A Weighted Scheduling Mechanism to Reduce Multicast Packet Loss in IPTV Service over EPON

YoungHwan Kwon, Jun Kyun Choi, Seong Gon Choi, Tai-Won Um, and Sang Gug Jong

ABSTRACT—This letter proposes a weighted scheduling mechanism for Internet protocol television (IPTV) to improve the loss performance of multicast transmission over an Ethernet passive optical network (EPON). We propose a new weight policy from the number of multicast receivers to proportionally allocate the downstream bandwidth of IPTV traffic. The proposed mechanism is used in an optical line terminal to decrease lost packets of favorite IPTV services because the lost multicast packets are proportional to the number of receivers. The total proportion of lost multicast packets is reduced by up to 73% in an EPON.

Keywords—Weighted scheduling, IPTV, multicast, EPON, packet loss.

I. Introduction

Internet protocol television (IPTV) has become a killer Internet application. As the service generates an enormous amount of data in a network, multicast and broadband network technologies are required to support IPTV. An Ethernet passive optical network (EPON) is one of the most popular access technologies to support IPTV because it easily supports a large amount of bandwidth and multicast capability [1], [2].

An EPON improves its performance by aggregating and rescheduling the flows in an optical line terminal (OLT) [3]. The EPON supports differential quality of service (QoS) with a bandwidth allocation mechanism [4]. A weighted round-robin (WRR) scheduling mechanism reduces complexities with flow aggregation and also provides a different QoS to aggregated flows with different weights.

Previous RR mechanisms do not consider the property of multicast packet loss in an EPON. Packet loss is one of the most important parameters of IPTV QoS [5]. A multicast packet loss cumulates all losses of multiple receivers [6]. In an EPON, if a multicast packet is lost in an OLT, none of the IPTV receivers can receive the packet, and the number of lost packets equals the number of receivers. Therefore, we propose a weight, which is from the number of multicast receivers, for the RR mechanism to allocate more bandwidth to popular IPTV services in an OLT. The weight increases when the multicast receivers of IPTV increase. The proposed mechanism reduces multicast packet loss of IPTV over an EPON by providing more bandwidth for popular IPTV services and also reduces the average queuing delay in the OLT.

II. Weighted Scheduling Mechanism Based on the Number of Receivers over EPON

The number of lost multicast packets is affected by the number of receivers because the number of transmitted multicast packets equals the number of receivers. To improve the loss performance of multicast packets, multicast packets with many receivers are preserved more than those with few receivers. Therefore, the proposed mechanism schedules IPTV multicast traffic in an OLT using new weights. The weights are calculated using the number of multicast receivers of IPTV services. As a result, the proposed mechanism provides more

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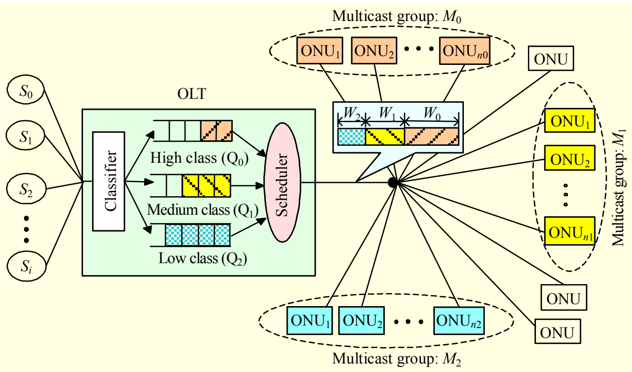

Fig. 1. EPON architecture for the proposed mechanism.

Table 1. Multicast information of IPTV services in an OLT.

IPTV ID	Multicast ID	No. of receivers	Queue
S_0	M_0	n_0	q_0
S_1	M_1	n_1	q_1
S_2	M_2	n_2	q_2
⋮	⋮	⋮	⋮
S_i	M_i	n_i	q_i

Note: n_0 > N1 > n_1 > N2 > n_2

bandwidth to favorite IPTV services and reduces the multicast packet loss of favorite IPTV services in an EPON.

