Changes in IPTV users' needs: model of user's behaviour and preferences on channel change process

R. Bruzgiene, L. Narbutaite and T. Adomkus

Abstract**—**The each user behaviour and preferences for the television channels transmission at anytime and anywhere makes changes in broadcast of the digital Internet Protocol Television. These changes are affected by the different users' behaviour for the channel search and selection during the channel change process. It affects on the quantity of requests for the channel change and its processing time in the network. Due to this, the authors proposed a method that modifies the process of the channel change in order to reduce the processing time of the requests. This method was created according the authors' proposed model of users' behaviour for television channel change process. The results of experiments showed, that it also increase the user's perceived quality assessment for Internet Protocol Television service.

Keywords**—**Behaviour, Channel zapping time, IPTV, QoE.

I. Introduction

THE IPTV (Internet Protocol Television) service providers are looking for the newer ways to attract the users and retain them due to the increasing offers of TV (Television) services and the expansion of the number of new competitors. According to the users, there is a need for an easily used electronic program guide (EPG), the fast change process of IPTV channel, the functionality during TV program selection and so on. The supply of IPTV channels must meet the viewing tastes for the each of users. So many researchers are working on new methods and platforms, which allow automatically recommend the list of user's favorite channels or use IPTV services at any time [1]-[3]. All these needs influence the attractiveness of IPTV service in respect of QoS (Quality of Service) and QoE (Quality of Experience) parameters. TV channel change duration, called channel zapping time, is the most important criteria influencing the subjective IPTV QoE evaluation [4], because the user's visual perception of IPTV quality based on the evaluation of TV channel change process. It was determined that the biggest impact on the user's visual perception has a black screen on TV tuner during the channel change process [5]. It means that, the longer the user does not see the selected channel, the more negative attitude formed on IPTV quality. A longer channel zapping time not only negatively affects the user of the service, but also increases the problems in the delivery process. A longer channel change process affects the parameters of the service quality: higher network delay, the loss of IP (Internet Protocol) packets, wrong IP packets, etc. The scientific research showed that IPTV service becomes unacceptable if the channel zapping time is longer that defined by ITU – T G.1030 [6]. According to this recommendation the channel zapping time should not exceed 2 seconds. Shorter than 500 ms channel zapping interval is perceived as instantaneous and the user doesn't perceive adversely effect of the change process. If the channel zapping time takes longer than 2 seconds, the user may become frustrated.

Many research methods have been proposed to reduce channel zapping time and to increase IPTV QoE. Some methods that improve the video encoding, flow scheduling methods, prejoining channels, predictive tuning or modify Protocol Independent Multicast-Sparse Mode (PIM-SM) protocol have been proposed [7]-[12]. Every single or a set of components of TV channel change process affect IPTV service delivery by problems tracked both of service users and service providers [13]. However, in addition to main components, IPTV channel change process and its zapping time is also affected by factors of user's behaviour. Due to this, the model of TV channels' search and the selection of TV programs must be evaluated individually for each user in order to improve the current prediction's accuracy. Therefore, we proposed the modified IPTV channel change process method, which includes the main new aspect - loading the streams of the IPTV channels of small resolution Picture in Picture (PiP) in the aggregated devices. The impact of the proposed method on the processing time of the TV channel change requests and IPTV QoE according to the model user's behaviour presented in this paper. The created modified process enable to ensure require parameters of QoS to the service provider by reducing the load of the network due to smaller number of the requests for the TV channel change and a shorter route for transmission of the requests.

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Rasa Bruzgiene is with Department of Telecommunications at Kaunas University of Technology, Studentu str. 50-452, Kaunas LT-51368, Lithuania (corresponding author to provide by e-mail: rasa.bruzgiene@ktu.lt).

Lina Narbutaite is with Department of Telecommunications at Kaunas University of Technology, Kaunas, Lithuania (e-mail: lina.narbutaite@ktu.lt).

Tomas Adomkus is with Department of Telecommunications at Kaunas University of Technology, Kaunas, Lithuania (e-mail: tomas.adomkus@ktu.lt).

II. IPTV CHANNEL CHANGE PROCESS WITH THE PROPOSED PIP EPG METHOD

The proposed method called PiP EPG (Picture in Picture Electronic Program Guide) and the flowchart of the proposed method for the transmission of IPTV channel change flow are presented in Fig. 1 and Fig. 2.

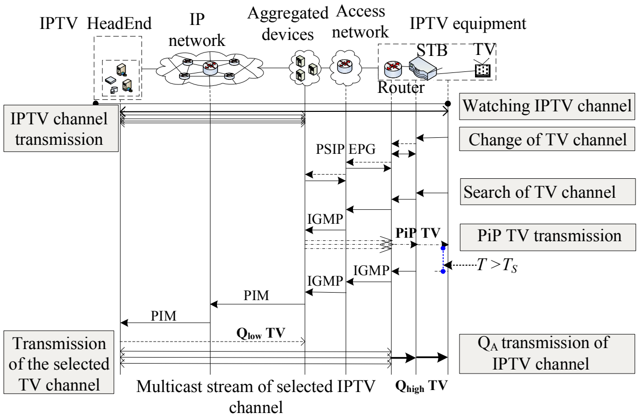

Fig. 1. The proposed method of IPTV channel change flow transmission during the channel change process

The IPTV service provider forms the statistics of the most commonly viewed - the most popular TV channels' selection according to the prediction of the user‘s behaviour in TV channel search and selection. The statistics are regularly updated. The statistics are used for the TV channels' grouping by their audiences. The groups of the users for these TV channels' broadcast and the TV schedule of IPTV channels in the EPG are based on these statistics also. The low quality (Q_{low}) streams of these TV channels' groups are hosted in the aggregated devices (AG) according to the formed groups of the users and the most popular TV channels assigned to them. These TV channels are transmitted to the user as a picture in picture (PiP) data streams of a lower resolution at the process of TV channel change. When the user initiates the process of TV channel change, the STB (Set Top Box) sends the

