

First experimental demonstration of combined multicast and unicast video streaming over an optical-label switching network

Junqiang Hu, Zhong Pan, Zuqing Zhu, Haijun Yang, Venkatesh Akella, S. J. B. Yoo

Department of Electrical and Computer Engineering, University of California, Davis, California 95616

yoo@ece.ucdavis.edu

Abstract: This paper experimentally demonstrates, for the first time to our knowledge, the combined multicast and unicast video streaming applications over an optical-label switching network, with edge routers connecting the end-to-end multicast server and clients.

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1. Introduction

The Internet traffic continues to grow at an accelerating pace while demanding and diverse new applications are emerging rapidly. The wide adoption of video conferencing, voice-over-IP (VoIP), IP television (IPTV), and other applications will be demanding larger capacity and flexible network topology including multicast [1], putting more challenges on the Internet. Optical-label switching (OLS) technology meets the Internet capacity requirements by accommodating IP-over-optical on a wavelength-division-multiplexing (WDM) network platform, using a shim layer that employs optical labels [2]. The OLS router processes the labels in electronic domain while leaving the data payload in the all-optical domain. With the help of electronic processing, the OLS router is flexible in supporting various quality-of-service (QoS) or class-of-service (CoS) for the emerging applications, and capable of supporting point-to-multipoint topology for applications such as IPTV. We have successfully demonstrated the OLS router with scalable multicast capability [3]. To evaluate the application-layer performance, the OLS networks require the edge routers to provide seamless end-to-end connections. As the further research progress of the unicast-only video streaming demonstration [4], this paper presents the first end-to-end combined multicast and unicast video-streaming demonstration over an OLS testbed at multi-gigabit data rate through the OLS edge routers.

2. End-to-End Testbed Description

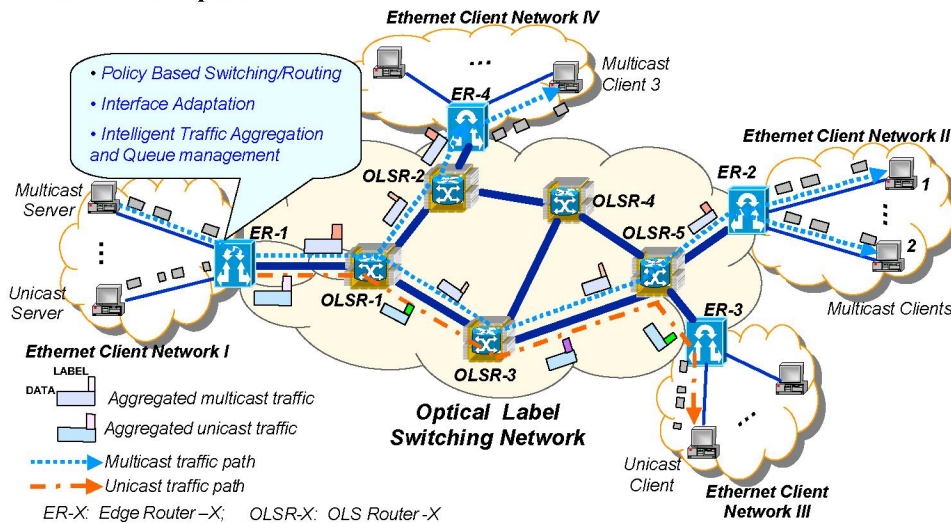


Fig. 1. End-to-end combined multicast and unicast -over-OLS-network testbed.

The end-to-end multicast testbed in Fig. 1 consists of the client network (including the multicast and unicast server/clients and the edge routers) and the OLS core network. This testbed implements the protocol stacks defined in the conventional open systems interconnection (OSI) from layer-1 up to layer-7, to provide a platform for the end-to-end applications over the OLS network. The edge routers function from layer-1 up to layer-4: the layer-3/layer-4 processing performs policy-based IP packet forwarding while layer-1/layer-2 adapts the interfaces to the OLS network. The video streaming traffic starts from the multicast and unicast servers and ends at the Ethernet client networks. The edge router aggregates the traffic from the servers based on the destination address and CoS, attaches an optical label, and forwards it to the OLS core network. The routers in the OLS network process the labels and

make the forwarding decisions. In Fig. 1, since OLSR-1 has two downstream nodes, it will make two copies for each downstream link separately. The two copies pass through the following routers and reach the destination client networks. The unicast traffic is processed similarly with the multicast traffic, except that each OLS router will forward it to exactly one downstream link, until it reaches the destination – Ethernet client network III.

