# Popular Channel Concentration Schemes for Efficient Channel Navigation in Internet Protocol Televisions

Eunji Lee, Jiyoung Whang, Uran Oh, Kern Koh, and Hyokyung Bahn

**Abstract** — *Internet Protocol Television (IPTV) is becoming increasingly popular as an emerging Internet application due to its variety of contents and services. However, hundreds of IPTV channels make it difficult to find one's desired channel. To relieve this problem, this paper presents a popular channel concentration scheme for efficient channel navigation in IPTV. Based on the property that TV channel selections concentrate on several frequently selected channels, the proposed scheme reorganizes channel sequences by clustering popular channels. Specifically, channels are rearranged in a frequency interleaved way to minimize the seek distance. Simulation studies show that the proposed scheme reduces the seek time of IPTV channel navigation significantly when up-down channel selection interfaces are used.* [1]

**Index Terms — IPTV, channel navigation, channel selector, channel seek time, watching behavior.**

## I. Introduction

With the widespread adoption of broadband Internet service and recent advances in video technologies, Internet Protocol Television (IPTV) is becoming increasingly popular. Unlike terrestrial or satellite broadcasting TVs in which channels are limited to radio frequency bandwidth, IPTV delivers digital TV services using Internet protocol over the computer network infrastructure. This enables IPTV to provide hundreds of channels and ever-growing contents. However, the explosion of IPTV channels makes finding one's desired channel difficult. This problem becomes even more serious with channel zapping delay that occurs during channel switching in IPTV. Therefore, a specialized channel selection system for IPTV is needed.

Users can make a request to the IPTV channel selector in two types of interfaces, up-down buttons and agent-based tools such as contents browser. The up-down buttons are used for the sequential search of channels and the agent-based tools are used for selecting desired contents by title, time, genre, etc. The channel selection interface used in this paper is the up-down buttons for the linear search of channels. With this interface, users search the desired contents in numerical order of channels, which incurs a large amount of seek distance as the number of channels increases.

This paper presents a popular channel concentration scheme that reduces the seek time utilizing the locality of human's channel selection behavior. For example, user's choice does not vary rapidly but mostly concentrates on a limited set of popular channels. The key idea of the proposed scheme is the reordering of channel sequences by clustering scattered hot channels into a certain location in the linear search sequences.

To this end, the proposed scheme analyzes user's preference of channels from the previous behaviors, and creates the priority list of channels in terms of frequency. This is based on the property that TV channels with a larger view count have a higher probability to be selected again. The scheme, then, reorganizes the channel sequences by collecting popular channels together. When a user pushes up-down buttons, the channel selector displays channels not in numerical order, but in reorganized order where popular channels are clustered. In this situation, there is a high probability that users' favorite channels are placed in the nearby locations. This allows users to find their favorite channels without spending a large amount of scanning time in most cases.

There has been a similar scheme called MFS (most frequently selected) that maintains the priority list of TV channels based on the past view frequency [1]. Unlike the proposed scheme, however, MFS modifies the interface of up-down buttons, causing inconvenience to traditional users. Specifically, MFS shows the most frequently viewed channel first whenever a user pushes the up button to start navigation.

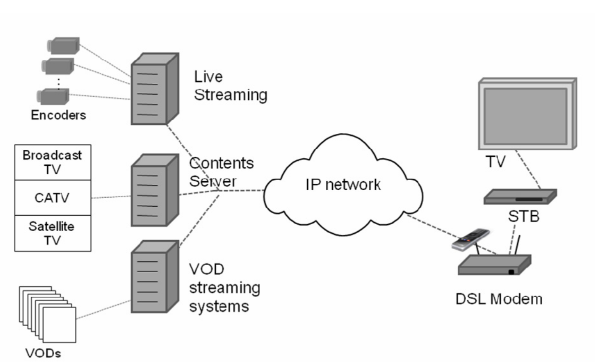


**Fig. 1. Architecture of an Internet Protocol Television (IPTV). An IPTV set-top box (STB) is linked to a digital subscriber line (DSL) modem, and TV contents are delivered through the Internet Protocol (IP) networks.**

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It has a weakness in that the interface is quite different from the conventional up-down scanning functions, and thus difficult to become familiar to users.