PSIP (Program and System Information Protocol) query to the aggregated device for information presentation of the user‘s most frequently watched IPTV channel. This user sees the information in the graphical interface of the electronic program guide. When the user selects the TV channel on the EPG and presses the remote control button, the Set Top Box sends the IGMPv3 (Internet Group Management Protocol version 3) Join request for the selected TV channel to the aggregated device. The aggregated device starts transmission of the selected TV channel of low quality and lower resolution as the PiP data stream. The user sees both channels in the TV screen: the previously watching TV channel and the transmission of the selected TV channel in the graphical interface of the EPG. In this case, the main TV channel stream is not terminated and the user watches the selected TV channel broadcasting on TV screen at the same time. If the IPTV user watches the transmission of the selected TV channel for a longer than the minimum viewing period (T_s), the selected TV channel low quality transmission is changed to high quality

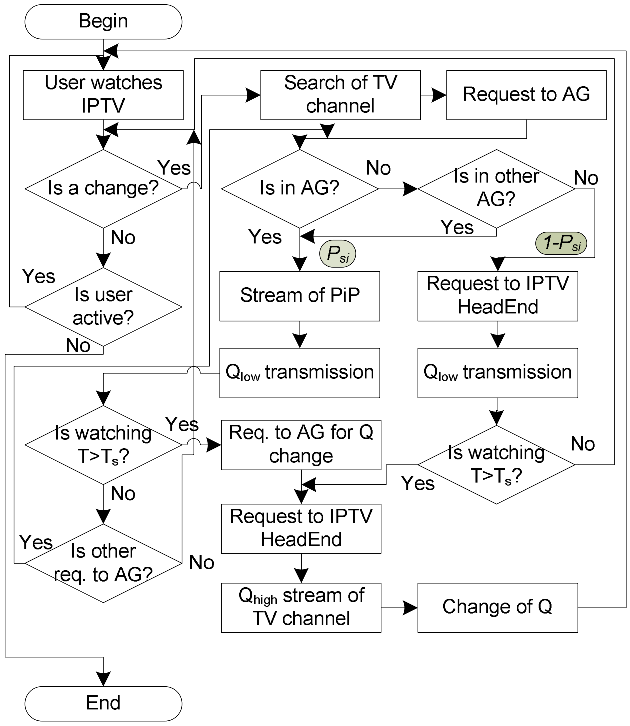

Fig. 2. The flowchart of the proposed PiP EPG method

(Q_{high}). The marking P_{si} is the probability, that the selected IPTV channel will be transmitted from the aggregated device in Fig. 2.

The use of different search methods for TV channels leads to the different amount of the requests for TV channel's change performance. It results the processing time of the requests for TV channel's change. The aggregated device serves for the multiple users' groups, so the number of the requests to change TV channels can greatly increase at the same time. In this case, the channel zapping time will be much longer. The proposed PiP EPG method will reduce the amount of the channel change requests, as well as its processing time. The next positive aspect of this method - the user will be able to search for the other IPTV channel without interrupting the broadcasting of watched digital IP television channel.

III. THE MODEL OF USERS' BEHAVIOUR FOR IPTV CHANNEL CHANGE PROCESS

The analytical model for the evaluation of the performance of the proposed PiP EPG method during the channel change process was created. This model enables evaluation of the IPTV channel change process and its zapping time according to 3 main components (Fig. 3):

- the users‘ behaviour;
- the popularity of TV channels;
- the processes in the aggregated device.

IPTV service provider acquires the statistics of the user's usually selectable TV channels TV_i according to the user's behaviour, and puts this statistics in the N aggregated devices (AG). All TV channels in the AG are grouped into the categories Q according to the statistics of the most popular

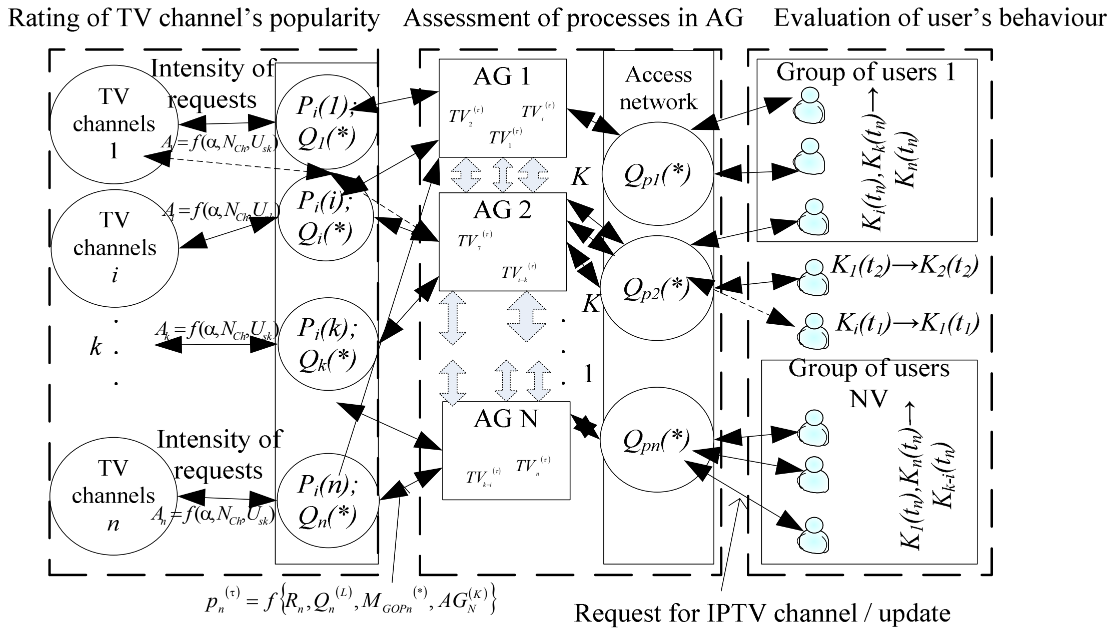

Fig. 3. The components of the analytical model for IPTV channel change process evaluation