In this testbed, we implemented the intelligent programmable edge routers to interface with the client and core networks by providing Fast Ethernet interfaces to the client networks and asynchronous OLS interfaces to the core networks. The basic features of the edge router include policy-based unicast and multicast packet forwarding, interface adaptation, and protocol transformation. The policy-based forwarding uses the typical 5-tuplet IP header: source/destination IP address, source/destination port number, and the protocol field. To provide consistent CoS with the OLS network, the edge router maps the CoS into the optical label according to the OLS network's policy. Another key feature of the edge router is the intelligent maximum transport unit (MTU) adaptation to improve the network performance, by dynamically aggregating the packets from the client networks based on the traffic load and the characteristics of the OLS network. At the egress direction (from OLS network to the client networks), the edge routers must disaggregate the packets.

3. Experimental Setup

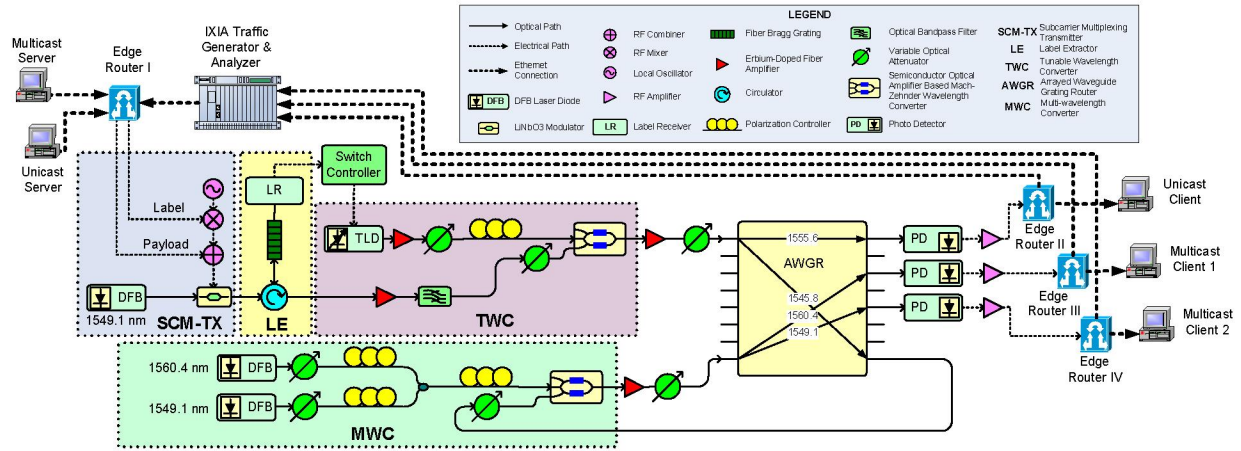


Fig. 2. Experimental setup for multicast video streaming using edge routers and an OLS core router.

Fig. 2 shows the experimental setup of the end-to-end multicast testbed. VideLAN [5], a PC-based video-streaming server, together with an IXIA traffic generator, generates the packets that travel to the ingress edge router through Ethernet ports. The ingress edge router aggregates the traffic into 2.488 Gb/s payloads and generates the corresponding 155 Mb/s labels. The SCM transmitter modulates the labels on a 14 GHz subcarrier and combines them with the baseband payloads to form optical packets [6]. Upon receiving such packets, the label extractor separates the labels and the payloads utilizing a fiber Bragg grating and an optical circulator [6]. The label receiver recovers the labels and forwards them to the switch controller. Based on the label content, the switch controller performs routing table look-up and makes forwarding decisions. The tunable laser tunes to a corresponding wavelength following the instruction from the switch controller, and the semiconductor optical amplifier based Mach-Zehnder interferometer (SOA-MZI) wavelength converter imprints the payload onto the target wavelength by the cross-phase modulation effect. The packets with address “0000” in the labels are imprinted onto 1555.6 nm and the arrayed waveguide grating router (AWGR) guides them to the unicast output port. Packets with address “1111” are imprinted onto 1545.8 nm and switched to the multi-wavelength converter (MWC) for multicast. The MWC is an SOA-MZI that copies the multicast payload onto two wavelengths simultaneously: 1560.4 nm and 1549.1 nm. For simplicity the demonstration uses two fixed-wavelength lasers instead of tunable lasers controlled by the switch controller. These wavelengths guide the multicast packets to the two multicast ports. The receivers at the unicast and multicast destinations consisting of O/E converters and electrical amplifiers convert the packets back to the electrical domain and send them to the egress edge router. The egress edge router disaggregates the packets and forwards them to the PC-based video-streaming client and the IXIA performance analyzer for performance evaluations.

