Prototype Demonstration of IP Multicasting over Optical Networks with Dynamic Point-to-Multipoint Configuration

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Abstract: We demonstrate a novel overlay multicasting architecture: IP multicasting over optical networks with dynamic point-to-multipoint configuration. Experimental results show that the proposed architecture exhibits better performance than pure IP multicasting under heavy traffic load.

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1. Introduction

Broadband IP-based new services such as content distribution, interactive multimedia and video conferencing are coming into the sight of carriers as promising revenue-adding services. In transport networks, multicasting can significantly reduce the consumption of bandwidth in the networks and thus is critical in supporting those profitable applications. However, those services are sensitive to the quality of service (QoS). The guaranteed QoS or traffic engineering (TE) is difficult to be satisfied with traditional IP multicast due to the best-effort feature of IP forwarding. The multi-protocol label switching (MPLS) brings QoS control features into IP networks, whereas MPLS was originally designed for point-to-point connections. Therefore, the requirements for point-to-multipoint TE MPLS label switched paths (LSP) are now being discussed in IETF [1]. Point-to-multipoint LSPs provide efficient and scalable connectivity between a source (root) and a set of destinations (leaves), and can be regarded as layer 2 multicasting with guaranteed QoS. Recently, NTT proposed an extension to Resource reSerVation Protocol RSVP -TE protocol for point-to-multipoint TE MPLS LSP [2] and demonstrated a network with the proposed extension in MPLS’2003. In that demonstration, the network consisted of IP routers based on personal computers.

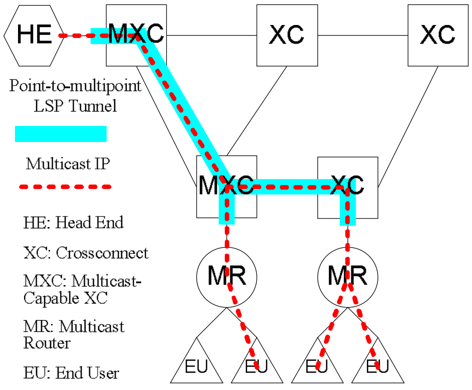

Fig. 1 The overlay multicasting network model

In a separate effort, an overlay multicasting network model to support large-scale stream media was proposed [3] and is shown in Fig.1. The difference between the proposed model and conventional video-over-IP model [4] is that the optical network with dynamic point-to-multipoint configuration replace IP multicasting network in the core. The optical crossconnects with multicasting capability (MXCs) provide dynamic connections between an input port and multiple output ports. Thus, the packets from head end to end users experience two layers of multicasting, one being optical multicasting and the other IP multicasting. The access multicasting routers (MRs) are the leaves of the optical multicasting tree. The network architecture employing optical MXCs offers several attractive features. Firstly, it has the same bandwidth efficiency as IP multicasting because an optimal point-to-multipoint tree is established for each IP multicasting session instead of emulation by multiple point-to-point connections Secondly, it is compatible with current video-over-IP architecture as the network edge is still IP based. Therefore it is not required to change or upgrade deployed client-side equipments and end users devices such as video head-end, access aggregation routers, access lines, and home gateways. Thirdly, it can provide multicasting with improved QoS due to the fact that point-to-multipoint connections in the core network are circuit-switched with negligible delay and jitter and there is only one IP-hop from end to end.

In this paper, we describe the detailed principle of the proposed overlay multicasting network model with emphasis on automatically dynamic change of the trees in the optical network. A prototype is implemented to concept-prove the proposal. We also experimentally compare the performance of traditional pure IP multicasting model with that of the proposed model using the network prototype. The measurement results show that the delay and jitter of the overlay multicasting model are reduced under heavy traffic load.

2. Prototype description

In the network core of the architecture shown in Fig. 1, the structure of the MXCs can be based on previously proposed scalable splitter-and-delivery (SaD) switches [5], or a simple combination of splitters and space switches.