(most watched) TV channel selection. Each category has a separate cluster (group) of active IPTV users who mostly tend to select these TV channels. When in time t_1 the user initiates the change of the i-th TV channel into the n-th TV channel $K_i(t_1) \to K_n(t_1)$, the Join request for the transmission of the selected TV channel TV_n is sent to that aggregated device to which the users‘ group is assigned. The transmission of low quality $Q_i^{(L)}$ TV channel data stream to the user starts if the selected TV channel data is loaded in that AG in the analysing time period τ. Otherwise, the search of the selected TV channel TV_n is performed in another aggregated device AG_i, because all aggregated devices are connected to the logical interfaces in the network. When the selected TV channel TV_n was look out, the $Q_i^{(L)}$ transmission of that TV channel begins. The aggregated device sends the Join request for $Q_i^{(L)}$ transmission of the selected TV channel TV_n to the IPTV HeadEnd if that channel is not detected in all the aggregated devices in the network.

It is necessary to analyze the processes of TV channel change using the different methods of channel search, in order to assess the impact of the processing time of the channel change requests. The processes of TV channel change using the sequential, random and proposed methods of IPTV channel search are presented in Fig. 4 – Fig. 6.

The user initiates the request for IPTV channel change $K_i(t)\rightarrow K_j(t)$ at the time t. IPTV channel K is described as a function $K=f\{R,Q,M_{GOP}\}$, which variables are: R – the transmission rate of the video data stream; Q – the quality of broadcasting IPTV channel; M_{GOP} – the length of Group of Pictures (GoP) in the video stream of IPTV channel. The aggregated device initiates the channel change process after

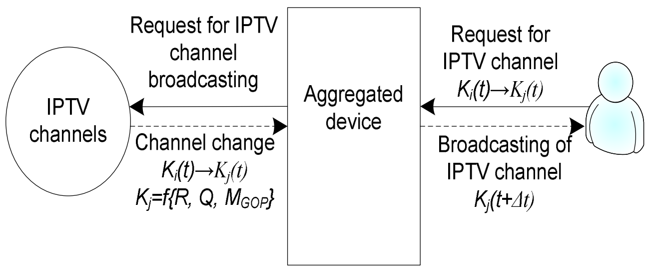

Fig. 4. IPTV channel change process using the sequential TV channel's selection

the request for IPTV channel from the user. The broadcasting of the changed IPTV channel starts at the time $t+\Delta t$ (Fig. 4) or $t_n+\Delta t$ (Fig. 5).

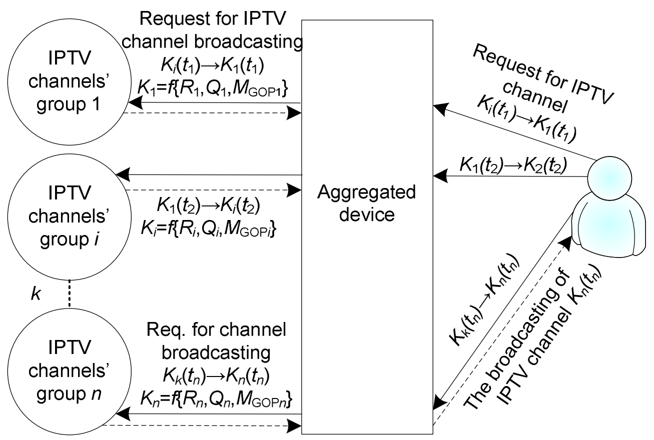

Fig. 5. IPTV channel change process using the random TV channel's selection

The situation is different if the user uses the proposed PiP EPG method for IPTV channel's selection (Fig. 6). The user may choose the television channels from the list of IPTV channels in the electronic program guide, but it does not generate any additional requests. The user performs his choice on seeing the different programs of IPTV channels and the broadcasting of selected K_n channel starts in time t_n.

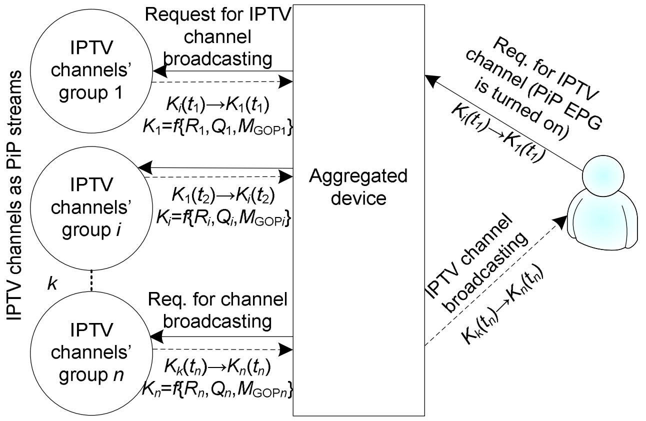

Fig. 6. IPTV channel change process using the proposed PiP EPG method

The *Markov* processes were used for the simulation of TV channels searching methods and evaluation the duration of the process of requests in the aggregated device. The user generates the requests for IPTV channel change with the intensity λ and these requests are processed with intensity μ in the aggregated device. The probabilities of the stationary states in system p_s are:

- in the case of the sequential TV channels searching method

$$p_s = \frac{\lambda^n \cdot \mu}{(\lambda + \mu)^{n+1}}; \quad (1)$$

- in the case of the proposed PiP EPG TV channels searching method

$$p_1 = \frac{\mu}{\mu + \lambda \cdot p_{12}}; \quad p_2 = \frac{\lambda \cdot p_{12}}{\mu + \lambda \cdot p_{12}}. \quad (2)$$