The intuitive way to cluster hot channels is employing the frequency priority list. This approach, though exhibits improved performance, has a weakness in that unpopular channels are adjacent to highly preferred channels, due to the circular structure of the channel sequences. To reduce the seek distance further, this paper presents the priority interleaved ordering scheme. The scheme first fixes the position of the most popular channel, and deploys channels with odd rankings on the left side, and channels with even rankings on the right side, by their frequency priority. This makes a more efficient permutation of channels with respect to the expected seek distance.

Experimental results from trace-driven simulations show that the proposed scheme performs better than the conventional channel selector that maintains and navigates channels in numerical order. Specifically, when the number of TV channels is 150, the average channel seek distance of the proposed scheme is reduced to 44.8% of the conventional numerical ordering. This implies that almost half of the channel flipping can be removed with the proposed scheme.

The remainder of this paper is organized as follows. Section II presents related works on the overall IPTV researches. Section III describes the new channel navigation scheme, and Section IV shows the performance results of the proposed scheme against conventional channel selection systems. Finally, Section V concludes the paper.

## II. Related Works

There have been a number of approaches to reduce the channel search overhead in IPTV, most of which focus on reducing the channel zapping time. Cho et al. presented the Adjacent Groups Join-Leave method to reduce the channel zapping delay in IPTV [2]. Their scheme sends an IGMP (Internet Group Management Protocol) membership report message not only for the currently requested channel but also for the adjacent channels. This allows users to watch adjacent channels without network delay because multicast streams for the adjacent channels come along to their home gateway. Kim et al. introduced the IGMP used as the channel zapping protocol in the hybrid wavelength division multiplexing based on passive optical networks (WDM-PON) [3]. They try to reduce the channel zapping time by diminishing the general query interval that is the time to join a group.

There are studies regarding video coding schemes to reduce the channel zapping delay in IPTV. Lee et al. presented the H.264 scalable video coding scheme in order to reduce channel change time [4]. In their scheme, a base layer and enhancement layers of each channel are allocated to two separate multicast groups. In the preview mode, users access the base layers of different channels already stored in the buffer, so they can switch channels without delay. In the watching mode, they use both the base and enhancement layers of the selected channel to achieve high quality. Boyce and Tourapis presented a system for enabling fast channel change response time in a set-top box while improving video compression efficiency [5].

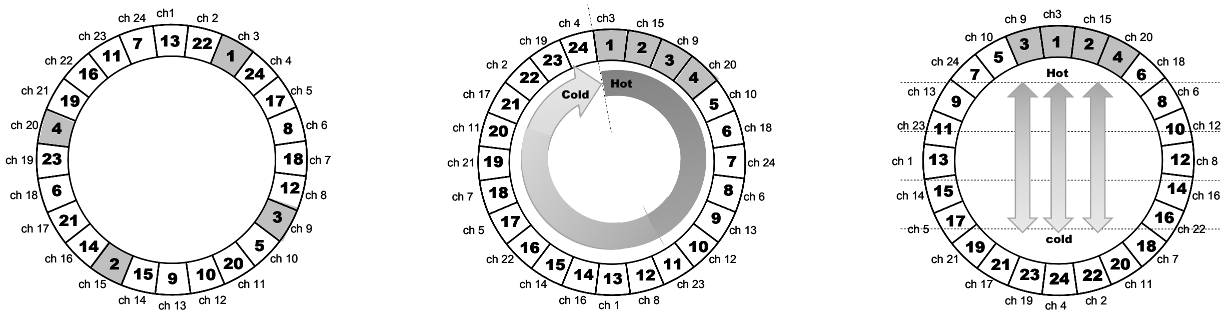
More recent research considers both the network delay and video decoding delay. Joo et al. proposed an IPTV channel control algorithm that keeps channel zapping time in the tolerable range with high network utilization [6]. They presented how to effectively reduce the network delay by adjusting the number of broadcasting channels to be serviced from closer routers. They also discussed how to efficiently decrease video decoding delay by adding extra I-frames to normal video frames.

