Reducing the Channel Switching Delay in IP-based Multi-channel Streaming

Citation:

Toshiaki Ako, Hiroki Nishiyama, Nirwan Ansari, Nei Kato, "Reducing the Channel Switching Delay in IP-based Multi-channel Streaming," IEEE Communication Society Multimedia Communications Technical Committee E-Letter, Vol. 5, No. 8, pp. 54-58, Sep. 2010.

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1. Introduction

The rapid growth in network speed and bandwidth has empowered audio/video streaming services such as Internet TV and IPTV [1]. Most streaming services broadcast a large number of channels from which a user may choose to watch. These multi-channel streaming services enable viewers to change channels at will. However, the channel switching delay via the Internet, which is the amount of time from which the demand for a new channel is issued until the request is satisfied, is typically quite long. Long channel switching time degrades the quality of experience (QoE) of IP-based multi-channel streaming. Reducing this channel switching delay is an important problem.

So far, most streaming technologies are based on unicast communications between a server and a client. However, as an alternative to unicast-based streaming communications which increases the traffic load of the network and server, multicast-based streaming communications has been developed. In IP multicast, which is one type of multicast-based communications, routers make copies of the streaming packets and forward them to other routers and end-nodes. IP multicast, which requires specialized routers, incurs a significant cost. As an alternative to IP multicast, Application Layer Multicast (ALM) [2] has recently been proposed. In ALM, copies and deliveries of streaming packets are done by end-nodes. Since ALM does not require any specialized equipment, it is quite easy to deploy. However, unreliable end-nodes may degrade the entire quality of service (QoS).

In this position article, we will give a brief overview of some of the existing techniques to reduce the channel switching delay based on multicast techniques, and provide a glimpse into the future of multi-channel streaming technologies. Readers are referred to various references for further studies.

2. Channel Switching Delay

In IP multicast and ALM, multicast groups are constructed to distribute the content of each channel, and nodes may join the multicast group of their desired channels. Since network bandwidth is limited, nodes cannot join all of the multicast groups and receive streams from all channels. Therefore, to preserve resources, nodes should initiate an efficient participation/leaving procedure with the multicast group when they switch channels.

According to [3], as for the case of IPTV, the channel switching delay depends on the following: the command processing time, the network delay, and the Set Top Box (STB) delay, which mainly consists of the buffering delay and the Moving Picture Experts Group (MPEG) decoding delay, as shown in Fig. 1.

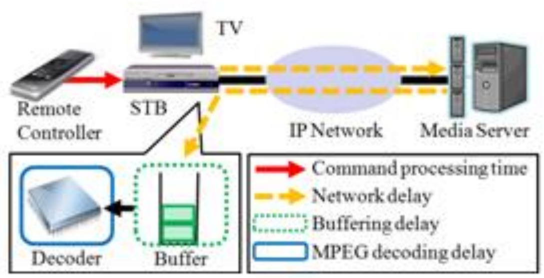

Fig. 1: Components of making up the channel switching delay in IPTV.

A viewer requests STB to switch channel by using a remote controller. Time until this request is accepted is referred to as the command processing time. The network delay is the time interval between the transmission of the join message and the reception of the first multicast packet of the requested channel. The buffering delay is the time from the first multicast packet is received until the buffer reaches a threshold prior to the transmission of the video signal to the decoder function. The threshold is designed to circumvent network jitter. The MPEG decoding delay is the time interval required by the decoding process.

3. Existing Proposals

Several approaches have been proposed to reduce the channel switching delay in multi-channel streaming, which can be categorized into two groups: IP multicast based and ALM based.

3.1. IP Multicast Based Approach

One approach to reducing the channel switching delay is by predicting channel requests and preparing reception of additional channels [4]–[6]. In [4], a viewer of channel number *N* joins multicast groups of channel number *N* -1, *N* and *N* +1. This allows for smooth "channel surfing" between adjacent channels. In [5]–[6], the viewer's profile, history, and other information are used to predict the next channel.

Fast channel switching based on reducing the decoding delay was studied in [7]–[11]. MPEG-2 and H.264/MPEG AVC video coding standards encode and transmit videos by using a Group Of Pictures (GOP) model where the video stream is defined as a series of interdependent frames. The video is encoded into a series of I, P, and B frames. The I frame contains the reference image and the P and B frames contain only difference information about the previous frame. Therefore, when a node switches channels, decoding is impossible until the next I frame is obtained. In [7], additional lower quality I frames are sent in addition to the normal quality coded pictures, as shown in Fig. 2. Responsive channel switching is achieved since I frames are frequently available. Synchronization Frames for Channel Switching (SFCS) [8] is another technique by using additional I frames, and is similar to that of [7]. Readers are referred to [9] for further studies on the trade-off between the channel switching delay and network efficiency.