- in the case of the random TV channels searching method

$$p_s = \begin{cases} \dfrac{\mu \cdot (1-p_{12})}{\lambda \cdot p_{12} + \mu \cdot (1-p_{12})}, & if \quad s=0 \\ \dfrac{\lambda \cdot \mu \cdot (1-p_{12})}{(\lambda \cdot p_{12} + \mu \cdot (1-p_{12}))^2}, & if \quad s=1 \\ \dfrac{\lambda^i \cdot p_{i-1,i}^{i-1} \cdot \mu \cdot (1-p_{i,i+1})}{(\lambda \cdot p_{i,i+1} + \mu \cdot (1-p_{i,i+1}))}, & if \quad s=2\ldots n \end{cases}; \quad (3)$$

The duration T_{proc} of the process of requests in the aggregated device is calculated using the probabilities of the stationary states in the system:

$$T_{proc} = \frac{\overline{N}}{\mu}; \quad (4)$$

where $\overline{N} = \sum_{s=0}^{n} s \cdot p_s$ is the mean number of requests; μ is the average intensity of the processing of requests in AG; s is the system number of the state.

The evaluation of the popularity of TV channels enable the user to select the most viewed TV channels from the package of TV channels proposed by the service providers. The results of the selection are used for the formation of the proposed PiP EPG for each group of users. The proposed model assumed that only a part of total number of IPTV users will be active. So, it is necessary to determine the number of active users at the time t for the evaluation of the stochastic popularity of TV channels. The probability $P^u(i)$ describes that the IPTV user is active [14]:

$$P^u(i) = \begin{cases} P_a, & i \in \{1 \ldots N_{TV}\} \\ 1 - P_a, & i = 0 \end{cases}; \quad (5)$$

where, P_a is the probability that the user is watching one of the IPTV proposed channels N_{TV} of service provider; $1 - P_a$ is the probability that the user is not watching any of IPTV channels.

The next step is to determine which IPTV channel number is watched by the users and how many users are watching S_k [14]:

$$S_k(i) = \sum_{n=1}^{N_u} U_{sk}(n,i); \quad (6)$$

where U_{sk} is the set of the users' states; i is the index of the TV channel watched by the users, N_u is the total number of IPTV users.

The number of users watching different IPTV channels is calculated using:

$$N_{dTV} = \sum_{i=1}^{N_{TV}} S_{dTV}(i); \quad (7)$$

where N_{TV} is the total number of IPTV channels; S_{dTV} is the set of users watching different TV channels.

The analysis in scientific literature showed that *Zipf* function is mostly suggested to be used by other authors for the evaluation of the popularity of IPTV channels. The probability that the user will select the popular TV channel is P_i [15]:

$$P_i = \frac{f(\alpha, N_{TV})}{i^a}, \ i = [1..N_{TV}]; \quad (8)$$

where, α is the index of *Zipf* function which shows the character of the distribution law – the TV channel distribution by popularity; i is the index of TV channel selection according to popularity; f is the rationing constant of *Zipf* function.

The IPTV service provider can make grouping of all TV channels into categories Q with the determined popularity of IPTV channels and the statistics of watching of these channels by each user. The grouped channels are allocated in to the aggregated devices according to the groups of the users. The processes of channel change among the groups of users and the aggregated devices are shown in Figure 7. Each group of the users is defined as a set $NV_j \in \{1...N_{ui}\}$ in which there can be N_{ui} active users.

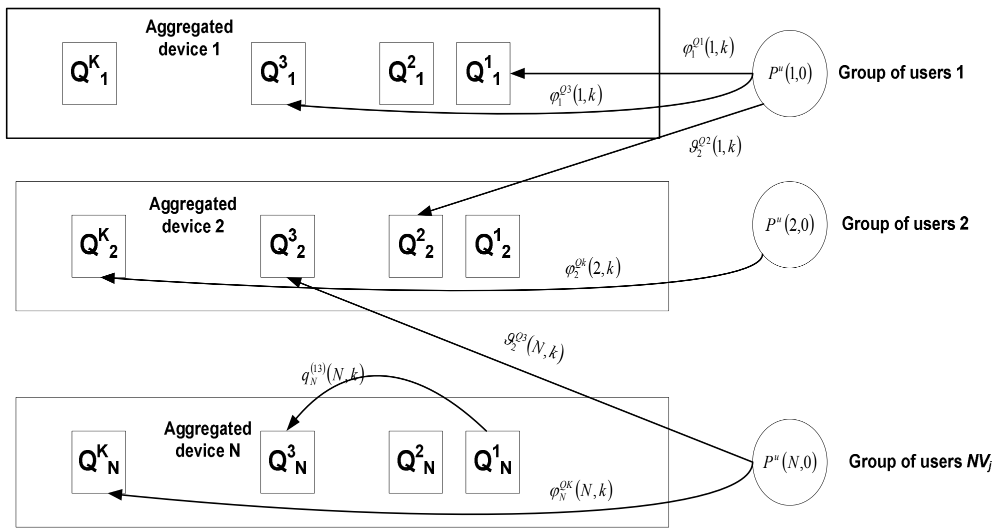

Fig. 7. The IPTV channel change process between the groups of users and the aggregated devices

The processes of IPTV channel change are described by the probabilities. The probability that no user from the *NV-th* group watches any of the IPTV channels is $P^u(NV_j,0)$. This probability is calculated according:

$$P^u(NV_j,0)=(1-P_a(j))^{N_{ui}^{(j)}};\qquad(9)$$

where, P_a is the probability that the user from j^{th} group watches any of the IPTV channels N_{TV}; $N_{ui}^{(j)}$ is the number of users in j th group.