4. Experimental Results

Fig.3 is the experimental results that show the optical spectra, packet sequences, and the video snapshots captured in the testbed. The optical spectra (A and B) are captured at the unicast and multicast input ports of the AWGR

separately. The packet sequences (C, D and E) at the output ports show the switching functionality of the OLS router. Comparing the video snapshots at the unicast and multicast destinations with those at the video servers, we find that there is no noticeable quality difference. Actually, the combined unicast and multicast demonstration runs smoothly during the entire testing period, without noticeable frame loss, which means the testbed, including the OLS router and the edge routers, are functioning correctly for both multicast and unicast video-streaming applications.

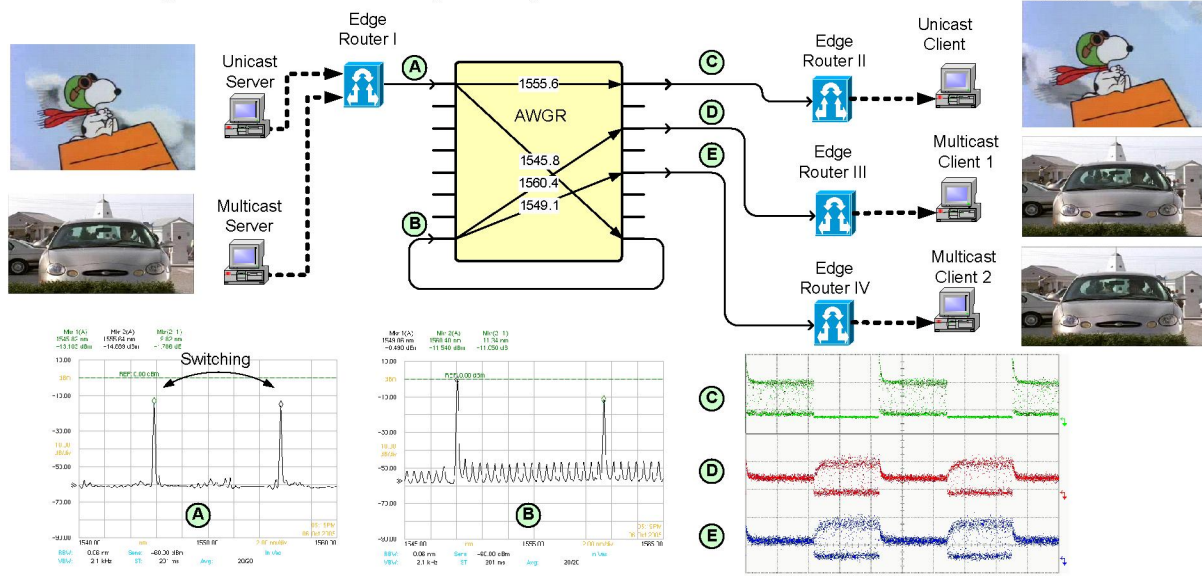


Fig. 3. Optical spectra, packet sequences, and video snapshots captured in the testbed.

Fig. 4 is the packet loss rate with different packet sizes using IXIA's packet performance analyzer. This testbed does not offer layer 1 testing since the edge routers function as layer2+ equipments resulting in no layer-1 testing access.

Packet Size (Bytes)	64	128	256	512	1024	1152	1518
Pkt Loss Rate (%) at Unicast Client	0.01	0.01	0.01	0.04	0.09	0.04	0.07
Pkt Loss Rate (%) at Multicast Client 1	0.01	0.01	0.01	0.00	0.00	0.04	0.02
Pkt Loss Rate (%) at Multicast Client 2	0.01	0.00	0.07	0.04	0.02	0.00	0.05

Fig. 4. End-to-end packet loss rates for both the unicast and multicast packets

5. Conclusion

This paper experimentally demonstrates, for the first time, end-to-end combined multicast and unicast video streaming applications over an OLS network testbed, with edge routers interfacing the client networks and the OLS core network. The results prove that the OLS router and the edge routers are functioning as designed for both multicast and unicast video-streaming applications.

6. References

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