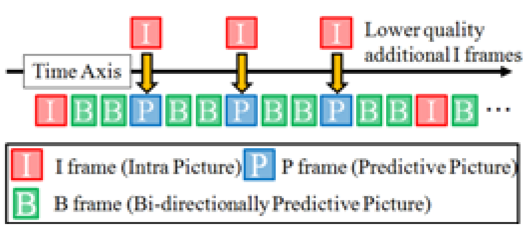

Fig. 2: Additional I frames to the normal quality coded pictures.

By decreasing the buffer delay time, the channel switching delay is also decreased. For example, an accelerator server [10], which can send a copy of the original stream with a fixed delay, is set up for each channel. The viewer of channel *G* receives streaming packets from both the main server and the accelerator server until the initial play-out buffer is filled up, as shown in Fig. 3. As a result, the channel switching delay introduced by the initial buffering delay can be reduced.

In another proposal, Multicast Assisted Zap Acceleration (MAZA) [11], each channel has several time-shifted sub-channels. When a viewer switches the channel, he can select and join the sub-channel which is closest to sending the next I frame, as shown in Fig. 4.

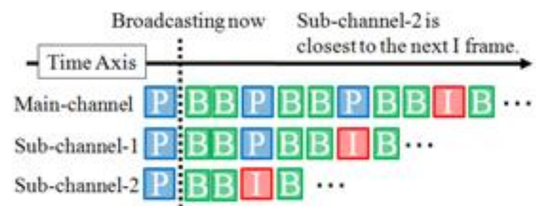

Fig. 3: Decreasing buffer delay time by the accelerator server.

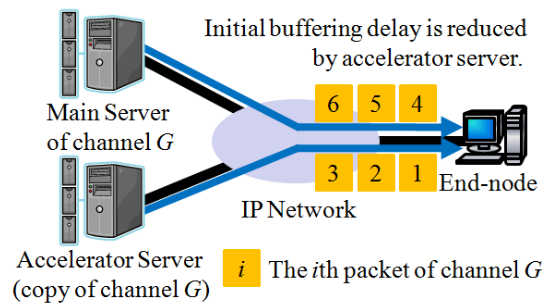

Fig. 4: Multicast Assisted Zap Acceleration.

3.2. ALM Based Approach

A few ALM based techniques have been proposed for multi-channel streaming [12]–[14], but the authors left the channel switching delay issue as their future works. One recent work, View Upload Decoupling (VUD)[15]–[16], did consider the channel switching delay. In VUD, nodes not only join the channel they are watching, but they also join several other channels according to the amount of unused available bandwidth. Since they receive additional channel information as shown in Fig. 5, the channel switching delay is reduced.

4. Multi-channel Streaming over Heterogeneous Networks

Most existing approaches require a large amount of node bandwidth for channels which are not even viewed. However, in a real network, each node's available bandwidth is heterogeneous and limited. Therefore, in multi-channel streaming, an efficient approach which not only reduces the channel switching delay but also reduces
bandwidth usage must be developed. Network-aware Hierarchical Arrangement Graph (NHAG) [17] is an ALM based single-channel streaming approach applied to the participatory nodes'

available bandwidth and dynamic networks. Among ALM based approaches, NHAG demonstrates robustness and efficient utilization of bandwidth for end-nodes, and can be potentially extended to reduce the channel switching delay.

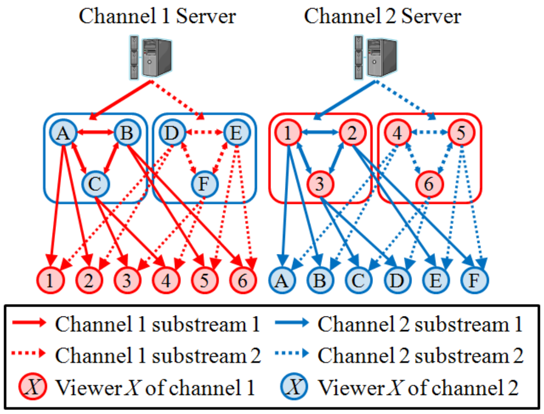

Fig. 5: View Upload Decoupling.

5. Conclusion

Audio/video multi-channel streaming is becoming widespread across the Internet. However, the channel switching delay still poses a significant issue. In this position article, we have described several existing approaches to reduce the channel switching delay based on IP multicast and Application Layer Multicast. These approaches are effective at reducing the channel switching delay, but require additional bandwidth from the network. Minimizing the channel switching delay with the minimum additional network resource is critical for future multi-channel streaming.

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