International Journal of Advanced Computer Technology (IJACT)
ISSN:2319-7900

A FAST CHANNEL ZAPPING MECHANISM BASED ON PRACTICAL USER'S BEHAVIOR PREDICTION MODEL FOR IPTV SERVICE

Chuan-Ching Sue, Chi-Yu Hsu, Yung-Yi Shieh
Department of Computer Science and Information Engineering
National Cheng Kung University, Taiwan, R.O.C

Abstract

In recent years, Internet Protocol Television (IPTV) has been widely deployed, where Quality of Experience (QoE) is a critical factor for customers' satisfaction because the nature of IPTV is a delay sensitive service. To achieve this goal, channel zapping is one of QoE factors. This paper proposes a fast channel zapping prediction model based on practical user's behavior for reducing IPTV channel zapping time. As a result, the proposed scheme can efficiently reduce channel zapping time based due to higher prediction hit rate with the considered user's prediction model.

Introduction

In recent years, Internet Protocol-based Television (IPTV) has been widely deployed around the world[1]–[3]. The commercial IPTV system architecture is shown as Figure 1, where IPTV headend provides the channel content and channel content streaming flows are transmitted through First Hop Router (FHR), core network, Least Hop Router (LHR) and reach the end users with access networks. IPTV is a delay sensitive service, in which Quality of Experience (QoE) is a critical factor for customers' satisfaction[1], [4]. Unlike traditional broadcasting TV channels, IPTV only can transmit favorite or required channels over the network because network bandwidth is limited and desired QoE level needs to meet. Channel zapping time (CZT) is one of QoE factors for IPTV due to channel zapping will introduce delay time when the channel is requested and transmitted from head end to customers[4]–[8]. In IPTV network, multicast is a popular transmission protocol as shown in Figure 2, in which routers use Internet Group Management Protocol (IGMP) to manage a group relationship that some end users watch the same channel and there is one copy of channel content in core network and the edge routers will duplicate the channel content to each end user according to the channel group relationship. In last decade, a lot of researches for channel zapping (also knows change, selection, surfing) have been studied. These research paper reduce channel zapping time based on video structure, network architecture, user's preference and behavior, and network or device buffing techniques, in which the proposed methods to reduce channel zapping time can be divided into five steps as shown in Figure 3. In order to simulate practical user's channel zapping behavior, this paper defines a user's behavior model based on the button operation of a conventional remote control. A transient state is defined between channel zapping states, each state defines a user's channel zapping using the specific function button on the remote control, such as user's favorite buttons, user's preference buttons, popular channel buttons, and up/down buttons.

The objective of this paper is to meet the practical user's channel zapping behavior and proposes a user's prediction model to reduce channel zapping time. The results of analysis and simulation show that the proposed paper can achieve a higher channel hit rate and less request blocking rate than previous works [9] and [10], in other words this study can reduce channel zapping time for IPTV service and promote QoE.

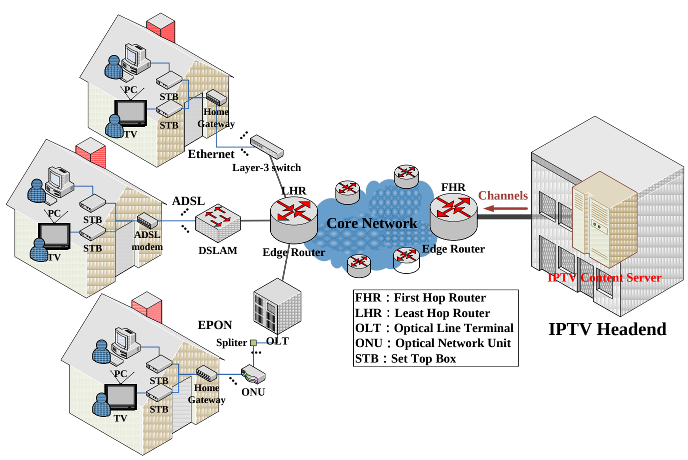

Figure 1. The basic configuration of IPTV service

Related Work

In recent years, many studies have been proposed to reduce channel zapping based on different considerations that include video structure, network architecture, user's preference and behavior, and network or device buffing techniques.