The probability that the users from the 1^{st} group is watching k^{th} TV channel from Q_1 group of IPTV channels is $\varphi_1^{Q1}(1,k)$. In this case, the watching of k th IPTV channel is evaluated by the probability of the popularity of the TV channel (Eq. 8).

The user does not always select the TV channels which are loaded in the aggregated device at time *t*. In this case, the probability that TV channels will be sent from the other aggregated device $\vartheta_N^{Qk}(N,k)$ is

$$\vartheta_N^{Qk}(N,k)=\prod_{i=1}^{N-1}\left(1-\varphi_i^{QN}(N,k)\right).\qquad(10)$$

The search of TV channel can be performed within the same AG that is assigned for that group of users. Then the probability of the channel change q_{ij} is calculated as follows in Eq. 11.

$$q_{ij}=\begin{cases}\dfrac{Q_j}{K_{TV\,j}}\cdot P_{ui}, & if\quad i\neq j\\[2mm] \dfrac{Q_j}{K_{TV\,j}-1}, & if\quad i=j\end{cases};\qquad(11)$$

Here Q_i is a group of TV channels; $K_{TV\,j}$ is the number of TV channels in Q_i group; P_{ui} is the probability of the popularity of TV channels.

IV. The Results of the Evaluation of IPTV Channel Selection by the Users

For determine the of the popularity of TV channels at first evaluate the number of active IPTV users at time instance t. The investigations have been carried and assuming that the total number of IPTV users is $N_u=1000$ and the total number of TV channels are $N_{TV}=57$. The determination of watching of IPTV channels was done for different probability of active users of IPTV $P^u(i)=0.3;0.5;0.7$. The results of the simulation, when $P^u(i)=0.7$, are shown in Fig. 8.

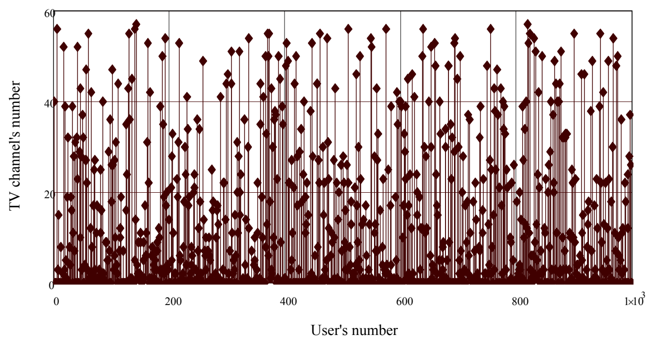

Fig. 8. The active IPTV users and they watching of IPTV channels

One of the important aspects of proposed method of IPTV channel change flow transmission process is determine the watching of the TV channels by a group of users in the each AG. According to the technical characteristics of aggregated devices the total number of active IPTV users is divided into four groups each contains 250 users. The evaluation of the number of TV channels watching by the users in each group was done for different probability of active users of IPTV $P^u(i)=0.5;0.7$. The results of the simulation of watching of the TV channels by a group of users in every AG are shown in Fig. 9 and Fig. 10.

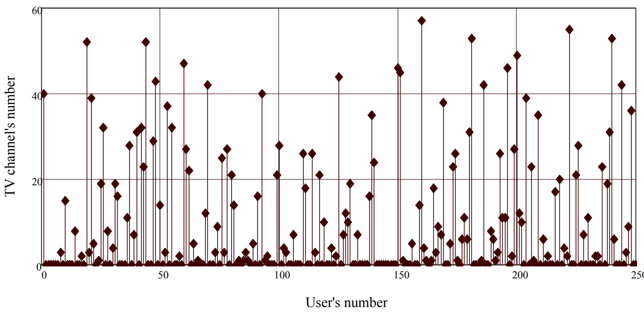

Fig. 9. Watching of the TV channels by a group of users in AG_1 for $P^u(i) = 0.5$

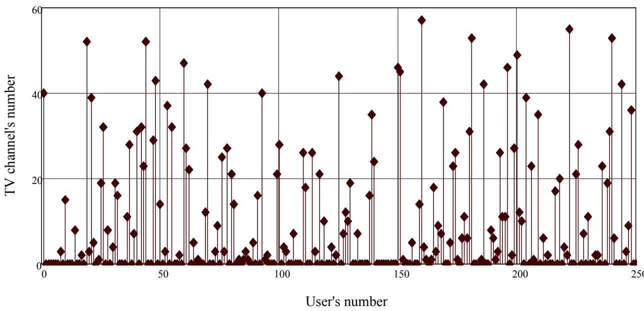

Fig. 10. Watching of the TV channels by a group of users in AG_2 for $P^u(i) = 0.5$

According to the results shown in Fig. 9 and Fig. 10, the requests of TV channel change for the aggregated device AG_1 are generated by $N_{ui} = 122$ active users and for aggregated device AG_2 - $N_{ui} = 175$ active users at time instance t. The next investigation is carried out for the evaluation of the total number of users in every AG_i watching the same IPTV channel. The results of this investigation are represented in Fig. 11 and Fig. 12.

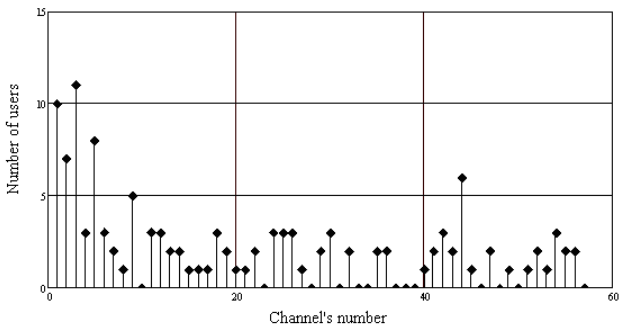

Fig. 11. The number of users in AG_1 watching the same IPTV channel

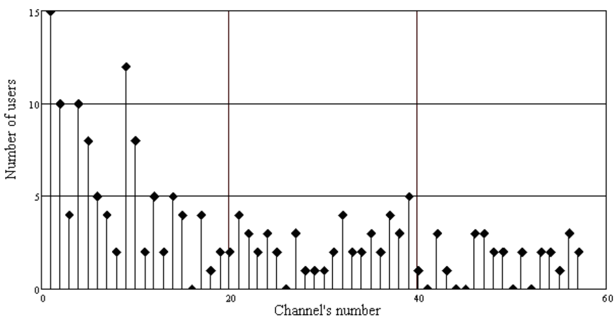

Fig. 12. The number of users in AG_2 watching the same IPTV channel

According to the results, it is obvious that the same IPTV channel is watched by a particular number of users at time instance t (the 1st TV channel is watched by 10 users; the 3rd TV channel is watched by 12 users, etc.). Taking into account the previous results all these IPTV channels can be assigned to a specific group of users in the aggregated devices.

