Reducing IPTV Channel Zapping Time Based on Viewer's Surfing Behavior and Preference

Yuna Kim, Jae Keun Park, Hong Jun Choi, Sangho Lee, Heejin Park, Jong Kim
Dept. of CSE, POSTECH
Pohang, Korea
{existion, ohora, formetel, sangho2, parkhj84, jkim}@postech.edu

Zino Lee, Kwangil Ko
Alticast Corp.
Seoul, Korea
{zino, kik}@alticast.com

Abstract

This paper presents a method of prejoining the expected next TV channels for reducing IPTV channel zapping time with a consideration of the channel surfing behavior and the particular preference of each viewer. In this method, a home gateway of multicast protocol proxy for set-top boxes (STB) prejoins the expected and preferred channels based on aggregated data from STBs. The experimental results show that the method improves the prediction accuracy of prejoin channels with little network bandwidth overhead, which leads to reduce the channel zapping time for IPTV services.

Keywords

Channel zapping time, Channel surfing behavior, Set-top box, Home gateway, IPTV, IP multicast.

INTRODUCTION

Channel zapping time of IPTV (Internet Protocol Television) services is considerably affected by IP multicast operations of IGMP (Internet Group Multicast Protocol), such as joining and leaving multicast groups that serve the IPTV channels, which were not needed for the conventional all-channel broadcasting TV systems. According to the test results from Agilent Technologies, the multicast operation time for 1000 users varies from 0.9 seconds to 70 seconds when changing channels [1]. This value does not satisfy the quality of experience (QoE) of users [2].

In order to reduce the multicast operation time, the prejoin methods [3, 4] were proposed. In their methods, IPTV set-top boxes (STB) or a home gateway (HG) that performs the function of IGMP proxy for the STBs predicts the channels to be requested next and then joins them in advance. The predicted next channel may be the adjacent channels of currently watching ones and the top rating channels. The prediction is performed based on the assumption that most of viewers surf channels using up/down button or watch the popular programs. However, each TV viewer exhibits discriminative surfing behavior, for example, watching several favorite channels or specific programs like entertainment or documentary.

In such prejoin methods, improving the prediction accuracy can be a key factor of reducing the multicast operation time. Consequently, in order to improve the prediction accuracy, channel surfing pattern and program preference of each user should be considered. The surfing pattern can be extracted from the pushed buttons of a remote controller, and the program preference information can be obtained from the personalized recommendation system for electronic program guide (EPG) [5, 6] installed in STBs.

In this paper, we propose a prejoin method for reducing IPTV channel zapping time by reflecting the channel surfing behavior and the particular preference of each viewer. The proposed method specifies a message protocol between STBs and HG for transmitting the information on surfing behavior and preference, and an algorithm of predicting the prejoined channels.

The contribution of this paper is as follows. We classify a channel surfing behavior into four categories resembling button types on a remote controller. We also present how the HG aggregates the information on surfing behavior and preference of each STB. Lastly, we evaluate the performance of our method and previous ones in terms of the prejoin hit rate and the bandwidth usage for prejoin. This experimental evaluation is conducted first as far as to our best knowledge.

RELATED WORK

Previous Prejoin Methods

In order to reduce the multicast operation time for channel zapping, two prejoin methods [3, 4] were proposed. In Cho *et al.*'s scheme [3], a HG that performs the function of IGMP proxy for several linked STBs predicts the channels to be requested next, such as the adjacent channels of watching one, and then joins to the channels in advance. This method can reduce the channel zapping time when a user performs up/down channel surfing. However, it does not support the random channel surfing. Hence, if a user jumps over the channels randomly then the bandwidth for the prejoined channels would be wasted.

To decrease the channel zapping time for the random channel surfing pattern, Lee *et al.'s* scheme [4] prejoins the top rating channels additionally with a help of the rating server. This scheme is based on the assumption that most of users may watch the popular channels. However, the top rating channels cannot reflect each user's preference. Accordingly, the prediction accuracy of the scheme may lower than their expected results.

Personalized Recommendation System

A STB is equipped with a personalized recommendation system for EPG [5, 6], which recommends a list of on-air programs that a viewer prefers, by calculating the similarity between program information and the viewer's preference based on viewer's watching history.

