Channel Reordering and Prefetching Schemes for Efficient IPTV Channel Navigation

Uran Oh, Soojung Lim, and Hyokyung Bahn

**Abstract — ***As Internet Protocol Television (IPTV) has become one of the major Internet applications, IPTV users increase rapidly and hundreds of channels emerge to satisfy users' demands. However, the increased number of channels makes users difficult to find their desired channels. Along with this problem, the channel zapping time of IPTV incurs serious user-perceived delay. To alleviate these problems, this paper presents hybrid schemes that combine channel prefetching and reordering schemes. Specifically, adjacency and popularity based prefetching schemes are combined with popular channel reordering schemes and their performances are simulated under various conditions. Experimental results show that the proposed schemes reduce the channel seek time by up to 44.7% when up-down channel selection interfaces are used.* [1]

Index Terms — IPTV, Channel navigation, Channel surfing behavior, Channel zapping time, Prefetching.

I. Introduction

Internet Protocol Television (IPTV) has become one of the major Internet applications and its growth is highly expected to rise annually. To enhance their competitiveness in the market, the main focus of IPTV enterprises is to improve the quality of service by providing various contents with numerous channels. However, due to the limitation of network bandwidth, IPTV set-top box cannot receive all the contents of channels simultaneously and this incurs zapping delay during channel switching. Since the channel zapping delay varies from 0.9 to 70 seconds [1], it is the main factor that discomforts IPTV users [2].

In this paper, we aim to provide better quality of experience (QoE) by adopting channel prefetching techniques together with channel reordering schemes. We previously presented channel reordering schemes that cluster popular channels into a certain location in the linear search sequences [8]. Since user's preference does not vary rapidly but mostly concentrates on a limited set of popular channels, these schemes are shown to be effective in reducing channel seek distance to find one's desired channel.

In order to reduce the channel seek time further, we use prefetching schemes together with the channel reordering schemes. Prefetching schemes aim to reduce zapping delay during channel switching by fetching the contents of channels before they are actually requested. Two prefetching schemes are used in this paper. The first one prefetches adjacent channels of the currently watching channel in the linear search order since they have more possibilities to be visited during channel switching in the future. The second prefetching scheme is popularity-based scheme, which observes the popularity of each channel, and then requests top ranking channels in advance.

Combining these prefetching techniques to the channel reordering schemes, our goal is to reduce not only the channel seek distance but also the channel seek time by considering asymmetric channel switching delay between the prefetched channels and non-prefetched ones. The prefetched channels that are highly expected to be visited during the channel seeking process will not make users feel extra delay since prefetching is performed when the users are watching and staying at a specific channel.

Experimental results from trace-driven simulations are performed to show the efficiency of the proposed schemes. Specifically, the performance improvement is up to 44.7% in terms of the channel seek time compared to the conventional numerical ordering with non-prefetching.

The rest of this paper is organized as follows. Section II describes related works on the recent IPTV researches. Section III explains channel reordering and prefetching schemes

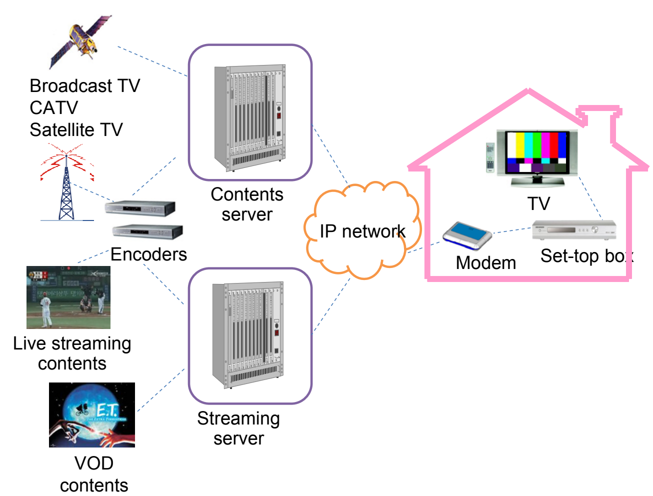

Fig. 1. Overview of an Internet Protocol Television (IPTV). An IPTV set-top box (STB) is linked to a digital subscriber line (DSL) modem, and TV contents are delivered through the Internet Protocol (IP) networks.