ISSN:2319-7900

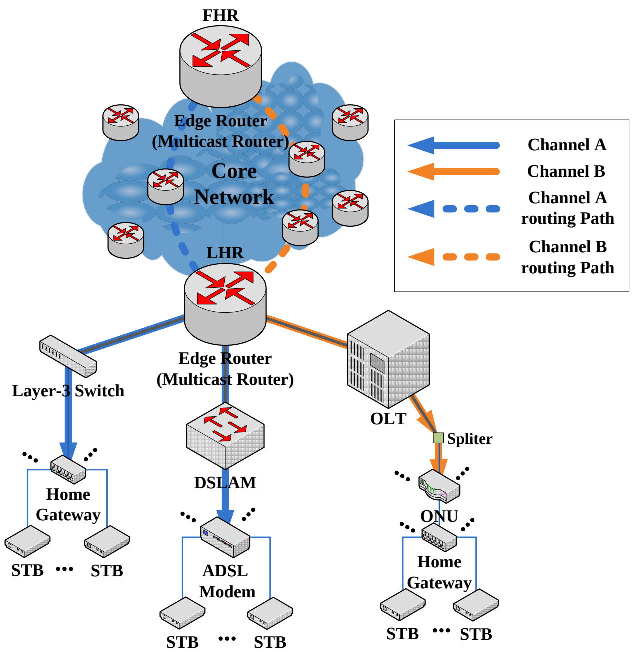

Figure 2. Multicast over IPTV service

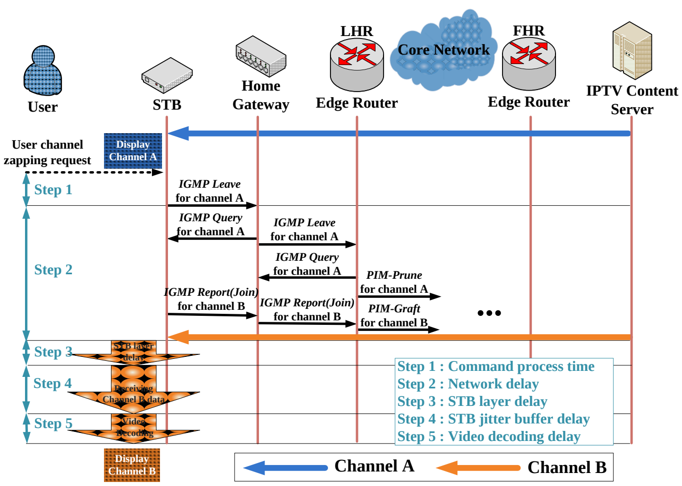

Figure 3. The channel zapping process

A host agent performs the function of IGMP proxy is proposed to process that users use Up/Down buttons to change IPTV channels, therefore the host agent joins the adjacent channels in advance to reduce channel zapping time . In order to reduce the network latency of prejoin channels, a method is proposed to use Set Top Box (STB) buffers to store prejoin channels. Some studies propose channel zapping reduction methods that adopt the nature of H.264 codec to reduce network latency and buffer usage. A study considers the relationship of channel popularity with geometric and time. Local service headend transmits the corresponding popular channels in advance to the neighboring node according to the time period. If user has a zapping to popular channels, the network delay will be decreased because of the requested channel has been transmitted to neighboring node[5], [9], [11], [11]–[20]. In mobile IPTV network, some studies have proposed to reduce channel zapping time using the nature of Wifi or mobile telecommunication [19].

Previous works do not consider user's practical operation behavior and preference. In this paper, we also adopt pre-join method to store some channels in advance, but this paper consider user's temporary behavior as shown in Figure 4. The definition of user's temporary behavior includes two situations. One situation is that the user uses different function on the remote controller and STB just pre-joins the same kind of adjacent channels. The other situation is that if STB need not to consider user's behavior has a temporary change, these pre-joined channels not only can't shorten channel zapping time but also occupy network bandwidth resource.

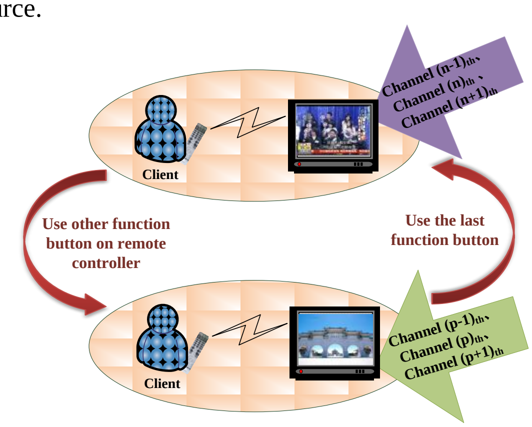

Figure 4. User's temporary behavior

The proposed scheme

A. System Architecture

This paper defines the functions in the remote controller and STB will pre-join some channels according to functions include: B_1: *One's own choice button* which means user can use number button to make a channel zapping. B_2: *Personal preference button* which means user can define some preference channels. B_3: *Up/Down button* that user can use this button to watch the previous or next one channel. The last functional button is B_4: *Popular channel button* that STB will get the popular channel list from edge router which will sort each channels by the number of watching users and send this popular channel list to each STB. In the propsed system, several states are defined to represent the user's behavior transition. Table 2 shows the definition of each state and the relative channels which will be pre-joined at each state and Table 3 illustrates the notation of probability which will be used in our scheme. In addition to S_1, each other state will pre-join the same kind of the adjacent channels and whether the transient state pre-joins channels is decided by the prediction of user's behavior. In order to save the bandwidth for uncertain user's behavior, when user transits to

ISSN:2319-7900

state S_1 and user uses "One's own choice button" to make a channel zapping and STB can't predict what the next channel user wants to watch is so STB doesn't pre-join any channel.

Table 1. State definition and Related projoin channel

State	Pre-join channels	Representation
User's own choice channel State	STB only receive the user requested channel	S_1
Preference Channel State	STB requests the user prefers $(u-1)_{th},(u)_{th},(u+1)_{th}$ channels.	S_2
Up/down Channel State	STB request the $(n-1)_{th},(n)_{th},(n+1)_{th}$ three channels	S_3
Popular Channel State	STB request the $(p-1)_{th},(p)_{th},(p+1)_{th}$ popular channels.	S_4
Transient State	The pre-join channels in transient state are decided by prediction of user's behavior.	$T_{i-j}, i=2\sim4, j=1\sim4, i\neq j$

Table 2. Notation of probability

Notation	The definition of probability
P_x, $\{x\} \in \{S_i, T_{i-j}\}$	The probability of each state
$P_{x\text{-}y}$, $\{x,y\} \in \{S_i, T_{i-j}\}$ $(i=2\sim4, j=1\sim4, i\neq j)$	The probability of the user's behavior that transits from state *x* to state *y*

According to the states as defined in Table 1, figure 5 describes the state transition diagram to model user's zapping behavior. There are nine transient states $T_{i-j}, i=2\sim4, j=1\sim4, i\neq j$ between user's transitions from state $S_i, i=2\sim4$ to state $S_j, j=2\sim4, i\neq j$ used to prevent user's temporary behavior. When users change channel zapping behavior such as user uses "Up/Down button" to make a zapping in the beginning, but changes to "Popular channel button" suddenly, then there is a transition from state S_3 to transient state T_{3-4}. In order to increase the channel hit rate, state S_1 which will transit to $S_i, i=2\sim4$ directly without entering any transient state. When user's behavior transits to each transient state, there will execute a user's behavior prediction to decide what type of channel will be pre-joined. Following is the user's behavior prediction procedure.

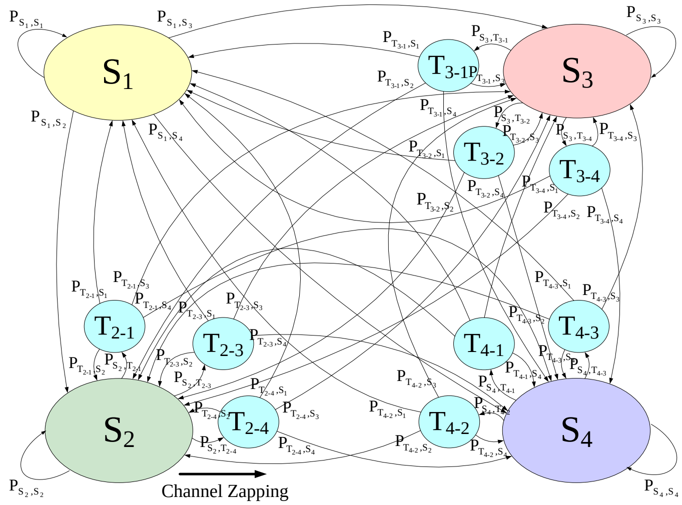

Figure 5. User's behavior transition diagram

B. User's behavior prediction

In order to make a user's behavior prediction, the collection of the user's behavior information is required to consider the user's behavior probability distribution. According to the user's behavior probability distribution, STB can make a prediction when user's behavior has a suddenly change. As shown in figure 6, an example is illustrated to the prediction procedure. At the initial step1, user's behavior is at state $S_i, i=2\sim4$ and user transits to transient state T_{i-j} when user uses the function button corresponded to state $S_j, j=1\sim4, i\neq j$ at step2. And then STB will compare P_{T_{i-j},S_i} which means the probability of backing to S_i and P_{T_{i-j},S_j} which means the probability of going to S_j at step3 to decide what is the user's behavior prediction of STB in transient state is like S_i or S_j. We will give the analysis and simulation result of our proposed scheme in next section.