Hsu *et al.* [5] proposed a program recommendation system that accounts for both user viewing contexts and personal attributes. The system predicts the next channel based on a user-oriented perspective by using the predictors of user AIMED (Activity, Interest, Mood, Experience, and Demographic) information. The performance evaluation result shows that the AIMED model significantly increases the recommendation accuracy and decreases the prediction errors for program preferences. However, the process of gathering user information explicitly can be cumbersome.

To calculate user preference automatically, Lum et al's [6] proposed the viewer's preference learning algorithm based on a Bayesian network to which weighted usage history data on multimedia consumption is taken as input. The optimal weights are calculated by the mutual information between the old and the current user preferences. This method shows dynamic learning behavior, which timely changes a user preference for content consumption by weighting the usage history data. According to the experimental results for a large set of realistic usage-history data of TV programs, this algorithm can predict a user preference automatically.

Internet Group Management Protocol (IGMP)

IPTV uses IP multicast techniques to reduce overall bandwidth requirements for delivering contents and services. IGMP is a standard protocol to realize the IP multicast service by giving the membership status of hosts connected to the network to the multicast routers. IGMP has two types of messages: a membership query and a membership report.

The multicast router sends the membership query messages to the connected hosts for checking their status periodically (the default interval is 125 seconds). Then the receiving hosts reply to the router by sending the membership report message. If no host sends the message anymore then the router terminates the multicast delivery service. The membership report message is also sent to the router by a new host who wants to join to a multicast group.

Table 1: IGMPv3 membership query message

Type=0x11			Max resp. code	Checksum
Group Address				
Resv	S	QRV	QQIC	Number of Sources (#S)
Source Address [1]				
…				
Source Address [#S]				

Table 1 represents the structure of IGMPv3 membership query message. *Max resp. code* field states the maximum response time from hosts. The *group address* field is set to zero when the message is a general query and set to the IP multicast address when the message is a group-specific query or a group-and-source-specific query. The *source address* fields are used to support the source filtering.

Table 2: IGMPv3 membership report message

Type=0x22	Reserved	Checksum
Reserved		Number of Group Records (#R)
Group Record [1]		
…		
Group Record [#R]		

Table 2 represents the structure of IGMPv3 membership report message. Each *group record* is a block of fields containing a multicast address to receive data from the address and several source addresses to support the source filtering mechanism. See RFC3376 for details [7].

Proposal

To improve the accuracy of predicting the next channel, we consider both the surfing behavior and the preference of each viewer. The surfing behavior can be extracted from the pushed buttons of a remote controller, and the preference information can be obtained from the personalized recommendation system.

Message Format

A STB can predict the next channel based on the input from a remote controller. We assume that the remote controller has four types of buttons: up/down, toggle, preset-favorite[1], and channel number. Viewers tend to keep pushing the same button for changing channels, and the STB can match a channel number with any pushed button. Hence, the STB infers the

[1] A viewer presets some favorite channels in STB explicitly, thus pushing the preset-favorite button enables him/her to conveniently access to only the channels in succession.

next channel from the pushed button and the channel is called *Expected-Channel (E-CH)*. The *E-CH* would be an up channel when pushing the up button, a down channel when pushing the down button, the previous channel when pushing the toggle button, and the next preset channel when pushing the preset-favorite button. When the STB sends a channel request to HG, it attaches an *E-message* including *E-CH* to the request.

A STB can predict the next channel based on a recommendation given by the personalized recommendation system [5,6]. The channels corresponding to the recommended programs are called *Preferred-Channels (P-CH)*. When the STB sends an IGMP report message periodically to HG, it attaches the *P-message* to the report. The *P-message* includes STB's ID, the current time, and a list of *P-CHs*.

The *E-message* or the *P-message* is included in the *Auxiliary Data* field in a *group record* block of the report message format of IGMP v3, and the message length is written in the *Aux Data Len* field. This adoption of IGMP makes it compatible to the case of using conventional STB or HG, and to the case of not even using HG.

W-CH table	*Channel Number*	*WCount*	
P-CH table	*Channel Number*	*PCount*	*wflag*
pP-CH table	*Channel Number*		
E-CH table	*Channel Number*	*STBList*	

Figure 1: Tables managed in HG

Tables Management

The HG manages four tables with the aggregated *E-messages* and *P-messages* as shown in Fig. 1: *W-CH table, P-CH table, pP-CH table, E-CH table*.