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mentioned above. The performance results are presented in Section IV, and the conclusion is in Section V.

II. Related Works

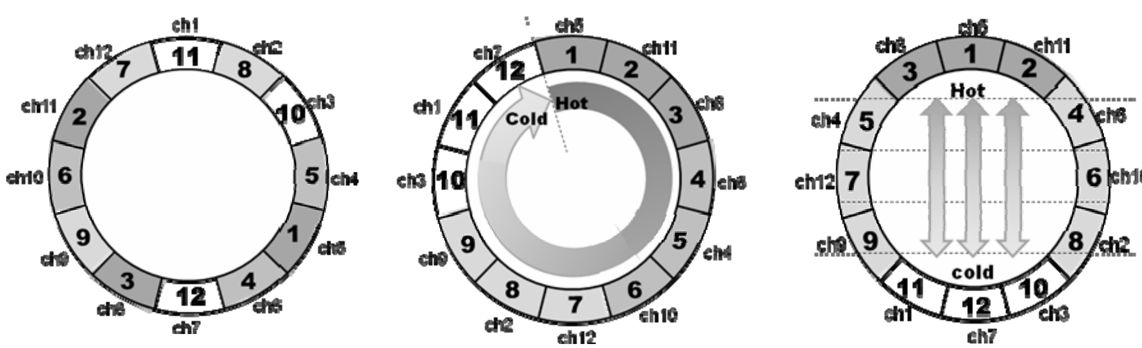
There have been various approaches to improve the quality of experience in IPTV services. In this section, we discuss existing approaches focusing on minimizing the channel zapping delay which consists of command processing time, network delay, STB jitter buffer delay, and video decoding delay. Lee et al. presented a scalable video coding scheme that reduces the channel zapping delay in IPTV [6]. Their scheme provides a preview mode so that users can access the channels already stored in the buffer without delay. Joo et al. proposed another approach that reduces network delay as well as video decoding delay [7]. They optimize the number of broadcasting channels seeking high network utilization and add extra frames to reduce the video decoding delay.

There are several approaches to reduce the channel zapping time based on prejoining methods. Cho et al. proposed the adjacent groups join-leave method to reduce the channel zapping time [3]. Their scheme requests adjacent channels along with the channel that is on demand so that users can watch the adjacent channels without network delay. Lee et al. presented a scheme that prejoins the top rating channels assuming that these channels may be watched more frequently by most users [4]. However, this scheme does not reflect each user's watching behavior. Kim et al. predict the candidate channels to be watched next according to the local favorite list of each user and prefetch the channels in advance [5].

This paper takes a different approach from these previous works in a sense that our goal is to reduce the channel switching delay in the user level by adopting prefetching methods together with channel reordering schemes rather than to minimize the channel zapping delay that is easily influenced by the network environment.

III. The Proposed Schemes

This section first reviews channel reordering schemes, and then describes prefetching schemes for IPTV. Fig. 2 shows an example of the channel reordering schemes with the popularity ranking of each channel marked inside the circles. We classified three channel reordering schemes including the conventional linear search scheme which displays channels in numerical order. Other schemes, namely frequency circular ordering scheme and frequency interleaved ordering scheme, are devised to reduce the channel seek distance by clustering popular channels according to the channel popularity list that is defined by analyzing the user's past view history. Channel seek distance means the number of channels to pass by while seeking the user's desired channel. The frequency circular ordering scheme reorganizes a user's favorite channels in the popularity ranking order from ranking 1 to ranking *n* in a circular way. This scheme performs much better than the original ordering scheme, but it has a drawback in that the least popular channel is adjacent to the most popular one. For this reason, the seek distance between the two channels is closer than the distance between any other channels. To relieve this weakness, the frequency interleaved ordering scheme, which places the hottest channel in the center and channels with odd rankings on its left side and channels with even rankings on its right side, is proposed. By concentrating on popular channels, it brings significant reduction on channel seek time especially when the frequency interleaved ordering scheme is used.