Analysis and Simulation Results

A. User's behavior probability estimation

As a result, STB cannot recognize the user's behavior distribution, therefore STB needs a criterion to summarize the collected user's historical record. In the proposed scheme, we use Maximum Likelihood Estimation (MLE) [9] to summarize user's behavior probability distribution. Following is the inducting procedure.

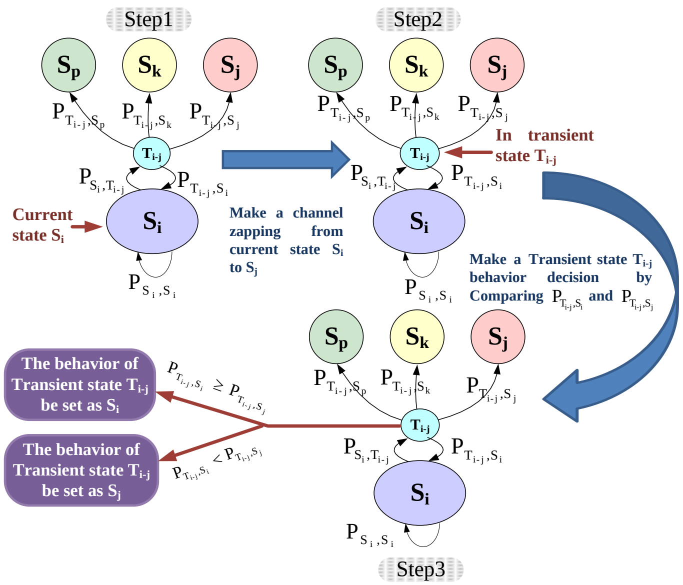

Figure 6. User's behavior prediction procedure

1). *Given the collection of user's behavior at transient states.*

A random vector is defined as $N_B = [N_{B_1}\ N_{B_2}\ N_{B_3}\ N_{B_4}]'$, and $N_{B_i}, i = 1 \sim 4$ is the random variable of the times of each button used after several channel zappings. A sample vector is defined as $n_B = [n_{B_1}\ n_{B_2}\ n_{B_3}\ n_{B_4}]'$ and $n_{B_i}, i = 1 \sim 4$ is the sample value of $N_{B_i}, i = 1 \sim 4$ to indicate the historical record after n times for channel zapping at transient state.

$$\sum_{i=1}^{4} n_{B_i} = n \qquad (1)$$

2). *The conditional PMF of n_B*

a random vector is defined as $P_X = [P_{T_{i-j},S_1}\ P_{T_{i-j},S_2}\ P_{T_{i-j},S_3}\ P_{T_{i-j},S_4}]'$, $i = 2 \sim 4, j = 1 \sim 4, i \neq j.$ and $P_{T_{i-j},S_k}, k = 1 \sim 4$ is the random variable of the user's behavior probability distribution of the transient state. A sample vector is defined as $p_x = [p_1\ p_2\ p_3\ p_4]$ and $p_i, i = 1 \sim 4$ is the sample value of $P_{T_{i-j},S_k}, k = 1 \sim 4$ to represent user's behavior at transient state.

$$\sum_{x=1}^{4} p_x = 1 \qquad (2)$$

For any $P_X = p_x$, the conditional PMF of n_B is shown as following.

$$P_{n_B|p_x}(n_{B_1}, n_{B_2}, n_{B_3}, n_{B_4} \mid p_1, p_2, p_3, p_4) = \binom{n}{n_{B_1}}\binom{n-n_{B_1}}{n_{B_2}}\binom{n-n_{B_1}-n_{B_2}}{n_{B_3}}\binom{n-n_{B_1}-n_{B_2}-n_{B_3}}{n_{B_4}}(p_1)^{n_{B_1}}(p_2)^{n_{B_2}}(p_3)^{n_{B_3}}(p_4)^{n_{B_4}} \qquad (3)$$

3). *The MLE of user's behavior probability distribution given $N_B = n_B$.*

The value of eq. 3 is expected to satisfy the n times for channel zapping properly therefore a partial differentiation is made on $p_i, i = 1 \sim 4$ separately shown as eq. (4). The general solution is induced with eq. (1) and (2) to introduce eq. (5).

$$\hat{p}_{x\_ML}(n_{B_x}) = \arg\max_{p_x \in [0,1]} P_{n_B|p_x}(n_{B_1}, n_{B_2}, n_{B_3}, n_{B_4} \mid p_1, p_2, p_3, p_4), x = 1 \sim 4 \qquad (4)$$

$$\hat{p}_1 = \frac{n_{B_1}}{n}, \hat{p}_2 = \frac{n_{B_2}}{n}, \hat{p}_3 = \frac{n_{B_3}}{n}, \hat{p}_4 = \frac{n_{B_4}}{n} \qquad (5)$$

The general solution is shown as eq. (5) to summarize the user's probability distribution in the simulation.