An entry of *W-CH table* contains a channel number that one or more STBs are watching and the number of STBs (*Wcount*) that are watching the channel. An entry of *P-CH table* contains a *P-CH*, the number of STBs (*PCount*) which recommend the *P-CH*, and a flag (*wflag*) which represents whether the *P-CH* is in the *W-CH table* or not. Among the entries in the *P-CH table*, the *P-CHs* of the highest *PCount* that any STB is not watching are maintained in *pP-CH table*. The number of entries in *pP-CH table* is determined by HG configuration. An entry of *E-CH table* contains an *E-CH* that one or more STBs keep requesting as the expected channel, and the list of such STBs (*STBList*) which do not send a new *E-message* yet after sending the *E-message* including the *E-CH*. All the channels in the *pP-CH table* and the *E-CH table* are prejoined by a HG.

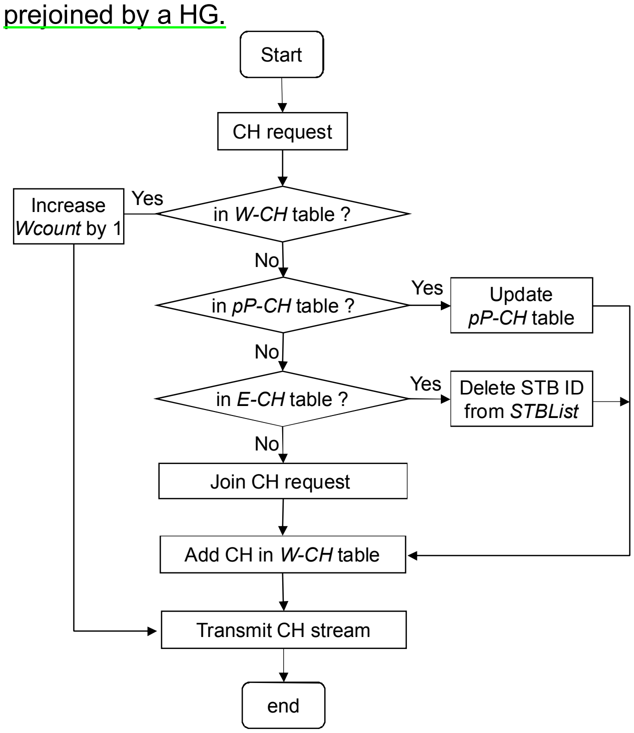


Figure 2: Channel join process in HG

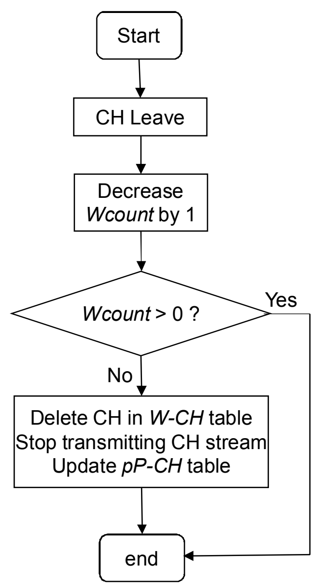


Figure 3: Channel leave process in HG

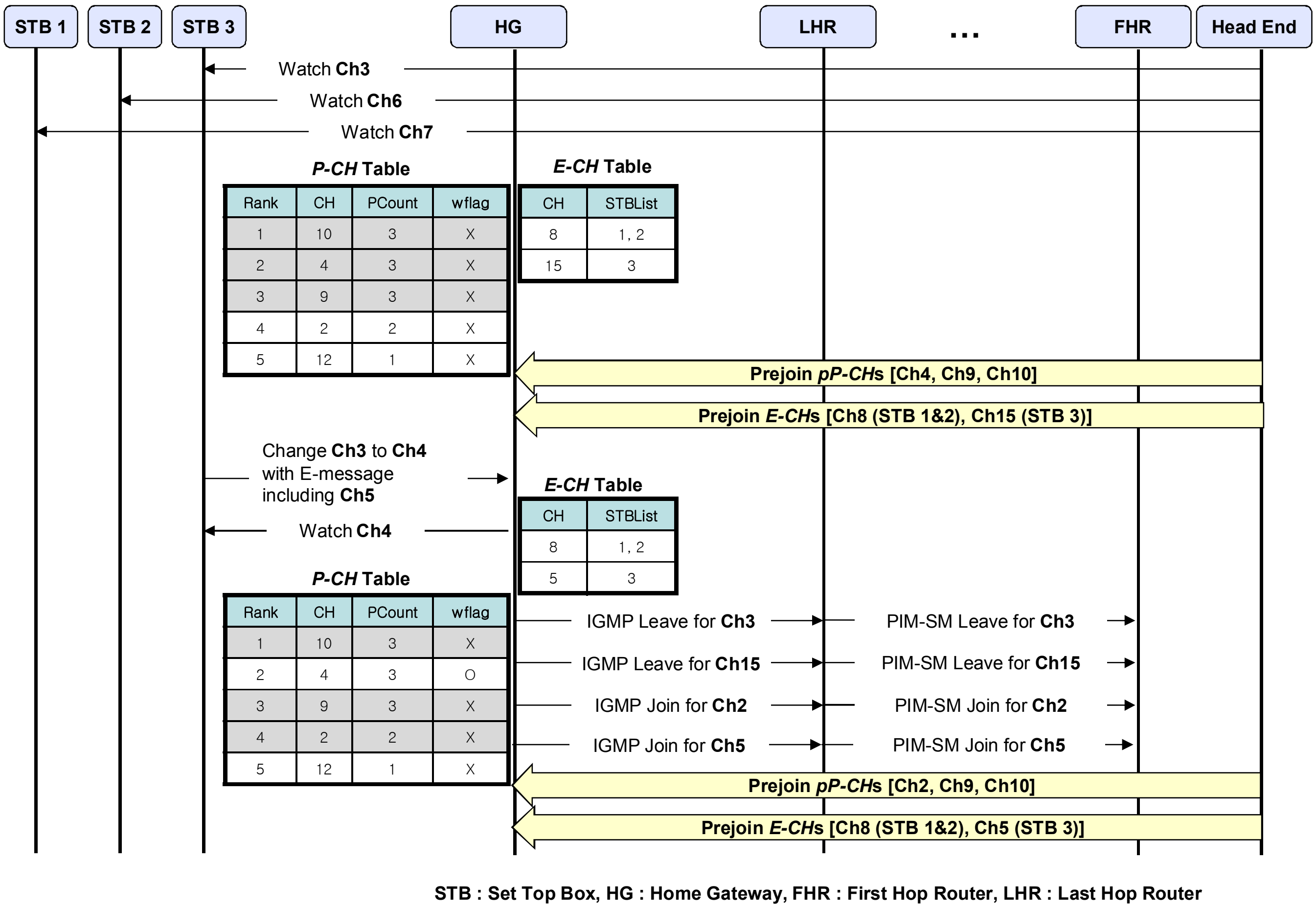


Figure 4: An example scenario for channel zapping in our proposed scheme

Channel Join/ Leave Process

When a STB requests a new channel, the HG starts the channel join process as shown in Fig. 2. The HG transmits immediately the stream of the channel if the channel is in *W-CH*, *pP-CH*, or *E-CH tables.* Otherwise, the HG requests the channel join, appends a new entry of the requested channel with setting *WCount* as 1 into the *W-CH table*. When the requested channel is in *pP-CH table*, the channel is deleted from *pP-CH table* and then the next top ranking channel of *P-CH