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# Realization of extended IGMP in GPON for IPTV

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**Abstract:** The extended Internet group management protocol (EIGMP) is a method which allows simultaneous reception of channel streams being broadcasted for other users in shared networks. Recently, implementation of EIGMP in gigabit Ethernet passive optical network (GEPON) was suggested to reduce the channel change response time (CCRT) especially for Internet protocol television (IPTV) systems. In this paper, we extend EIGMP in gigabit-capable PON (GPON) with a cross-layer approach. With the proposed method, the CCRT in GPON can be reduced by up to 10.3% in comparison with that of traditional IPTV systems.

**Keywords:** GPON, IPTV, channel change response time, IGMP, Port-ID

**Classification:** Fiber-optic communication

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## 1 Introduction

In recent years, gigabit-capable passive optical network (GPON), which consists of an optical line terminal (OLT) located at the head end and multiple optical network units (ONUs), has become a popular solution for broadband PON-based shared access networks [1]. In a PON-based network, all ONUs connected to the same fiber physically receive all channel streams on the network. The quality of experience (QoE) of IPTV services has been impaired in part due to somewhat excessive channel change response time (CCRT) in comparison with other traditional TV services such as cable and satellite TV services. CCRT is the time delay between the request for a channel change and the display of the channel on the TV screen. CCRT is decided by various underlying network performances such as multicasting processes, the network latency between servers and subscriber devices, and decoding complexity and buffering among others. One of the significant factors causing CCRT is the delay due to the Internet group management protocol (IGMP) leave/join process. A number of researchers have proposed methods in order to reduce this delay.

In particular, Lee et al. [2] proposed a method called extended IGMP (EIGMP), which allows an ONU to logically share the optical signals addressed to other ONUs in a PON-based shared network architecture. ONUs connected to a fiber physically share signals but not logically. Moreover, an implementation method of EIGMP in gigabit Ethernet passive optical network (GEPON) for IPTV services was recently proposed by involving the media access control (MAC) and IP layers across in [3]. Although the overall architectures of GEPON and GPON share much commonality, an actual implementation method has not been suggested maintaining the overall architecture of GPON at the same time. In practical IPTV systems using GPON, all channel streams in a fiber arrive at an ONU first and the GPON encapsulation method (GEM) frames of unwanted streams are filtered out by port-ID in the GPON transmission convergence (GTC) sublayers [4]. ONUs, therefore, should be able to extract GEM frames in advance. Otherwise, the frames may be discarded in the GTC sublayers. For this reason, we propose a new method to implement EIGMP in GPON by modifying the filtering operations of two layers: the GTC sublayers and the IP layer. With the proposed method, each ONU can classify GEM frames according to a proposed channel mapping table (CMT). IP packets obtained from the classified GEM frames can be used in the IP layer according to EIGMP. We also present how much CCRT in this paper can be reduced with EIGMP for IPTV systems in comparison with traditional ones.

## 2 Implementation of EIGMP

In order to implement EIGMP in GPON, it is important to control GEM frames in the GTC sublayers of ONU when a user requests to change a channel. As shown in Fig. 1 (a), IP packets for the EIGMP in layer 3 can be extracted or discarded by the port-ID of the GEM frame header in the


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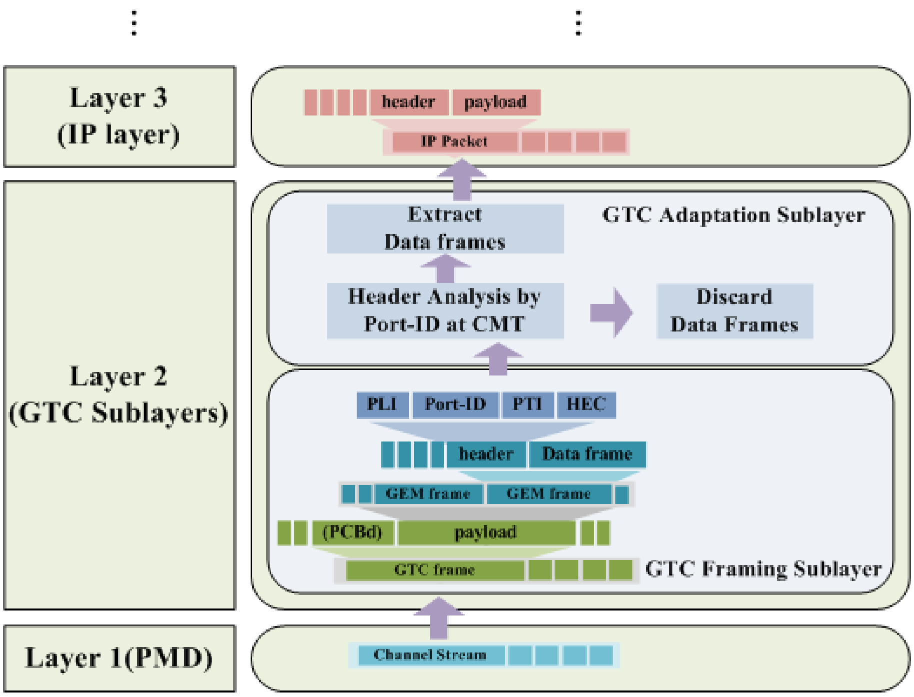
GTC sublayers according to the CMT. If a user's host receives a channel change request, the host checks if the selected channel is being broadcasted for other users in the same fiber node. It can be achieved by checking the channel IDs and the multicast group addresses at the CMT which plays an important role to implement EIGMP as shown in Fig. 1 (b) at each host. The CMT provides the mapping information between channel streams and port-IDs. In the CMT, a channel ID indicates the channel number which is being broadcasted to an ONU in the same fiber node. A port-ID indicates the identifier of a corresponding channel stream. The multicast group address indicates the group addresses of channels for multicast. Therefore, the user's host can recognize whether the selected channel is being broadcasted for other users in the same fiber node or not using the CMT.