Figure 1 shows an EPON architecture that comprises an OLT, a passive optical splitter, and several optical network units (ONUs). The OLT has a classifier, several queues, and a scheduler to support the proposed mechanism. The proposed mechanism aggregates IPTV multicast flows into three classes to reduce the complexity of the OLT. Each of the classes is allocated to one of the following queues: a high-class queue (Q_0), medium-class queue (Q_1), and low-class queue (Q_2).

Table 1 shows the multicast information of IPTV services in an OLT. Each record includes an IPTV ID (S_i), a multicast ID (M_i), the number of receivers (n_i), and the queue (q_i). Here, S_i is an identifier of an IPTV service, M_i is a multicast identifier for the IPTV service over an EPON, n_i is a counter for the number of its receivers, and q_i is a classified queue for its multicast flow.

The classifier classifies multicast flows into a queue (q_i) that aggregates multiple IPTV multicast flows, and q_i is determined by comparing n_i with two threshold values, N_1 and N_2. We assume that N_1 is higher than N_2. An EPON operator can adjust N_1 and N_2 according to multicast flows and queue size. If the operator increases N_1, fewer multicast flows are classified to Q_0 and more multicast flows are classified to Q_1:

$$q_i = \begin{cases} Q_0, \text{ if } n_i \geq N_1 \\ Q_1, \text{ if } N_1 > n_i \geq N_2 \\ Q_2, \text{ if } n_i < N_2. \end{cases} \quad (1)$$

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w0 ← 0; w1 ← 0; w2 ← 0;
while
      if (there are packets in Q0 and w0≥1)
            send a packet in Q0 ;
            w0 ← w0-1 ;
      else if (there are packets in Q1 and w1≥1)
            send a packet in Q1;
            w1 ← w1-1 ;
      else if (there are packets in Q2 and w2≥1)
            send a packet in Q2;
            w2 ← w2-1 ;
      else if (w0 < 1 and w1 < 1 and w2 < 1)
            w0 ← w0+W0 ;
            w1 ← w1+W1 ;
            w2 ← w2+W2 ;
      else
            if (w0 ≥ 1)    w0 ← w0-1 ;
            if (w1 ≥ 1)    w1 ← w1-1 ;
            if (w2 ≥ 1)    w2 ← w2-1 ;
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Fig. 2. Proposed weighted scheduling mechanism with 3 classes.

To reduce the lost multicast packets of popular IPTV flows with many users, a weight is proposed to allocate a large amount of bandwidth for the popular flows. The weight is determined using the number of their receivers and increases as the number increases. Increasing the weight reduces the multicast packet loss due to the greater amount of bandwidth.

A determined weight (W_i), which is the bandwidth assigned to queues by the scheduler, is given by

$$W_i = \sqrt{\sum_{j=1}^{k_i} n_{i,j} \bigg/ k_i}, \quad (2)$$

where n_{ij} is the number of multicast receivers of the j-th multicast flow in the i-th queue, k_i is the number of multicast flows in the i-th queue, and W_i is a real number and is calculated when the OLT receives a multicast join/leave message from the ONUs. Here, W_0, W_1, and W_2 are the determined weights for Q_0, Q_1, and Q_2, and because of (1),

$$W_0 > W_1 > W_2. \quad (3)$$

A real weight (w_i) is the available bandwidth of a queue at a specific time in the scheduler. The 1 value of w_i indicates the transmission time for a multicast packet within an EPON frame including inter-frame guard time. If w_i is less than 1, there is not enough bandwidth for Q_i.

Figure 2 shows the proposed mechanism in an OLT. The scheduler schedules multicast packets using w_i's among the classes. Initially, all w_i's are 0. The scheduler checks from Q_0 to Q_2 whether to transmit multicast packets. If there are packets in Q_i and its w_i is greater than 1, Q_i sends a multicast packet and the scheduler decreases w_i by 1. If any queue cannot transmit a multicast packet, the scheduler checks all w_i's. If all w_i's are less than 1, the scheduler increases them by W_i's. If any w_i is greater than 1, the w_i is decreased by 1 to prevent discordance between availabilities of real weight and packets in all queues. Thus, an IPTV service with many users is provided more bandwidth than an IPTV service having a few users. This reduces the packet loss of IPTV services with many users.