table* is added *to pP-CH table* for keeping the size of the *pP-CH table*. If the requested channel is in the *E-CH table*, the requesting STB ID is deleted from the STBList of the corresponding entry in the *E-CH table*. In addition, if *E-CH* included in *E-message* is not in *E-CH table*, it is appended to *E-CH table* as a new entry with the requesting STB ID. Otherwise, only the STB ID is added to STBList of the corresponding entry in *E-CH table*.

When a STB begins to receive the stream of the new channel after the channel join request, it sends the leave message to the HG. Then the HG performs the channel leave process for the previously watching channel as shown in Fig. 3. If no STB is watching the channel, the channel is deleted from *W-CH table*. If the channel is in *P-CH table*, the channel replaces the lowest ranking entry in *pP-CH table* if the *PCount* of the channel is higher than the entry. If a STB does not send any report message for some time interval that is supposed to be sent periodically, the HG regards the STB as being leaved. Hence, the STB ID is removed from the STBList.

An Illustrative Example Scenario

For illustration purpose, we present an example scenario of channel zapping in the proposed scheme. Suppose that STB1, STB2, and STB3 are watching Ch3, Ch6, and Ch7, respectively, and the HG maintains a *P-CH table* of five entries and a *E-CH table* of two entries as shown in the Fig. 4. The HG prejoins Ch4, Ch9, and Ch10 of the top rank channels in the *P-CH table*. Indeed these three channels are maintained apart in *pP-CH table*, and the number of *pP-CHs* is configured to be the number of the connected STBs.