(a) Original ordering (b) Frequency circular ordering (c) Frequency interleaved ordering

Fig. 2. The channel allocation examples of the original scheme and the channel frequency-based schemes.

Channel selection	ch.5	ch.6	ch.11	ch.4	ch.8	
Channel seeking process	ch.5	ch.11→ ch.8 → ch.6	ch.8 → ch.11	ch.8 → ch.6 → ch.4	ch.6→ ch.8	Seek distance: 10
Prefetched popular channels		ch.5, ch.11	ch.5, ch.11	ch.5, ch.11	ch.5, ch.11	Accessing frequency: 2
Prefetched adjacent channels		ch.7, ch.11	ch.4, ch.8	ch.5, ch.8	ch.6, ch.11	Accessing frequency: 4

Fig. 3. An example of prefetching schemes when the frequency circular ordering scheme is used.

Based on these channel reordering schemes, we present two prefetching schemes in order to reduce the channel seeking time further. One is the popular channel prefetching scheme and the other is the adjacent channel prefetching scheme. The popular channel prefetching scheme prejoins a certain number of channels that have high popularity rankings assuming that these channels are more likely to be the next wanted channel. For example, this scheme prefetches channels from rankings 1 to n when the prefetching size is n. If the prefetching size is 4, then Ch.5, Ch.11, Ch.8, and Ch.6 are prefetched for all of the three reordering schemes in Fig. 2. Whenever the user passes these prefetched channels while reaching the target channel, the seek time can be reduced. This scheme, however, does not consider the location of the currently watched channel in the circular list. The adjacent channel prefetching scheme prefetches the channels that are adjacent to the currently watching channel. These channels are assumed to have high possibility to be visited when seeking the next desired channel. For instance, if a user currently wants to watch Ch.5 with the same prefetching size of 4, the original ordering scheme prefetches Ch.3, Ch.4, Ch.6, and Ch.7 as adjacent channels. Similarly, the frequency circular scheme prefetches Ch.1, Ch.7, Ch.11, and Ch.8, and the frequency interleaved scheme fetches Ch.4, Ch.8, Ch.11, and Ch.6 in advance. The adjacent channel prefetching scheme is more efficient than the popular channel prefetching scheme and gives constant benefit no matter what reordering scheme is used together since this prefetching scheme accesses at least one prefetched channel while the popular channel prefetching scheme cannot guarantee this effect. Fig. 3 shows an example of the prefetching schemes when prefetching size is two in the frequency circular ordering scheme. If a user watches five different channels starting from Ch.5, then the popular channel prefetching scheme prefetches top ranking channels Ch.5 and Ch.11 regardless of the channel that is currently being watched. On the other hand, the adjacent channel prefetching scheme prefetches channels that are adjacent to the channel that the user is currently watching. To be more specific, if Ch.6 is being watched now, then this scheme prefetches Ch.4 and Ch.8. These prefetched channels can reduce the total seek time by lessening the channel switching delay. As shown in Fig. 3, unlike the popular channel prefetching scheme, at least one prefetched channel is accessed during the process of seeking the next desired channel in the adjacent channel prefetching scheme and consequently always brings better results.

IV. Experimental Results

We performed simulation experiments to validate the improvement of prefetching schemes combined with channel reordering schemes with synthetically-generated traces. Popularity of the channels is followed by the Zipf distribution which has an ability to represent the skewed popularity distribution of objects [9]. In the experiments, the request probability P_i of the i-th popular channel is determined by the Zipf distribution and calculated by Equation (1).

$$P_i = \frac{(1/i)^{\theta}}{\sum_{k=1}^{n}(1/k)^{\theta}} \tag{1}$$

where n is the total number of distinct channels and θ ($0 \le \theta \le 1$) is the Zipf parameter that determines the degree of popularity skew. When θ is 0, all channels are equally popular. As the value of θ increases, the popularity of channels is increasingly skewed, and finally when it becomes 1, the popularity is most skewed. The number of requested channels in the traces is 10,000 and the number of prefetched channels ranges from 2 to 14.