B. User's behavior probability estimation

In order to estimate channel zapping time [9], the probability of each state are required to calculate, as shown in figure 5. The transition probability of each state is given such as $P_{S_i,S_i}, i = 1 \sim 4$, $P_{S_j,T_{j-k}}, j = 2 \sim 3, k = 1 \sim 4, j \neq k$ and $P_{T_{i-j},S_k}, i = 2 \sim 4, j = 1 \sim 4, k = 1 \sim 4, i \neq j$. Eq. (6) is the general set of ratio balance equation listed by $\pi = \pi \times p$ [9], [10] to calculate the value of $P_{S_i}, i = 1 \sim 4$ and $P_{T_{i-j}}, i = 2 \sim 4, j = 1 \sim 4, i \neq j$ when the state transition diagram is at steady state.

$$\begin{cases} P_{S_1} = P_{S_1} \times P_{S_1,S_1} + \sum_{i=2}^{4}\sum_{j=1, j\neq i}^{4} P_{T_{i-j}} \times P_{T_{i-j},S_1} \\ P_{S_k} = \sum_{i=2}^{4}\sum_{j=1, j\neq i}^{4} P_{T_{i-j}} \times P_{T_{i-j},S_k} + P_{S_1} \times P_{S_1,S_k} + P_{S_k} \times P_{S_k,S_k}, k = 2,3,4 \\ P_{T_{k-i}} = P_{S_k} \times P_{S_k,T_{k-i}}, k = 2,3,4 \quad i = 1,2,3,4 \quad i \neq k \\ P_{S_1} + \sum_{i=2}^{4}(P_{S_i} + \sum_{j=1, j\neq i}^{4} P_{T_{i-j}}) = 1 \end{cases} \qquad (6)$$

C. Channel Zapping Time and Bandwidth Utilization

After calculating the probability of each state in the user's behavior transition diagram, the analytical channel hit rate and bandwidth utilization need to estimate. Table 4 shows the parameter definition used in the performance analysis.

ISSN:2319-7900

Table 4. Parameter definitions

Parameter	Definition
P_{hit}	The probability of the prediction meets user's behavior (*Channel hit rate*)
$P_{un\text{-}hit}$	The probability of the prediction doesn't meet user's behavior
D_{hit}	The channel zapping time that the prediction of STB meets user's behavior is about 25ms[18]
$D_{un\text{-}hit}$	The channel zapping time that the prediction of STB doesn't meet user's behavior is about (725ms[18]+network delay)
$P_{predict\_S_1}$	The probability of the STB only request one channel
$B_{nChannel}$	The bandwidth requirements of *n* channels

1). Channel Zapping Time Estimation:

In the channel zapping time estimation, the expected value of average channel zapping time needs to be considered. Two cases are considered for the estimation. The first cast is that channel request matches the pre-joined channels with its corresponding delay and the other case is that the channel request doesn't match the pre-joined channel as shown in eq. (7).

$$Channel zapping time = D_{hit} \times (P_{hit}) + D_{un\text{-}hit} \times (1 - P_{hit}) \quad (7)$$

There are two cases considered in channel hit rate (P_{hit}). The first case indicates that user continues to use the same functional button except for "User's own choice button". The second case indicates the prediction of user's behavior at the transient state is correct and STB has pre-joined channels in advance shown as eq. (8).

$$P_{hit} = \sum_{i=2}^{4} P_{S_i} \times P_{S_i,S_i} + \sum_{i=2}^{4} \sum_{j=2, j\neq i}^{4} P_{T_{i-j}} \times MAX\,(P_{T_{i-j},S_i}, P_{T_{i-j},S_j}) + \sum_{i=2}^{4} P_{T_{i-1}} \times P_{T_{i-1},S_i} \times u(P_{T_{i-1},S_i} - P_{T_{i-1},S_1}) \;, u(x) = \begin{cases} 0, x < 0 \\ 1, x \ge 0 \end{cases} \quad (8)$$

2). Bandwidth Estimation:

In the bandwidth estimation, the bandwidth utilization is considered for one user in the system. Because the proposed scheme will not pre-join channels when the current state is S_1 or the predicted behavior at transient state is like S_1, the probability of state S_1 and transient states $T_{i-1}, i = 2 \sim 4$, in which user's behaviors have been predicted as S_1 shown at eq. (9).

$$bandwidth\ consumption = B_{oneChannel} \times (P_{predict\_S_1}) + B_{threeChannel} \times (1 - P_{predict\_S_1}) \quad (9)$$

Two cases considered in $P_{predict\_S_1}$. The first case is the current state is S_1 and the second case is the predicted behavior at transient state is like S_1 shown at eq. (10).

$$P_{predict\_S_1} = P_{S_1} + \sum_{i=2}^{4} P_{T_{i-1}} \times P_{T_{i-1},S_1} \times u(P_{T_{i-1},S_1} - P_{T_{i-1},S_i}) \,, u(x) = \begin{cases} 0, x < 0 \\ 1, x \ge 0 \end{cases} \quad (10)$$

D. Network delay estimation

If the requested channel is not in the pre-joined channels, there is a network delay needed to be considered in channel zapping time estimation. Because IPTV network is a hierarchical network, we assume there are 1000 channels and the delay of each hop is 100ms and there are 500 clients under an Access Network Device (AND) showed like Fig.7.

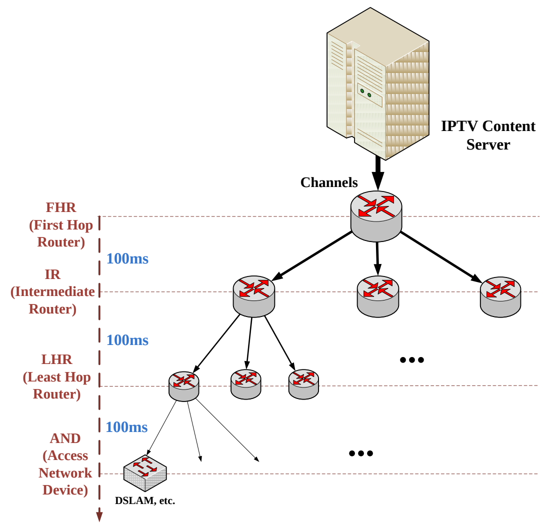

Figure 7. IPTV hierarchical struture.

Because the popularity of each channel is different, Zipf probability distribution needs to be applied to the popularity of each channel to give the probability that a channel will be watching [21]. The definition of Zipf distribution $f_i = K / i^{\alpha}, i = 1 \sim N$, N is the number of channels and K is applied to let the summation of popularity of each channel equal to one. We apply the popularity f_i of each channel to estimate the possible channels at each network device. E.g. the possible channels at AND is $CH_{AND} = \sum_{i=1}^{N} (1 - (1 - f_i)^p) = 210$ (p is the number of users) [18] which means the expected value of there is at least one user watching all of channels. Eq. (11) shows the average network delay $Delay_{AVG}$.

$$Delay_{AVG} = 100 \times \frac{CH_{LHR} - CH_{AND}}{N} + 200 \times \frac{CH_{IR} - CH_{LHR}}{N} + 300 \times \frac{CH_{FHR} - CH_{IR}}{N} \quad (11)$$

ISSN:2319-7900

$Delay_{AVG}$ is estimated by the probability of the requested channel at one of the network devices with the corresponding network delay.