Ch8 and Ch15 of *E-CHs* included in the last *E-messages* sent by STBs are prejoined.

When STB3 changes from Ch3 to Ch4 with *E-message* including Ch5, the HG performs the channel join process as shown in Fig. 2. Because Ch4 is already prejoined in this scenario, the HG can transmit to the STB the stream of Ch4 immediately. The *wflag* of the Ch4 entry in *P-CH table* changes from 'X' to 'O'. In addition, Ch4 is replaced with Ch2 in *pP-CH table*, and then the HG sends the IGMP join message for Ch2 and the IGMP leave message for Ch3 to FHR since no STB watches Ch3.

In the meantime, STB3's next *E-CH* changes from Ch15 to Ch5, thus the HG sends the IGMP join message for Ch5 and the IGMP leave message for Ch15.

The HG prejoins all the channels in the *pP-CH table* and the *E-CH* table. The HG performs the channel join process as shown in Fig. 1, and the channel leave process as shown in Fig. 2.

PERFORMANCE EVALUATION

We evaluated the performance of our method and the previous methods in terms of the prediction accuracy and the system overhead. The evaluation is carried out by simulating the methods based on TV watching history data.

Table 3: Schemes observed for the performance comparison

Scheme	Implementation description
ADJ-HG	HG prejoins two adjacent channels of the watching channels [3].
ADJ-POP-STB	STB prejoins two adjacent channels of the watching channel, and the top rating channel without HG [4].
EP-HG	HG prejoins one *E-CH* per STB and top rank *P-CHs* as many as the number of STBs. (Our scheme)
EP-STB	STB prejoins one *E-CH* and two *P-CH*s without HG. (Our scheme without HG)

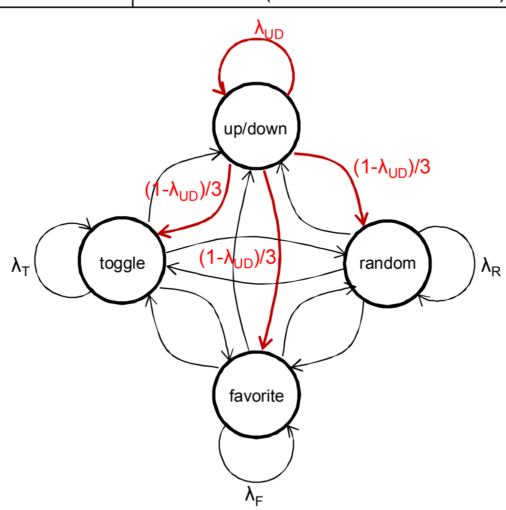


Figure 5: Transition probabilities among surfing modes of a STB

Experimental Setup

We implement four schemes including ours for comparing their performance: ADJ-HG, ADJ-POP-STB, EP-HG, and EP-STB as shown in Table 3. The former two schemes are the representative previous work that employs prejoin methods in HG [3] and STB [4] respectively. EP-HG is our proposed scheme, and EP-STB emulates the prejoin method of EP-HG on the STB, so that we compare EP-HG with ADJ-HG and EP-STB with ADJ-POP-STB.

The performance comparison should be carried out under the same condition. Thus EP-HG is manipulated to prejoin at most 2*N* channels, because ADJ-HG can prejoin at most 2*N* channels as such, where *N* is the number of STBs connected to the HG. Likewise, EP-STB is manipulated to prejoin three channels because ADJ-POP-STB should prejoin at least three channels as such.

For simulation, we used the generated data of watching history of 1000 STBs for 5 hours. Each STB changes channels randomly at a random interval, and its surfing behavior follows the transition probabilities between surfing modes as shown in Fig. 5. There are four surfing modes: up/down, toggle, favorite, and random selection. Once one of the modes is selected randomly, the mode is changed at the given rate; for example up/down to up/down at λ_{UD}, toggle to toggle at λ_T, random to favorite at (1- λ_R)/3, and so on. The channel rating is calculated by counting the number of watching STBs every minute, which is needed for simulating the rating server exploited in ADJ-POP-STB.