Fig. 4 shows the percentages of seek time reduction with various reordering and prefetching schemes as a function of the Zipf parameter, compared to the non-prefetching and conventional numerical ordering scheme. In this experiment, the number of channels is 150 and the number of prefetched channels is 4. In terms of the channel reordering scheme, the result was consistent with the previous paper [8]. The performance of the frequency circular ordering scheme is better than the original ordering scheme, and the frequency interleaved ordering scheme

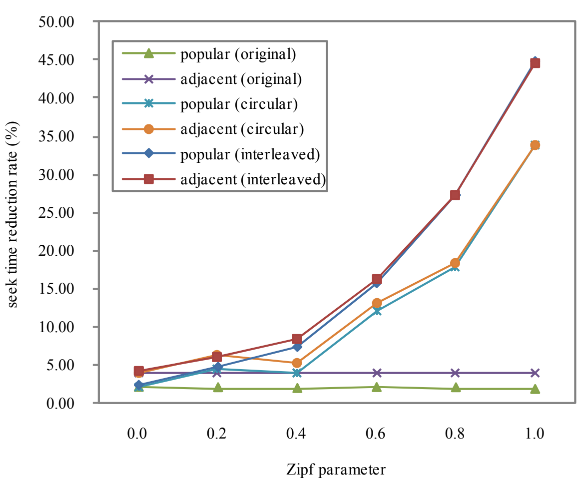


Fig. 4. The seek time reduction rate compared to the conventional non-prefetching scheme as the Zipf parameter increases.

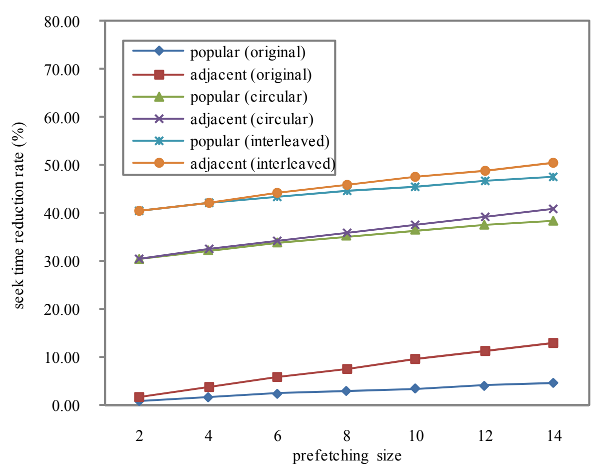
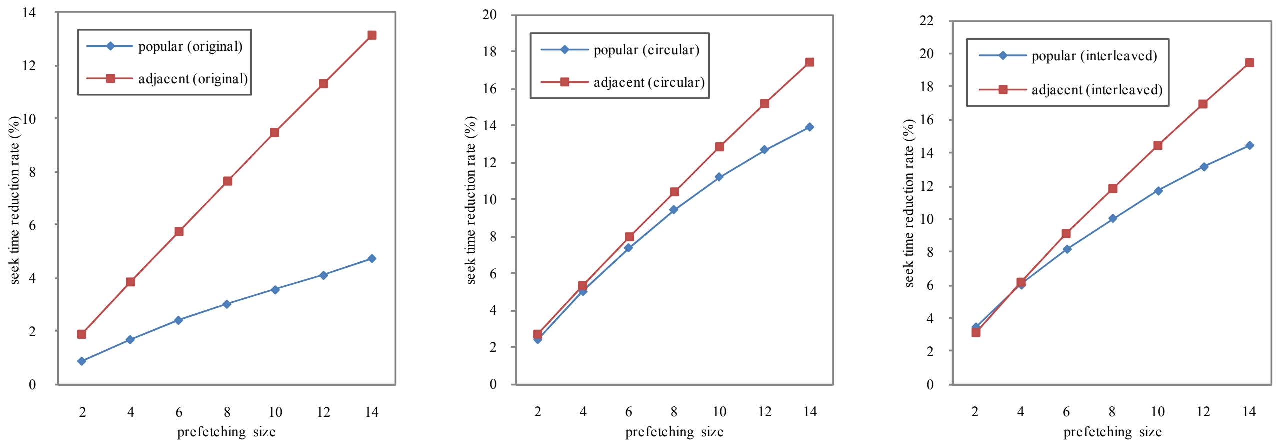


Fig. 5. The seek time reduction rate compared to the conventional non-prefetching scheme as the prefetching size increases.