E. Simulation environment

Figure 8 shows the simulation environment. The downlink bandwidth is 1Gbps from edge router to building gateway and the bandwidth consumption of one channel is 3Mbps[9], so the maximum loading of our simulation environment is 333 channels and if the channel request is out of the loading, the request will be blocked. This paper defines personal preference channel for each user and building gateway will sort the channel by the number of watching users to get the popular channel list and the list will be transmitted to user's STB. In order to let the channel zapping request to be closer to reality, the user whose request was blocked will have high priority to make a channel zapping again and the user who watches the channel which is not in the preference channel list or popular channel list will have a medium priority to make a channel zapping than other users.

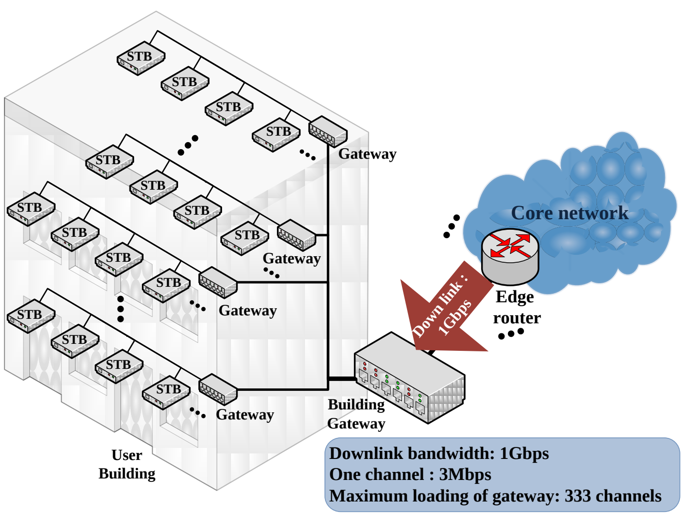

Figure 8. The IPTVsystem architecture in the simulation

F. Results

1) Compare the analysis and simulation under one user:

Figure 9 illustrates the comparison of analysis and simulation with increasing P_{T_{i-j},S_i}. Simulation result is closer to analysis result and the average absolute related percentage error [22] ($ARPE = \frac{|(Simulation - Analysis)|}{Simulation} \times 100\%$) is 1.4% which means the simulation program is correct. Table 4 shows the default value used in simulation and analysis. Because of the unit step function of eq. (8), there is a jump point at $P_{T_{i-j},S_i} = 0.45$. And we can see from Fig. 9 that the hit rate shows a concave-shaped distribution and the lowest point is at $P_{T_{i-j},S_i} = 0.45^-$. Since $P_{T_{i-j},S_j} = 0.9 - P_{T_{i-j},S_i}$, P_{T_{i-j},S_j} and P_{T_{i-j},S_i} share 0.9, if $P_{T_{i-j},S_j} = P_{T_{i-j},S_i} = 0.45$, user's behavior has no tendency to P_{T_{i-j},S_j} or P_{T_{i-j},S_i}. For the reason we mentioned above, if user's behavior at transient state exists an obvious tendency to P_{T_{i-j},S_j} or P_{T_{i-j},S_i}, STB will have more probability to make a proper prediction.

Table 4. Default value of the figure 9

Parameter	Default value
$P_{S_i,S_i}, i = 2 \sim 4$	0.5
P_{S_1,S_1}	0.3
$P_{S_i,T_{i-j}}, i = 2 \sim 4, j = 1 \sim 4, i \neq j$	$(1 - P_{S_i,S_i})/3$
P_{T_{i-j},S_j}	0.9- P_{T_{i-j},S_i}
Experiment trials	1000

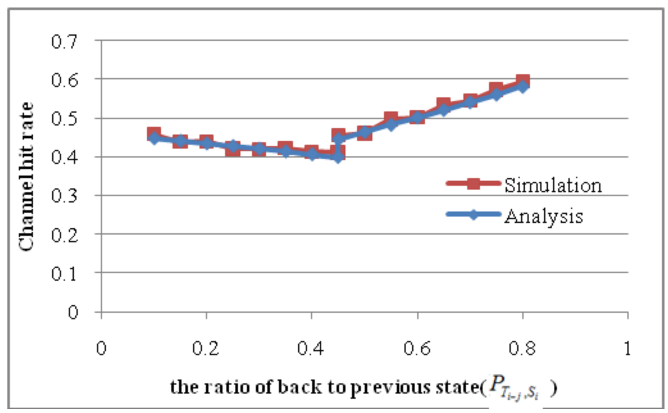

Figure 9. Compare the analysis and simulation result at the different ratio of surfing back

2) Use's behavior probability distribution modification:

Figure 10 shows the user's behavior probability modification process by MLE. Because user's STB doesn't recognize what user's behavior is, STB need warm-up time to collect user's behavior at each transient state to modify the user's behavior probability distribution. Table 5 is adopted to be the default user's behavior probability distribution and the user's behavior prediction becomes more accurate and close to the analysis result after many times of channel zapping.

Table 5. Default value of user behavior

Parameter	Default value
$P_{S_i,S_i}, i = 2 \sim 4$	0.5
P_{S_1,S_1}	0.3
P_{T_{i-j},S_i}	0.7
P_{T_{i-j},S_j}	0.2

ISSN:2319-7900

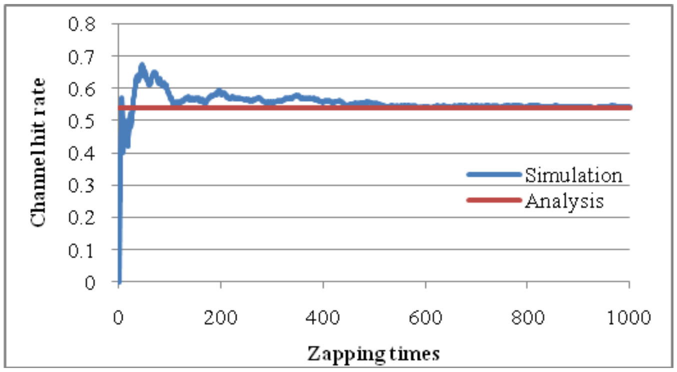

Figure 10. User's behavior probability distribution modification compares with analysis under increasing CZT

3) Channel hit rate at STB

Figure 11 shows the channel hit rate at STB under multiple users and the default values are showed in Table VII. Under multiple users, STBs still need warm-up time to learn user's behavior, so the average channel hit rate will increase apparently and close to the analysis result. We can see from Fig. 11 that our solution has much higher channel hit rate at STB than only pre-join adjacent channels [9] and untreated.