Since understanding the channel selection behavior of users can be utilized to improve their channel search latency, there have been researches to analyze user's channel surfing behavior. Cha et al. analyzed the channel selection behavior in the live IPTV streaming systems [7]. They also characterized the properties of viewing sessions, channel popularity dynamics, geographical locality, and channel switching behaviors [8]. Qiu et al. analyzed and modeled the popularity of channels in an IPTV system [9]. Mamun-Or-Rashid et al. presented a framework to acquire a user's channel surfing behavior and proposed an algorithm to mine the user's preferred channel sequences to reduce channel zapping delay [10]. The basic idea is to supply as many channels as possible at the STB based on the preferred list of channels obtained from the channel mining algorithm. If an end user switches channels within the preferred list, the channel can be immediately viewed without any zapping delay. Mandal and MBuru also suggested similar ideas [11]. Their scheme minimizes channel switching delay through an intelligent prefetching technique, exploiting both spatial and temporal channel surfing behavior of users. Kim et al. presented a method of pre-joining the expected next TV channels in order to reduce IPTV channel zapping time considering the channel surfing behavior and the particular preference of each viewer [12].

This paper is different from the previous works in that the goal is to reduce the seek distance of channels in the user level, rather than to reduce the channel zapping delay in the data transfer or processing layer.

## III. Popular Channel Concentration for Efficient Channel Navigation in IPTV

This section describes an efficient channel navigation scheme for IPTV. In a conventional linear search scheme, an IPTV channel selector displays channels in numerical order. Since it does not consider user's preference, popular channels are likely to be scattered. This incurs long seek distance for most cases. For example, there are one hundred channels, namely Ch1, Ch2, Ch3, … , Ch100, and the most popular channels are Ch1 and Ch50. In the case that the user watches these two channels alternately, every channel switch entails seek distance of 49, almost half of the whole channels. As a




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

**Fig 2. The channel sequences of numerical ordering and popular channel concentration schemes**

Channel selection: ch.3 → ch.15 → ch.9 → ch.3 → ch.15 → ch.3 → ch.20 → ch.15 → ch.3 → ch.20 → ch.3
Frequency priority: (1) (2) (4) (1) (2) (1) (3) (2) (1) (3) (1)

| | Total seek distance |
|---|---|
| Numerical ordering | 12+6+6+12+12+7+5+12+7+7= 86 |
| Frequency circular ordering | 1+1+2+1+1+3+2+1+3+3 = 18 |
| Frequency interleaved ordering | 1+2+1+1+1+2+1+1+2+2+1 = 14 |

**Fig 3. An example of popular channel concentration schemes**

result, the user wastes a plenty of time in passing through many rarely selected channels to find the desired channels.

Aforementioned inefficiency can be improved if favorite channels are placed adjacently in the navigation sequence. To this end, we suggest a popular channel concentration scheme for efficient channel navigation.

The proposed scheme analyzes user's past watching history and creates the priority list of channels in terms of reference popularity, assuming that a TV channel with a larger view count has a higher probability to be selected again. Based on the popularity of channels, the navigation sequences are reorganized such that hot channels are placed adjacently. To quantify the seeking cost of the navigation schemes, we define the ESD (expected seek distance) as follows,

$$ESD = \sum_{i,j=1}^{n} p(i,j)\, d(i,j) \quad (1)$$

where $n$ is the number of channels, $d(i, j)$ is the scanning distance to switch from channel $i$ to channel $j$ and $p(i, j)$ is the probability of switch occurring between channels $i$ and $j$.