(a) Original ordering scheme (b) Frequency circular scheme (c) Frequency interleaved scheme

Fig. 6. The seek time reduction rate to show the effect of adopting prefetching schemes to each reordering scheme compare to the scheme without prefetching

shows the best performance. The performance gap of reordering schemes becomes wider as the Zipf parameter increases. Unlike these schemes, it is shown that the performance of the original ordering scheme does not influenced by the Zipf parameter, but with prefetching its performance improves.

With respect to prefetching schemes, the adjacent channel prefetching scheme shows better performance than the popular channel prefetching scheme for all of the three reordering schemes. This is because adjacent channels are more likely to be passed when seeking the next desired channel rather than popular channels. When the Zipf parameter is 1, however, the performance of the popular channel prefetching scheme reaches just the same as the adjacent channel prefetching scheme. The reason is that there is high possibility of switching channels to popular ones under this condition.

When the Zipf parameter becomes zero, there is no difference between the channel ordering schemes. In this case, however, prefetching is effective in reducing the channel seeking time even though there is no popularity skew among all channels. Moreover, prefetching adjacent channels performs better than prefetching popular channels even when the Zipf parameter is 0. This implies that prefetching is always effective and its performance is better when the location of channels relative to the currently watching channel is exploited.

Fig. 5 shows the seek time reduction rate of the reordering and prefetching schemes compared to the non-prefetching original ordering scheme as a function of the prefetching size. In this experiment, we set the Zipf parameter to 1.0 and the number of channels 150. The performance improves as the prefetching size increases. When it comes to the original ordering scheme, the performance gaps between the adjacent channel prefetching and the popular channel prefetching schemes are even wider than using other reordering schemes. The reason is that popular channels are scattered throughout the circular list in this case, and thus adjacent channels are more likely to be visited during seeking the desired channel.

To confirm the performance improvement resulted from prefetching, we have compared the reduction rate of channel seek time for each scheme.

Fig. 6 shows the seek time reduction rate in each scheme without prefetching in terms of the prefetching size and the prefetching schemes. The results show that adjacent channel prefetching improves linearly as the size of prefetching channels increases but the performance growth of popular channel prefetching slows down starting from the prefetching size of 4. According to this result, we can conclude that the adjacent channel prefetching scheme is more efficient than the popular channel prefetching scheme when the prefetching size becomes large.

Comparing the performance improvements of each scheme, the frequency interleaved scheme showed the best performance from prefetching by up to 20% with the adjacent channel prefetching scheme.

Although the result shows only about 10% of performance improvement when the prefetching size is 5% of the total number of channels, this reduces the seek time per channel by 0.6 second. This is significant reduction of channel seek time to satisfy the quality of experience.

V. Conclusions

This paper presented hybrid channel prefetching and reordering schemes for efficient channel navigation in IPTV. We have validated effectiveness of various schemes through trace-driven simulations. Experimental results showed that the adjacent channel prefetching scheme shows better performance than the popular channel prefetching scheme no matter what reordering scheme is used. We also observed that the performance improvement by combining prefetching becomes largest when the frequency interleaved scheme is used since the scheme itself considers the channel popularity and the possibility of accessing channels.

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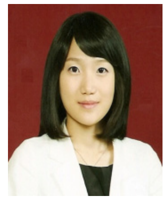
BIOGRAPHIES



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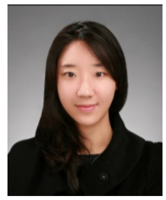

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