Table 6. Default value of simulation under multiple users

Parameter	Default value
Number of channels	1000
Number of users	500
Total zapping times	500000
Max channels loading of gateway	333

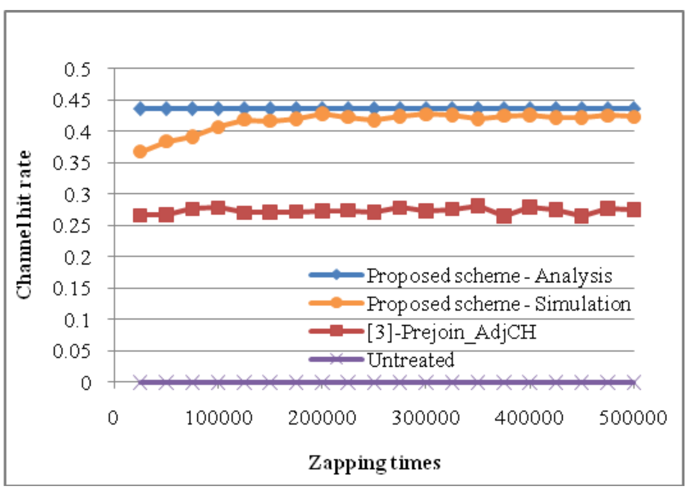

Figure 11. STB channel hit rate compares with analysis and the reference 9

Figure 12 shows the channel hit rate comparing with [9] and untreated. When the user increases, the channel request will be more diversified therefore the condition of channel request blocked by building gateway will increase and the channel hit rate at STB will decrease.

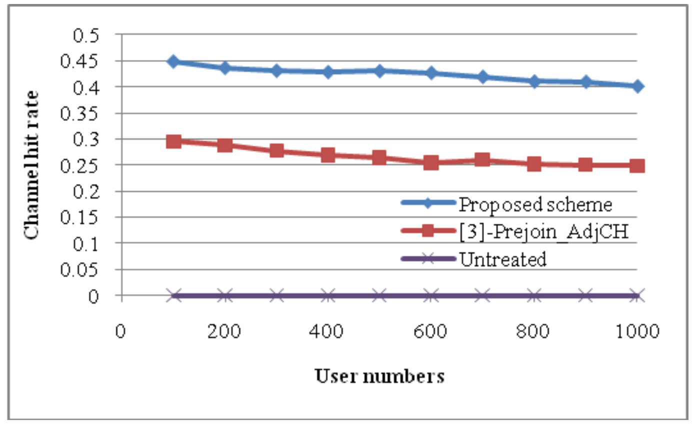

Figure 12. Channel hit rate compares with the reference 9 under different number of users

4) Channel hit rate at Building gateway

Because [10] considers to pre-join popular channels to neighboring node, we let building gateway to be the neighboring node and compare channel hit rate at building gateway with [9] [10]. The default values are showed in Table VII. As shown in figure 13, the proposed scheme has higher channel hit rate because of we consider much more user's profile and provide a preventive measure for user's temporary behavior. As a result of the initial watching channel of each user is closer and each user doesn't satisfy the current channel, every user will generate channel zapping request result in the number of channels in building gateway increase quickly but the hit rate will increase gradually after the overall channel zapping becomes stable.

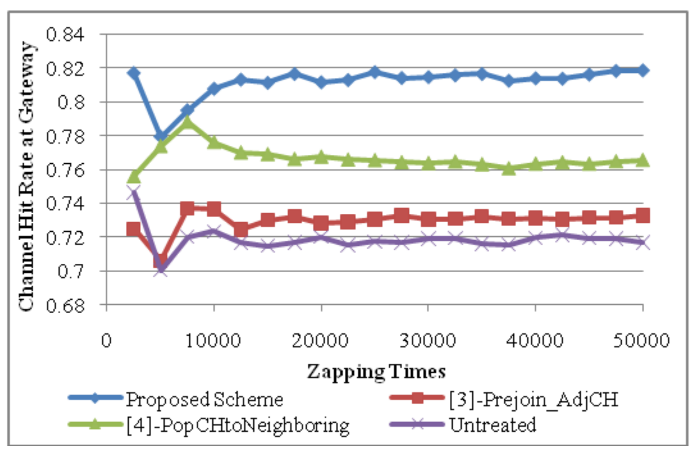

Figure 13. Channel hit rate at the gateway compares with analysis and reference 3 and 4

Figure 14 shows the channel hit rate at gateway. The more users are in the system, the more channels will be watched. As a result, the channel hit rate will increase when the number of channels increase. But because the bandwidth is limited, the maximal number of channels in the gateway is also limited which results in the channel hit rate will not increase unlimitedly.

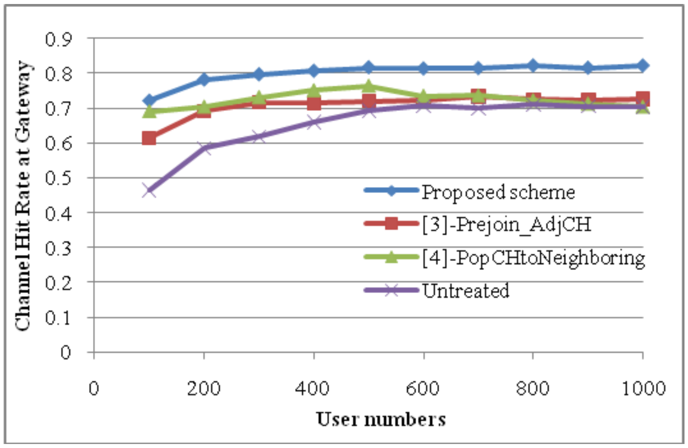

Figure 14. Channel hit rate at the gateway compares with reference 3 and 4 under different number of users

5) Blocking rate

Figure 15 shows the blocking rate at building gateway and the default values are showed in Table VII. Because our scheme will not pre-join any uncertain channel when user's behavior transits to state s_1 and the predicted behavior at transient state is S_1, The blocking rate of our scheme is better than [9]. And because [10] considers the popularity of channel and untreated scheme doesn't pre-join any channels, the blocking rate is less than each other schemes. Because users are not satisfied for the current view of the channel, every user will make a channel zapping let the blocking rate increase in the beginning. After users are satisfied for the current channel, the overall blocking rate becomes stable and our scheme will be better than initial condition.