The aim of the proposed scheme is to reduce ESD compared to the conventional scheme. This can be obtained because channels with a higher probability of switching have a smaller expected distance.

As for specific schemes for clustering hot channels, the basic scheme is to employ the priority circular list of channels according to their popularity. This approach concentrates popular channels in a certain location of the list, eventually leading to better performance than the conventional scheme. However, this scheme has a weakness in that the least popular channel is adjacent to the most popular one when navigating the circular list. Although the probability of switching between these two channels is very low, their distance is shortest. This is against the principle to minimize ESD.

To resolve the aforementioned problem, this paper presents a new scheme that interleaves the deployment of channels by their frequency priority. The most preferred channel is fixed in the center, and channels with odd rankings are positioned on its left side, and channels with even rankings on its right side by frequency ranking. This generates an efficient circular list with respect to the expected seek distance if the popularity of channels is heavily skewed such as the Zipf distribution [13].

Figs. 2(a), 2(b), and 2(c) illustrate the channel sequences of the numerical ordering, frequency circular ordering, and frequency interleaved ordering, respectively. Fig. 3 shows an example of them. In this example, the total number of channels is 24 and the ring represents the circular structure of channel sequences. The number in each cell represents the frequency priority and the numbers outside the cell are channel numbers. Then, the seek distance of each scheme to find desired channels is as follows.

For the conventional linear search scheme, the total seek distance is 86. Such a large amount of seek overhead is incurred because popular channels are scattered.

In the frequency circular list scheme, on the other hand, as channels are sorted by their frequency priority, popular channels are concentrated formulating a hot zone. Thus, to watch popular channels, there is no need to visit the channels which are unlikely to be selected. The total seek distance in this scheme is 18, which is only 21% of the numerical ordering. The total seek distance of the interleaved ordering scheme is 14, which performs even better than the priority circular list. This improvement results from that hot channels are clustered in a more efficient way.

The proposed navigation scheme in this paper uses up-down buttons for the quick search of the desired channels. Although hot channels may be selected directly by the numerical buttons since users usually remember a certain number of their favorite channels, the number of channels that can be memorized is very limited. Furthermore, even they remember their favorite channels, users usually search the channels by the up-down buttons.

When the channel navigation system makes use of the observation report of a user's previous behaviors, inadequate information can be included. For example, skipped channels may be included in the priority list during the search operations. The channel navigation system can filter out these channels when the staying time at a channel is not longer than a specific period of time. In order to remove such noise information, a threshold time is set. If the staying time at a channel is longer than the threshold time, it is included in the user's preference information. Otherwise, the channel is just considered as a skipped channel and filtered out.

## IV. Experimental Results

Simulation experiments were performed to assess the effectiveness of the proposed channel navigation scheme 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 [13]. In the experiments, the request probability $P_i$ of the $i$-th popular channel is determined by the Zipf distribution and calculated by Equation (2).

$$P_i = \frac{(1/i)^\theta}{\sum_{k=1}^{n}(1/k)^\theta} \tag{2}$$

where $n$ is the total number of distinct channels and $\theta$ ($0 \le \theta \le 1$) is the Zipf parameter that determines the degree of popularity skew. When $\theta$ is 0, all channels are equally popular. As the value of $\theta$ 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 distinct channels ranges from 10 to 150.