III. Simulation Results

We evaluated the proposed mechanism using an OPNET simulator. We developed an EPON environment to simulate the proposed mechanism and an RR scheduling mechanism that equally schedules all classes without weights. In a queue, packets are scheduled by a first-in-first-out mechanism for both scheduling mechanisms.

We assume the following conditions for the simulation: i) an OLT is connected with 32 ONUs; ii) an ONU is a receiver that can receive several IPTV flows; iii) each class (queue) has 1 IPTV flow and 1 background traffic; iv) an IPTV flow is 10 Mbps of HD IPTV traffic [5]; v) the background traffic is aggregated multiple IPTV flows, and each background traffic per queue is identical; vi) the bandwidth of each link is 1 Gbps; vii) the offered load is the load of background traffic on the link; viii) the packet inter-arrival time of the IPTV flow and the background traffic have an exponential distribution; ix) each queue size is 100,000 bits; x) the transmission time of the 1 value of w_i is 0.011 ms because the packet size of IPTV is 10,528 bits [5]; and xi) W_0 is 3, W_1 is 2, and W_2 is 1.

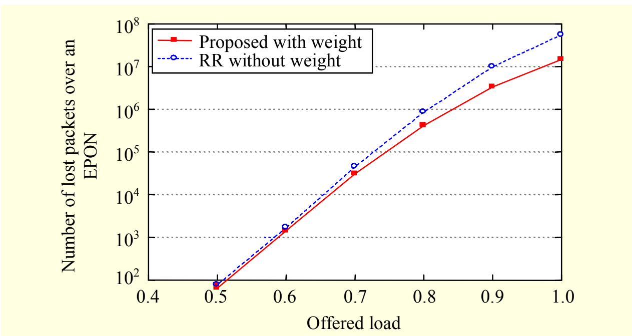

Fig. 3. Number of lost multicast packets over an EPON.

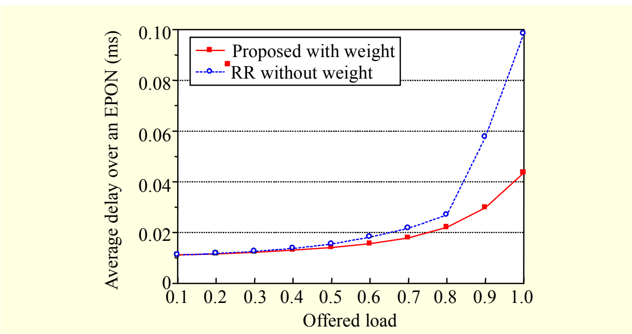

Fig. 4. Average delay of multicast packets over an EPON.

Figure 3 shows the number of total lost packets over an EPON accumulated at the ONUs. The number of lost packets is dependent on the number of receivers [6]. The proposed mechanism reduces packet loss by 73% compared with the RR mechanism because Q_0 and Q_1 have smaller packet loss ratios than Q_2 due to the proposed weights and because they send packets to more receivers than Q_2, that is, as many as the number of multicast receivers.

Figure 4 shows the average queuing delay of multicast packets in an OLT. The proposed mechanism reduces the average queuing delay by 55% compared with the RR mechanism because Q_0 and Q_1 send more multicast packets and have smaller occupied queues than Q_2 due to the proposed weights.

As seen in Figs. 3 and 4, the proposed mechanism can safely and quickly deliver multicast packets to many receivers by reducing the packet loss and queuing delay of IPTV services with many viewers.

IV. Conclusion

The proposed mechanism classifies IPTV multicast flows using the number of multicast receivers to aggregate the IPTV flows and schedules aggregated IPTV flows with weights which are determined by the number of multicast receivers. The proposed mechanism allocates more bandwidth to favorite IPTV services to decrease multicast packet loss and average queuing delay in an EPON. Our results show that the proposed mechanism reduces the total lost multicast packets of receivers by 73% and average queuing delay in an OLT by 55%.

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