decoupling of the control and the data planes. The router controller uses the contents of the extracted labels to perform the forwarding decision and forwards the packets towards their egress edge router. Since optical queuing buffers are not available, the OLS core router performs all-optical packet contention resolution using a wavelength-, time-, and space-domain switching scheme [4]. At the egress edge router, the OLS PLI receives and recovers the encapsulated packets. Since the OLS network is asynchronous, the incoming packets must be byte-aligned. The byte-aligned packets are sent to the

DBTC for forwarding across the PDB to the POS interface's DBTC. The POS interface encapsulates the IP packets in PPP, frames them in SONET, and forwards them to the POS network.

Two Hop Experimental Description

Fig. 3 shows the experimental setup for the two-hop IP client-to-IP client communication using edge routers and OLS core routers. The IXIA OC-48c POS Load Module emulates the POS client networks. It generates and sends three different 1500 byte IP packets, P1, P2, and P3 to the ingress edge router. Each packet has a different destination IP address. The edge router reads the IP headers, generates OC-3 labels L1, L2, and L3, and sub-carrier multiplexes them on the three OC-48 payloads, P1, P2, and P3, thus creating three kinds of optical-label encoded packets.

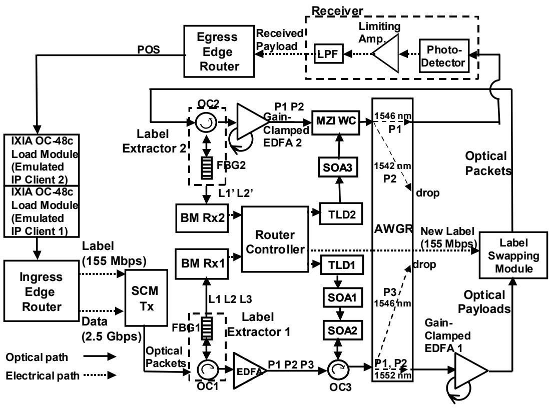
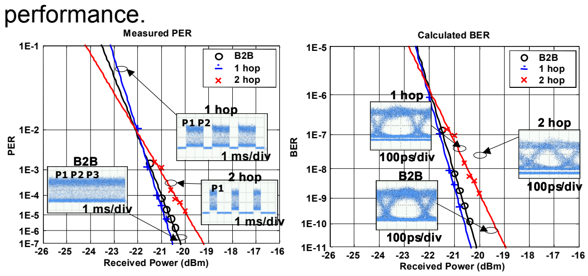


Fig. 3. Experimental setup for two-hop IP client-to-IP client communication

The OLS core router employs all-optical label extraction using label extractor 1 and achieves seperation of the control and the data planes. The first burst-mode receiver (BM Rx1) recovers the contents of labels L1, L2 and L3 and sends them to the router controller, while the payloads P1, P2, and P3 are amplified and delayed using an erbium-doped fiber amplifier (EDFA) to match the ~260 nsec processing time through the router controller. Using the recovered labels, the router controller makes the forwarding decision and sends the appropriate control signals to the first tunable laser diode (TLD1). Thus, TLD1 with the semiconductor optical amplifier (SOA2) converts P1 and P2 to 1552nm and P3 to 1546nm. The two wavelengths then assume the switching paths determined by the well-known wavelength routing characteristics of the arrayed-waveguide grating router (AWGR). This results in dropping P3 at the first hop drop port and forwarding P1 and P2 to the EDFA1 where gain clamping is used to reduce the gain transient. The router controller generates two new labels, L1' and L2', updating the contents if necessary. In the label-swapping module [5], P1 and P2 are sub-carrier multiplexed with their new labels L1' and L2'. The optical packets with new labels now enter the second hop through label extractor 2 where the OLS core router performs forwarding similar to the first hop with a Mach-Zehnder interferometer wavelength converter (MZI WC) used in place of the SOA. The router forwards P2 to a drop port (1542nm) and forwards P1 to the receiver and egress edge router (1546nm). The egress edge router receives P1, performs byte alignment, converts the received OLS packet to SONET frames and sends them back to the IXIA OC-48c POS Load Module for performance analysis.

Results

Fig. 4 shows the measured packet-error-rate (PER) and calculated bit-error-rate (BER) along with packet patterns and eye diagrams. The experimental setup with IP-over-optical using optical label switching does not offer layer 1 or layer 2 testing since the edge router functions as a layer 3 device resulting in no layer 1 or 2 testing access. Hence, in this experiment, an estimation of the BER based on the measured PER is used. The estimation utilizes the formula, $PER = 1 - (1 - BER)^N$ where N is the number of bits in a packet. This estimation assumes uniform error rates for all bits, regardless of their position within the packet, and the probability of an error is the same for all bits in a memoryless system. The results show a low power penalty at BER = 1E-9 for two-hop switching. These results also show that the edge router - OLS core router combination works well together with a good performance.



(a) (b)

Fig. 4. Experimental results for two-hop IP-client to IP-client communication (a) Measured packet-error-rate (PER) with packet patterns (b) Calculated bit-error-rate (BER) with eye diagrams.

Conclusion

We demonstrate the transport and routing of IP traffic from IP client-to-IP client over a two-hop OLS core router. Edge routers interface the IP clients and the OLS router with low packet-error-rates.

References

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