Performance Metrics

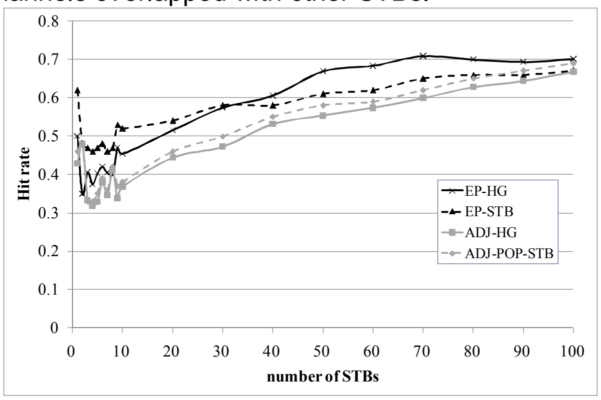
The performance metrics are the prejoin hit rate and the usage of network bandwidth. The hit rate is defined as the percentage of all the first accesses that already reside in the HG (if ADJ-HG or EP-HG) or the STBs (if ADJ-POP-STB or EP-STB). The first access of a channel means that there is no STB watching the channel at the moment. The first access cannot be hit unless prejoining the channel. Therefore the hit rate indicates the prediction accuracy of the prejoin scheme.

The bandwidth usage is defined as the aggregated number of prejoin channels per second. It can be calculated by counting the number of non-duplicate channels prejoined at all the STBs in case of EP-STB or ADJ-POP-STB, where no HG exists; in case of EP-HG or ADJ-HG, it can be simply the number of channels prejoined at the HG. The bandwidth usage indicates the overhead of the prejoin scheme.

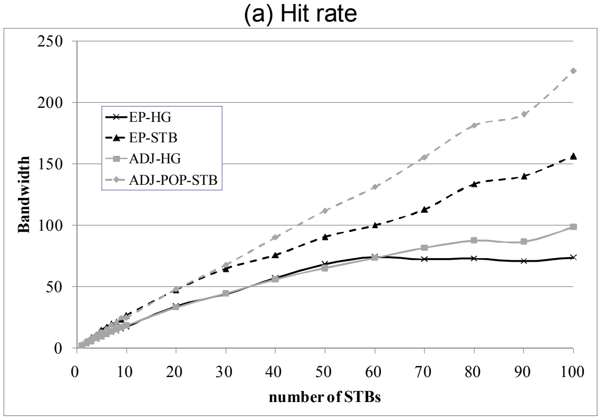
Evaluation Result

As shown in Fig. 6, EP-HG and EG-STB have higher hit rate with less bandwidth than ADJ-HG and ADJ-POP-STB respectively. The results are due to that the former schemes reflect on surfing behavior and particular preference of each STB. Consequently, the proposed method increases the prediction accuracy with little bandwidth overhead.

In addition, the hit rate lines of EP-STB and EP-HG are crossed at the point of 30 STBs, owing to the effect of overlapping prejoin channels. In other words, the more STBs connected to a HG, the more prejoin channels overlapped with other STBs.



(a) Hit rate



(b) Bandwidth usage

Figure 6: Hit rate and bandwidth usage of four schemes according to the number of users ($\lambda_{UD}=\lambda_T=\lambda_R=\lambda_F=0.55$)

CONCLUSION

We proposed a method of a prejoin method for reducing IPTV channel zapping time by reflecting the channel surfing behavior and the particular preference of each viewer. A STB sends to a HG (1) an expected next channel number along with the channel request based on the pushed buttons of a remote controller, and (2) timely-preferred channel numbers periodically based on the recommendation of EPG. The HG joins both the expected channels and the preferred channels in advance.

Our method supports all of four surfing bahaviors contrary to the previous works (Table 4). It prejoins the expected channels for three surfing modes such as up/down, toggle and preset-favorite, and prejoins the preferred channels for the random surfing mode of explicitly choosing a channel number. The experimental results show that our scheme has higher prediction accuracy and lower network bandwidth overhead than the previous schemes, thus it can reduce channel zapping time over them.

We will consider a way to charge to the viewers for the network bandwidth amount as much as they consumed for prejoining the channels.

Table 4: Comparison of prejoin schemes

Surfing behvaior	Cho *et al.*'s scheme [3]	Lee *et al.*'s scheme [4]	Proposed scheme
Up/down	O	O	O
Toggle	X	X	O
Preset-favorite	X	X	O
Random	X	O (popularity rating-based)	O (preference -based)

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