The overlay IP-over-optical network model requires user-network-interfaces (UNI) between the optical transport network and users. However, UNI supporting of point-to-multipoint connection is not specified in Optical Interworking Forum (OIF) version 1.0 and 2.0. There are two possible approaches to support point-to-multipoint connection: 1) Defining multicast transport network assignment (TNA) addresses with a group of management protocols as in traditional IP multicasting. 2) Placing all the leaf TNA addresses in one UNI connect request message, which is termed as “all-in-one” strategy in the following parts. Both of these two approaches require numerous extensions of the current UNI specification. In our implementation, we setup/teardown/graft/prune leaves one by one even if multiple leaves concurrently send requests to join/leave a tree.

With respect to network-network-interfaces (NNI), both routing and signalling have to be extended to support point-to-multipoint connections. In our implementation, we assume all nodes have the same multicasting capabilities. Thus, link state routing protocols such as OSPF do not need to be extended. The problem of multicasting-route computation that tries to find a Steiner tree has been proven NP complete. We use a nearest node first (NNF) heuristic [6] to find optimal routes for each pair of root and leaf set. The output of the routing algorithm is encoded as one main route and several secondary branch routes. Then RSVP-TE protocol is extended to carry explicit hop information of all the routes. Finally, a complete point-to-multipoint tree is established by associating multiple point-to-point LSPs on branching nodes.

Another critical question for this overlay model is how to trigger the setup/teardown/graft/prune process of a tree via UNI. In conventional video-over-IP models, one channel corresponds to one IP multicasting address. If one end user requests for a channel, the user shall get the corresponding multicast address from the portal web site and send an IP group management protocol (IGMP) request to MR to join the multicast group and then the multicast tree is pulled toward this end user. In our network model, the end users operate the same way as the conventional video-over-IP model. A leaf control unit (LCU) co-located with destination UNI-C periodically sends simple network management protocol (SNMP) GET messages to MRs to retrieve information of multicasting groups. In the case that group membership changes, LCU sends notification to head end control unit (HECU) according to predefined policies to avoid frequent change of a tree. For example, if a LCU finds there is no member on a given IP multicast address in several polling periods, it sends prune notification to HECU. Upon receiving notification, the same UNI signalling procedure is triggered from the source UNI-C co-located with HECU as OIF specification.

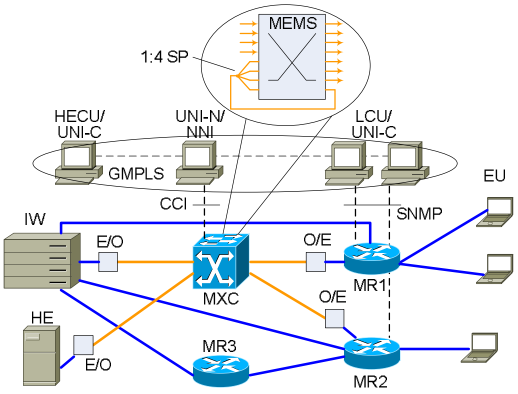

Fig.2(a) Schematic p of prototype

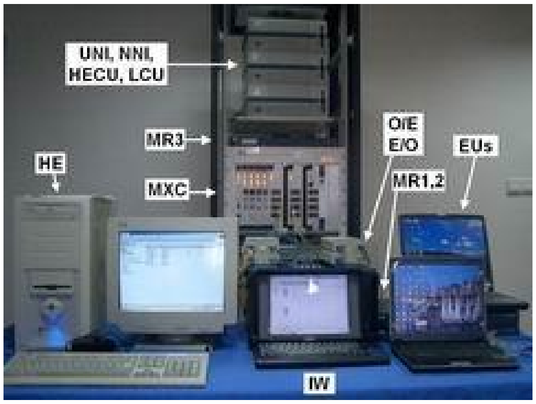

Fig. 2(b) Photograph of prototype

3. Experimental Setup

Fig.2 (a) and (b) show the schematic and the photograph of prototype respectively. In the prototype, the head end (HE) is a PC server connected to an MXC via an electronic-to-optical (E/O) converter. The MXC is implemented by using a 1:4 splitter (SP) and an 8x8 micro-electro-mechanical system (MEMS) optical switch as shown in the inset of Fig. 2. The MXC is connected with two Cisco routers (MR1 and MR2) via optical-to-electronic (O/E) converters. A Navtel Interwatch 95000 (IW) is also connected to MXC to generate Internet traffic and to measure the network performance. For this prototype experiment, all the links connected to the optical network are fast Ethernet (100Mbps). Note that, the E/O and O/E are different from conventional Ethernet media converters since optical multicasting can only provide uni-directional connections. All the control plane elements (UNI, NNI, HECU and