When the activity of IPTV users is bigger, the number of users watching the same TV channel is more. For this reason, it is necessary to evaluate the popularity of TV channels by the probability of the selection of the TV channel by dividing all these TV channels into categories which will be assigned to specific groups of users. This was done for different the index of *Zipf* function – the TV channel distribution by popularity $\alpha = 0.2; 0.6; 0.95; 1.7$. The results of the simulation are shown in Fig. 13.

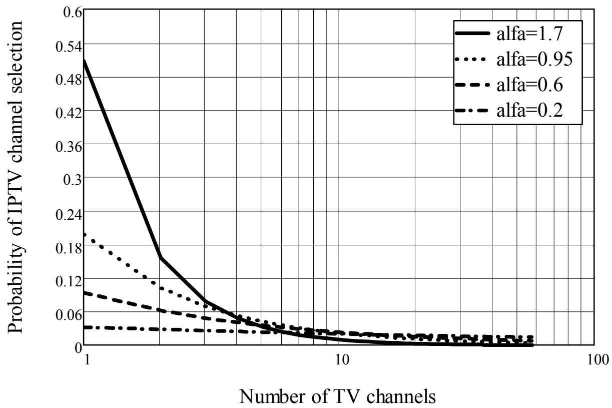

Fig. 13. The dependency of the probability of IPTV channel selection on the number of TV channels

According to the results shown in Fig. 13, it can be state that as the index of the TV channel distribution in terms of popularity is bigger, the probability, that the user will select that particular IPTV channel, is growing. In this case, 10 IPTV channels in the proposed PiP EPG are a good choice for the IPTV service provider, according to the statistics of TV channel selection in terms of its popularity. Such schedule of TV channels in the proposed PiP EPG enable a fast search of TV channels by the users and reduction of the load of IPTV network.

V. The Results of the Evaluation of the Processing Time of IPTV Channel Change Requests

One of most important parameters, affecting total TV zapping time is processing duration of the requests for TV channel change in the aggregated device. For assessment of the IPTV channel change process, it is necessary to evaluate the influence of the user's behaviour on the processing of the channel change requests in the aggregated device. Therefore the analysis of influence of this parameter in the case of different TV channel search methods was carried out. The processing time of requests for TV channel change in the aggregated device was calculated using (4). The dependencies of the processing time of requests for IPTV channel change in the aggregated device T_{proc} versus the intensity of the channel change requests λ and the intensity of the requests processing μ were determined in order to evaluate the effect of the proposed PiP EPG method on the IPTV channel change process. The probability, that there would be initiated more than one channel change request until the channel will be selected is variable $P_{i,j}$=0.01;0.4;0.6;0.8;0.9. The intensity of the requests processing in the aggregated device is μ = 90 reqps. The results are presented in Fig. 14 and Fig. 15.

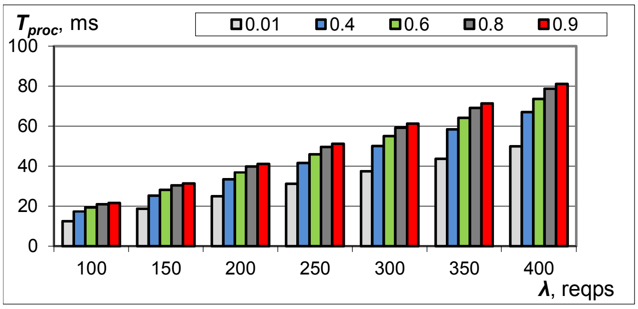

Fig. 14. The dependence of the processing time of IPTV channel change requests on the intensity of the requests, when TV channel is selected randomly

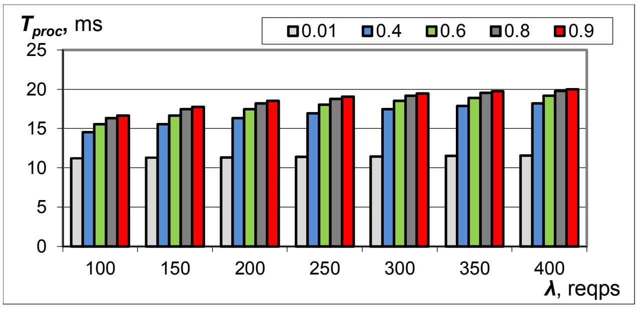

Fig. 15. The dependence of the processing time of IPTV channel change requests on the intensity of the requests, when TV channel is selected using the proposed PiP EPG

According to the results in Fig. 14 and Fig. 15, it can be seen, that the proposed PiP EPG method allows to reduce the processing time of the requests for IPTV channel change ~60 ms compared to a random TV channel search, if the intensity of requests is λ = 400 reqps and $P_{i,j}$=0.9.