(a)

| Channel ID | Port-ID | Multicast Group Address |
|---|---|---|
| 136 | 0x0F3 | 231.60.21.94 |
| 011 | 0x4E5 | 230.126.44.54 |
| 060 | 0x8A2 | 237.109.38.87 |
| 087 | 0xB71 | 229.15.58.39 |
| 005 | 0x38C | 232.45.167.46 |
| 101 | 0xD16 | 228.29.10.63 |
| ⋮ | ⋮ | ⋮ |

(b)

**Fig. 1.** Implementation of EIGMP in GPON (a) Block diagram (b) Channel mapping table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If a user selects a channel which exists in the CMT, the ONU extracts the data frames which have the port-ID of the selected channel immediately. Consequently, IP packets for the selected channel are generated from GEM frames without the traditional IGMP network delay. If the selected channel does not exist in the CMT, the host requests the selected channel streams in accordance with the traditional IGMP process. The CMT is updated during the next membership query, such as either a group specific query or a general query after receiving selected channel streams.

## 3 Performance evaluation

According to [3, 5], $T_{CCRT}$ and $T_{IGMP}$ are CCRT and the time for IGMP, respectively.

$$T_{CCRT} = T_{system} + T_{process} + T_{decode} + T_{IGMP}. \quad (1)$$

$$T_{IGMP} = 2 \times \left( \frac{P_{IGMP} \times M_{ONU} \times N_{ONU}}{LU_{rate} \times u \times B_{rate}} \right) + MRT. \quad (2)$$

As shown in Eq. (1), $T_{CCRT}$ consists of several delay factors. $T_{system}$ indicates the time for video buffering and reordering, $T_{process}$ indicates the time to transmit the remote control command and to process the channel change command, $T_{decode}$ indicates the time to decode by the video decoder in the host, and $T_{IGMP}$ indicates the IGMP leave/join process time. The parameters and the value for modeling are assumed in Table I according to [5, 7].

**Table I.** Parameters for CCRT modeling

| Parameters | Elements | Value |
|---|---|---|
| | Waiting time for PSI Tables | 100 ms |
| | Waiting time for RAP | 625 ms |
| $T_{system}$ | Video buffer fill time | 1250 ms |
| | Reordering delay | 100 ms |
| $T_{process}$ | Transmission of remote control command | 20 ms |
| | Processing time for channel change command | 30 ms |
| $T_{decode}$ | Video decoder closing time | 75 ms |
| | Video decoder configure and start time | 75 ms |
| | Zipf parameter ($\theta$) | 0.55 |
| | The Maximum number of ONU ($M_{ONU}$) | 64 |
| | The number of active ONUs ($N_{ONU}$) | 60 |
| | The size of the IGMP packet ($P_{IGMP}$) | 8 bytes |
| $T_{IGMP}$ | Up/Downstream line rate ($LU_{rate}/LD_{rate}$) | 1 Gbps |
| | Up/Down traffic load rates of IGMP message ($u/d$) | 0.01 |
| | IGMP message packet delivery success rate ($B_{rate}$) | 0–1 |
| | Maximum response time ($MRT$) | 200 ms |
| | The number of channels ($N$) | 150 |

EIGMP is highly related to reducing the IGMP leave/join process time. Therefore, $T_{EIGMP}$, which is CCRT when EIGMP is applied, can be calcu-


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lated by Eq. (3) because $T_{IGMP}$ in $T_{CCRT}$ is eliminated by EIGMP.