LCU) are based on personal computers and connected by an out-of-band 100Mbps signalling network. We extend UNI, NNI and implement a routing algorithm to support dynamic point-to-multipoint LSP connection in the optical network in the framework of GMPLS. The NNI proxy communicates with MXC via proprietary connection control interface (CCI) over TCP. In addition, there is another Cisco router (MR3) connecting IW and MR2 to emulate a pure IP multicasting network.

4. Experimental Results

In this experiment, a constant unicast IP traffic load occupying 20% of the link capacity is added to MR1, MR2 and MR3 to emulate background service in the IP networks. We measure the end-to-end transmission delay and jitter of IP multicasting packets when IP multicasting load at the source (IW) is increased from 40% to 80% of the total link capacity as shown in Fig. 3. The traffic from IW via MXC to MR1 and MR2 follows overlay multicasting model, while the traffic from IW via MR 3 to MR1 is transmitted in the pure IP multicasting networks. It is observed that the delay and jitter of the two models are almost the same when the multicasting load is less than 50% (plus 20% unicast load totaling a load of 70%). However, when the multicasting load is greater than 50%, the delay and jitter in the overlay multicast model is reduced nearly 20% compared with traditional pure IP multicasting model. Under the heavy traffic load (total load > 90%), the jitter is even reduced nearly 50%. The results prove that the overlay multicasting network is more suitable for transmitting stream media whose flow characters is more similar to circuit switching.

Fig. 4 is the setup-time for the comparison of two UNI strategies. The setup time of "one by one" strategy is slightly longer than that of "all in one" strategy as the number of the branches grows. However, "one by one" strategy will significantly simplify implementation of both UNI and NNI. Furthermore, the probability of concurrent join/leave requests for a tree is very small in general because the behaviour of the leaves in the optical multicasting network depends on the statistics of many end users in IP multicasting networks.

5. Conclusion

We report the first demonstration of an IP multicast over optical network with dynamic point-to-multipoint configuration of MXCs and the extension of current GMPLS-based UNI and NNI. The experimental results show that the proposed overlay multicasting network is more suitable for transmitting stream media compared with traditional pure IP multicasting.

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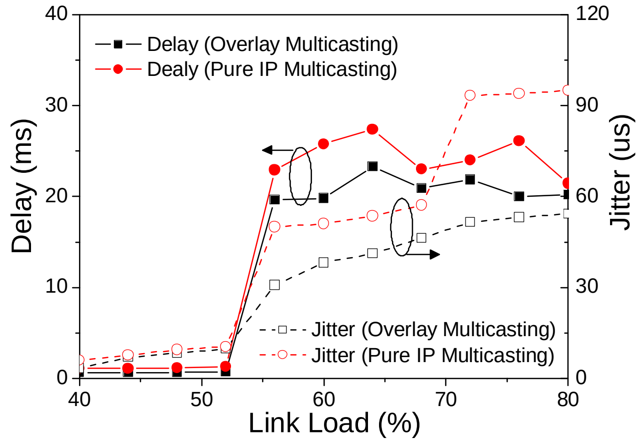

Fig.3 Delay and jitter vs. link load

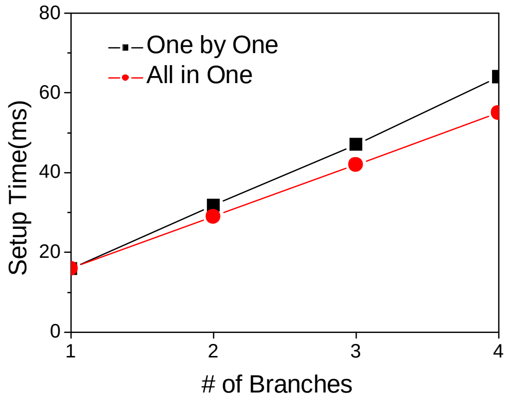

Fig. 4 Setup speed vs. branches