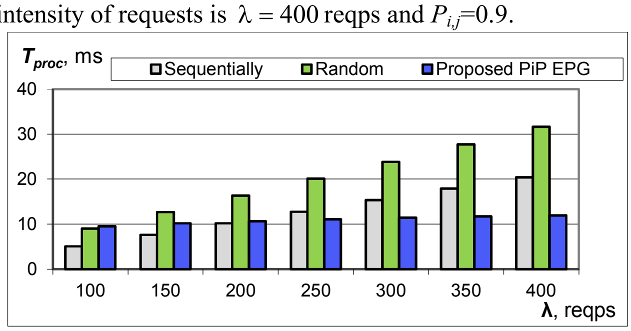

Fig. 16. The dependence of the processing time of IPTV channel change requests on the intensity of requests

The results (in Figure 16) obtained in the case when $P_{i,j}$=0.7 and the intensity of the requests processing is 90 reqps. According to these results (Fig. 16), it can be seen, when the intensity of the requests of TV channel change increases, the use of the proposed PiP EPG method for the channel search helps to reduce the processing time compared to a random and the sequential search of the TV channel. The proposed PiP EPG method allows to reduce the processing time of the requests for IPTV channel change ~20 ms compared to a random TV channel search or ~8 ms compared to a sequential TV channel search, if the intensity of requests is λ = 400 reqps and $P_{i,j}$=0.7.

The dependence of the processing time of requests for TV channel change on the intensity of the processing of requests, when λ is 270 reqps, is presented in Fig. 17.

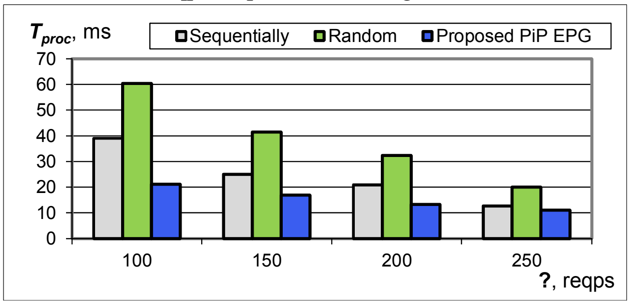

Fig. 17. The dependency of the processing time of requests for IPTV channel change on the request processing intensity

The results in Fig. 17 showed, that the proposed PiP EPG method allows to reduce the processing time of the requests for IPTV channel change ~10 ms compared to a random TV channel search, if the intensity of requests' processing is μ = 250 reqps. The processing time of requests for TV channel change is only a few milliseconds longer in the aggregated device compared to the channel search using the proposed PiP EPG method, if the user selects IPTV channel sequentially.

VI. The Influence of the Channel Zapping Time to IPTV QoE

For the evaluation of the influence of proposed PiP EPG method to IPTV channel zapping time and QoE the experiments were carried out, according to the behaviour of the user for TV channel search. The three methods for TV channel search were used: sequential, random and proposed PiP EPG. During the sequential TV channel selection users switch TV channels one after another in fixed order, recording the selected TV channel after the initial channel change. During the random TV channel selection, IPTV service users switch TV channels randomly, repeating channel change process until desired TV channel selection and record. Measurements of IPTV channel zapping times were made during the highest load hours, determined according to the statistical data from TV audience – on Saturdays and Sundays from 6 p.m. to 10 p.m. Measurements were performed by changing 57 IPTV channels. Experiments were lasted for 5 weeks. The independent respondents, from 29 to 72 years old, all different gender and with different levels of education ranked IPTV QoE, according to the TV channel zapping time. One respondent submitted 57 assessments of IPTV QoE during single experiment. The respondents evaluated IPTV QoE using the subjective method MOS (Mean Opinion Score) and expressing the perceived quality of service on MOS scale of 1 (*TV channel zapping time is very long and particularly* *unacceptable to the user*) to 5 (*TV channel zapping time is quick and user is satisfied of provision of IPTV services*).

In order to evaluate the relationship between the user perceived quality of service in MOS scale and TV channels zapping times the statistical regression analysis for collected data during the experiments were performed [16]. However, the regression analysis does not reveal critical thresholds of the changes in the user's reactions. Therefore, it is relevant to determine which of IPTV channel zapping times value is critical the user‘s reaction to the perceived quality of service. The determination of this critical value was made by the approximation of the experimental data by using the arctangent function and optimization (Fig. 18).

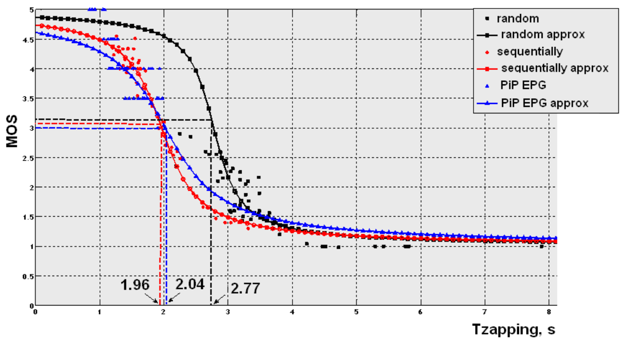

Fig. 18. The relationship between the user perceived quality of service (MOS) and TV channels zapping times using the different methods for IPTV channel search

The analysis of user’s reaction for channel zapping time increase shows, that the biggest negative reaction of user to the delivery of IPTV service is using a method of random channel search. Using the proposed PiP EPG method, user’s reaction for channel zapping time increase is equal and if the channel zapping time exceeds 2.04 s the user assess it as an acceptable delivery of IPTV service. After the analysis of the experimental data, it was found that the standard deviation of the TV channel zapping time was $\sigma_1 = 0.52$, when TV channel was selected sequentially. The standard deviation of the TV channel zapping time was $\sigma_2 = 0.9$, when TV channel was selected random.