$$T_{EIGMP} = T_{system} + T_{process} + T_{decode}. \tag{3}$$

In this paper, we assume constant values for $T_{system}$, $T_{process}$, and $T_{decode}$ for analytical modeling purpose whereas $T_{IGMP}$ is calculated according to Eq. (2) and Table I. When a user wants to watch a new channel, the probability that the channel is being watched by others is proportional to the given channel's popularity and the number of people watching TV at the same time. When the channel popularity is assumed to be Zipf-like distributed [6], the probability of selecting channel $i$ is represented as

$$P_i = \frac{\frac{1}{i^{1-\theta}}}{\sum_{k=1}^{n} \frac{1}{k^{1-\theta}}}, \tag{4}$$

where $P_i$ indicates the request probability of $i$-th popular channel, $n$ indicates the total number of distinct channels, and $\theta$ ($0 \leq \theta \leq 1$) is the Zipf parameter that determines the degree of popularity skew. If $P_i$ is high, it indicates the probability that the $i$-th channel is popular is also high and indicates the probability that at least one user is watching the $i$-th channel. Consequently, we can assume that $P_i$ is proportional to the probability that $i$-th channel is being broadcasted to at least one user. Thus, $T_i$, which is the average CCRT by the EIGMP when a user switches to the $i$-th channel, is represented assuming 150 channels are being provided by IPTV company as

$$T_i = (P_i \times T_{EIGMP}) + ((1 - P_i) \times T_{CCRT}), i = 1, 2, \ldots, 150. \tag{5}$$

The analytical results are depicted in Fig. 2. Fig. 2 (a) shows that the EIGMP gives better performance than traditional IPTV systems and the improvement becomes distinct as $P_i$ approaches to 1. As we explained earlier, $P_i = 1$ indicates that at least one user is watching a newly selected channel. It is observed from Fig. 2 (a) that EIGMP can reduce the CCRT up to 10.3% in comparison with the traditional system after the EIGMP is applied to the IPTV system when $B_{rate}$ is 1 and the number of active ONUs for IPTV services is 30. Notice that the maximum number of ONUs connected to a fiber is 64.

Recently, the importance of N-screen services has been increasingly recognized. The N-screen service is to provide the same content or services on a variety of devices. For this reason, the number of users using the same server is increased, and the server has to accommodate the increased users with a limited bandwidth. In traditional IPTV systems, the server loads as well as the CCRT increase when the number of users increases as shown in Fig. 2 (b). On the other hand, it is observed the system with EIGMP has a great improvement in reducing CCRT in comparison with traditional systems as the number of users increases. CCRT does not increase when $P_i$ approaches to 1 regardless of the number of users. As the number of users increases, newly switched channels are more likely to be being broadcasted in the same fiber; therefore, the server can make an efficient use of the bandwidth, and the user can watch the selected channel immediately without the traditional IGMP leave/join process. This is true especially during TV golden hours.


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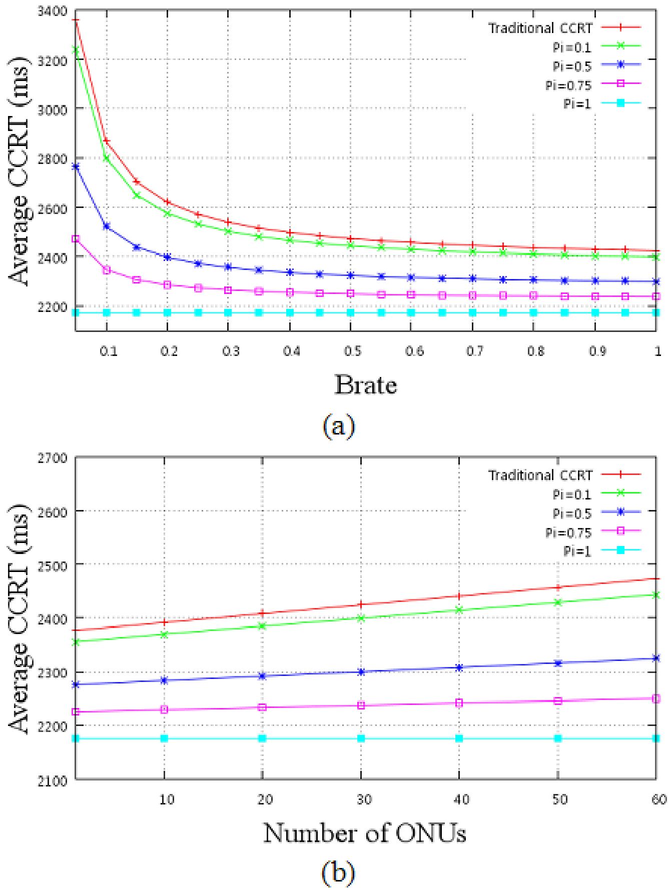


**Fig. 2.** (a) Decrease of the CCRT when the number of active ONUs is 30 as $P_i$ and $B_{rate}$ increase (b) Increase of the CCRT as the number of active ONUs increases

## 4 Conclusion

In this paper, we proposed a new method which can implement EIGMP in GPON for IPTV services by involving the GTC sublayers and the IP layer, across. If a user switches to a channel and the channel is being broadcasted for other users in the same fiber, GEM frames which have the port-ID of selected channel can be extracted immediately according to the CMT. Consequently, the IP packets of the selected channel for the EIGMP can be generated from the GEM frames without IGMP network delay. Analytical results show that EIGMP in GPON can reduce the CCRT up to 10.3% in comparison with traditional systems. This method may be more efficient at the system for N-screen services. As the number of users increases, EIGMP significantly reduces CCRT and off-loads the server loads because a newly selected channel is more likely being shared in the same fiber.

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