Figure 16 shows the blocking rate under different number of users. Because the channel requests will be more diversified when the number of users increases, the blocking rate will increase more apparently. Because [10] pre-joins popular channels to neighboring node and we apply Zipf distribution to calculate the possible number of popular channels under different number of users showed in table 6, the more number of popular channels will be pre-joined, the more possibility of the channel request will be blocked.

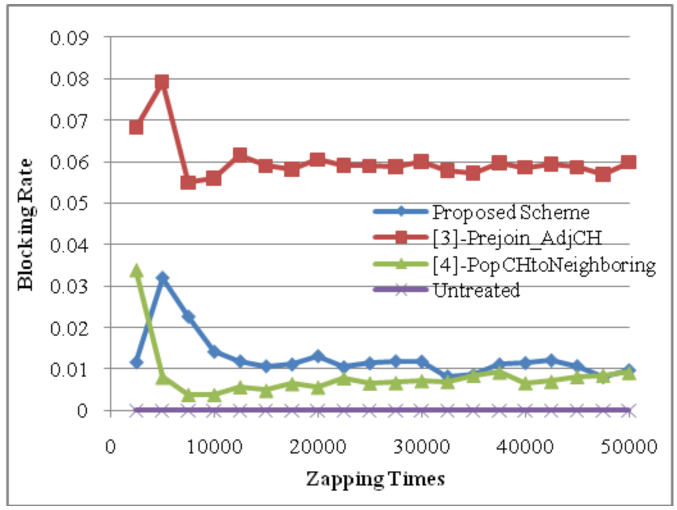

Figure 15. Blocking rate at the gateway compares with reference 3 and 4 under different channel zapping times

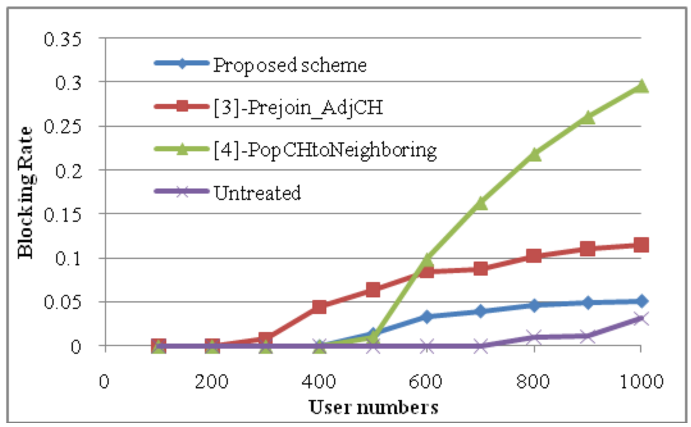

Figure 16. Blocking rate at the gateway compares with reference 3 and 4 under different the number of users

Table 6. Prejoin channels of the reference 4

Number of users	Pre-join channels
100	63
200	108
300	146
400	180
500	210
600	238
700	265
800	289
900	312
1000	332

6) Channel Zapping Time

We consider the channel hit rate at building gateway and the user's channel request can't be blocking in general, so we modify the eq. (7) to eq. (12) and combine the blocking rate to channel un-hit rate. In eq. (12), $D_{gateway\text{-}hit}$ is the delay of D_{un-hit} without considering network delay and $P_{gateway-hit}$ is the probability of the requested channel at building gateway.

$$Delay = D_{hit} \times (P_{hit}) + D_{gateway\text{-}hit} \times (P_{gateway-hit} - P_{hit}) + D_{un-hit} \times (1 - P_{gateway-hit}) \quad (12)$$

Using the network delay estimation at eq. (11), we can estimate the average network delay under different number of users and the result shows in table 7. Figure 17 shows the average channel zapping time using the average network delay. Figure 17 shows that there is no significant fluctuation in the average time estimation. As shown in figure 12 that the channel hit rate at STB is higher when a small number of users but with higher average network delay at Table IX. On the contrary, the channel hit rate at STB decreases when the number of users increase but with lower average network delay, so there is a complementary between the channel hit rate at STB and average network delay.

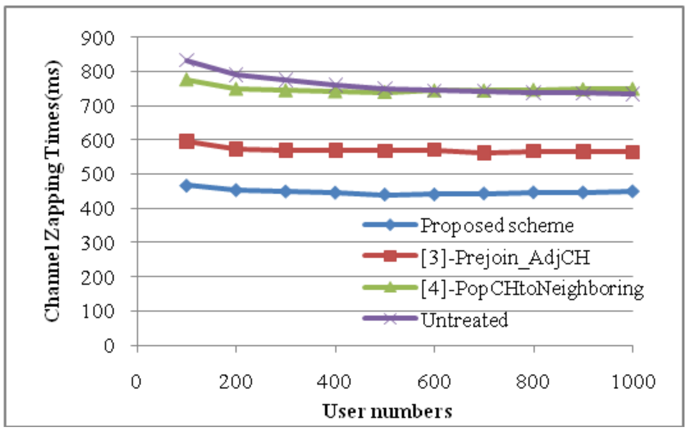

Figure 17. Channel zapping time estimation

Table 7. Average Network Delay

Number of users	Average network delay(ms)
100	247
200	218
300	196
400	178
500	164
600	152
700	141
800	132
900	124
1000	117

Conclusions and future works

IPTV channel zapping time is inherent in IPTV network. Some mechanisms try to pre-join channels to reduce channel zapping time but the consideration of user's behavior is too simple. In our proposed scheme, we make a user's behavior prediction by considering the user's behavior probability distribution to achieve a higher channel hit rate and less request blocking rate than [3][4]. Because the user's behavior exists diversity, it is difficult to consider overall user's behavior [19] and we just consider the behavior that user has a temporary change for channel zapping. Some advanced researches focus on Artificial Neural Network (ANN) [20] to perform nonlinear statistical modeling for developing predictive models. We think we can use ANN to model the diversified user's behavior by the real user's channel zapping record provided by service provider.

Acknowledgments

This work was supported in part by the Ministry of Science and Technology, Taiwan, R.O.C., under Grant MOST 104-2221-E-006-038

References

[1] G. O'Driscoll, *Next Generation IPTV Services and Technologies*. 2007.