The basic mathematical expression of the evaluation of MOS values for the objective assessment of IPTV QoE were carried out by the evaluation of the TV channel zapping time according to the behaviour of the users for the TV channels selection [11].

$$MOSo = \begin{cases} 5, & if \quad T_{zapping} \le 1.96 - \sigma_1 \\ MOS1, & if \quad 1.96 - \sigma_1 < T_{zapping} \le 1.96 + \sigma_1 \\ MOS2, & if \quad 1.96 + \sigma_1 < T_{zapping} \le 2.7 + \sigma_2 \\ 1, & if \quad T_{zapping} > 2.7 + \sigma_2 \end{cases}, \qquad (12)$$

where: $T_{zapping}$ is IPTV channel zapping time; σ is the standard deviation of the experimental data of IPTV channel zapping time.

The mathematical expression for MOS evaluation using the experimental results was carried out depending on the range of the interval of the IPTV channel zapping time and this expression is presented below [11].

$$MOSo = \begin{cases} 5, & if \quad T_{zapping} \le 1.4 \\ MOS1, & if \quad 1.4 < T_{zapping} \le 2.5 \\ MOS2, & if \quad 2.5 < T_{zapping} \le 3.6 \\ 1, & if \quad T_{zapping} > 3.6 \end{cases}, \qquad (13)$$

where $MOS1$ is the expression presented in (14) and $MOS2$ is the expression presented in (15). These expressions were carried out during the determination of the regression analysis by third and fifth degree polynomials [11].

$$MOS1 = -0.032 \cdot (T_{zapping})^3 + 0.627 \cdot (T_{zapping})^2 - \\ - 4.020 \cdot T_{zapping} + 9.372 \quad ; \qquad (14)$$

$$MOS2 = -0.072 \cdot (T_{zapping})^5 + 0.273 \cdot (T_{zapping})^4 + \\ + 2.014 \cdot (T_{zapping})^3 - 12.752 \cdot (T_{zapping})^2 + . \qquad (15) \\ + 21.276 \cdot T_{zapping} - 6.756$$

The proposed mathematical expression for the evaluation of MOS values can be used for the objective assessment of IPTV QoE according the channel zapping time.

Taking into account influence of user behaviour to channel zapping time, it is important to assess influence of integrated QoE of IPTV service. The comparison of integrated QoE according channel zapping time using different methods for channel search was carried out. The results are presented in the Fig. 19.

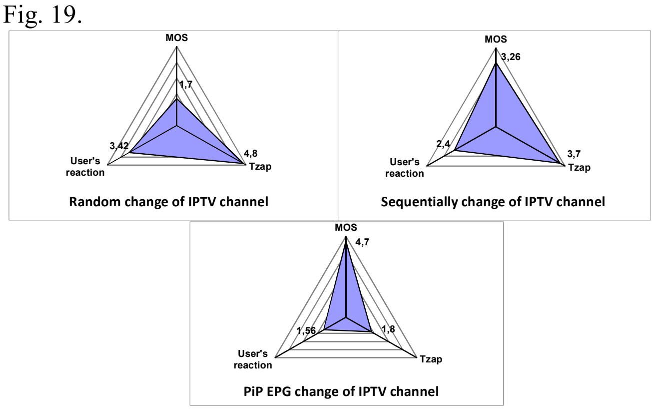

Fig. 19. The integrated IPTV QoE according the channel zapping time, using the different methods for channel search

The results shows, that proposed PiP EPG method allows to increase common QoE of IPTV service at least 2 times, compared with other methods for TV channel search. The integrated QoE evaluation of IPTV service is most sensitive of users when the method of random channel search is used.

It can be stated, that the proposed PiP EPG method for IPTV channel change allows for service providers to increase the attractiveness of digital IP television. So, increasing service attractiveness will grow the demand for IPTV service, which will provide the economic benefit for IPTV service’s providers.

VII. Conclusions

The results of the experimental investigations showed, that the analytical model of users’ behaviour for IPTV channel change process is suitable for evaluation of the IPTV channel change process and the influence of the components of the proposed method on its zapping time.

The results of the evaluation of the processing time of IPTV channel change requests showed that the proposed PiP EPG method enables to reduce the processing time of requests on average 15 ms in the aggregated device compared to other methods for IPTV channel search. It can be concluded also that the processing time of requests for TV channel change very little depends on the intensity of the channel change requests in the aggregated device if users of IPTV service are using the proposed PiP EPG method. This is very important fact because the processing time of requests for TV channel change has big influence on total TV channel zapping time.

The authors' solution for MOS evaluation enables the objective assessment of IPTV quality of experience (QoE). Due to this, the proposed PiP EPG method for IPTV channel change allows for service provider to analyze users' demands for TV channel transmission, enabling IPTV service more attractive and increasing service QoE more than 2 times.

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Rasa Bruzgiene received her Ph.D. degree in Electrical and electronics engineering from the Department of Telecommunications at Kaunas University of Technology (KTU), Lithuania, in 2012. Her current title is the lecturer in the Department of Telecommunications at Kaunas University of Technology. Dr. R. Bruzgiene's current research interests include wireless networks, wireless sensors, the integration of the next generation mobile networks, reliability and efficiency of the telecommunications systems, QoS and QoE in telecommunications services.

Lina Narbutaite received her Ph.D. degree in Electrical and electronics engineering from the Department of Telecommunications at Kaunas University of Technology (KTU), Lithuania, in 2001. Her current title is the associate professor in the Department of Telecommunications at Kaunas University of Technology. Dr. L. Narbutaite's current research interests include hybrid and heterogeneous broadband networks, wireless sensors, interactive real time services, reliability, QoS/QoE, efficiency of the telecommunications systems.

Tomas Adomkus received his Ph.D. degree in Electrical and electronics engineering from the Department of Telecommunications at Kaunas University of Technology (KTU), Lithuania, in 2006. His current title is the associate professor in the Department of Telecommunications at Kaunas University of Technology. Dr. T. Adomkus's current research interests include QoS of data transfer and multimedia services, data security, wireless sensors, the integration of the next generation mobile networks, reliability and efficiency of the telecommunications systems.