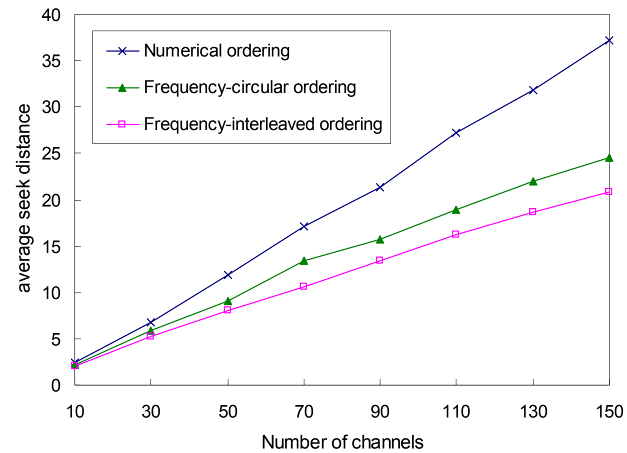



**Fig. 4. The average seek distance of the numerical ordering, frequency-circular ordering, and frequency-interleaved ordering as the number of IPTV channels increases.**

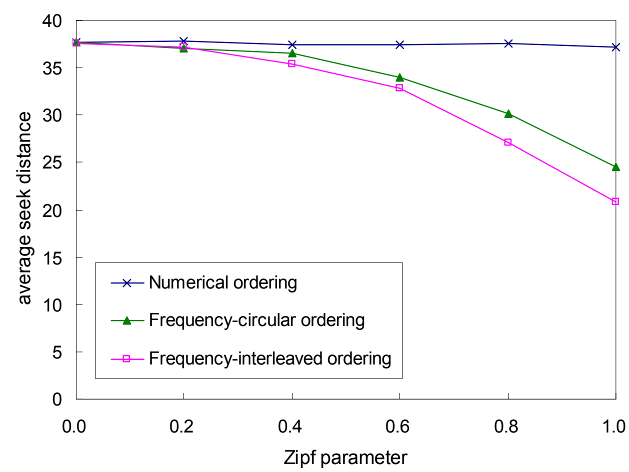



**Fig. 5. The average seek distance of the numerical ordering, frequency-circular ordering, and frequency-interleaved ordering as a function of the Zipf parameter.**

The two popular channel concentration schemes, namely the frequency-circular ordering and the frequency-interleaved ordering are compared with the conventional navigation scheme that searches TV channels in numerical order. Fig. 4 shows the average channel seek distance of the three schemes as the number of IPTV channels increases. As can be seen, the proposed schemes outperform the conventional scheme by a large margin when the number of channels is sufficiently large. Specifically, when the number of TV channels is 150, the conventional scheme requires average flick counts of 37.7 in finding the requested channel while the frequency-interleaved ordering and frequency-circular ordering schemes requires 20.8 and 24.6, respectively. The frequency-interleaved ordering scheme consistently shows better performances than the frequency-circular ordering scheme. The reason is that the expected seek distance of the frequency-interleaved ordering scheme is shorter than that of the frequency-circular ordering scheme.

Fig. 5 shows the average channel seek distance of the three schemes as a function of the Zipf parameter. When the Zipf parameter $\theta$ is equal to 0, the three graphs merge to a single point. This is because the Zipf parameter value of 0 implies all the channels are equally requested which means the distribution is reduced to random. This is an unrealistic scenario and actually there is no way to improve the performances under this assumption. As the value of Zipf parameter $\theta$ increases, the performance gap between the conventional scheme and the two proposed schemes becomes wider. Specifically, the performance improvement of the frequency-interleaved ordering scheme against the conventional scheme is up to 44.8% in terms of the average seek distance when the Zipf parameter is set to 1.0.

## V. Conclusions

This paper presented a popular channel concentration scheme for the quick channel navigation in IPTV. The scheme analyzes user's past watching history to identify preferred channels in terms of frequency and generates the channel sequence by clustering them. This paper presented the frequency interleaved ordering as a specific way of clustering that deploys channels symmetrically on the hottest channel by frequency ranking. Results from trace-driven simulation with various experimental environments demonstrated that the frequency interleaved ordering performs better than priority circular list, as well as the conventional navigation scheme in terms of the seek distance to find the target channel.

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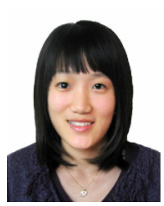

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