[2] Y. Xiao, X. Du, J. Zhang, F. Hu, and S. Guizani, "Internet protocol television (IPTV): The killer application for the next-generation internet," *IEEE Commun. Mag.*, vol. 45, no. 11, pp. 126–134, 2007.

[3] E. Shihab and L. Cai, "in Broadband Home Networks," pp. 765–768, 2007.

[4] J. Kishigami, "The role of QoE on IPTV services," *Proc. - 9th IEEE Int. Symp. Multimedia, ISM 2007*, pp. 11–13, 2007.

[5] Kwang-Jae Kim, Wan-Seon Shin, Dae-Kee Min, Hyun-Jin Kim, Jin-Sung Yoo, Hyun-Min Lim, Soo-Ha Lee, and Yong-Kee Jeong, "Analysis of key features in IPTV service quality model," *IEEE Int. Conf. Ind. Eng. Eng. Manag.*, pp. 595–598, 2008.

[6] H. Uzunalioglu, "Channel change delay in IPTV systems," *2009 6th IEEE Consum. Commun. Netw. Conf. CCNC 2009*, 2009.

[7] H. Y. Jang and M. J. Noh, "Customer acceptance of IPTV service quality," *Int. J. Inf. Manage.*, vol. 31, no. 6, pp. 582–592, 2011.

[8] D. A. G. Manzato and N. L. S. Da Fonseca, "A survey of channel switching schemes for IPTV," *IEEE Commun. Mag.*, vol. 51, no. 8, pp. 120–127, 2013.

[9] C. Sue, C. Hsu, Y. Su, and Y. Shieh, "A new IPTV channel zapping scheme for EPON."

[10] J. Caja, "Optimization of IPTV multicast traffic transport over next generation metro networks," *Networks 2006 12th Int. Telecommun. Netw. Strateg. Plan. Symp.*, 2007.

[11] C. Cho, I. Han, Y. Jun, and H. Lee, "Improvement of channel zapping time in IPTV services using the

ISSN:2319-7900

adjacent groups join-leave method," *6th Int. Conf. Adv. Commun. Technol. 2004.*, vol. 2, pp. 971–975.

[12] Y. Kim, J. K. Park, H. J. Choi, S. Lee, H. Park, J. Kim, Z. Lee, and K. Ko, "Reducing IPTV channel zapping time based on viewer's surfing behavior and preference," *IEEE Int. Symp. Broadband Multimed. Syst. Broadcast. 2008, Broadband Multimed. Symp. 2008, BMSB*, 2008.

[13] Z. Begic, M. Bolic, and H. Bajric, "Effect of Multicast on IPTV Channel Change Performance," *Proc. Elmar-2008, Vols 1 2; Monogr. COTSEN Inst. ARCHAELOGY, UCLA; 50th Int. Symp. ELMAR*, no. September, pp. 151–155, 2008.

[14] Y. Lee, J. Lee, I. Kim, and H. Shin, "Reducing IPTV channel switching time using H. 264 scalable video coding," *Consum. Electron. IEEE Trans.*, vol. 54, no. 2, pp. 912–919, 2008.

[15] M. Sarni, B. Hilt, and P. Lorenz, "A novel channel switching scenario in multicast IPTV networks," *Proc. 5th Int. Conf. Netw. Serv. ICNS 2009*, pp. 396–401, 2009.

[16] M. Z. Ahmad, J. Qadir, N. U. Rehman, A. Baig, and H. Majeed, "Prediction-based channel zapping latency reduction techniques for IPTV systems - A survey," *2009 Int. Conf. Emerg. Technol. ICET 2009*, pp. 466–470, 2009.

[17] L. B. Sofman and B. Krogfoss, "Analytical model for hierarchical cache optimization in IPTV network," *IEEE Trans. Broadcast.*, vol. 55, no. 1, pp. 62–70, 2009.

[18] S. Zare and A. G. Rahbar, "Program-driven approach to reduce latency during surfing periods in IPTV networks," *Multimed. Tools Appl.*, 2015.

[19] A. A. Khosroshahi, S. Yousefi, and A. Ghaffarpour Rahbar, "IPTV channel switching delay reduction through predicting subscribers??? behaviors and preferences," *Multimed. Tools Appl.*, 2015.

[20] N. Liu, H. Cui, S.-H. G. Chan, Z. Chen, and Y. Zhuang, "Dissecting User Behaviors for a Simultaneous Live and VoD IPTV System," *ACM Trans. Multimed. Comput. Commun. Appl.*, vol. 10, no. 3, pp. 1–16, 2014.

[21] H. Joo, D. Lee, and H. Song, "<title>Effective IPTV channel management method over heterogeneous environments</title>;," vol. 6777, no. 54, pp. 677705–677705–9, 2007.

[22] Y. M. Tu and H. N. Chen, "The effect of downtime frequency at fixed machine availability in queuing systems," *Proc. 2008 IEEE Int. Conf. Serv. Oper. Logist. Informatics, IEEE/SOLI 2008*, vol. 2, pp. 2696–2701, 2008.

Biographies

Chuan-Ching Sue became a Member (M) of the IEEE in 1998, and received a B.S. and Ph.D. in electrical engineering from National Taiwan University, Taipei, Taiwan, R.O.C., in 1994 and 2001, respectively. He is currently a Full Professor in the Department of Computer Science and Information Engineering, National Cheng Kung University, Tainan, Taiwan, R.O.C. His Current research interests are fault-tolerant WDM networks and high-speed computer networks. Prof. Sue may be reached at suecc@mail.ncku.edu.tw.

CHI-YU HSU received the B.S. and M.S. degree in Department of Management Information System from National Pingtung University of Technology and Science, Pingtung, Taiwan, R.O.C. Currently, he is a Ph.D. candidate in Department of Computer Science and Information Engineering from National Cheng Kung University, Tainan, Taiwan, R.O.C. He also is a founder of the Sunshine Tech. R&D Co., Ltd. and WoT Technology Inc. His research areas include IPTV, Internet of Things, Web technology, Property Management System, and System Integration. Mr. Chi-Yu Hsu may be reached at cyhsu@stech.tw.

Yung-Yi Shieh received the M.S. degree in Computer Science and Information Engineering from National Cheng Kung University, Tainan, Taiwan, R.O.C. His research focuses on Fast Channel Zapping for IPTV Service.