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

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Toshiaki Ako, Hiroki Nishiyama, Nirwan Ansari, Nei Kato
ako@it.ecei.tohoku.ac.jp

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.](image-url)

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.](image)

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.](image)

![Fig. 4: Multicast Assisted Zap Acceleration.](image)

### 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.

![Fig. 5: The ith packet of channel G (copy of channel G).](image)

### 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'...
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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.

![Diagram of Channel Streaming]

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.

References
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Toshiaki Ako received the B.E. degree in information engineering from Tohoku University, Sendai, Japan, in 2010. Currently, he is pursuing the M.S. degree in the Graduate School of Information Science (GSIS) at Tohoku University. His research interests are in areas of multimedia systems and overlay networks.

Hiroki Nishiyama received his M.S. and Ph.D. in Information Science from Tohoku University, Japan, in 2007 and 2008, respectively. He also worked as a Research Fellow of the Japan Society for the Promotion of Science (JSPS) for one and a-half years since 2007. He has been an assistant professor at Graduate School of Information Sciences (GSIS), Tohoku University since Oct. 2008. He received "The Best Paper Prize" of Student Award from IEEE Sendai Section in 2006, the Best Paper Award at 2009 IEEE International Conference on Network Infrastructure and Digital Content (IC-NIDC 2009), and the 2009 FUNAI Research Incentive Award of FUNAI Foundation for Information Technology (FFIT). He has been engaged in research on traffic engineering, congestion control, satellite communications, ad hoc and sensor networks, and network security. He is an IEEE member.

Nirwan Ansari received the B.S.E.E. (summa cum laude with a perfect gpa) from the New Jersey Institute of Technology (NJIT), Newark, in 1982, the M.S.E.E. degree from University of Michigan, Ann Arbor, in 1983, and the Ph.D. degree from Purdue University, West Lafayette, IN, in 1988. He joined NJIT’s Department of Electrical and Computer Engineering as Assistant Professor in 1988, tenured and promoted to Associate Professor in 1993, and has been Full Professor since 1997. He has also assumed various administrative positions at NJIT. He authored *Computational Intelligence for Optimization* (Springer, 1997, translated into Chinese in 2000) with E.S.H. Hou, and edited *Neural Networks in Telecommunications* (Springer, 1994) with B. Yuhas. His current research focuses on various aspects of broadband networks and multimedia communications. He has also contributed over 350 technical papers, over one third of which were published in widely cited refereed journals/magazines. He has also guest-edited a number of special issues, covering various emerging topics in communications and networking. He is an IEEE Fellow (Communications Society), and was Visiting (Chair) Professor at several universities.

He was/is serving on the Advisory Board and Editorial Board of eight journals, including as a Senior Technical Editor of IEEE Communications Magazine (2006-2009). He had/has been serving the IEEE in various capacities such as Chair of IEEE North Jersey COMSOC Chapter, Chair of IEEE North Jersey Section, Member of IEEE Region 1 Board of Governors, Chair of IEEE COMSOC Networking TC Cluster, Chair of IEEE COMSOC Technical Committee on Ad Hoc and Sensor Networks, and Chair/TPC Chair of several conferences/symposia. He has been frequently invited to deliver keynote addresses, distinguished lectures, tutorials, and talks. Some of his recent awards and recognitions include IEEE Leadership Award (2007, from Central Jersey/Princeton Section), the NJIT Excellence in Teaching in Outstanding Professional Development (2008), IEEE MGA Leadership Award (2008), the NCE Excellence in Teaching Award (2009), and designation as an IEEE Communications Society Distinguished Lecturer (2006-2009, two terms).

Nei Kato received the M.S. and Ph.D. degrees in information engineering from Tohoku University, Japan, in 1988 and 1991, respectively. He joined the Computer Center of Tohoku University, Sendai-shi, Japan, in 1991, and has been a full professor in the Graduate School of Information Sciences since 2003. He has been engaged in research on computer networking, wireless mobile communications, network security, image processing, and neural networks. He has published more than 180 papers in journals and peer-reviewed conference proceedings.

Dr. Kato currently serves as vice chair of IEICE
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Satellite Communications TC, secretary of IEEE Ad Hoc & Sensor Networks TC, a technical editor of IEEE Wireless Communications (2006-), an editor of IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS (2008-), and an associate editor of IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY (2009-). He served as a co-guest-editor for the Special Issue on Wireless Communications for E-Healthcare, IEEE Wireless Communications Magazine, a workshop cochair of VTC2010-Fall, a symposium cochair of GLOBECOM'07, ICC'10, ChinaCom'08, ChinaCom'09, and WCNC2010 TPC vice Chair. His awards include the Minoru Ishida Foundation Research Encouragement Prize (2003), the Distinguished Contributions to Satellite Communications Award from the IEEE Communications Society, the Satellite and Space Communications Technical Committee (2005), the FUNAI Information Science Award (2007), the TELCOM System Technology Award from Foundation for Electrical Communications Diffusion (2008), and the IEICE Network System Research Award (2009). Besides his academic activities, he also serves as member of the expert committee of Telecommunications Council, Telecommunications Business Dispute Settlement Commission Special Commissioner, Ministry of Internal Affairs and Communications, Japan, and as the chairperson of ITU-R SG4, Japan. He is a member of the Institute of Electronics and Information and Communication Engineers (IEICE).